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Detailed Project Report: Solar Mini-Grid in Khost

Part 1 – Power Plant and Remote Monitoring Design

Submitted by
IT Power Consulting Private Limited

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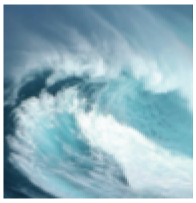

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EXECUTIVE SUMMARY

1. Government of Islamic Republic of Afghanistan (GoIRA) is committed to provide energy access to rural communities through state of art projects and increase productivity of enterprises, improve education and health, local employment and overall quality of life. Within the same objective, the Ministry of Rural Rehabilitation and Development (MRRD), with the support of UNDP, is proposing to implement a solar mini-grid at Gurbuz in Khost province under Afghanistan Sustainable Energy for Rural Development (ASERD) programme.
2. The proposed mini-grid project aims at providing clean, reliable and affordable electricity access to communities in Khost province of Afghanistan. The overall objective of this project is to improve the quality of life of rural communities through provision of electricity services to households, enterprises and institutions.
3. This detailed project report (DPR) is prepared & being submitted as a part of deliverable (Phase 2) under the project awarded to M/s IT Power Consulting Private Limited. This report presents the findings of each of the following tasks under the project:
    - Produce detailed technical design of power plant and remote monitoring
    - Produce detailed technical design of reticulation network
    - Produce load growth scenario
    - Develop tariff model
    - Produce the pay-as-you-go solution
    - Develop monitoring & evaluation plan
    - Develop community development and awareness plan
4. Each of the above-mentioned tasks have been provided in reports as sub parts of this DPR. Following are the contents of the detailed project report (DPR) and each of these reports have been summarized below:
   Part 1: Power plant and remote monitoring design
   Part 2: Technical design of reticulation network
   Part 3: Load growth scenario
   Part 4: Tariff model
   Part 5: Pay-as-you-go solution
   Part 6: Monitoring and evaluation plan
   Part 7: Community development and awareness plan

<u>Part1: Power plant and remote monitoring design</u>

5. This part of the detailed project report incorporates the power plant and remote monitoring design for solar mini-grid project in Gurbuz district of Khost province. This report also summarizes the outcomes of technical survey (phase I).
6. The project site for solar power plant has been identified in Mangal Borikhel village of Gurbuz district, 1.8 km (0.4 km asphalt road plus 1.4 km dirt road) away from the Khost district center. The geographical coordinates of the site are 33.277^{0}N, 69.931^{0}E and elevation is 1,206 m above MSL.

7. The hybrid system consists of solar PV plant having nominal power of 1,000 kW supported by a diesel generator unit of 330 kW operational capacity and 5,040 kWh of battery backup system. All three sources will be controlled by a central control and monitoring system consisting of EMS and BMS. The whole power plant will be connected to the electrical transmission and distribution grid having medium voltage of 20 kV 3-phase AC and low voltage of 400 V.
8. The project will provide electricity to 28 villages and all households, public institutions and enterprises inside these villages. During operation, the system will supply power to the load and charge the batteries if there are excess energy, when there is sufficient solar energy available. The priority is given to supply the loads at all times. When sufficient solar energy is not available, the system will supply the loads from the battery backup until minimum state of charge is reached. After this point, diesel generator will start up and supply the loads and charge the batteries if there are excess energy. The system monitors all parameters and can be set to operate automatically or manually. It can also feed and cut the power at the scheduled times.
9. The system includes 4,000 numbers of 250 W polycrystalline PV modules designed in 250 strings of 16 modules connected in series. There are 25 inverters (three-phase) having 3 MPPT inputs of 40 kW each inverter. The photovoltaic system consists of 25 electrical DC panels having ten inputs. The total annual energy produced by the PV system has been estimated to be 1,780,220 kWh.
10. The battery backup system consists of 6,300 numbers of 2V/400Ah batteries with bi-directional inverters to charge and discharge the batteries. The total capacity of battery storage is 5,040 kWh with 80% depth of discharge. There will be two groups of batteries and each group's capacity shall be 2,016 kWh. Each group of batteries will be connected in series to 600 V DC. One unit of 330 kW diesel generator has been considered as a backup generator. The output of 400V/50 Hz from DG will be stepped up to 20 kV by step-up transformer and fed into the grid.
11. The remote monitoring system for solar mini-grid in Gurbuz district will include SCADA system with the ability of automatic data acquisition and monitoring technology. Data from the weather station, inverters, junction boxes, meters and transformers will be collected in data loggers and passed to the monitoring station, typically via Ethernet, CAT5/6, RS485 or RS232 cables.
12. The support structure for the solar PV array has been proposed to be ground mount fixed type. All the module structure shall be installed in such a way that it utilizes optimum land surface and there must not be shadow on the solar array during day time. The structure shall meet minimum of technical standards and specifications detailed in the report.
13. The design specifications of all civil structures have been elaborated in the report. Bill of materials and quantities have also been developed for the project and elaborated in the report.

Part 2: Technical design of reticulation network

14. The transmission and distribution network of the project area in Gurbuz district of Khost province has been designed, analyzed, simulated and verified using standard electrical engineering practices and codes.

15. It has been ascertained that the design conforms to the DABS standards and technical specifications. The important criteria which have been considered while designing are voltage level, voltage drop limits, short circuit current limits, short circuit studies, power factor and transformers.
16. After having the no. of consumers and understanding their connected demand, a stable network has been designed, to supply the required power to the consumers, based on applicable DABS standards.
17. The 20-kV switchyard comprising of one transformer of 1,250 kVA capacity has been designed. An open-air switchyard has been chosen based on minimal cost, availability of sufficient space, proximity to the power station and ease of maintenance and repair work.
18. Pole spotting criteria, foundation design for poles and transformer sizing sheets have been prepared according to the site conditions and the engineering practices.
19. The transmission line route starts at the switchyard of the power station and supplies the 28 villages of Gurbuz district with 20/0.4 kV distribution transformers. ACSR conductors have been proposed for MV conductors complying with Afghan standards.
20. In order to carry the required power from the source to the consumers, standardized pole top hardware has been designed. This hardware will ensure that the mechanical and electrical requirements of the conductors are met at any conditions. The total length of the low voltage ABC cables will be 45 km with additional 6 km for contingency and 75 km for MV conductors with additional 2 km for contingency.
21. All transformer substations are pole mounted. The pole mounted transformer substation will comprise of 20-kV line breaker/disconnector surge arrestor, high voltage fuse, transformer and low-voltage switchboard including main MCB and consumption meter.
22. The distribution system consists of 400 V overhead line feeders leading from the transformer to the consumer’s meter box and the compound connections from the meter box to the compound. In total, 43 distribution transformers with a total capacity of 1,545 kVA are required to cover the entire project area
23. Service cables are part of the LV network which take the power from the main distribution board of the transformer LV side to the consumers’ meter boxes. The cross section depends on the amount of power they deliver in each feeder. CT and PT together with fuses and other protection and control equipment are installed in the main distribution panel of the transformer LV side to protect and control the service cables.
24. Meter boxes are made of a metal water proof cover and a lockable door and are installed at the feeder poles. Each box is protected via a MCCB fuse breaker of respective size.
25. Surge arresters protect electrical networks against atmospheric voltage surges (lightning). These voltage surges can be one of two types: a “direct lightning stroke” or an “induced voltage surge”.
26. For determination of electrical conductors sizing for MV and LV lines, ampacity, short circuit current and voltage drop have been taken into account. ACSR with 35 mm^2 cross sections and ABC cables with 50, 70, 95 and 120 mm^2 cross sections have been used for the MV & LV respectively. Each of these conductors have limited tensile strength which must not be reached at any given point in time.

27. Safety of people, equipment and other assets in an electrical project is very important and has been taken into consideration while designing the project. 'NSP 004/011 guidance on overhead line clearance' document issued on April 2014 have been referred to propose the clearances in MV and LV live conductors for this project. This guidance is based on the standards listed in its contents and is followed by DABS. The electrical clearance is the sum of three components - electrical limitation, mechanical limitation and basic distance.
28. Grounding system is very critical for all electrical systems. A proper grounding system design ensures that safety is in place at all times. This project has been designed to establish proper grounding system at the main power plant and across the entire distribution network. Grounding pits are provided at the main power plant and are filled with appropriate material to keep the resistance as low as possible.
29. As part of this project design, 12-meter-long outdoor street lighting poles with lamps and fixtures are provided. A total of 11 lighting poles with lamps & fixtures are provided at 28 substations and a total number of 308 street lighting systems are included in this project.
30. Bill of quantity and material has been developed for the project and has been elaborated further in the report.
31. The reticulation network design is elaborated and explained in detail in the 'Part 2 – Technical design of reticulation network' which is a part of this detailed project report.

Part 3: Load growth scenario

32. The objective of the load growth scenario is to construct a realistic scenario of future loads that are likely to come about in the project area. For this, load growth scenarios have been classified into immediate term (comprising of loads that will be operational at the time of commissioning of the power plant; existing loads identified during survey), medium-term (comprising of loads that are likely to come about within 3-5 years of plant commissioning) and long term (beyond 5 years).
33. To arrive at estimates of load growth, the team carried out consultations at the CDC level, as well as one-to-one conversations with prospective entrepreneurs seeking to set up new shops and enterprises. The team also surveyed households to assess levels of latent (and future) energy demand. Population dynamics and economic growth being the key variables have been considered while determining the trajectory of energy demand.
34. In immediate term, all existing loads and those that are expected to be operational at the time of commissioning of the proposed project have been considered which indicates a total connected load of 926 kW at the time of commissioning of plant. In medium term, the possible additions to load growth is expected to be from households and enterprises. As many as thirty-four (34) new ventures have been proposed during the survey which are expected to add 289 kW to the connected load in immediate term. The average connected load per household in the project area is expected to rise on account of lighting demand and use of white consumer goods and therefore, the connected load per household could range around 1.5 kW. In long term, the load growth at household level is not anticipated to be more than medium term. However,

it is expected that, from public institutions, there could be an addition of 30% to the level of demand in immediate term and the enterprise loads could be around 40% more than the medium term.

35. Overall view of load growth for the project area in Gurbuz district clearly shows that the demand is expected to rise significantly in the medium term. The total connected load in medium term and long term are expected to be around 6,132 kW and 6,339 kW respectively. However, actual demand is expected to have high degree of diversity in terms of actual load on the system. The proposed project in Gurbuz district of Khost province having system configuration of 1000 kWp solar PV plant along with diesel generator of 330 kW capacity is able to meet the total connected demand in immediate term. However, the medium and long-term load growth as projected above, is unlikely to be met by the 1000 kWp capacity plant.
36. The technical option for the project site to meet the loads in medium and long term clearly require power plant capacity to be augmented. Operating diesel genset more than stipulated duration could also be considered as an option, even though it may increase the overall diesel fraction. The non-technical options such as smart load management, partial delivery, awareness training have also been identified for the project in order to meet the demand in medium and long term.
37. Load growth scenario is elaborated and explained in detail in the 'Part 3 – Load growth scenario' which is a part of this detailed project report.

<u>Part 4: Tariff model</u>

38. The ability of tariff revenues to sustain operation and maintenance (O&M) expenses at the plant level is the key to long term and effective operations of the project. As such, for the proposed project, tariff revenues have been determined by a combination of top-down and bottom-up considerations. The former involves achieving sustainability by structuring tariff levels to make the project operationally viable. The latter is determined by an estimate of the willingness to pay (WTP) for energy services at the community level.
39. The tariff model is based on the premise that project level cash flows are able to support the levelized cost of electricity, and therefore support the financial outflows needed to sustain the project throughout its twenty-five (25) year lifetime. Following three scenarios have been developed based on the capital expenditure to be loaded on the project.
    - Scenario I: CapEx of both P&M and PDN are loaded on the project
    - Scenario II: CapEx of only P&M are loaded on the project
    - Scenario III: CapEx of P&M and benchmark CapEx of PDN are loaded on the project

    Within each scenario, sensitivity analyses have been carried out to include project-level capital subsidy i.e. 0% (no subsidies) and 100% (full subsidy).
40. Among the results of tariff modelling, with 100% capital subsidy, the tariffs across three scenarios, vary from Afs 8.6 (Scenario 2) to Afs. 13.2 (Scenario 1), with an intermediary value of Afs 10.2 (Scenario 3). The scenarios without any subsidy on CapEx are clearly not sustainable, with the lowest tariff level also over 15 Afs (Scenario 2). The scenario 3 has been understood to be the most practical and viable option for the solar mini-grid project in Khost. Within that scenario, the composite

tariff of 10.2 Afs/kWh for the case of 100% CapEx subsidy appears to be a viable option.

41. Willingness to pay (WTP) survey was carried out in parallel with the technical survey in the project area of Gurbuz district of Khost. The objective of WTP survey was to assess and analyze current energy use & expenses across households, enterprises and others in the region.
42. Based on the discussion on willingness to pay, DABS prevailing tariff and the estimated composite tariff for the project, recommendation on tariff setting for each category of consumers have been done. The study has recommended that the households tariffs should be cross subsidize, by charging higher tariff from enterprises, large commercial shops and public institutions keeping the composite tariff at 10.2 Afs/kWh. For small shops that do not use any electrical appliances such as freezers, energy tariff shall be considered at par with households. To reduce the energy expenses and give the necessary impetus to enterprise development, the tariff should ideally be slightly less than their current average DG tariff.
43. Tariff model is elaborated and explained in detail in the 'Part 4 – Tariff model' which is a part of this detailed project report.

Part 5: Pay-as-you-go (PAYG) solution

44. Pay-as-you-go (PAYG) is a techno-financial construct, which involves a process of making small, convenient payments by the user as one 'goes on' consuming a product or service. The purpose of a PAYG model for solar mini-grid in Khost is to allow consumers to break their pre-payments into manageable, flexible and smaller instalments like daily, weekly or fortnightly (or any other) against which electricity is delivered.
45. The PAYG model for solar mini-grid in Gurbuz district of Khost has been recommended to be a hybrid design, which requires a mix of smartphone and basic mobile phone users. The smart meter, metering device for the consumers, can be enabled with Radio Frequency (RF) of GSM capabilities which can unlock the connection once the payment confirmation reaches the server as well as lock the connection in case of non-payment.
46. In hybrid design, a user with basic mobile phone will be required to visit the nodal point appointed for each village and make cash payment to recharge the account as per his/her requirement. The nodal entity provides an alphanumeric or numeric code that needs to be sent as a text by the user to a dedicated number (known as portal). Once the text reaches the server, the account is credited.
47. For smartphone users, the process is eased by using a mobile app. This can be used to credit a mobile wallet by depositing cash at the nodal point. This app can then be used to make PAYG payments till the mobile wallet is exhausted. Once exhausted, funds need to be credited again through the nodal entity.
48. In the energy space in Afghanistan, non-payment of tariff revenues has often been cited as a barrier to sustainability in energy access projects based in the rural parts. In this overall setting, PAYG can reduce commercial risks associated with revenue collection. Prepaid tariffs can take care of revenue uncertainty by ensuring that consumers pay in advance as well as the consumers will have the option of deciding on how much and how often to top up their credit for electricity usage.

49. Pay-as-you-go solution is elaborated and explained in detail in the 'Part 5 – Pay-as-you-go (PAYG) solution' which is a part of this detailed project report.

Part 6: Monitoring and evaluation plan

50. The objective of the monitoring and evaluation (M&E) plan for solar mini-grid in Khost is two folds – first to monitor the system (power plant and distribution network) performance and second to monitor the social impact generated by the project.
51. Monitoring framework has been developed to provide a guide on monitoring the system performance and the socio-economic impact generated by the project. Monitoring of system performance focuses on the management and supervision of technical parameters, seeking to improve efficiency and overall effectiveness of solar mini-grid. As part of the monitoring plan, meteorological data, energy generated and energy consumed, performance of power plant and the transmission & distribution network performance of solar mini-grid will be monitored continuously with the help of identified indicators. Social indicators will be monitored as a part of the M&E plan for assessing the overall impact of the project. Indicators of social impact are both quantitative and qualitative.
52. The evaluation will basically consist of analyzing the estimate of each indicator and compare the result against the baseline. The evaluation process for solar mini-grid in Khost will include a complete annual review of the project to understand and analyze the progress. The results of evaluation will be used to improve performance of the project under implementation as well as to use them as a feedback for planning of future rural electrification projects.
53. Monitoring and Evaluation (M&E) plan is elaborated and explained in detail in the 'Part 6 – Monitoring and Evaluation Plan' which is a part of this detailed project report.

Part 7: Community development and awareness plan

54. The purpose of developing a community awareness and development plan for solar mini-grid project in Gurbuz district of Khost province is to collect and analyze community-level perspectives about energy access currently existent in the area. The assessment throws light on communities' awareness on the role and scope of change that is possible through improved energy access. The feedback is then utilised to develop community development and awareness plan for the site.
55. The community level survey was carried out in the project area, at the same time as the technical survey, however, a separate and dedicated team was engaged to execute this assessment. The survey has assessed overall wellbeing, gender perspectives, enterprise development, community vulnerability and community development issues in the project area.
56. The project site comes across as one with levels of disparity observed in incomes and gender balance. Women's roles are by and large limited to the kitchen and household, and as such their education is not given a very high priority. The needs assessment points the potential for both agro-based and non-agro-based enterprises, and there have been several new enterprises proposed following the implementation of the proposed project.
57. Community consultations (at CDC level) carried out in the site were focused on soliciting information on energy access and scoping on the developmental impact of

the proposed project. Primary feedback provided was in favour of energy access enhancement.

58. Community development and awareness plan (CDAP) has been developed and presented which seeks to maximize impact of proposed project, by empowering the local community to avail existing opportunities for energy access, especially for enterprise development.
59. Community Development and Awareness Plan (CDAP) is elaborated and explained in detail in the 'Part 7 – Community Development and Awareness Plan' which is a part of this detailed project report.

Part 1

Power Plant and Remote Monitoring Design

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ABBREVIATIONS AND ACRONYMS

AC	Alternating Current
ASERD	Afghanistan Sustainable Energy for Rural Development
BMS	Battery Management System
BMU	Battery Module Unit
CAPEX	Capital Expenditure
CDC	Community Development Council
DABS	Da Afghanistan Breshna Sherkat
DC	Direct Current
DG	Diesel Generator
DOD	Depth of Discharge
DSM	Demand Side Management
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EMS	Energy Management System
GHI	Global Horizontal Irradiance
GOIRA	Government of Islamic Republic of Afghanistan
GSM	Global System for Mobile
HMI	Human Machine Interface
HOMER	Hybrid Optimization Model for Electric Renewables
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IMPP	Current at Maximum Power
ISC	Short Circuit Current
LPSC	Lightning Protection System Components
LS	Lump Sum
LV	Low Voltage
M&E	Monitoring and Evaluation
MCB	Miniature Circuit Breakers
MPP	Maximum Power Point
MPPT	Maximum Power Point Tracking
MRRD	Ministry of Rural Rehabilitation and Development
MSL	Mean Sea Level
MV	Medium Voltage
O&M	Operation and Maintenance
P&M	Plant and Machinery
PAYG	Pay-As-You-Go
PDN	Power Distribution Network
PID	Potential Induced Degradation
PV	Photovoltaic
PVC	Polyvinyl Chloride
RE	Renewable Energy
RF	Radio Frequency
SCADA	Supervisory Control and Data Acquisition
SOC	State of Charge

SPD	Surge Protection Device
STC	Standard Test Conditions
TCO	Total Cost of Ownership
UNDP	United Nations Development Programme
UPS	Uninterruptible Power Supply
VMPP	Voltage at Maximum Power
VOC	Open Circuit Voltage
WTP	Willingness to Pay

1 INTRODUCTION

1.1 Background

Afghanistan is rich in energy resources, both fossil fuel based and renewables. However, it still depends heavily on imported electricity and fuels and has one of the lowest per capita consumption of electricity in the world. Lack of domestic generation remains the key challenge for energy security and energy access in Afghanistan.

Renewable energy (RE) development is receiving increasing attention on the part of the Afghan government and international development partners as it offers the promise of providing energy access in areas where the grid is unlikely to reach as well as enhancing the energy security of the country while supporting employment generation and economic activity.

Government of Islamic Republic of Afghanistan (GoIRA) is committed to provide energy access to rural communities through state of art projects and increase productivity of enterprises, improve education and health, local employment and overall quality of life. Within the same objective, the Ministry of Rural Rehabilitation and Development (MRRD), with the support of UNDP, is proposing to implement a solar mini-grid at Gurbuz in Khost province under Afghanistan Sustainable Energy for Rural Development (ASERD) programme.

1.2 Objective of the project

The proposed mini-grid project aims at providing clean, reliable and affordable electricity access to communities in Khost province of Afghanistan. The overall objective of this project is to improve the quality of life of rural communities through provision of electricity services to households, enterprises and institutions. The project outcomes will include the followings:

- Provision of affordable and reliable electricity
- Increase in rural commercial activities
- Reduction of indoor pollution caused using indigenous sources of energy
- Increased awareness & training through solar power plant development

This part of the detailed project report incorporates the power plant and remote monitoring design for solar mini-grid project in Gurbuz district of Khost province. This report also summarizes the outcomes of technical survey (phase I).

2 KEY OUTCOMES OF PHASE I

2.1 General Information

The project site for solar power plant has been identified in Mangal Borikhel village of Gurbuz district, 1.8 km (0.4 km asphalt road plus 1.4 km dirt road) away from the Khost district center. However, the site is easily accessible by vehicle and trucks so there is no barrier in transporting equipment and material to this site. The geographical coordinates of the site are 33.277ºN, 69.931ºE and elevation is 1,206 m above MSL. Available land area at the project site is more than 15,000 m^2. It is a private land currently being used for agricultural purposes. Land area of 12,000 m^2 has been granted for the project and the agreement has been signed in presence of the MRRD representative and the district governor.

The survey has identified twenty-eight (28) villages based on the list provided by the official representative of MRRD to the survey team. The load centers of the villages which will be served by this project have been identified during the survey and are presented in Table 1 below. The layout of the beneficiary villages is as shown in Figure 1 below.

Table 1 List of villages and load centres

S. No.	Name of village	Households	Government Buildings	Police Stations	Schools	Health Clinics	Mosque	Commercial Shops	Enterprises
1	Sheikh Amir	183	3	1	1	1	8	180	4
2	Waru kalay	335					11	7	
3	Kamkay kalay	194					4	4	
4	Sheikhano kalay	135					3	4	
5	Sherpaw kalay	216			1		7	5	
6	Gagar kalay (Hamideen)	113			1		2	1	3
7	Shershay kalay	93	1	1			2	1	
8	Zarin kalay	75					3	2	1
9	Poldano kalay	185					4	3	
10	Buda kalay	88					2	1	
11	Hafizullah kotkay kalay	89					2	3	
12	Faqir hasan khan kalay	113					4	5	
13	Omar khan kalay	95					1	3	
14	Tani Nasruddin	145			1		3	6	
15	Khargay Nasruddin	78						1	
16	Gulkhan borikhel	112					1		
17	Mawiz khan kalay	83					1		
18	Borikhel kalay	316	1		2	1	2	28	
19	Mangal borikhel	88					2	1	
20	Nawab khan zhdan	118					3	3	
21	Mangal zhdan	95					1	1	
22	Chinar kalay zhdan	111			1		2	3	
23	Tekadaar kalay	125					3	4	
24	Shaheed kalay	158					3	1	

25	Bagikhel kalay	145					2	7	
26	Satar kalay	98					3	2	
27	Zharmandgay kalay	54					1		
28	Patalan kalay	85				1	2	8	
Total		**3,725**	**5**	**2**	**7**	**3**	**82**	**284**	**8**

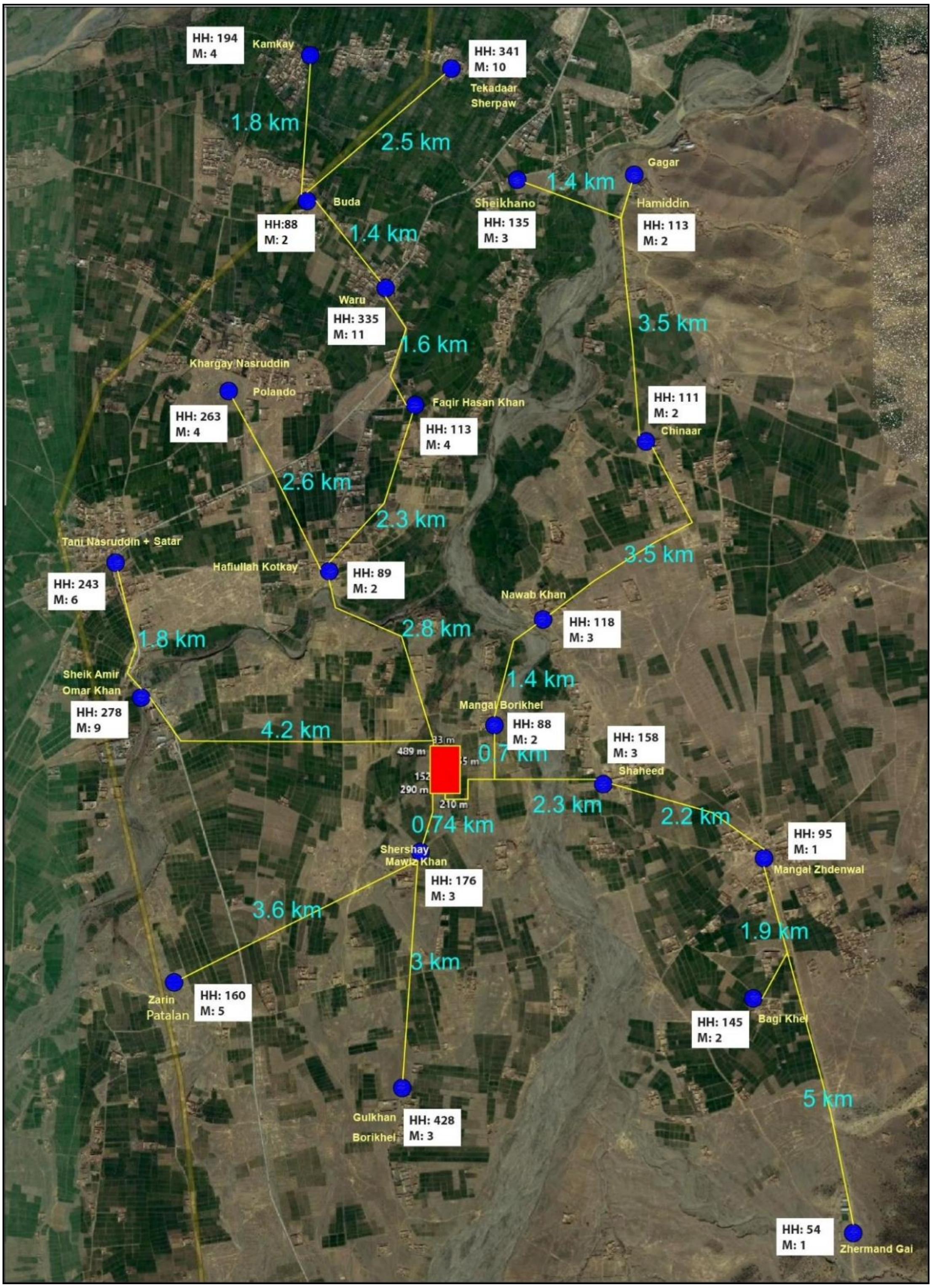


Figure 1 Village layout

Water availability: There is a water fountain adjacent to the site which will facilitate the water requirement during the construction and O&M (cleaning of solar panels and others) phase of the project.

Security: The project site falls in secure area, due to the presence of Afghan government official forces and Afghan local police. The local people also help to maintain the security of the area. Police check points are dispersed along the main road.

Availability of labor: Unskilled manpower is available near the project area. However, skilled labor for solar power project development are not available in the province.

2.2 Survey Results

2.2.1 Topographical & geotechnical study

The topography of the project site is flat, with stepwise declination from south to north. The land at the project site has no storm gulley and the elevation is high as compared to the nearby ground surface. The land requires little grading work for proper cabling and water drainage is required. Compaction of earth layers is also required for improved stability of the plant. Geographically, project site is not located in a flood zone.

2.2.2 Solar resource availability and potential

The average annual solar resource at the project site in Gurbuz is very good with an annual global irradiation of about 1,950 kWh/m^2/year according to 3TIER data and 1,943 kWh/m^2/year according to Meteonorm data. There is suitable environment with minimum dust and no proximate shading to the solar power plant in the project site.

2.2.3 Power scenario

In the project site, there is no electricity grid available. There is sporadic use of small scale solar PV systems for lighting, fans and water pumps in the area. Governmental entities, apart from solar systems, use diesel generator as a standby source. The primary source of fuel for lighting, cooking and other purposes in the 28 villages are wood, diesel and kerosene.

The electricity requirement during construction work needs to be provided by temporary diesel generators because diesel and gasoline is available in the nearby areas. No alternative option is available as of the survey date.

2.2.4 Construction materials

Construction material such as cement, steel, aggregates, bricks, stones, woods are readily available. Few construction machineries are available. However, project specific electromechanical equipment such as solar modules, inverters, battery storage systems, cables, switchgears, transformers, pole-top hardware and charge controllers which are required for the project implementation are not available in the market and needs to be imported from abroad.

2.2.5 Mobile network coverage

The project area has good mobile connectivity where Roshan, AWCC, Salaam, MTN and Etisalat are few of the active mobile operators. 2G and GPRS internet network is available in the project area but DSL, fiber communication and 3G network is not available as of the survey date.

2.3 Load Profile and Energy Demand

Based on the survey, four categories of users have been identified in Gurbuz district. These are households, public institutions (government buildings, police stations, health clinics, schools, mosques, street lights), commercial shops and enterprises. The list of entities and their connected load have been provided in the Table 2 below.

Table 2 Connected load of different consumers

S. No.	Entities	Connected load per entity (kW)	Number of consumers
1	Households	0.18	3725
2	Government	1.45	5
3	Police Stations	1.35	2
4	Health Clinic	2.00	3
5	Schools	0.43	7
6	Mosques	0.94	82
7	Shops	0.45	284
8	Enterprises	3.20	8
9	Street lights	0.02	308

Following multi-tier framework developed by World Bank is used for measuring access to household electricity supply. Tier 0 refers to no access to electricity.

Attributes	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Power capacity rating		Min 3 W	Min 50 W	Min 200 W	Min 800 W	Min 2 kW
		Min 12 Wh	Min 200 Wh	Min 1000 Wh	Min 3425 Wh	Min 8219 Wh
Services		Task lighting AND Phone charging	General lighting AND Phone Charging AND Television AND Fan (if needed)	Tier 2 AND Any medium-power appliances	Tier 3 AND Any high-power appliances	Tier 2 AND Any very high-power appliances

As already discussed, in the Khost Survey Report, currently majority of the beneficiaries are without electricity and thus are categorised within Tier 0. Few of them are using solar panels or DG sets for lighting purposes only and thus they classify under Tier 1 or 2.

The households in the project area will be provided with 180 watts of connected load through the mini-grid project. Consequently, according to the multi-tier framework, all households will have access to electricity and thus they will classify under the tier level between Tier 2 and Tier 3, with the majority shift towards Tier 3.

On the basis of the load assessment, hourly load profile for winter as well as summer season was created separately. The summer months range from March to October and winter months from November to February. Demand side measures including application of diversity factor have been applied to smoothen the load curve. Figures below show the summer and winter load profile of Gurbuz district in Khost province. From the load profile generated, peak demand of 382.4 kW is observed at 18:00 to 19:00 hours in summer season and peak demand of 226.7 kW is observed at 17:00 to 18:00 hours in winter season respectively.

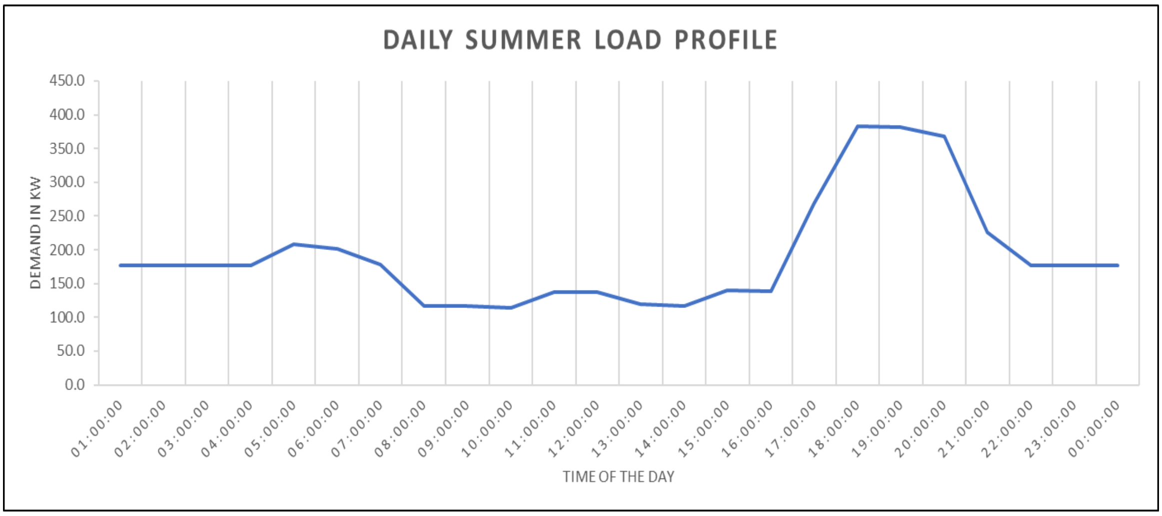


Figure 2 Daily summer load profile

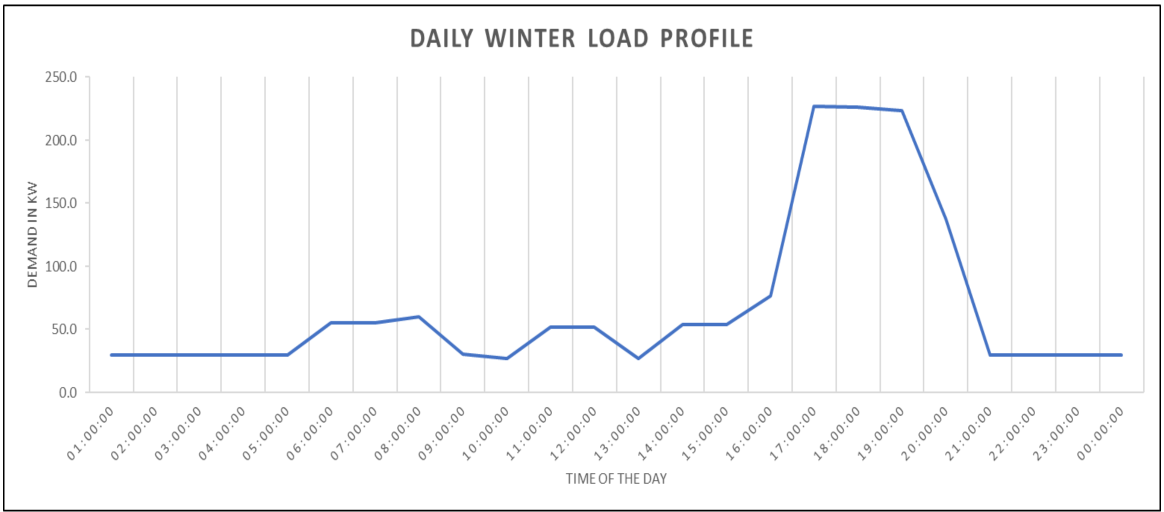


Figure 3 Daily winter load profile

Table 3 Energy demand in summer months at different times of the day

Time of day (Hours)	Load category									Total
	Household	Government Building	Police Stations	Health clinics	Schools	Mosque	Street lights	Commercial shops	Enterprises	
01:00:00	156.5	0.1	0.2	0.5	0.1	3.0	4.9	11.3	0.1	**176.6**
02:00:00	156.5	0.1	0.2	0.5	0.1	3.0	4.9	11.3	0.1	**176.6**
03:00:00	156.5	0.1	0.2	0.5	0.1	3.0	4.9	11.3	0.1	**176.6**
04:00:00	156.5	0.1	0.2	0.5	0.1	3.0	4.9	11.3	0.1	**176.6**
05:00:00	178.8	0.1	0.2	0.5	0.1	11.8	4.9	11.3	0.1	**207.8**
06:00:00	186.3	0.1	0.2	0.5	0.1	3.3	0.0	11.3	0.1	**201.8**
07:00:00	163.9	0.1	0.3	0.5	0.1	2.3	0.0	11.3	0.1	**178.5**
08:00:00	67.1	3.8	1.3	2.4	1.9	2.3	0.0	17.6	20.0	**116.3**
09:00:00	67.1	3.8	1.4	2.4	1.9	2.3	0.0	17.6	20.0	**116.4**
10:00:00	67.1	2.3	0.8	1.5	1.9	2.3	0.0	17.6	20.0	**113.4**
11:00:00	67.1	2.3	0.7	1.5	1.9	26.8	0.0	17.6	20.0	**137.8**
12:00:00	67.1	2.3	0.7	1.5	1.9	26.8	0.0	17.6	20.0	**137.8**
13:00:00	67.1	2.3	0.7	1.5	1.9	8.2	0.0	17.6	20.0	**119.2**
14:00:00	67.1	2.3	0.7	1.5	2.0	2.3	0.0	20.3	20.0	**116.2**
15:00:00	90.9	2.5	0.7	1.6	2.0	2.3	0.0	20.3	20.1	**140.4**
16:00:00	90.9	2.5	0.8	1.6	0.1	2.3	0.0	20.3	20.1	**138.5**
17:00:00	238.4	0.1	0.3	1.5	0.1	9.8	0.0	17.6	0.1	**267.9**
18:00:00	342.7	0.1	0.4	1.6	0.1	11.8	4.9	20.7	0.1	**382.4**
19:00:00	342.7	0.1	0.4	0.5	0.1	11.8	4.9	20.7	0.1	**381.3**
20:00:00	342.7	0.1	0.4	0.5	0.1	7.9	4.9	11.3	0.1	**367.9**
21:00:00	201.2	0.1	0.3	0.5	0.1	7.9	4.9	11.3	0.1	**226.3**
22:00:00	156.5	0.1	0.2	0.5	0.1	3.0	4.9	11.3	0.1	**176.6**
23:00:00	156.5	0.1	0.2	0.5	0.1	3.0	4.9	11.3	0.1	**176.6**
00:00:00	156.5	0.1	0.2	0.5	0.1	3.0	4.9	11.3	0.1	**176.6**
Average Load (in kW)										**191.1**

Table 4 Energy demand in winter months at different times of the day

Time of day (Hours)	Load category									Total
	Household	Government Building	Police Stations	Health clinics	Schools	Mosque	Street lights	Commercial shops	Enterprises	
01:00:00	22.4	0.1	0.1	0.0	0.0	1.0	4.9	1.4	0.1	**29.9**
02:00:00	22.4	0.1	0.1	0.0	0.0	1.0	4.9	1.4	0.1	**29.9**
03:00:00	22.4	0.1	0.1	0.0	0.0	1.0	4.9	1.4	0.1	**29.9**
04:00:00	22.4	0.1	0.1	0.0	0.0	1.0	4.9	1.4	0.1	**29.9**
05:00:00	22.4	0.1	0.1	0.0	0.0	1.0	4.9	1.4	0.1	**29.9**
06:00:00	44.7	0.1	0.1	0.0	0.0	3.9	4.9	1.4	0.1	**55.2**
07:00:00	52.2	0.1	0.1	0.0	0.0	1.3	0.0	1.4	0.1	**55.1**
08:00:00	29.8	3.1	1.0	3.7	0.0	0.3	0.0	2.5	19.4	**59.8**
09:00:00	0.0	3.1	1.2	3.7	0.0	0.3	0.0	2.5	19.4	**30.1**
10:00:00	0.0	1.6	0.6	2.8	0.0	0.3	0.0	2.5	19.4	**27.1**
11:00:00	0.0	1.6	0.4	2.8	0.0	24.8	0.0	2.5	19.4	**51.5**
12:00:00	0.0	1.6	0.4	2.8	0.0	24.8	0.0	2.5	19.4	**51.5**
13:00:00	0.0	1.6	0.4	2.8	0.0	0.3	0.0	2.5	19.4	**27.0**
14:00:00	23.8	1.6	0.4	2.8	0.0	0.3	0.0	5.2	19.4	**53.6**
15:00:00	23.8	1.8	0.4	2.8	0.0	0.3	0.0	5.2	19.5	**53.9**
16:00:00	44.7	1.8	0.5	2.8	0.0	2.3	0.0	5.2	19.5	**76.8**
17:00:00	208.6	0.1	0.2	2.8	0.0	4.3	4.9	5.7	0.1	**226.7**
18:00:00	208.6	0.1	0.3	2.8	0.0	3.9	4.9	5.7	0.1	**226.4**
19:00:00	208.6	0.1	0.3	0.0	0.0	3.9	4.9	5.7	0.1	**223.6**
20:00:00	126.7	0.1	0.2	0.0	0.0	3.9	4.9	1.4	0.1	**137.3**
21:00:00	22.4	0.1	0.1	0.0	0.0	1.0	4.9	1.4	0.1	**29.9**
22:00:00	22.4	0.1	0.1	0.0	0.0	1.0	4.9	1.4	0.1	**29.9**
23:00:00	22.4	0.1	0.1	0.0	0.0	1.0	4.9	1.4	0.1	**29.9**
00:00:00	22.4	0.1	0.1	0.0	0.0	1.0	4.9	1.4	0.1	**29.9**
Average Load (in kW)										**67.7**

2.4 Project Option

On the basis of the load profile generated and the resources available, HOMER software was used to optimize the project design for provision of electricity access in the project area of Gurbuz district. Load shedding as an additional Demand Side Management (DSM) measure will be applied when power demand exceeds 325 kW. A system configuration of 1 MW solar PV, 330 kW diesel generator and battery has been selected as the optimized solution which will provide energy access to all 28 villages surveyed. Power plant will be hybrid of PV, Battery and Diesel. The total annual energy demand from the area after application of load shedding has been estimated to be around 1,280,187 kWh and a load factor of 45%.

The following chapters present the detailed technical design of power plant and remote monitoring for solar mini-grid in Khost.

3 INTRODUCTION TO POWER PLANT DESIGN

This document explains the design and engineering of a 1 MW hybrid PV system along with bill of materials and quantities that will be constructed in Gurbuz district of Khost province. The hybrid system consists of solar PV plant having nominal power[1] of 1,000 kW supported by a diesel generator unit of 330 kW operational capacity and 5,040 kWh of battery backup system. All three sources will be controlled by a central control and monitoring system consisting of EMS and BMS. The whole power plant will be connected to the electrical transmission and distribution grid having medium voltage of 20 kV 3ϕ AC and low voltage of 400 V. The project will provide electricity to 28 villages and all households, public institutions and enterprises inside these villages.

During operation, the system will supply power to the load and charge the batteries if there are excess energy, when there is sufficient solar energy available. The priority is given to supply the loads at all times. When sufficient solar energy is not available, the system will supply the loads from the battery backup until minimum state of charge is reached. After this point, diesel generator will start up and supply the loads and charge the batteries if there are excess energy. The system monitors all parameters and can be set to operate automatically or manually.

The following facilities will be installed at the project site:

i. Solar PV system
ii. Outdoor substation
iii. Battery storage room
iv. Diesel generator
v. Fuel storage tank
vi. Power plant building
vii. Warehouse
viii. Water well house
ix. Parking area and access roads

The whole power plant area will be protected by the perimeter fence, pole mounted outdoor lighting system and CCTV monitoring system. A weather monitoring and measurement tower will be erected at the power plant to record the data from meteorological conditions of the site.

All calculations and computer simulations have been done using the latest engineering standard practices and the IEC regulations. The list of reference standards can be found in section 9. Results are presented in the following sections.

3.1 Project data

The table below shows the main geographical data for the installation site.

[1] The nominal power of the photovoltaic system is intended as the sum of the nominal power of each module measured at standard test conditions (STC).

Table 5 Geographical data

Location	Gurbuz district, Khost province
Address	Mangal Borikhel village, Gurbuz, Khost
Latitude	33°16'34.23"N
Longitude	69°55'55.25"E
Altitude	1,206 meters above sea level
Maximum temperature	29.40 °C
Minimum temperature	-2.72 °C
Annual Global irradiation on hor. plane	1,943 kWh/m²
Irradiance data	Meteonorm
Albedo	20%

Following table provides the daily irradiation on a horizontal surface obtained according to Meteonorm data source.

Table 6 Solar resource data for the project site in Gurbuz district from Meteonorm

Month	**Monthly GHI**	**Monthly Diffuse**
	kWh/m^2/month	kWh/m^2/month
January	103.0	27.3
February	117.6	34.2
March	163.8	49.3
April	182.5	64.6
May	221.4	64.3
June	218.5	75.1
July	209.4	80.0
August	182.4	82.2
September	173.5	53.4
October	150.3	39.7
November	119.4	22.6
December	101.1	22.8
Annual	1942.9	615.5

Considering the above data source, the annual global irradiation on a horizontal surface for the location of the power plant have been determined to be equal to 1,943 kWh/m². The sun path is shown as follows:

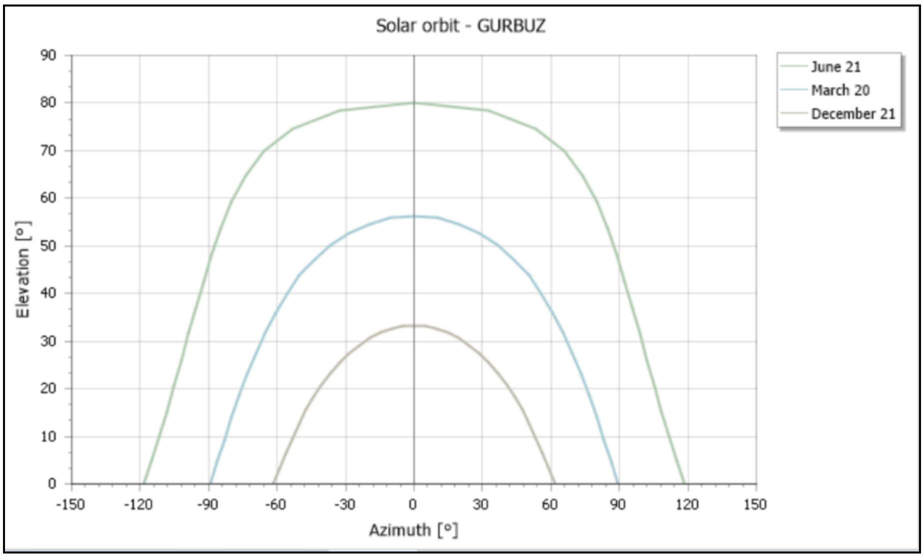


Figure 4 Sun path diagram

3.2 Technology selection

The technology for each equipment has been selected and the details have been provided below

3.2.1 PV modules

The main technical characteristics of the selected PV module have been summarized below.

Table 7 Solar PV module specification

Manufacturer	To be specified at a later stage
Model	As per the manufacturer datasheet
Technology	Si-poly
Nominal power	250 W
Tolerance	+3.00%
Open circuit voltage (Voc)	40.90 V
Voltage at maximum power (Vmpp)	33.30 V
Short circuit current (Isc)	8.14 A
Current at maximum power (Impp)	7.52 A
Area	1.38 m²
Efficiency	18.1%
Degradation	Not more than 10% degradation in first 10 years and 20% degradation in 25 years. The solar panels should have linear degradation of not more than 2.5% in the first year and not less than 0.7% in the subsequent years.

3.2.2 Inverters

Inverters has been selected considering the following conditions:

- DC input voltage
- Load
- Site temperature
- Product reliability
- Maintainability
- Serviceability
- Total cost
- Altitude
- Inputs from PV panel manufacturer

The main technical characteristics of the selected inverter have been summarized below.

Table 8 Inverter specification

Manufacturer	To be specified at a later stage
Model	As per the manufacturer datasheet
Nominal power	40.00 kW
Maximum power	40.00 kW
Maximum efficiency	97.50%
European efficiency	97.50%
Maximum voltage from PV	1,000.00 V
Minimum voltage MPPT	380.00 V
Maximum voltage MPPT	850.00 V
Maximum input current	108.00 A
Number of MPPT	3
AC output voltage	600.00 V
Output	Three-phase
Isolation transformer	True
Frequency/Range	50 Hz/49.3 to 50.5 Hz

3.2.3 Battery and diesel generator

Lead carbon battery of 2V/400 Ah capacity has been selected for the battery backup system. The battery has a maximum efficiency of 97.0 % (Euro: 95.0 %).

One unit of DG system having 330 kW capacity has been selected for the project.

4 ELECTRICAL SYSTEM

The hybrid photovoltaic system with nominal power of 1,000 kWp from solar, 330 kW from diesel generator (DG) and 5,040 kWh from battery storage will be connected to electrical transmission and distribution grid. The characteristics of the system are summarized below. Appendix 1 shows the single line diagram of the system.

Table 9 Characteristics of power plant and remote monitoring design

Components	Description
PV system	• 250 strings of 16 modules connected in series • Group of 25 inverters (three-phase) • Group of interfaces • Equipment for measurement of energy & other parameters
Battery	• 6,300 pieces of 2V/400Ah batteries • Group of 2 bi-directional inverters • Group of interfaces • Equipment for measurement of energy & other parameters
Diesel Generator (DG)	• 330 kW diesel generator 400V (three phase) • Synchronization panel • Group of interfaces • Equipment for measurement of energy & other parameters
SCADA	• Monitoring modules • HMI interface • Control modules
Weather monitoring System	Weather monitoring tower to measure following parameters and report it to the monitoring and control system for further analysis • Irradiance • Wind speed • Temperature • Moisture • Diffusion of sun

4.1 Plant layout

The layout of the system has been chosen in order to optimize the system production, land availability, installation and operation & maintenance. Following criteria have been taken into account:

- Orientating the modules to face a direction that yields the maximum annual power production. For Gurbuz, as it is in the northern hemisphere, this will be true south
- Choosing a tilt angle and module configuration that optimizes the annual energy yield according to the latitude of the site and the annual distribution of solar resource
- Designing inter-row spacing to avoid inter-row shading and associated shading losses during the lowest solar angle in the winter season

- Designing the layout to minimize cable runs and associated electrical losses and also occupy minimum land
- Creating access routes and sufficient space between rows to allow movement for maintenance purposes

Appendix 2 provides the layout drawing of the plant

Orientation

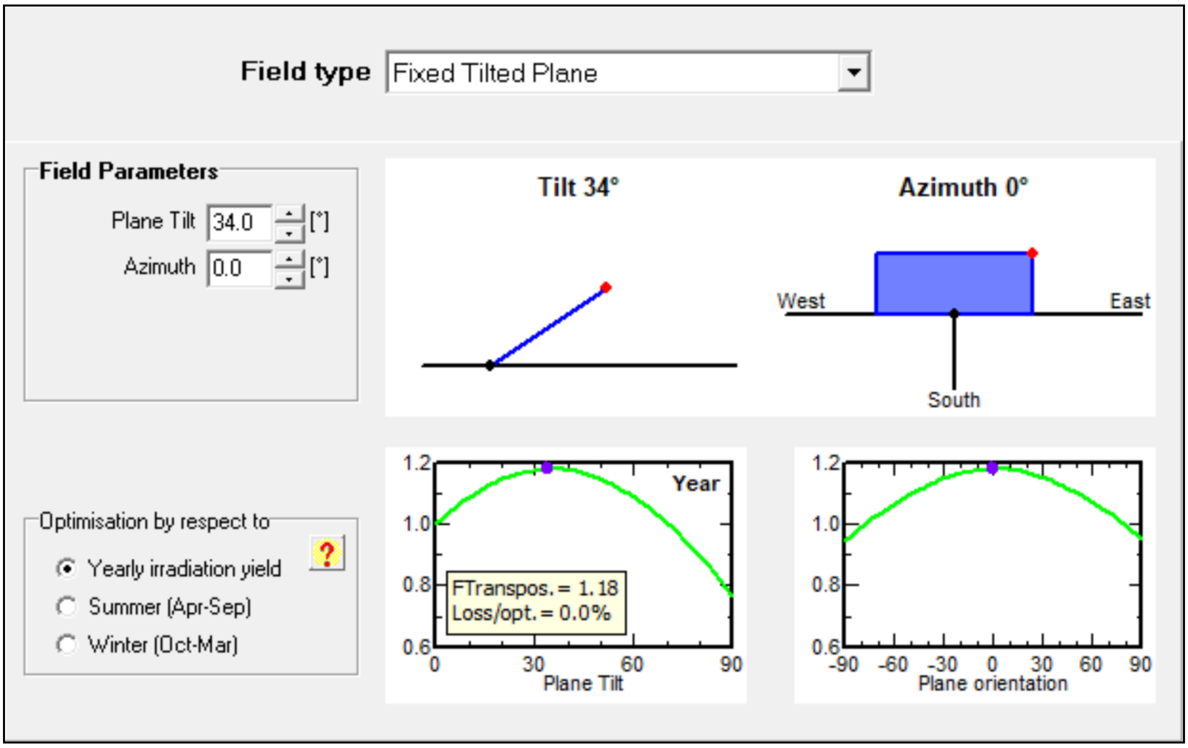
Afghanistan is situated in the northern hemisphere; the orientation that optimizes the total annual energy yield is true south. In this project production in the peak hours is not recommended so the orientation chosen for this site is true south.

Tilt angle

The optimal tilt angle that maximizes the total annual irradiation (averaged over the whole year) on the plane of the collector has been found using PVsyst simulation software. The system configuration is fixed tilt angle of 34^{0} for the whole year. Following consideration are taken while selecting the optimal tilt angle:

- Soiling: Higher tilt angles have lower soiling losses. The natural flow of rainwater cleans modules more effectively and snow slides off more easily at higher tilt angles.
- Shading: More highly tilted modules provide more shading on modules behind them.

Therefore, the tilt angle has been found through optimization by respect to maximizing yearly irradiance yield.



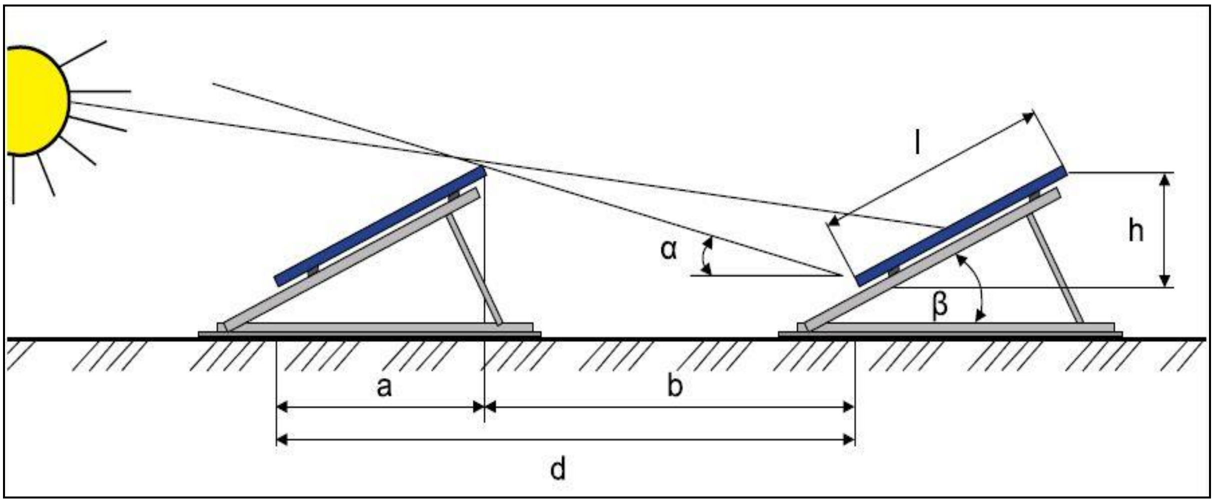
Module configuration

The module configurations having series and parallel combination has been selected to reduce the ohmic losses and the bypass effects. The details are provided in the Appendix 2.

Inter-row spacing

The choice of row spacing is made by making a compromise between reducing inter-row shading, keeping the area of the PV plant within reasonable limits, reducing cable runs and keeping ohmic losses within acceptable limits. Inter – row shading shouldn't be too short because at the beginning and end of the day, the shadow lengths are extremely long. A reasonable ground cover ratio has been utilized. Following formula has been used to calculate the inter-row spacing:

$$Row\ spacing = length\ of\ module * \sin(tilt\ angle) * \frac{\cos(azimuth\ angle)}{\tan(altitude\ angle\ at\ winter\ solstic)}$$

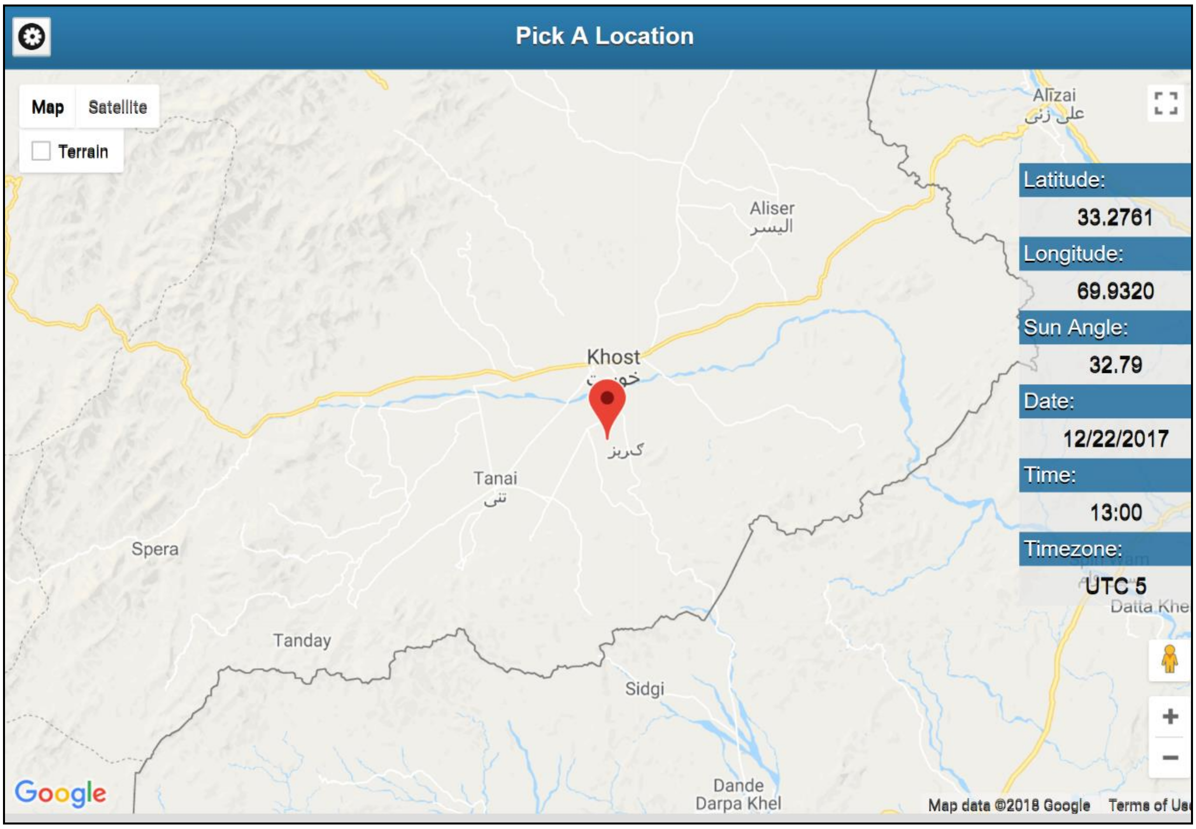


Where: α – Shading limit angle;

β – Tilt angle and

d – Row pitch

Inter-row spacing has taken into consideration the inter panel shading for December 22 at 1:00 PM. Following results were found and subsequently optimized for site conditions. Other constraints like the arrangement of the modules and the number of vertical modules in the support structure as well as the maintenance consideration have also been considered.



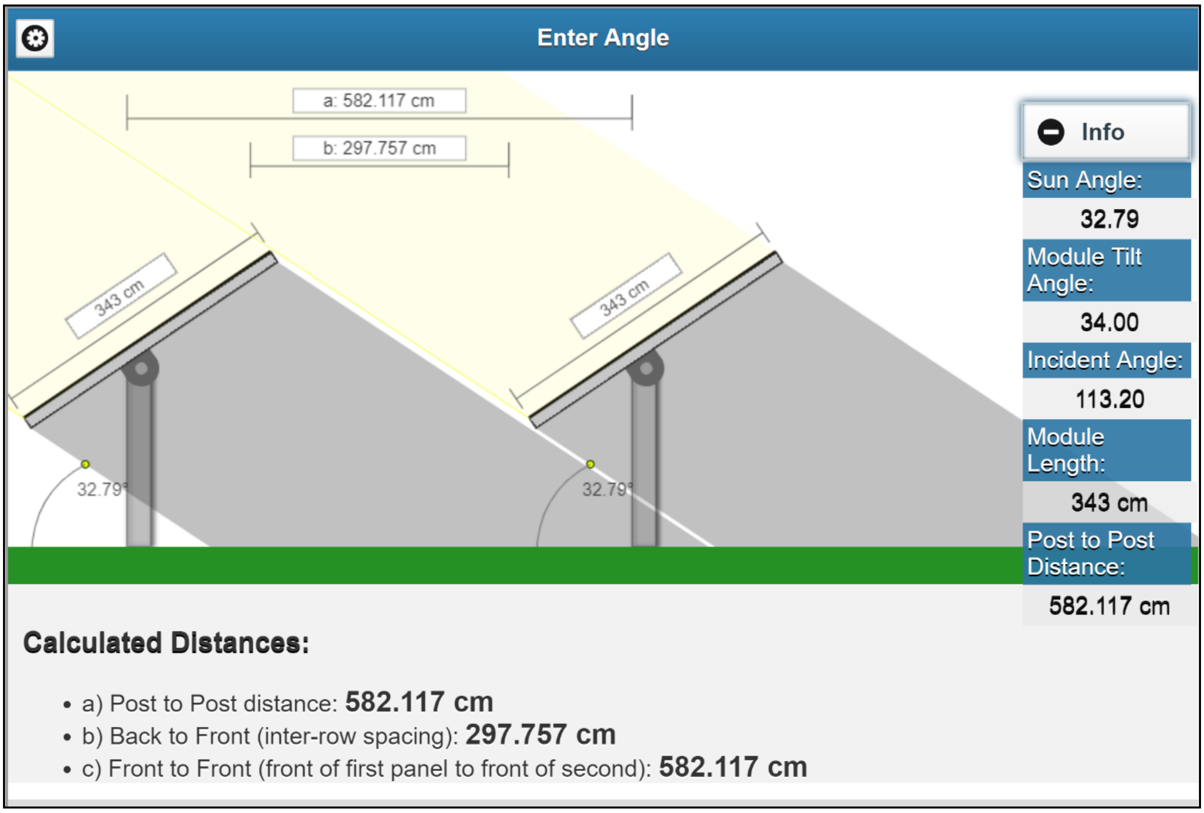


Figure 5 Estimates of Inter-row spacing

Cable runs and access routes

Minimizing cable runs and associated electrical losses will allow positioning (MV) transformer station close to the plant. However adequate space has been allocated to avoid the risk of the transformer station shading the PV modules near to it. The layout is chosen such that it allows adequate distance from the perimeter fence to prevent shading. It also incorporates access routes for maintenance staff and vehicles at appropriate intervals. Another precaution has been taken so that no loops were created in the cabling system layout.

Far shadings

Normally in a photovoltaic system the shading should be avoided because they cause loss of power and therefore loss in energy production. In this project, the far shading has been analyzed to be absent. The plant location is in plain agricultural landscape.

4.2 Array design

The array has been designed according to the system architecture and the inverter specifications. The design has made provision to increase voltage of arrays to the limit of safety requirements, inverter voltage limits and national regulations in order to reduce ohmic losses. Please see Appendix 2 for details.

Maximum number of modules in a string: Under no circumstances the voltage of the string crosses the maximum allowable inverter DC input because it will reduce the inverter operational lifetime. Therefore, the following condition is considered:

$$V_{OC(Module)@coldest\ module\ operating\ temperature} X n_{max} < V_{\max(inv,DC)}$$

Where:

$n_{max} = Maximum\ number\ of\ modules$

$V_{\max(inv,DC)} = Maximum\ inverter\ voltage\ at\ DC\ side$

Minimum number of modules in a string: Design ensures that the system voltage will remain within the MPP range of the inverter to prevent under performance of the system. Therefore, the following conditions is considered:

$$V_{MPP(Module)@highest\ module\ operating\ temperature} X n_{min} > V_{\mathrm{MPP}(inv\ min)}$$

Where:

$n_{min} = Minimum\ number\ of\ modules$

$V_{\min(inv\ min)} = MPP\ voltage\ of\ inverter$

Voltage optimization: The design has made an approach to maintain the inverter efficiency at its maximum point and keep the array operating voltage as close as possible to the inverter optimum voltage. Design has referred to the efficiency-voltage graph provided by the manufacturer of inverter. It has been observed that there will be substantial increase in energy yield when these two parameters match.

Number of strings: Design recommends string type inverters for the power plant, hence the maximum number of strings connected to a single inverter will be limited by its number of inputs and allowable current rating to prevent premature aging.

4.3 Estimation of energy production

The energy production from the solar PV system has been calculated on the basis of solar resource data derived from Meteonorm. The calculation of the energy production from the system takes into account the nominal solar PV power (1000 kW), angle of tilt and azimuth (34°, 0°) of PV module, losses on DC side (resistive losses, losses due to temperature, mismatch loss etc.), loss due to the inverter and other system components. The coefficient of reflectance of the ground in front of the modules (i.e. albedo) has been taken as 20%.

The annual horizontal radiation of 1943 kWh/m^2 has been used to estimate the annual radiation on the plane of module after deducting the soiling (3%) and the IAM factor losses (2.6%) and thus, the annual radiation on the plane of the module is 2132 kWh/m^2.

The energy produced by the system on an annual basis (Ep, y) is calculated as follows:

$$E_{p,y} = P_{nom} * I_{rr} * (1 - Losses) = 1{,}780{,}220\ kWh$$

Where:

- P_{nom} = Nominal power of system: 1000 kW
- I_{rr} = Annual irradiation on the surface of the modules: 2132 kWh/m^2
- Losses = Power losses: 16.50 %

The power losses are due to various factors. The table below lists down all the loss factors and their values for the calculation of energy production.

Table 10 Various type of losses in PV energy production

Loss due to temperature	7.40 %
Loss due to mismatch	1.10 %
Ohmic wiring loss	1.30 %
Loss due to DC/AC conversion	2.50 %
Other system losses	4.20 %
Loss due to shading	0.00 %
Total losses	**16.50 %**

The graph below shows the trend of monthly PV energy production expected during the year. The PVsyst simulation report have been provided in Appendix 3.

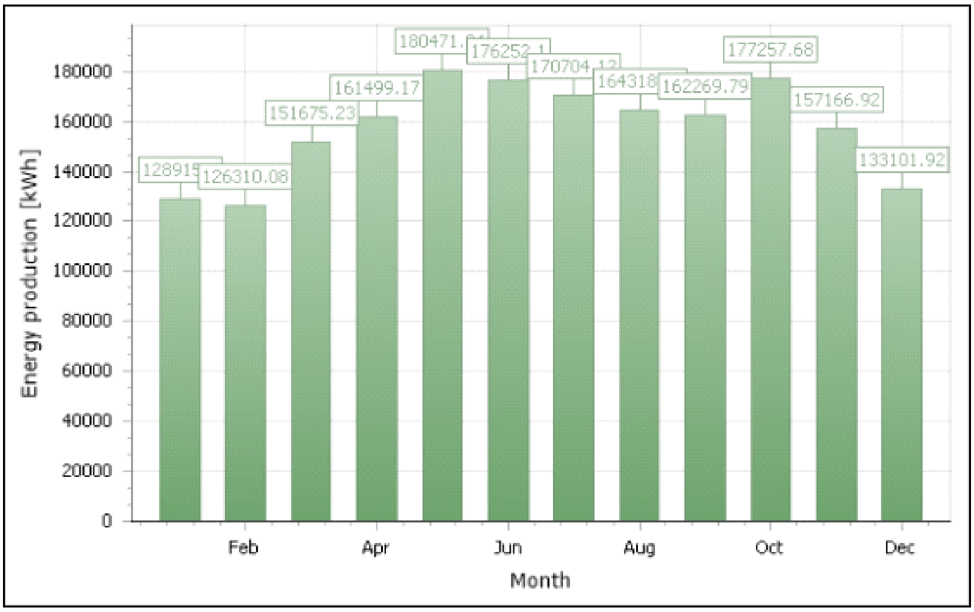


Figure 6 Monthly PV energy production

4.4 Land required by the power plant

The land required by various components of the power plant has been estimated and presented in the table below:

Table 11 Land required at the power plant

S. No.	Component of the power plant	Land required (Sq. m.)
1.	Solar PV system	17,000
2.	Outdoor substation	300
3.	Battery storage room	28
4.	Diesel generator room	14
5.	Control room	21
6.	Guard room and personnel room	49
7.	Warehouse	50
8.	Water well house	15
9.	Parking area	240
10.	Spare area	300

4.5 Solar PV system

The characteristics of solar PV system are given below.

Table 12 Electrical characteristics of the photovoltaic power plant

Nominal power	1,000 kWp
Number of PV modules	4,000
Intercepting surface	5,520 m^2
Number of strings	250
Maximum voltage @STC (Voc)	654.4 V

Voltage at maximum power @STC (Vmpp)	532.8 V
Short circuit current @STC (Isc)	81.4 A
Current at maximum power @STC (Impp)	75.2 A

The photovoltaic generator having nominal power of 1,000 kW uses the series-parallel configuration and is divided into 250 strings of modules connected in series. The following lists the compositions of the strings of the system.

Table 13 Electrical characteristics of the strings

Number of PV modules in series	16
Nominal power	4 kW
Open circuit voltage (Voc)	654.4 V
Short circuit current (Isc)	8.14 A
Current at maximum power (Impp)	7.52 A

4.5.1 Junction boxes

Junction boxes are secured in the PV module support structure at the point where the individual modules forming a substring are connected in parallel before leaving for the inverter through the main DC cable. Junction boxes are provided with screw terminals and are of high quality to ensure lower losses and prevent overheating.

Junction boxes have protective and isolation equipment, such as string fuses, and are rated for outdoor placement using IP65. For safety reasons all junction boxes are correctly labelled. Disconnects and string fuses are provided to allow isolation and protection.

4.5.2 Electrical DC panels

The photovoltaic system consists of 25 electrical DC panels and features of the electrical DC panels in the system are listed below

Table 14 Characteristics of electrical DC panel

Number of inputs	10
Max current for each input	8.14 A
Max input voltage	1000.00 V
Max output current	81.4 A
Input device	As an example, ABB S804PV-S10 or equivalent
Nominal current of the input device	10.00 A
Protection	Yes
Nominal current protection	100.0 A
Blocking diode	Shall be integrated in the PV module
Nominal current of the blocking diode	120.0 A
Output device	As an example, Socomec Sirco MV PV 4P 22PV 4108 or equivalent
Nominal current of the output device	80.00 A
Discharger	As an example, ABB OVR PV 40 1000 P or equivalent
Category of discharger	II
Discharger voltage	1,000.00 V

4.6 Inverters

The conversion group of the photovoltaic system will consist of 25 high efficiency string type inverters of 40 kW each (three-phase) with a total output of about 1000 kW. The optimum inverter to array power is unity.

The inverters have 3 MPPT inputs and MPP range that includes PV array MPP points at different temperatures. The inverters are multi string type with bypass diodes, having capability of connecting to three strings from each MPPT input. Inverters have the capability to control the reactive power. Anti-islanding protection is integrated into the inverters as well. The following figure outlines the system further.

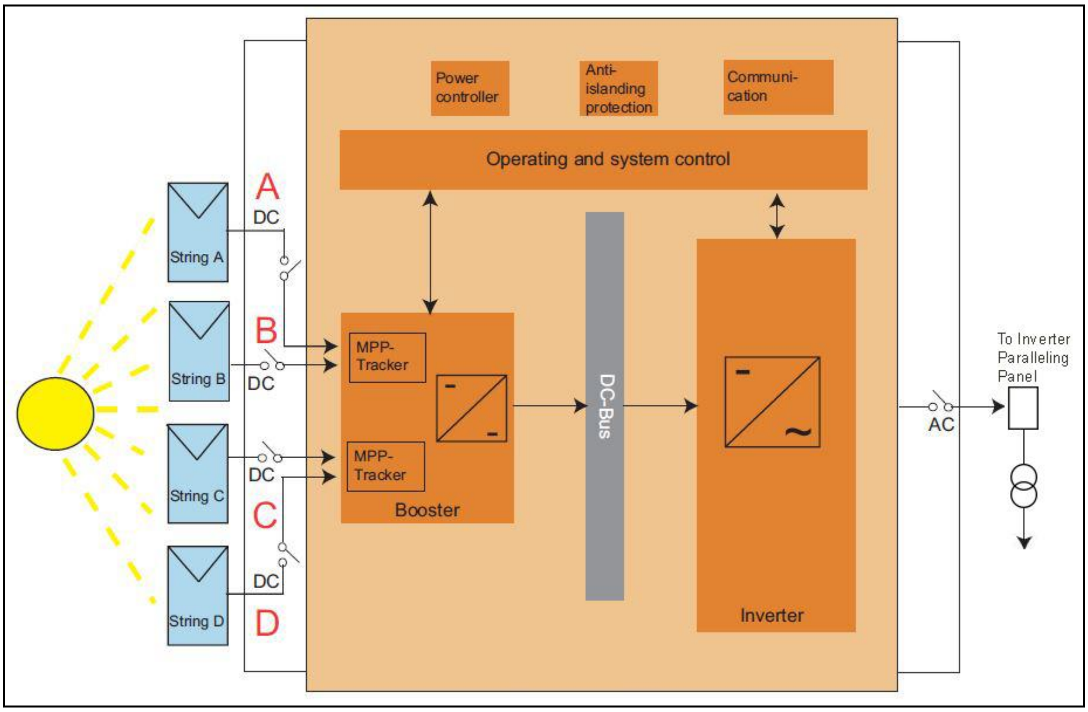


Figure 7 Inverter system architecture

Local conditions and the system components have been considered to tailor the inverter system for hybrid solar PV system. Care is taken in the integration of modules and inverters to ensure optimum performance and lifetime.

Control of operation of inverters are done individually and in groups by the central control system called Energy management system (EMS). The inverters have pre-installed easylink software system which supports data communication via TCP/IP, USB, RS485 and ModBus which is used by the EMS system for individual and parallel operation.

Concrete slabs with appropriate pergolas to protect the inverters from direct sun light, are considered. Cables from the strings to the inverter and from inverter to the transformer is laid out in a neat manner to match the code requirements. Inverter protection include:

- Protection against incorrect polarity for the DC cable
- Over-voltage and overload protection
- Islanding detection as it is grid connected system
- Insulation monitoring

4.6.1 Verification of compatibility between DC and AC components

The inverter and solar PV characteristics have been used to verify the compatibility between the design. The following verifications have been carried out:

- Verification of DC voltage
- Verification of DC current
- Verification of Power

Verification of DC voltage

The verification of the DC voltage includes checking that the set of voltages supplied by the photovoltaic field is compatible with the range of the input voltage of the inverter.

In other words, it is necessary to calculate the minimum and maximum voltage of the photovoltaic field and verify that the first is greater than the minimum input voltage acceptable for the inverter, and the second is less than the maximum input voltage allowed by the inverter.

Verification of DC current

The verification of the DC current is to check that the short circuit current of the PV field @ STC is less than the maximum permissible input current of the inverter.

Verification of power

The verification on the power of is to check the nominal power of conversion group DC / AC (sum of nominal power of the inverter) is more than 80.00% and less than 120.00% of the nominal power of the photovoltaic system (sum of nominal power modules photovoltaic).

The following tables show the result of these verifications.

Table 15 Results of verification on inverter and solar PV array compatibility

Voltage limits	Minimum voltage at module temperature of 66.9°C (436.83 V) > Minimum MPPT voltage (380 V)
	Maximum voltage at module temperature of -2.72°C (596.29 V) < Maximum voltage of MPPT (1000 V)
	Open circuit voltage at module temperature of -2.72°C (717.89 V) < Maximum inverter voltage (1000 V)
Limits on current	Short circuit current (81.4 A) < Maximum inverter current (108 A)
Power limits	Sizing factor on power (80 %) < (100%) < (120 %)

Since same inverter type and same array size have been recommended in the project design therefore the above verification tests hold good for each of the 25 inverters.

4.7 Battery storage

The whole system is configured with 4032 kWh battery backup and 2 bidirectional inverters. The working principle is indicated as below:

Each group of batteries will be connected in series to 600 V DC. The total capacity of battery storage is 5040 kWh. In order to protect the batteries from fully discharging, 80% depth of discharge has been considered and the BMS will ensure that this limit will never crosses. There will two groups of batteries and each group shall supply a maximum of 2016 kWh. This energy is the useful energy which will be available for utilization in the project area.

4.7.1 DC distribution

Two groups of the batteries will be connected with one DC distribution cabinet, and then will be collected in the mother line of DC distribution cabinet.

The inverter of the batteries has duplex operation, that is, charge the battery in AC/DC, discharge the battery in DC/AC and supply electricity to the grid. The whole system is configured with 2 battery inverters.

Both inverters of the battery are equipped with one two-winding step up transformer to increase voltage from 600 V (AC) to 20 kV, which then will be collected to the mother line of 20 kV transmission line.

The communication mode: inverters will collect the data of the battery, such as the charge & discharge, voltage, current, temperature, voltage of the grid, frequency, etc., and feed to the central control room by inlet of RS485.

4.8 Diesel generator

The 330-kW diesel generator (DG) will be applied as either back-up power or supplementary power. One unit of DG will be either accessed to the grid individually or jointly. DG is equipped with one cabinet to adjust the parameters of voltage and frequency in order to synchronize the DG with other systems. The DG is also equipped with one outlet cabinet. The DG system is equipped with a cabinet to collect data from the grid and control the parameters. The output of 400V/50 Hz from DG will be stepped up to 20 kV by step-up transformer and then fed into the grid. The control appliances of the cabinets can be accessed by the computer through the means of RS485 protocol.

The computer software will enable the operator to monitor the operation data of DG, such as, the temperature of oil, voltage, current, frequency of DG. All data and its systems will be integrated into the overall SCADA system.

4.9 Cable system

Cabling system is one of the important parts of the solar farm electrical system. Selection and sizing of all cables have been done based on national and international codes[2]. The following criteria have been considered while selecting and designing the cables:

Cable voltage rating: The voltage limits of the cable to which the PV string or array cable will be connected has been taken into account. The value of maximum V_{OC} voltage of the modules adjusted for the site minimum design temperature have been used for the calculation.

Current carrying capacity of the cable: The cable has been sized according to the maximum current carrying capacity of the cable. Derating of cable have been applied appropriately, taking into account the location of the cable, the method of laying, number of cores and temperature. Care has been taken to size the cable for the worst case of reverse current in an array.

Minimization of cable losses: Cable design has been carried out such that the cable voltage drop and the associated power losses will be as low as possible. Normally, the voltage drop and the cable power losses must be less than 3 percent and 1 percent respectively. In the cable design, the minimization of voltage drops and associated power losses has been the limiting factor in most cases.

4.9.1 Verification of calculations for the cable selection and sizing

All of the above calculations are carried out with the help of modern computerized tools and technique and the design of each segment of the cable has been verified through in-built capability of the computer software. An explanation of the process has been provided below. The sizing of the electric cables involves the following calculations:

- Calculation of the voltage drop
- De-rating factors applied
- Current carrying capacity and short circuit withstand capabilities are checked

<u>Calculation of the voltage drop</u>

By knowing the length of the cable, type of the cable and the maximum DC current flowing through it, the percentage voltage drops in the cable with DC current has been obtained with the help of following formula:

$$\Delta V_{\%} = 2 \cdot \frac{R}{V_{nom}} \cdot I_{nom} \cdot \frac{L}{1000}$$

where:

[2] List of standards have been provided in section 9

L	is the length of the pipeline in meters
Inom	is the current in the cable @STC
Vnom	is the voltage on the cable @STC
R	is the resistance per km of cable at a temperature of 80 °C

For the cable with AC current, using the length of cable, type of cable and the maximum AC current flowing through it, the percentage voltage drop has been obtained with the help of following formula:

For a single-phase line:

$$\Delta V_{\%} = 2 \cdot \frac{\sqrt{R^2 + X^2}}{V_{AC}} \cdot I_{nom} \cdot \frac{L}{1000}$$

For a three-phase line:

$$\Delta V_{\%} = 1{,}73 \cdot \frac{\sqrt{R^2 + X^2}}{V_{AC}} \cdot I_{nom} \cdot \frac{L}{1000}$$

where:

L	is the length of the pipeline in meters
Inom	is the current in the cable @STC
VAC	is the voltage of Grid
R, X	are the resistance and reactance of the line per km, at a temperature of 80 °C

The following tables show the list of cables used in the system. The details of cable analysis have been provided as Appendix 4.

Table 16 List of cables & analysis

Label	Length (m)	Quantity (m)	Cross section (mm^2)	Voltage drop (%)	Power loss (W)
C1	25	50.00	70.00	1.48	5,659.75
C2	150	150.00	50.00	1.02	292.51
C3	20	40.00	10.00	1.26	506.69
C4	12	24.00	4.00	0.19	7.56
C5	14.4	14.40	4.00	0.23	9.07
C6	12	24.00	4.00	0.19	7.56
C7	14.4	14.40	4.00	0.23	9.07
C8	12	24.00	4.00	0.19	7.56
C9	14.4	14.40	4.00	0.23	9.07
C10	12	24.00	4.00	0.19	7.56
C11	14.4	14.40	4.00	0.23	9.07
C12	12	24.00	4.00	0.19	7.56
C13	14.4	14.40	4.00	0.23	9.07
C14	12	24.00	4.00	0.19	7.56

C15	14.4	14.40	4.00	0.23	9.07
C16	12	24.00	4.00	0.19	7.56
C17	14.4	14.40	4.00	0.23	9.07
C18	12	24.00	4.00	0.19	7.56
C19	14.4	14.40	4.00	0.23	9.07
C20	12	24.00	4.00	0.19	7.56
C21	14.4	14.40	4.00	0.23	9.07
C22	12	24.00	4.00	0.19	7.56
C23	14.4	14.40	4.00	0.23	9.07
C24	150	150.00	50.00	1.02	292.51

4.9.2 Cable management

Over-ground cables such as module cables and string cables are properly routed and secured to the mounting structure, either using dedicated cable trays or cable ties as appropriate. Cables are protected from direct sunshine, standing water and abrasion by the sharp edges of support structures. They are kept as short as possible. Underground cables are laid out inside the conduits.

Standard plug cable connectors used in PV power plants have been recommended because they offer benefits such as ease and speed in installation. Also, these connectors are normally touch-proof, which means they can be touched by human hand without any risk of electric shock.

Design has made sure that the laying of main DC cables in trenches should follow national and international codes and take into account specific ground conditions. All DC solar cables should conform to the IEC 60332-1-2 for fire protection performance and halogen free material must be used for the cable insulators.

4.9.3 Module and string cables

Single-conductor with double-insulation cables has been recommended for module connections. This type of cables protects against short circuits. When sizing string cables, the number of modules and the number of strings per array have been considered. The number of modules defines the voltage at which the cable should be rated. The number of strings is used to calculate the maximum reverse current that can flow through a string.

The cables are rated to the highest temperature that could be experienced. Appropriate de-rating factors for temperature, installation method and cable configuration have been applied. All cables have been rated for 0.6/1.0 kV.

4.9.4 Main DC cable

In order to reduce losses in the cable, the overall voltage drop between the PV array and the inverter have been minimized. A benchmark voltage drops of less than 1.5% have been used to size the cables. Over-sizing of cables to achieve lower power losses is a worthwhile investment. All cables are certified.

4.9.5 AC cabling

Cabling for AC systems has been designed to provide safe and cost-effective means of transmitting power from the inverters to the transformers and further to the grid. The same principles have also been used for DG system cabling. Cables are rated for the voltage and the conductors have been sized taking into account the operating currents and short-circuit currents (I_{SC}). Following design considerations have been taken into account while designing the DC cabling:

- Cable are rated for the maximum expected voltage
- Conductors are able to pass the operating current and I_{SC} safely for the set time until the breaker trips
- Conductor are sized appropriately to ensure that losses produced by the cable are within acceptable limits, and that the most economic balance is maintained between capital cost and operational cost
- Conductors are sized to avoid voltage drop outside statutory limits
- Insulation is adequate for the environment of installation (Underground trench)
- Earthing and bonding are suitably designed for the project application using computer simulation
- Installation methods and mechanical protection of the cable are suitably designed for the project

AC Cables for the solar PV power plant comply with relevant IEC standards and appropriate national standards, as follows:

- IEC 60502 for 20 kV cables
- IEC 60364 for LV cabling

4.9.6 Connectors

Specialized plug and socket connections of type MC4 have been considered to facilitate secure and touch-proof connections. Connectors are correctly rated and used for DC applications. For example, the connector current and voltage ratings are at least equal to those of the circuit they are installed on. Connectors should carry appropriate safety signs that warn against disconnection under load.

4.10 String fuses / Miniature Circuit Breakers (MCBs)

String fuses and miniature circuit breakers (MCBs) have been designed for over-current protection. They are rated for DC operation. National codes and regulations have been referred while selecting and sizing fuses and MCBs. Additionally, following points have been considered:

- All arrays formed of 10 strings will be equipped with breakers. Alternatively, breakers are used where fault conditions could lead to significant reverse currents. Breakers/switches are installed on all unearthed cables
- To avoid nuisance tripping, the nominal current of the breaker are at least 1.25 times greater than the nominal string current. Also, to avoid overheating of breakers, junction boxes are placed within the shade of support structures

- Criteria for tripping: the string fuse/MCB will trip at less than twice the strings short-circuit current (I_{SC}) at STC or at less than the string cable current carrying capability, whichever is the lower value
- Trigger current of fuse/MCB has been taken into account while sizing string cables. The design has made sure that the trigger current is not more than the current at which the string cable is rated
- The string fuse/MCB are rated for operation at the string voltage. The following formula is used to guide string fuse rating:

  $$String\ Fuse\ Voltage\ Rating = V_{OC(STC)}\ x\ M\ x\ 1.15$$

  Where, M is the number of modules in each string

4.11 DC switching

Switches are installed in the DC section of the solar PV plant to provide protection and isolation capabilities. DC switches/disconnects to be installed in the junction boxes will have the following design considerations:

- Double-pole to isolate both the positive and negative PV array cables
- Rated for DC operation
- Capable of breaking under full load
- Rated for the system voltage and maximum current expected
- Equipped with safety signs

4.12 Switchgears

Appropriately rated switchgear and protection systems are included to provide disconnection, isolation, earthing and protection. A switch disconnector will be provided on the output side of the inverters to isolate the PV array. The type of switchgear is compliant with the voltage of operation. Switchgear is metal-clad internally with air insulated bus bars and vacuum. The type of switchgear is outdoor installation type.

Switchgears are:

- compliant with relevant IEC standards and national codes
- designed to show the ON and OFF positions with appropriate labels
- provided with the option to be secured by locks in off/earth positions
- rated for operational and short-circuit currents
- rated for the correct operational voltage
- provided with suitable earthing

4.13 Transformers

Hermetically sealed step up transformers have been chosen with appropriate tap optimization to connect the whole PV system to the 20-kV side of the substation for power injection. PV system will be connected to the electrical grid separately to increase reliability and to provide galvanic isolation.

The transformer will be compliant to the national and international standards including IEC 60076. The following design criteria have been taken into account:

- Losses: In order to enhance the energy yield of the whole PV system, transformers with minimum iron and winding losses have been chosen. It will have a positive long-term impact on the performance
- Test Requirements: Transformers that are compliant with routine and type tests set out in IEC 60076 have been chosen. The manufacturers of transformer have been consulted for detail on such tests

Transformers are selected considering the minimum total cost of ownership (TCO), and high efficiency. Several other factors such as power rating, construction, site conditions, reliability, maintainability, serviceability and sound power have been considered during the design. All these factors have been used in a computer simulation to determine the optimal transformer option. Additionally, the following technical and financial criteria were consulted with the suppliers: efficiency, load/no-load losses, guarantee, vector group, system voltage, power rating, site conditions, sound power, voltage control capability and duty cycle

The location of transformer has been chosen in order to meet the following criteria: ease in maintenance, safe installation, replacement of spare parts and the transformer. As the transformers are oil immersed and have leakage risk, therefore, bunds have been provided to catch any oil leakage.

The detailed dimensions, drawings, specifications are not fixed at this stage, and as such the same shall be provided by the contractor at the bidding stage. The detailed technical specifications for step-up transformer

- The transformer shall be hermetically sealed, double winding, three phases, oil immersed, 50 Hz and shall have off-circuit tapping mounted in the primary winding. The type of cooling shall be oil natural air natural (ONAN)
- The transformer shall be capable of supplying its rated power being the product of rated voltage and rated current on the line side winding (at center tap) expressed in kVA, as defined in IEC 60076-1
- The transformers shall also be capable of delivering rated current at an applied voltage equal to 105% of the rated voltage
- The transformer shall be capable of supplying its rated power continuously under ambient temperature conditions without the temperature rise of the top oil exceeding 50ºC and without the temperature rise of the windings as measured by resistance exceeding 55ºC
- The Contractor / Manufacturer shall include calculations demonstrating that these requirements are met. These calculations shall disregard the effect of winding thermal capacity
- A guarantee must be given that the transformer losses to be indicated in the technical data sheets are not exceeded
- The transformer shall be filled to the required level with new, unused, clean, standard mineral oil in compliance with IEC 60296 and shall be free from all traces of polychlorinated biphenyl (PCB) compounds

4.14 Control and protection

4.14.1 Earthing and surge protection

A grounding grid system has been designed to protect against electric shock, fire hazard and lightning. This system will also make sure that the step and touches voltages are not crossing the allowed limits by standards. The system will prevent charge accumulation during storms and any other malfunctions. The IEC 60364-7 standard recommends that the whole installation on the DC side (switchboards, cables and terminal boards) is erected by use of class II devices or equivalent insulation. However, to make the insulation controller of the inverter operates properly and monitors the PV generator, it is necessary that the frames and/or the supporting structures of the modules (even if class II) are earthed.

For surge protection device (SPDs) and Enclosures, IEC 60364-5-534 and IEC 60439-1 have been referred respectively for the design.

The earth system for the project will encompass the following:

- Array frame earthing
- System earthing (DC conductor earthing)
- Inverter earthing
- Lightning arrestors and surge protection devices
- Fence and the transformer earthing
- Appropriate SPDs will be installed on appropriate parts to protect the system

Earth pits with 5-meter depth and appropriate material as solvents are needed for the project site to provide proper earth arrangements. The objective is to reduce the electric shock risk to people on site and the risk of damage and fire during a fault or lightning strike. The entire solar PV power plant along with the foundation and the electrical room will be protected from lightning. Air terminals that are capable of handling multiple strikes of lightning current and are maintenance-free have been suggested for protection against lightning. These air terminals will be connected to respective earthing stations. By doing this an earthing grid will be formed connecting all the earthing stations through the required galvanized iron tapes. Following factors have been considered in the design:

- National electricity requirements (consulted with DABS)
- Installation guidelines for module (consulted with manufacturer)
- Mounting system requirements
- Inverter requirements (consulted with the inverter manufacturer)
- Lightning risk

Using the IEEE method for earthing design, following additional safety steps have been taken:

- Ground rods are placed close to junction boxes. Ground electrodes will be connected between the ground rod and the ground lug in the junction box
- A continuous earth path is maintained throughout the PV array
- Cable runs are kept as short as possible
- Surge protection devices are installed at the inverter end of the DC cable and at the array junction boxes

- Surge protection devices are installed at the strategic points of the plant

Please see Appendix 1 to view the grounding grid details.

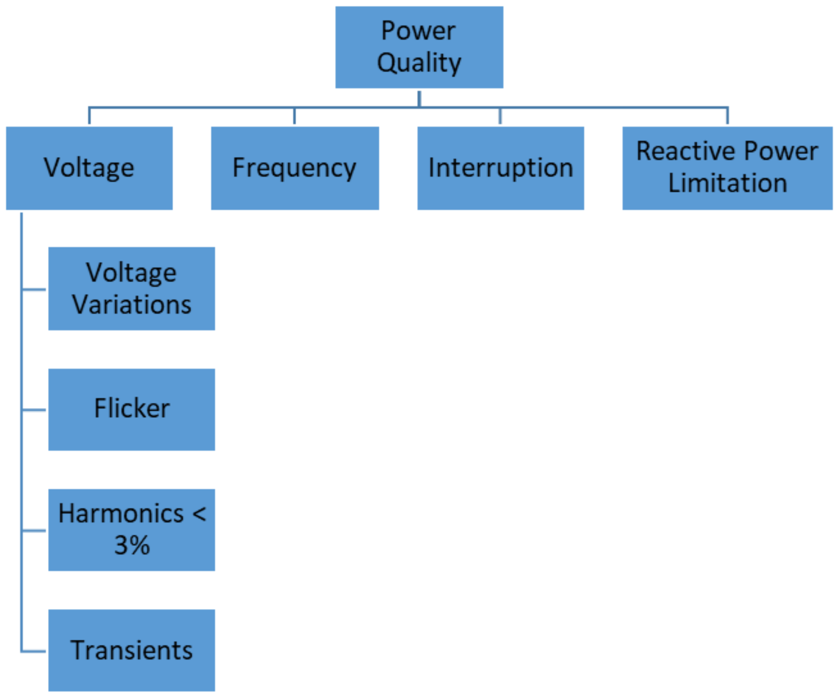
4.15 Grid connection

It is possible that this system will be connected to the national electricity grid in the future, that is why the design has selected components with maximum connection safety and suitability with Afghanistan standards. The system meets the following criteria for grid connection:

- Limits on harmonic emission: This parameter must be less than 3% and care has been taken to provide an inverter with the mentioned quality
- Limits on voltage flicker
- Limits on frequency variation
- Reactive power export requirements
- Voltage regulation
- Fault level requirements
- System protection

Connection voltage has been chosen as per DABS standards that is 20 kV for MV and 400/230 V for LV three and single phase accordingly.

Furthermore, quality requirements have been assessed as shown in the following diagram:



5 CIVIL STRUCTURES

The civil structure design specifications have been presented in this chapter.

5.1 Module support structure

The support structure for the solar PV array is proposed to be ground mount fixed type. All the module structure shall be installed in such a way that it utilizes optimum land surface and there must not be shadow on the solar array during day time. The structure shall meet minimum of following technical standards and specifications.

- The solar PV module structure shall be made of either Mild Steel (MS) angle or other industry standard materials
- All the metal items of array framing that are going to be used outdoor are hot deep galvanized of at least 70 microns
- The minimum clearance between the lower edge of the PV panel and the ground level shall be 700 mm
- Foundation type is pile foundation driven into ground. A ramming test will need to be done by the contractor before starting the works. These foundation posts are made of hot-dip galvanized steel
- The Structure design are appropriate with a safety factor of not less than 2
- The mounting structure is designed for minimum 25 years of life
- The structure allows easy replacement of any modules and easy access to the O&M staff and personal and protection
- The structure supports the solar PV modules at an orientation of 34°, absorb and transfer the mechanical loads to the ground properly
- The array structure is designed to withstand a maximum wind speed of 130 KMPH and withstand 5400 Pascal of snow load
- Nuts and bolts, supporting structures including the module mounting structures have been adequately protected with anti-corrosive paints of sufficient thickness
- All structures will be grounded, and the junction boxes will have IP 65 protection with water resistant cables.
- Civil work for foundations for module mounting structure shall commence only after proper leveling of the site. Hammering test and foundation piling is required before installation
- The contractor/manufacturer shall specify construction details of the solar PV modules and the support structures with appropriate drawings

The figure below illustrates the module structure arrangement and Appendix 2 presents the design drawing.

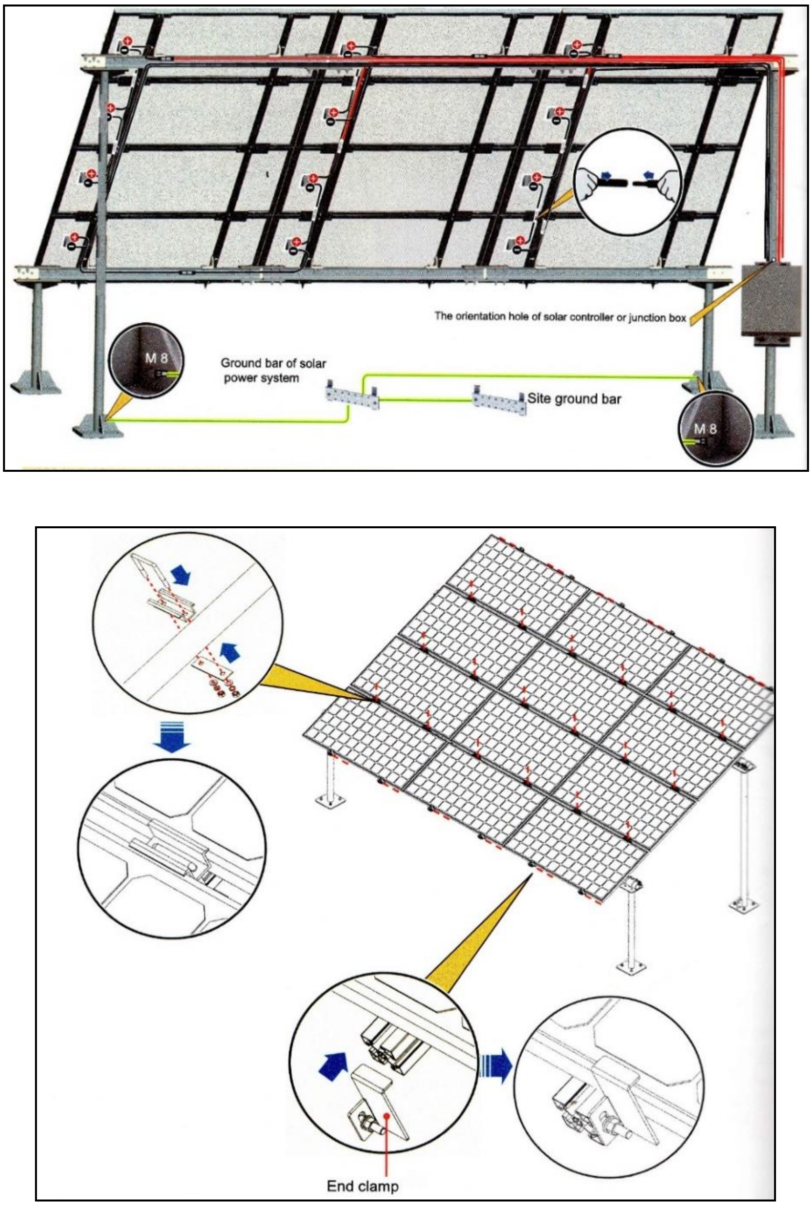


Figure 8 Module structure arrangement

5.2 Infrastructure Requirement

5.2.1 Site levelling & grading

All works related to site clearance including removal of bushes, trees, levelling, grading, finishing and other additional work shall be done by the Contractor. The site grading plan has been provided in the drawing (Appendix 5) for reference. Around 10,000 square meters of land is expected to be excavated & levelled in order to provide a suitable land for installation. The Contractor is expected to submit the complete site levelling & grading plan before construction. Site grading level shall be fixed with due reference to site drainage of the whole area, existing drainage pattern and maximum flood level. All buildings and substation area shall be constructed in levelled area.

5.2.2 Building infrastructure

The requirement for building infrastructures have been indicated in Appendix 2. The powerplant building and the warehouse building are single storey buildings and shall be constructed at the location identified in the site drawing. The powerplant building will house control room, meeting room and others including washroom & kitchen. Both buildings shall be constructed with stone masonry and RCC columns and shall be provided with windows and ventilators on each of the four sides and tiled angled roof. Walls of the building shall be made of stone masonry with reinforced cement concrete (RCC) columns.

The buildings have been located at a position to avoid any shadow on the panels. The powerhouse must be weather resistant to local climatic conditions at the project site for a minimum period of 25 years and shall withstand wind load of 50 m/s. The civil construction of the building shall follow Afghanistan National Construction Codes or other well recognized international standards such ASTM.

The Contractor shall provide the construction designs of the powerhouse building to the Engineer for approval before construction after all equipment have been selected. The contractor may suggest changes in the power plant buildings dimensions based on the equipment proposed by the contractor and seek approval of the Employer's Engineer before proceeding.

Space for parking area and road network has been considered in the overall design of the PV power plant. The approach road shall originate from the main approach road and connect to all inverter room and powerplant building. The Contractor is expected to supply and construct the access road as per Afghanistan National Construction Codes / ASTM / ISO or other well recognized international standards. The methodology of road construction with material specifications shall be in line with the above-mentioned standards and shall be submitted to the Engineer for approval before construction.

Electrification of building

Electrification of all buildings shall be carried out as per National Electric Code (NEC) / IEC standards / IS 732-1989 / IS: 4648-1968 or other well recognized international standards. Reference technical details and installation plan have been provided in Appendix 2 'Power plant building design'. The contractor may suggest changes in the power plant buildings electrification plan based on the equipment proposed by the contractor and seek approval of the Employer's Engineer before proceeding.

Lighting inside the building

The powerplant lighting arrangements shall conform to National Electric Code (NEC) / IEC standards or other well recognized international standards for illumination. It shall have concealed wiring to maintain safety and for aesthetic purposes. The Contractor shall calculate the illumination level for power house lighting system and submit the construction designs of the lighting system to the Employer/Engineer for approval. Each room shall be constructed such that to utilize maximum natural light during the day. The electric light shall be supplied & installed to achieve average illumination level as per the standard mentioned above. The technical details and installation plan has been provided in Appendix 2 'Power plant building design'.

Drainage

For proper drainage of water during rainy season as well as those collected after cleaning of modules, an appropriate drainage system shall be provided at the project site with the help of 60 cm by 80 cm ditch with a slope of 1% to carry the water collected out of the power plant area. The drains shall be rectangular section lined with concrete slabs / brick masonry / stone masonry / stone slabs. Detailed drawing has been provided in Appendix 5.

The Contractor shall ensure during construction that no water ponding and flooding occurs in the low-lying areas. All buildings shall be provided with plinth protection all around, sloped towards side drains.

The Contractor is expected to provide the construction designs of the drainage system to the Engineer for approval before construction.

Well house and clean water supply

A water well house has been considered for the project which will provide clean water for the powerplant building as well as for cleaning of the solar panels. The system shall include a water pump of appropriate rating to draw water up from the groundwater and store it in the water tank of appropriate size.

The water supply pipes shall run close to the solar arrays and carry water from the tank. A suitable nozzle with extendable pipes provided near each array shall be manually pulled during cleaning process to spray water on the panels. Wipers will be used to remove the water from the surface. The minimum size & requirements of the wellhouse shall be as per the detailed drawing presented in Appendix 6.

GI pipes of medium quality conforming to IS 1239 (Part I-1990) or other well recognized national/international standard shall be used for all water supply and plumbing works.

Water storage tank conforming to IS:12701 or other well recognized national/international standard shall be provided at the wellhouse area with adequate capacity complete with all fittings including float valve, stop cock, etc.

Construction of deep bore well and supply, installation of pipes, submersible pumping set including all mechanical & electrical accessories, fittings etc. shall be completed by the Contractor at the site for solar module cleaning and water supply to buildings. All plumbing works shall be done as per Uniform Plumbing Code (UPC) / International Plumbing code (IPC) or other well recognized international standards.

Sewage water from the powerplant building is proposed to be collected in a gravity septic tank. Provisions must be taken to empty the tank when necessary. The Contractor is expected to construct the gravity septic tank for removal of sewage water from the building at least 20 meters away from the building.

5.2.3 Battery storage room/container

The batteries will be installed in a 40 feet container which will be equipped with 30 cabinets of batteries. Cooling, ventilation and environment monitoring system shall be in place and operated by a UPS system. Cooling and ventilation inside the container shall be as per ASHRAE (American Society of Heating, Refrigeration and Air Conditioning Engineers) or other well recognized international standards or codes.

5.2.4 Perimeter fence and gate

Perimeter fencing has been provided around the whole power plant area. The galvanized steel wire mesh fences shall be provided with anti-climbing devices positioned on the top. The wire mesh fencing material shall conform to relevant national or international standards. Suitable foundation shall be made in the fencing arrangement to ensure intact fencing / safety. The fence will act as a safety mean for public. Measures have been taken to allow small animals to pass underneath the fence. The minimum size & requirements of the fencing has been provided in the detailed design drawing presented in Appendix 7.

A double swing gate for vehicles and a personnel gate have been designed for the site to facilitate easy and controlled access. The gate with all fittings and fixtures shall be complete. The minimum size & requirements of the gate has been provided in the detailed design drawing presented in Appendix 7.

The Contractor is expected to supply and construct the perimeter fence and gates as per relevant national / international standards. The Contractor shall submit the construction designs to the Employer’s Engineer for approval.

5.2.5 Firefighting system

The solar PV plant shall be equipped with suitable fire protection & firefighting systems for protection of entire equipment switchyard & control room as per ASTM (American Society for Testing and Materials) / NEC / National Fire codes of National Fire Protection Association (AFPA) or other well recognized international standards. The firefighting system for the proposed plant shall be consisting of

(i) Sand buckets,

(ii) portable fire extinguishers and

(iii) microprocessor-based fire alarm panel

5.2.6 Security measures

A complete CCTV solution with total IP system to cover the entire fence perimeter has been considered in the design. The system should provide automated entrance protection, perimeter protection and take action based on events. Security cameras with IR and day/night capabilities will be used to watch 24/7 the whole plant without any blind point.

Cameras should have strong zooming capabilities and are easy to monitor remotely. CCTV system will have pan/tilt support for external users to be able to identify sources of intrusion with more ease. Day/night cameras typically of range 50m to 100m and are coupled with infrared illuminators have been considered.

Appropriate motion sensors and other sensors have been incorporated in the CCTV system to detect intrusion and unauthorized access. Care is taken that the chosen system is not triggered by small animals.

CCTV system is chosen such that it can transmit data via communication means to an alarm center in the local control room or any other remote location using internet.

Other security measures that has been consider are

- Reducing the visibility of the power plant by planting shrubs or trees at appropriate locations. Care is taken that these do not shade the PV modules
- Anti-theft module mounting bolts are used

5.2.7 Outdoor lighting at power plant

Standard poles with lamps & fixtures will be used for outdoor lighting at the project site to provide adequate visibility. LED lights have been proposed to be installed. The lighting system can be controlled automatically and manually. These poles have been also used for installing lightning arrestors. All systems are grounded properly. LED lights shall meet minimum of the following technical specifications

- Metallic body with heat sink LED light
- Luminous efficacy ≥ 80 Lumens/Watt
- 3 years of replacement warranty
- LED fixture protection grade: IP65 or better
- Lifespan of LED shall be at least 30,000 hours
- View angle of individual LEDs ≥ 100^0
- Shall include mounting clamp, connector/switch arrangement for outdoor condition
- LED lamp power consumption: 15 Watt
- Control Mechanism: Photo-sensor and activation switch On/Off

6 REMOTE MONITORING SYSTEM

The remote monitoring system for solar mini-grid in Gurbuz district will include SCADA system with the ability of automatic data acquisition and monitoring technology which will enable high level of performance, reduce downtime and ensure rapid fault detection. This monitoring system allows the yield of the plant to be monitored and compared with theoretical calculations and raise warnings on a daily basis if there is a performance shortfall. Faults can therefore be detected and rectified before they have an appreciable effect on the energy production.

Steps have been taken to enhance the performance of the system to enable a reliable monitoring and fault detection by coupling the electrical parameter measurement equipment and the weather station to ensure simultaneous measurements of the solar irradiance, environmental conditions, wind speed & direction and the plant power output. The weather station on site will measure the irradiance on the array plane, module and ambient temperature, global horizontal irradiance, humidity, wind speed and direction.

The voltage and current will be monitored at the inverter input and output level. The system is capable of measuring detailed list of parameters of the plant.

Data from the weather station, inverters, junction boxes, meters and transformers will be collected in data loggers and passed to the monitoring station, typically via Ethernet, CAT5/6, RS485 or RS232 cables. Communication protocols of type Modbus, TCP/IP and DNP3 are available to choose from. The following figure illustrates the operation of the SCADA system by integrating the weather station and the power plant including both PV and DG with battery backup. The detailed dimensions, drawings, specifications are not fixed at this stage, and as such the same shall be provided by the contractor at the bidding stage.

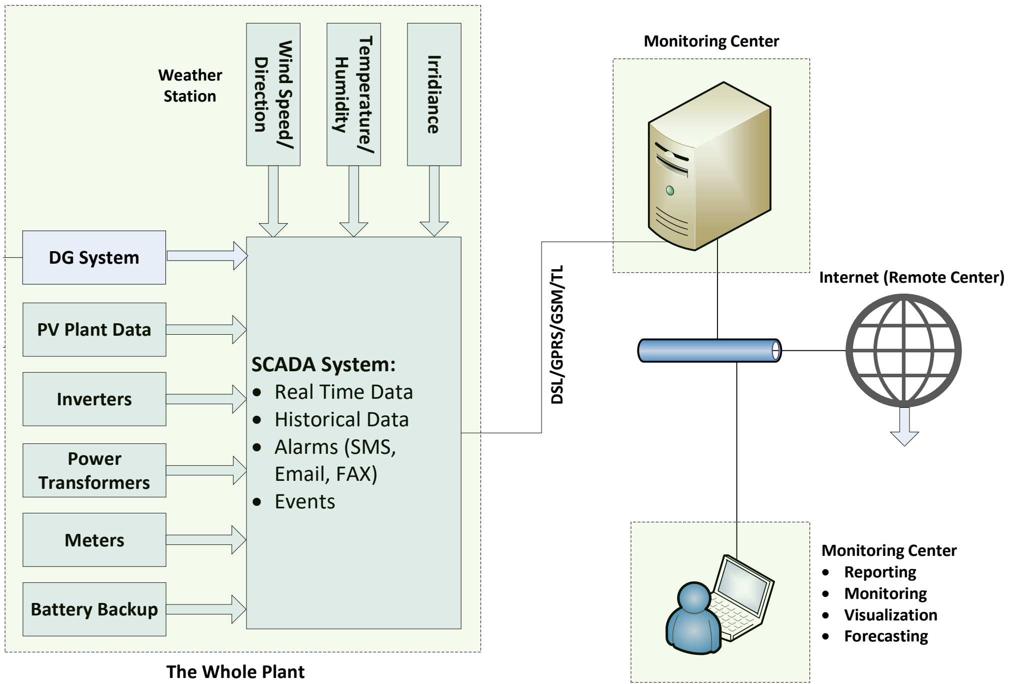


Figure 9 SCADA system architecture

Specifically, the SCADA system for solar mini-grid in Khost includes the following functions:

- Real-time data acquisition and supervisory control: The performance management (either onsite or remote) of the solar PV power plant and the DGs to enable the monitoring of the PV farm, generators, battery backup, transformers, inverters or strings at all levels
- Human machine interface (HMI) visualization
- Alarm management: Flagging any element of the power plant that falls outside pre-determined performance bands. Failure or error messages will be automatically generated and sent to the power plant service team via fax, email or text message.
- User-configurable security model
- Historical data collection and analysis
- Remote user access via web or smartphone
- Comprehensive system diagnostics to simplify troubleshooting
- Open communications interface using industry standard protocol
- Reporting: The generation of yield reports detailing individual component performance, and benchmarking the reports against those of other components or locations

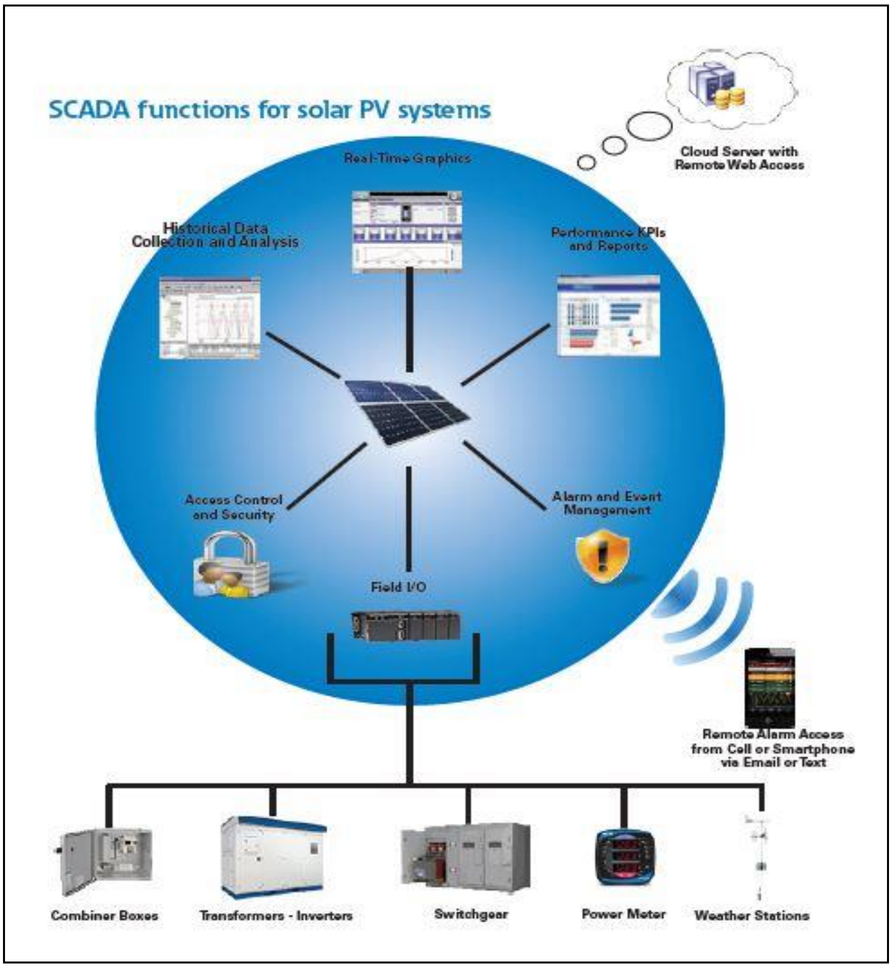


Figure 10 SCADA system operation

The detailed drawings, dimensions, specifications are not fixed at this stage, and as such the same shall be provided by the contractor at the bidding stage. Contractor shall provide complete SCADA system with all accessories, auxiliaries and associated equipment and cables. The detailed technical specifications for SCADA system shall have:

- Real time acquisition and display of data, status, alarms and trends
- Display of status of major equipment in Single Line Diagram (SLD) Format
- Display and storage of measured as well as derived values
- Display and storage of Alarm, Events and Trends
- Generate, store and retrieve user configurable reports
- Remote monitoring of essential parameters on the web using standard modem. The data shall be logged to a remote server. Only authorized person can access the data at any time at any place via the web server.
- The control system shall be designed to operate in non-air-conditioned area. However, the Contractor shall provide a Package/Split AC of suitable capacity decided by load requirement in SCADA room
- The PC shall be an industrial type, rugged and robust in nature to operate in a hostile environment. The PC shall have minimum intel core i5 processor having 1 TB HDD with minimum 8 GB RAM. The PC shall also have a 17” Color Monitor
- The Printer shall be of industrial type, robust and rugged in nature of reputed make
- Contractor shall provide the UPS/DC power supply of suitable rating to cater all the load requirements of SCADA system and its auxiliaries
- RS-485 communication port for receiving data from Inverter, string monitoring unit or power meter etc.
- RS-232 or LAN port for local monitoring or network monitoring
- Internet connection via GSM, CDMA, GPRS, ADSL, VSAT

6.1 Battery management system (BMS)

Battery management system (BMS) can monitor, evaluate, protect the operating status of the batteries, based on voltage, current, temperature, protection limits, state of charge (SOC), depth of discharge (DOD) and capacity data. BMS adopts intellectual technology to achieve monitoring of individual or total battery system in real time. The BMS system has been explained below:

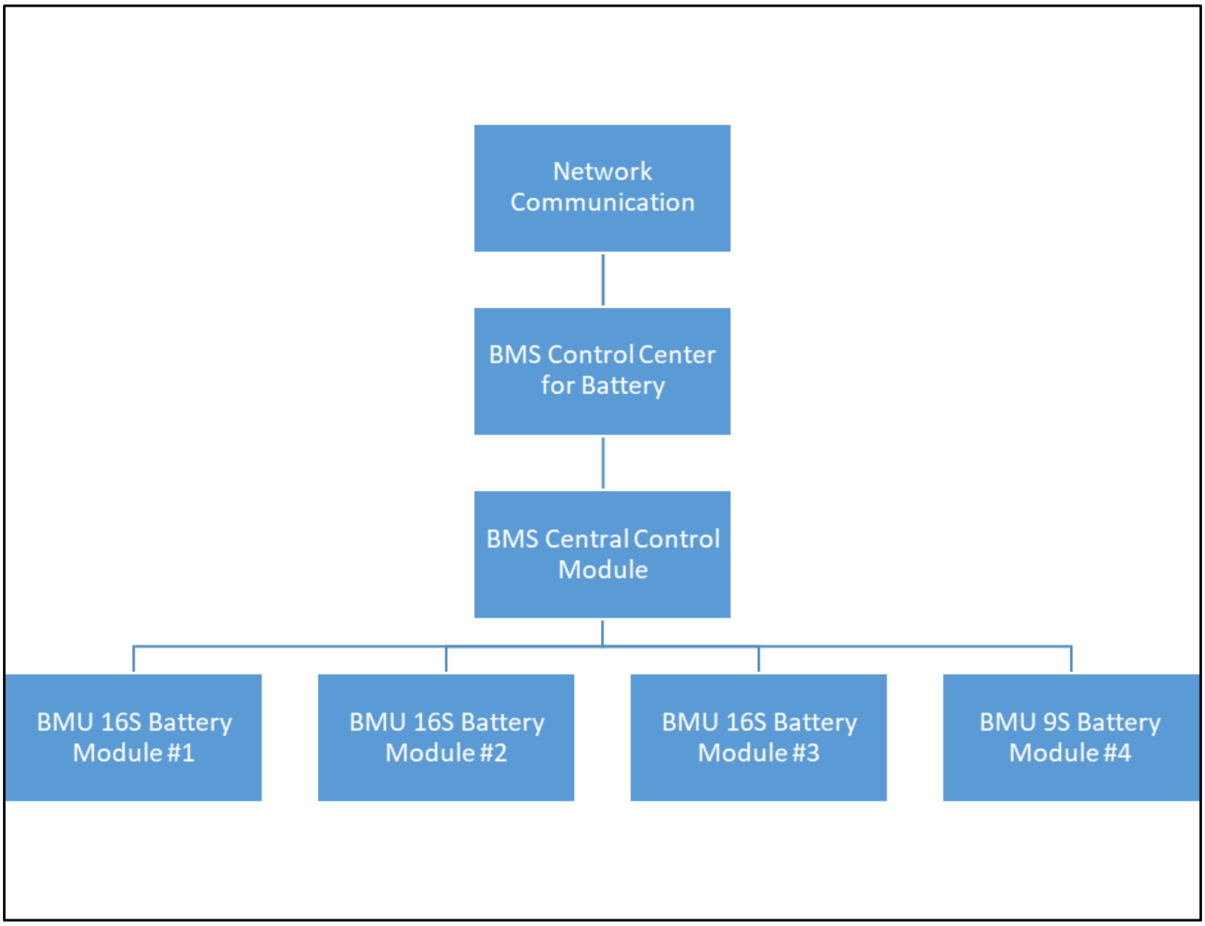


Figure 11 Battery management system

Chief control center

Responsible for collecting, sorting, calculating, controlling the data of battery module unit (BMU), and exchanging data with the central control room.

Composed of one server, exchange board, and software, responsible for collecting the data of central control module, and analysis, then send order of warning, alarming, and maintenance. Responsible for exchanging data with upper system and provide the remote-control mode.

BMU Specification

Table 17 Specification of BMU

Parameters	Description
BMU model	LS15/16 BMU
Compatible battery	Lithium, lead-acid, lead-carbon
Strings of battery	15/ 16
Power supply	By 12V DC power supply of BMS control cabinet, the radiation fans of the batteries shall be supplied by BMU

Type of restoring		Resistance, negative
Restoring current		300mA
Sample collection of temperature	Points	1-8
	Accuracy	±2℃
	Range	-40~100℃
	Accuracy	±10mV
	Range	0~4.5V
Self-discharge	Modes	<5mA
	Discharge	<5mA
	Storage	<1mA
Communication		CAN2.0B, RS485

BMS Interface

Table 18 Specification of BMS Interface

Interface	Data transfer rate	Description	Wire
CAN	500Kbps	By CAN, BMS communicates with the lower level, and check volt. and temperature and receive the certain alarm info.	Twisted, 1kV insulation, Open5
CAN 2	500Kbps	By CAN, BMS exchange order and data with PCs, and report volt. temp. current, and receive order from BMS System	Twisted, 1kV insulation, Open5
RS485	9.6~115.2Kbps	Exchange order and data with PCS	Twisted, 1kV insulation
Ethernet		Communicate with BMSS, report volt, temp., current, receive order from BMSS	Twisted, 1kV insulation

Software framework

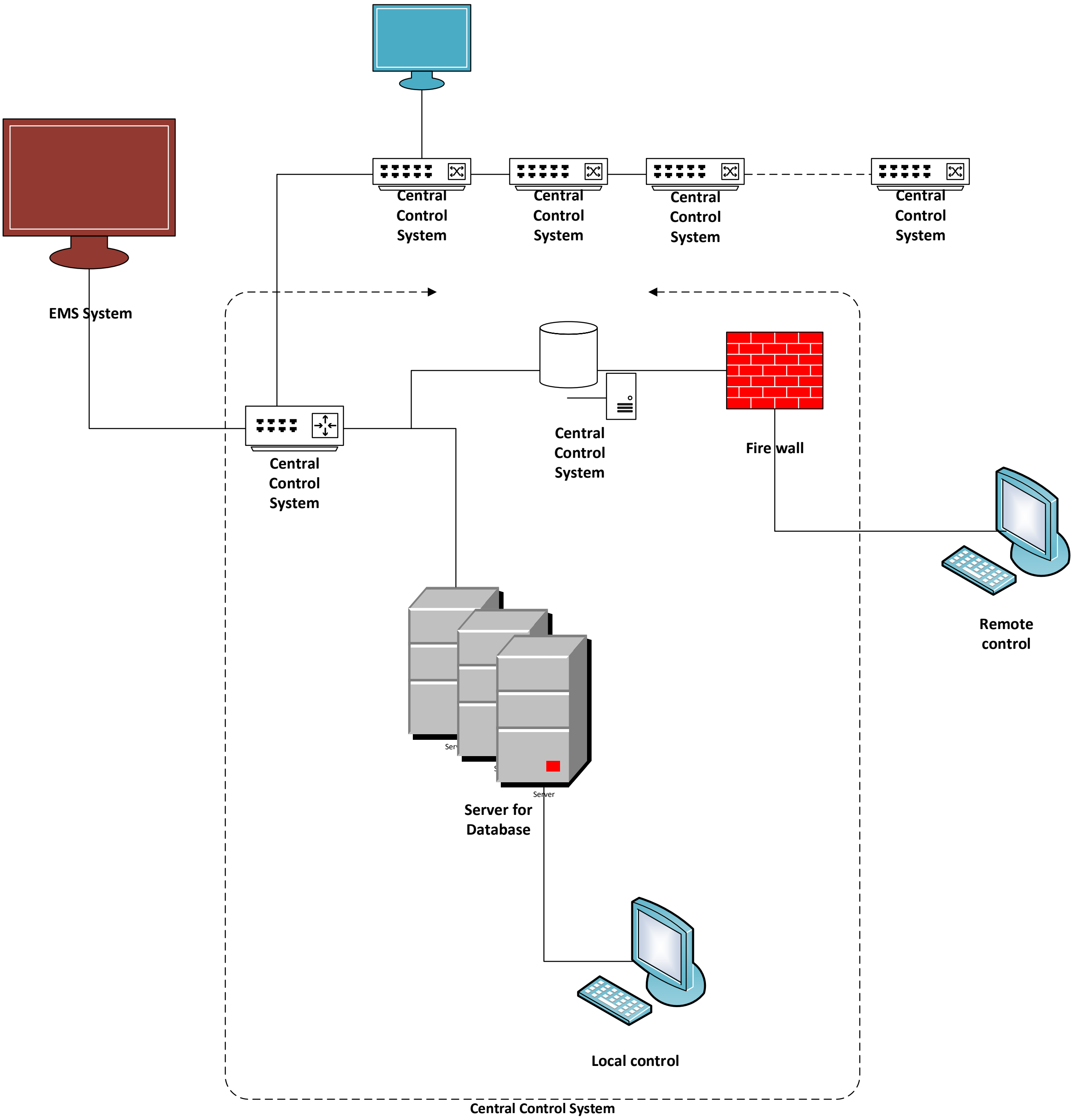


Figure 12 Software framework for BMS system

6.2 Energy management system (EMS)

With the help of SCADA server, history server and front server, energy management system (EMS) shall monitor and control the whole system on a daily basis. The system consists of

- One set of CSD-580 controller with certain programs to control the whole system in stable operation
- One set of CSD-582 protection appliance to protect the whole system and prevent outside danger
- One set of CSC-850E monitoring appliance to collect the quality of the power supply in the real time

EMS Software

CSGC-3000/MGMS can monitor and manage the whole system in the manner of flexibility, stability. This software uses MySQL, Oracle database.

6.3 Weather station solution

The weather station has been designed with equipment & sensors to measure direct and global irradiance, temperature, air pressure, wind speed and wind direction, and support communication protocols required by the SCADA system. The weather station will be installed at a strategic location at the site to monitor the environmental parameters. The weather station stores and send the data to a control center. It has been shown in the general layout of the site.

As a part of weather monitoring station, Contractor shall provide following measuring instruments with all necessary software & hardware required and integrate it with SCADA

- Pyranometer: minimum two number of pyranometers for measuring incident global radiation. One of them shall be placed on horizontal surface and other on adjustable inclined plane.
- Thermometer: minimum two thermometers – one for ambient temperature measurement and the other for module temperature measurement
- Anemometer: minimum one number of anemometer with wind vane of rotating cup type

7 SYSTEM OPERATION

7.1 Startup of the system

When the system is switched on the following actions are performed by the system:

- SCADA system keeps all contactors and switches at their off state. It will power up the weather station and start sensing the voltage and current of the PV farm. A startup test is performed on all inverters and the battery backup SOC. The SCADA system will then make sure that all inverters come online one by one taking one of the master inverters as a slack bus
- The battery backup system will start charging the batteries with the power output from the PV farm by making the rectifier's impedance a little bit lower than the network
- If all inverters report 'normal status' to the SCADA system, then the farm will proceed with normal operation and data is collected and stored in a database
- If for any reason, one or more of the inverters report 'alarming status', then the SCADA system disconnects that part and notify the operator through appropriate alarm in the control room
- When the SOC of the battery backup system is 100%, the full power will be directed to the network and the system will work in the best-case scenario as described in the following paragraph

7.2 Operations

Basically, the hybrid PV system has two levels of operation which have been explained below:

Firstly, the best case where the insolation is maximum and the battery is full. In this case, the BMS and EMS will make sure that the system is working just like an online UPS system. While it monitors the SOC of the battery banks, it bypasses the batteries in this operation. So, the sense of voltage and current of the supply load is monitored constantly. If for any reason the voltage drops below a specified percentage, the static switch transfers the load from PV feeder to the battery backup system in a fraction of a cycle.

The worst case, when batteries are empty (have reached 80% DOD) and the insolation level is minimum. At this regime, the system will close the relays which commands the DG to start up and take the loads. There are two possible sub-regimes available for the operator. One is that the batteries shall be kept disconnected from the supply bus and only the DG will operate until the system sense enough voltage/insolation from the PV farm. The other option is to charge the battery backup system with partial DG current

Also, separating both solar PV and DG system from each other and operating simultaneously when necessary has following advantages:

- reduce the fault current during fault events
- prevent the negative feed of power from solar system into the DG busbars and vice versa

- match impedance of both systems
- reduced cost and complexity of the paralleling switchgear

In addition to that, the BMS software system will treat both systems separately which enables the system to be much simpler having easier maintenance and lower cost.

Battery backup system is connected directly to the 20-kV line instead of directly being charged from the Solar PV Modules. This arrangement will enable batteries to be charged by both the solar system and the DG system based on the availability of solar resource. In addition, the 20-kV will enable the battery system to feed the network in case of outage from both solar and DG systems. In addition, the transformer will limit the short circuit fault resulting in a safer system overall and thus smaller damages. The high current switchgear will be required for the battery charging system if we directly connect the batteries to the PV system and thus increase in cost and complexity in the project design. Galvanic separation is another advantage that this dedicated transformer will provide between the batteries and the rest of the system.

7.3 Controlling program

The whole system includes PV, DG, battery and electrical load. The program has three operation states including on-grid, off-grid, and mode-switch.

Off grid: On the mode of off-grid, the inverter of the batteries shall be the main power supply of the whole system, by discharging to the batteries, to control the frequency and volt. In order to realize the stable and economic operation, the programs called "stable control "and "load control" are configured, and their main control includes the limits of PV power, PV switching, load switching, SOC control.

On grid: The program called "communication power control "shall send order of power from the distribution center, then realize the actual power in accordance with the estimation of the distribution center. In case that the output power (PV<load) is less than estimation, then to use battery to supply the power; in case the output power (PV>load) is larger than the estimation, then to charge the battery.

Charge & discharge, curve control: The program called "balance control" shall switch the modes of the operation according to the actual load, i.e. discharge to the load during peak time of the load, charge the battery during the low time of the load, by such way, to maintain the whole system in the max. economic state.

Switch of the modes: The switch of the modes shall include planned and unplanned. Planned un-delayed switch < 100ms, to realize the non-stop power supply. Unplanned switch shall be less than 2 second.

8 BILL OF MATERIALS & QUANTITIES

The bill of material and quantities have been provided in detail in below table

No.	Item Description	Unit	Qty	Unit price (USD)	Total price (USD)
1.	PV Modules - 250Wp Polycrystalline	PCS	4,000	130.00	5,20,000.00
2.	Ground Mounted PV Support Structure	kW	1000	80.00	80,000.00
3.	PV Lightning Protection System	Set	4	1,000.00	4,000.00
4.	Inverter Pergolas and Slabs	LS	1	4,000.00	4,000.00
5.	DC Array combiner box	Set	250	100.00	25,000.00
6.	Disconnect switch sets - 1000V, 80A	Set	250	85.00	21,250.00
7.	Switch Sets - 1200V, 10A, 5kA switch set	Set	250	50.00	12,500.00
8.	SPD and surge arrester sets - 20kA, 1000V, class II SA	Set	50	50.00	2,500.00
9.	Grounding system mesh network	LS	1	20,000.00	20,000.00
10.	Grid tied string inverters of 40 kW rating	PCS	25	4,100.00	1,02,500.00
11.	SCADA system	Set	1	20,000.00	20,000.00
12.	BMS and EMS	Set	1	26,500.00	26,500.00
13.	Weather Station - Complete Set	Set	1	1,950.00	1,950.00
14.	MC4 Waterproof Joints	Pairs	5,000	1.00	5,000.00
15.	DC Cables - PV 1*4mm^2; PV cable 1X16mm^2	LS	1	20,000.00	20,000.00
16.	Low Voltage AC Cables- ZRC-YJV22-0.6/1KV-3*35mm^2; ZRC-YJV22-0.6/1KV-3*120mm^2; ZRC-YJV22-0.6/1KV-3*16mm^2	LS	1	30,000.00	30,000.00

17.	Medium Voltage AC Cables - ZR-YJV22-10/35KV-3*120mm^2	LS	1	26,000.00	26,000.00
18.	24 kV High Voltage Feed Cabinet - KYN61-40.5	Set	1	48,000.00	48,000.00
19.	24 kV High Voltage Metering Cabinet - KYN61-40.5	Set	1	24,000.00	24,000.00
20.	24 kV High Voltage PT Cabinet - KYN61-40.5	Set	1	24,000.00	24,000.00
21.	24 kV High Voltage Outgoing Cabinet - KYN61-40.5	Set	1	15,000.00	15,000.00
22.	Low Voltage Feed Cabinet - GGD	Set	1	17,500.00	17,500.00
23.	Low Voltage Outgoing Cabinet - GGD	Set	3	11,500.00	34,500.00
24.	Low Voltage Feed Cabinet - GGD	Set	1	11,250.00	11,250.00
25.	Low Voltage Outgoing Cabinet - GGD	Set	1	11,500.00	11,500.00
26.	DC system for 4 hours backup - RBO-GZDW-65AH	Set	1	25,000.00	25,000.00
27.	Grid Connection	LS	1	16,000.00	16,000.00
28.	Buildings Civil Works	LS	1	1,00,000.00	1,00,000.00
29.	Electrical & mechanical installation inside power plant building	LS	1	30,000.00	30,000.00
30.	CCTV and Security fence & gates	LS	1	3,000.00	3,000.00
31.	Access Roads	LS	1	6,000.00	6,000.00
32.	Battery: 2V/400Ah	PCS	6,300	148.00	9,32,400.00
33.	Diesel Generator: 350 kW	Set	1	30,000.00	30,000.00
34.	Site lighting posts with fixtures and lamps	PCS	45	200.00	9,000.00
35.	Transformer 400 kVA for DG system	Set	1	5,000.00	5,000.00
36.	Transformer 500 kVA for battery storage	Set	2	6,500.00	13,000.00

37.	Transformer 1250 kVA for PV system	Set	1	14,000.00	14,000.00
38.	Site Grading and Preparation	LS	1	10,000.00	10,000.00
39.	Waste Management	LS	1	5,000.00	5,000.00
40.	Site Recovery	LS	1	8,000.00	8,000.00
41.	Trainings and Capacity Building	LS	1	2,000.00	2,000.00
42.	**GRAND TOTAL (USD)**				23,15,350.00

9 LIST OF REFERENCE STANDARDS

The standards that were referred while designing the solar PV power plant have been illustrated in below table:

Table 19 List of IEC standards referred

IEC Codes for Solar PV Panels	
IEC 61215	Design Qualification and Type Approval for Crystalline Silicon Terrestrial Photovoltaic (PV) Modules
IEC 61646	Design Qualification and Type Approval for Thin-Film Terrestrial Photovoltaic (PV) Modules
IEC 61701	Salt Mist Corrosion Testing of Photovoltaic (PV) Modules
IEC 61853- Part 1	Photovoltaic (PV) module performance testing and energy rating -: Irradiance and temperature performance measurements, and power rating
IEC 61730-1,2	Photovoltaic (PV) Module Safety Qualification – Part 1: Requirements for Construction, Part 2: Requirements for Testing
IEC 62804	Photovoltaic (PV) modules - Test methods for the detection of potential-induced degradation (PID). IEC TS 62804-1: Part 1: Crystalline silicon (Mandatory for system voltage is more than 600 VDC and advisory for system voltage is less than 600 VDC)
IEC 62759-1	Photovoltaic (PV) modules – Transportation testing, Part 1: Transportation and shipping of module package units
IEC 62716	Photovoltaic (PV) Modules – Ammonia (NH3) Corrosion Testing
IEC Codes for Solar PV Inverters	
IEC 62109-1, IEC 62109-2	Safety of power converters for use in photovoltaic power systems Safety compliance (Protection degree IP 65 for outdoor mounting, IP 54 for indoor mounting)
IEC/IS 61683 (For stand Alone System)	Photovoltaic Systems – Power conditioners: Procedure for Measuring Efficiency (10%, 25%, 50%, 75% & 90-100% Loading Conditions)
IEC 62891	Overall efficiency of grid-connected photovoltaic inverters:
IEC 62116/ UL 1741/ IEEE 1547	Utility-interconnected Photovoltaic Inverters - Test Procedure of Islanding Prevention Measures
IEC 60255-27	Measuring relays and protection equipment - Part 27: Product safety requirements
IEC 60068-2 (1, 2, 14, 27, 30 & 64)	Environmental Testing of PV System – Power Conditioners and Inverters
IEC 61000- 2,3,5	Electromagnetic Interference (EMI), and Electromagnetic Compatibility (EMC) testing of PV Inverters (as applicable)
IEC Codes for Fuses	
IEC 60947 (Part 1, 2 & 3), EN 50521	General safety requirements for connectors, switches, circuit breakers (AC/DC)
IEC 60269-6	Low-voltage fuses - Part 6: Supplementary requirements for fuse-links for the protection of Solar photovoltaic systems
IEC Codes for Surge Arrestors	

IEC 61643-11:2011	Low-voltage surge protective devices - Part 11: Surge protective devices connected to low voltage power systems - Requirements and test methods
IEC Codes for Cables	
IEC 60227, IEC 60502	General test and measuring method for PVC (Polyvinyl chloride) insulated cables (for working voltages up to and including 1100 V, and UV resistant for outdoor installation)
BS EN 50618	Electric cables for photovoltaic systems (BT(DE/NOT)258), mainly for DC cables
IEC Codes for Earthing /Lightning	
IEC 62561 Series (Part 1,2 & &) (Chemical earthing)	IEC 62561-1 Lightning protection system components (LPSC) - Part 1: Requirements for connection components IEC 62561-2 Lightning protection system components (LPSC) - Part 2: Requirements for conductors and earth electrodes IEC 62561-7 Lightning protection system components (LPSC) - Part 7: Requirements for earthing enhancing compounds
IEC Codes for Junction Boxes	
IEC 60529	Junction boxes and solar panel terminal boxes shall be of the thermo-plastic type with IP 65 protection for outdoor use, and IP 54 protection for indoor use
IEC codes for Battery	
IS 1651 & IS 13369,	Stationary lead-acid batteries – Vented types – General requirements and methods of test.
IS 15549	Stationary Valve regulated lead-acid batteries specification.
IEC 62259,	Secondary cells and batteries containing alkaline or other non-acid electrolytes-Nickel cadmium prismatic secondary single cells with partial gas recombination.
IEC 61951 – 1,	Secondary cells and batteries containing alkaline or other non-acid electrolytes-Portable sealed rechargeable single cells-Part 1: Nickel cadmium.
IEC 61951 – 2,	Secondary cells and batteries containing alkaline or other non-acid electrolytes-Portable sealed rechargeable single cells-Part 2: Nickel metal hydride. 70 IEC 61960, Secondary cells and batteries containing alkaline or other non-acid electrolytes-Secondary lithium cells and batteries for portable applications.
Standards for SCADA system	
C37.1-2007 -	IEEE Standard for SCADA and Automation Systems
Standards for mechanical components	
IS 875 Part 1 & 2	Code of practice for the design loads for buildings and structures
IS 875 Part 3	Code of practice for the design loads for buildings and structures - wind loads
IS 800: 2007	Code of practice for use of structural steel in general building structure

APPENDIXES

Following set of design documents related to power plant and remote monitoring design can be accessed from the below mentioned Dropbox link. Please download the documents for review purpose.

https://www.dropbox.com/sh/3lmjiv7fhrfubsc/AAADYDy6lFweRkXlH3hHgZcga?dl=0

Appendix 1 - System drawings (part 1)

Appendix 2 - System drawings (part 2)

Appendix 3 - PVsyst simulation results

Appendix 4 - Cable analysis

Appendix 5 - Grading and drainage

Appendix 6 - Wellhouse design

Appendix 7 - Fence & gate design

Detailed Project Report

Design of 600kW Solar Powered Utility, including Reticulation System for Bagram District of Parwan Province, Afghanistan

August 14th, 2018

Contract #: UNDP/AFG/PS/2018/xxxx

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY

Parwan province lies to the north of Kabul city and can be reached through the Kabul-Mazar highway. Its capital city, Charikar, is a bustling city, fairly peaceful and economically active. The cluster of six villages around Qalandar Khil is located about 7 km from the Bagram district center is located along the asphalted Parwan-Kapisa road. The cluster consists of villages of Qalandar Khil, Beg Muhammad Khil, Jafar Khil, Ghulam Shah, Turkman and Qala e Beland.

The population is mostly engaged in agriculture and horticulture but some commercial activities such as tailoring, flour milling, bicycle and motorcycle repair, shop keeping and other are also found. The cluster of villages has about 91 shops, one hospital (10 bed), three schools, three police posts and 44 mosques. About 80% of the households have a single solar panel plus a battery backup to meet their basic need for lighting and phone charging. The cluster of villages is not connected to the grid power, even though a 20 KV power line passes about 3,500 meters from the site of the planned solar plant in Qalandar Khil. It is not expected that the cluster of villages will be connected to the grid power in the foreseeable future.

The households in the target area are classified under tier 0 and tier 1 of the World Bank's Multi-Tier Framework. About 20% of households are classified under tier 0 and have no access to energy and are forced to solely depend on fossil fuels such as firewood, Kerosene, propane gas, etc. the like to meet their energy needs. About 80% of the households are classified under tier 1 and have access to a solar panel (less than 100 Watts) and a battery unit, which provides lighting for about four hours during the night. The energy demand is, therefore, fairly significant and the desire to benefit from other aspects of electrified dwelling is highly desired.

The overall system size installed in Parwan is expected to be 600 kW solar, with 2.4 MWh of Battery Energy Storage System (BESS) and two diesel generators sets of 300 kW and 75 kW. Thereby, the 300kW diesel generator will cater to peak demand, while the 75 kW diesel generator will ensure continuous power late at night when the BESS has reached its discharge limit and there is no solar radiation to provide power to the customers.

While the residential customers demanded about 3.1 kW power on a 24-hour basis, the project is able to provide only 200 Watts per household from 5 pm until 9 am. All commercial customers, with the exception of irrigation pumps and flour mills, who receive no solar power from the utility, receive power as per their need but from 9 am to 5 pm only. Institutional customers receive power as needed on a 24-hour basis.

The solar power plant produces 400 Volt power, which is stepped up with a 500 kW transformer to 20kV, which is then transmitted via overhead lines to the cluster of six villages.

Altogether 8 transformers will then step down the power and provide electricity to the villagers and commercial and institutional customer through about 280 meter boxes, which equipped with 6 to 9 meters. Prepaid metering system with associated components are installed.

The contractor is expected to use the 100% design documents to construct, install, commission, operate and maintain (for 12 months) the utility and collect power fees based on set tariffs.

2. INTRODUCTION

ASERD is a UNDP supported National Afghan Program that supports the Ministry of Rural Rehabilitation and Development (MRRD) to implement rural renewable energy projects. The program design is based on four pillars.

1. Rural energy services: implement renewable energy projects such as mini-grids powered by small hydro power, solar, wind and thermal energy. In electrified villages opportunities will be provided for local business developers, entrepreneurs and SMEs to take advantage of the availability of power.
2. Capacity building and outreach: the energy projects in rural area will also work closely with local MRRD staff and other government entities in order to improve their capacity.
3. Innovative models: the program will seek to use and introduce new delivery models to Afghanistan, ranging from technology choice to financial tools.
4. Rural Energy policy and Regulation: the program will closely coordinate with stakeholders, especially the Ministry of Energy and Water (MEW) in terms of addressing policy and regulation gaps.

UNDP is the owner of the project and will provide the required funding under its Afghanistan Sustainable Energy for Rural Development (ASERD) program.

MRRD
The Ministry of Rural Rehabilitation and Development (MRRD) as the implementing Agency will implement the project.

UNPD Consultant
An entity or individual who will act on behalf UNDP and or MRRD as an owner's engineer for execution of this contract.

3. GENERAL INFORMATION

Parwan province lies to the north of Kabul city and can be reached through the Kabul-Mazar highway. Its capital city, Charikar, is about 65 km from Kabul and is a bustling city, fairly peaceful and economically active. The district of Bagram, where the famous US military base with the same name is located, is where the project site is found. The cluster of six villages around Qalandar Khil is located about 7 km from the Bagram district center is located along the asphalted Parwan-Kapisa highway. The cluster consists of the villages of.

Qalandar Khail village in Bagram district is located about 75 km to the north of Kabul, along the Charikar-Kapisa road. It is about 10 km from Charikar city, the provincial capital of Parwan province (34 59 36.52"N 69 14 23.84"E). The proposed project will cater to the electricity requirements of seven (6) villages; namely Qalandar Khil, Beg Muhammad Khil, Jafar Khil, Ghulam, Turkman and Qala e Beland. These villages, which are managed by their own community development councils (CDC), have in total approx. 2,000 households and a population of about 11,880. Most of the village people are in the low-income group. The cluster of six villages have never been exposed to electricity with the exception of about 80% of the households that own between 50 and 10 Watt solar panels.

The design and construction of the envisaged PV Mini-grid shall provide safe and sustainable power supply to the connected Consumers.

The one year operation shall provide on-the-job training to the local operators in operation, maintenance and troubleshooting of the plant and the appertaining distribution network and to the administrative staff in metering, billing, and stock keeping.

The UNDP is engaging a capable and qualified Contractor to carry out construction, installation, commissioning, and one year operation and maintenance (O&M) of a PV hybrid mini grid system of 600 kW and associated reticulation in the cluster of six villages in and around Qalandar Khail village in Bagram district of Parwan province Afghanistan. The scope of work includes:

1. Procurement of equipment and supply for the complete PV system including:
    a. The PV panels and associated inverters and related components
    b. SCADA,
    c. Low Voltage Equipment and accessories
    d. Aux boards
    e. Diesel generators and associated controls
    f. Transformer and associated controls

    g. Li-Ion Battery Energy Storage System (BESS) and associated accessories
    h. Medium Voltage equipment and associated accessories
    i. System integration services
2. PV power plant site development including:
    a. Civil layout and design
    b. Buildings design
    c. Details, including
        i. Water supply, including water wells, storage tanks, water supply network
        ii. Plumbing
        iii. Roads, Parking, and Walk Ways
        iv. Electrical wiring
        v. Sewer system including septic tanks and leach fields
        vi. Drainage system for the complete site
        vii. Light Poles and area lighting
        viii. Concrete Pads
        ix. Security Cameras
        x. Fence
        xi. Other related structures and components
3. Manufacture, supply and installation of PV panel structures, including
    a. PV Panel Frames
    b. Poles
    c. Racking systems
    d. Concrete foundation
    e. Other related components
4. Manufacturing, supply and installation of T&D system consisting of:
    a. 20 kV MV network
    b. 20/0.4 kV substations including transformer, protection devices, LV distribution cabinets (seven)
    c. 0.4 kV LV network
    d. Meter boxes,
    e. Service lines
    f. Consumer connections

    Including testing and commissioning
5. Supply, installation and operation of pre-paid metering system and associated cloud-based management of the system throughout the cluster of villages
6. Collection and management of tariffs in collaboration with the local electricity supply board and MRRD/ASERD

7. Supply of spare parts for one years
8. Commissioning of the complete mini-grid.
9. Training of operators and administrative staff
10. Providing warranty over a period of one year after successful commissioning and issuing of Preliminary Acceptance Certificate (PAC)
11. Running the power station for one year starting from issuing of PAC including on-the-job training of operators and administrative staff during this time, monitoring of operation, output, billing and technical and non-technical losses including submission of monthly monitoring reports.

4. SURVEYS AND INVESTIGATIONS

A detailed site assessment was carried out, which yielded the following results:

The population of the target area is mostly engaged in agriculture and horticulture but some commercial activities such as tailoring, flour milling, bicycle and motorcycle repair, shop keeping and other are also found. The cluster of villages has about 91 shops, one hospital (10 bed), three schools, three police posts and 44 mosques. About 80% of the households have a single solar panel plus a battery backup to meet their basic need for lighting and phone charging. The cluster of villages is not connected to the grid power, even though a 20 KV power line passes about 3,500 meters from the site of solar plant in Qalandar Khil. It is not expected that the cluster of villages will be connected to the grid power in the foreseeable future.

The households in the target area are classified under tier 0 and tier 1 of the World Bank's Multi-Tier Framework. About 20% of the households are classified under tier 0 and have no access to reliable energy and are forced to solely depend on fossil fuels such as firewood, Kerosene, propane gas and the like to meet their energy needs. About 80% of the households are classified under tier 1 and have access to a solar panel (less than 100 Watts) and a battery unit, which provides lighting for about four hours during the night time. The energy demand is, therefore, fairly significant and the desire to benefit from other aspects of an electrified dwelling is highly desired. During the assessment, it was noted that at the household level, the female household members had significantly higher demand for power (average of 5.3 kW across all villages), while the male household members had a much lower demand for power (average 0.78 kW across all villages). This is primarily because of less presence at home by men compared to women and a much higher price sensitivity of men compared to women. In order to estimate the total demand for power by households, we averaged the load demand by men and women and concluded that their estimated load per household is about 3.1 kW. Based on the 3.1 kW demand by male/female members of the community, more than 2,367 MWh of energy will be needed to cover only the residential loads. This can be supported by running a diesel generator, in addition to the 500kW solar system, to produce 1,455 MWh of energy at an annual cost of $450,000 plus regular maintenance and repair costs. In addition, we will need to cover the cost of commercial and institutional loads that are also applicable. This is not supportable by the revenues from the operations of the system and as such not realistic. Even a 1 MW system would not be able to cater to this household demand, especially, if commercial and institutional loads are to be served. So, it was decided to reduce the supply of power to the households to a level that would enable the system to be built and operate efficiently. Such a system will be able to offer the households' power from 5 pm to 9 am and will be allocated the equivalent of 200 Watts peak and around 0.8kWh of energy per day per household. This means that even though the demand is there and the ability of the households to pay almost double the power made available to them, they will still only get a peak load of 200 Watts per household, assuming that this will last for their normal needs and its respective duration.

At the business level, the irrigation pumps are the single greatest power consumers across all villages. Additionally, these irrigation pumps are typically located away from the homes, so that extending the transmission lines to the pumps will be an additional cost burden for the project/the beneficiaries. Thus, it was decided to remove the irrigation pumps from the load portfolio. The government or the land owners may choose to fund purchase of decentralized solar powered irrigation pumps and thus minimize their fuel, repair and maintenance costs.

The flour mills also require significant amount of energy to operate. They are typically seasonal businesses, with 3-4 months (Aug to Nov) being their high season and the remainder of the year low season. During the low season, they operate only sporadically as and when needed. Some interviewed flour mill operators informed us that at times they do not operate their mill for more than a week. These mills use diesel-engines to run a belt that power the system. Hence, they would have to convert their mills to electric mills, in order to benefit from the utility's power. We, therefore, recommend that the flour mills also be eliminated from consideration.

At the institutional level, the hospital and the police posts are the two steady consumers of power with the schools and the mosques catering to spikes at their respective times of the day/night. The 44 mosques cater to the greatest load peaks with total of around 0.31 kW for main mosques and 0.18 kW for local mosques, which covers lights plus additional equipment.

It is also estimated, that the Battery Energy Storage System (BESS) will only cater to one night's power for the community, primarily households, mosques and the hospital and will not be able to be used if there are multiple cloudy days with very limited solar irradiation. As such, a Generator System must be installed that can cater to 272 kW peak load and can be operated, when needed. This can be as a combination of one 75kW diesel generator systems that will operate as and when needed to meet the community's power needs, where the few hours of peak load in excess of 200kW can be supported by the BESS. A 300kW diesel generator, along with the 75kW backup system will ensure that peak loads are fully supported on cloudy days with no BESS available to offset some of energy needed.

Based on a detailed assessment of the cluster of villages, the total load requirement for commercial, institutional and residential loads has a summer peak of 1,111kW with an annual energy consumption of 4,100MWh. Since, the scope of this project restricts the size of solar power plant to 1 MW, and the client is interested to provide around 200 Watts of power per residential household, the loads that will be supported in the near future will have to be curtailed. The preliminary design proposes a 600kW Solar PV plant with a 2.5MWh battery energy storage system. The mini-grid is designed to operate with around 74.65 MWh of diesel generator during six months of the year (October-May), provided by a 75 kW Genset. This amounts to a LoLP of 8.5%. An additional 300kW diesel generator will provide backup power, in case of consecutive cloudy days or fault in solar or battery system.

The proposed mini-grid is designed to support the commercial loads during day time (9am-5pm), residential loads during nights (5 pm-9 am) and the institutional loads during 24-hours in a day. With this approach, the peak loads can be maintained at around 272kW with a total annual generation of nearly 998MWh purely from solar production. The system can later be expanded to support increasing load requirements by adding more solar and batteries. The load growth profile shows increase of 60 kW in five years, with additional 68 kW, 77kW, 87kW and 100 kW in the subsequent five years intervals.

5. LOAD IDENTIFICATION/ASSESSMENT

The following load configurations for residential, commercial and institutional customers were identified during the preliminary design:

5.1 Residential Load Assessment

The project will tolerate a Loss of Load Probability (LoLP) of around 10%, which means that the project can cover the cost of diesel as part of the operating costs, if the amount of energy produced by the diesel generation system is around 10% of the overall system output.

After modeling multiple operating scenarios, the most stable system can be achieved by restricting the residential loads to the essential loads, namely, lights, fans, audio & video equipment and cell phone charging. Also, electricity to the residential customers will only be available from 5 pm to 9 am. During the day, the system will completely support the commercial and institutional customers and the remaining energy will be used to charge the batteries. The batteries will support night time loads and provide stable and reliable electricity.

For the residential customers, a load of approximately 200W will be supported per household. It is necessary to provide electricity to the highest number of households and provide that in a stable and reliable way. Once the system is operational, consumption behavior of the customers will be monitored over the period of several months and/or year, then changes to the system can be proposed. Once a reliable source of electricity is available the consumption will also go up, so it is essential to provide some scope of expansion for consumption.

Table 1 provides an insight into the revised calculation of the residential demand for power. The table shows that at this level, the PV system will have to be around 320 kW in size to cater to the residential demand of the population alone.

Residential Load Calculation- Scenario 3

Residential	Wattage (W)	Occurrence per HH	Load per HH (W)	Load for 2000 HHs (kW)	Average Hours per day	kWh/day	Days/Year	kWh/Year	
Lights	10	5	50	100	7.5	750	365.00	273,750.00	
Fans	60	0.75	45	90	0	0	91.25	0.00	
Audio	50	0.25	12.5	25	7	175	365.00	63,875.00	
Video	60	0.75	45	90	7	630	365.00	229,950.00	
Mobile Phones	2	4	8	16	3	48	365.00	17,520.00	
Iron	1000	0.5	500	1000	0	0	365.00	0.00	
AirConditioner	400	0.15	60	120	0	0	91.25	0.00	
Refrigerator	250	0.5	125	250	0	0	365.00	0.00	
Computer	150	0.25	37.5	75	0	0	365.00	0.00	
Water heater	300	0.5	150	300	0	0	273.75	0.00	
Water pump	500	0.1	50	100	0	0	365.00	0.00	
Heater	500	0.25	125	250	0	0	121.67	0.00	
TOTAL	**3282**		**1208**	**2416**	**24.5**	**1603**		**585,095.00**	**kWh/Year**
								1,603.00	**kWh/day**
Number of Households	**2000**					**GHI**	**5**	**kWh/day**	
						GHI *365	**1825**	**kWh/Year**	
						Solar PV	**320.60**	**kW-DC**	

Table 1: Revised Load Profile for Residential Customers

The diversification of loads for residential customers based on the modified peak load of about 200W per household is shown in the following Tables 2 (a) through (d) for each of the four seasons. The input tables describe the diversification model including the individual loads components in kW for all 2,000 households while the output tables show the kWh consumption as a result of the diversification of loads. In all of these cases, we have used load and diversification factors of 0.75 to 1, based on the time of day (as described in Section 6 of Appendix III – Design Methodology) to cater to worst case scenario, because we lack credible historic data or reliable customer input to enable sound engineering calculations.

January Input

Hours	Load in kW	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum
Lights	100	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	8
Fans	90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Audio	25	0	0	0	0	0	0	0.75	0.75	0	0	0	0	0	0	0	0	0.75	1	1	1	1	0.75	0	0	7
Video	90	0	0	0	0	0	0	0.75	0.75	0	0	0	0	0	0	0	0	0.75	1	1	1	1	0.75	0	0	7
Mobile Phones	16	0	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0	0.5	0.5	0.5	0.5	0	0	0	3

(a-I)

January Output

Hours	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum in kWh
Lights	0	0	0	0	100	100	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	0	0	**800**
Fans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Audio	0	0	0	0	0	0	18.75	18.75	0	0	0	0	0	0	0	0	18.75	25	25	25	25	18.75	0	0	**175**
Video	0	0	0	0	0	0	67.5	67.5	0	0	0	0	0	0	0	0	67.5	90	90	90	90	67.5	0	0	**630**
Mobile Phones	0	0	0	0	0	0	8	8	0	0	0	0	0	0	0	0	0	8	8	8	8	0	0	0	**48**

(a-O)

April Input

Hours	Load in kW	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum
Lights	100	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	8
Fans	90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Audio	25	0	0	0	0	0	0	0.75	0.75	0	0	0	0	0	0	0	0	0.75	1	1	1	1	0.75	0	0	7
Video	90	0	0	0	0	0	0	0.75	0.75	0	0	0	0	0	0	0	0	0.75	1	1	1	1	0.75	0	0	7
Mobile Phones	16	0	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0	0.5	0.5	0.5	0.5	0	0	0	3

(b-I)

April Output

Hours	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum in kWh
Lights	0	0	0	0	100	100	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	0	0	**800**
Fans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Audio	0	0	0	0	0	0	18.8	18.8	0	0	0	0	0	0	0	0	18.8	25	25	25	25	18.8	0	0	**175**
Video	0	0	0	0	0	0	67.5	67.5	0	0	0	0	0	0	0	0	67.5	90	90	90	90	67.5	0	0	**630**
Mobile Phones	0	0	0	0	0	0	8	8	0	0	0	0	0	0	0	0	0	8	8	8	8	0	0	0	**48**
TOTAL	0	0	0	0	100	100	94.3	94.3	0	0	0	0	0	0	0	0	186	223	223	223	223	186	0	0	**1653**

(b-O)

July Input

Hours	Load in kW	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum
Lights	100	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	6
Fans	90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Audio	25	0	0	0	0	0	0	0.75	0.75	0	0	0	0	0	0	0	0	0.75	1	1	1	1	0.75	0	0	7
Video	90	0	0	0	0	0	0	0.75	0.75	0	0	0	0	0	0	0	0	0.75	1	1	1	1	0.75	0	0	7
Mobile Phones	16	0	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0	0.5	0.5	0.5	0.5	0	0	0	3

(c-I)

July Output

Hours	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum in kWh
Lights	0	0	0	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100	100	0	0	**600**
Fans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Audio	0	0	0	0	0	0	18.8	18.8	0	0	0	0	0	0	0	0	18.8	25	25	25	25	18.8	0	0	**175**
Video	0	0	0	0	0	0	67.5	67.5	0	0	0	0	0	0	0	0	67.5	90	90	90	90	67.5	0	0	**630**
Mobile Phones	0	0	0	0	0	0	8	8	0	0	0	0	0	0	0	0	0	8	8	8	8	0	0	0	**48**
TOTAL	0	0	0	100	100	0	94.3	94.3	0	0	0	0	0	0	0	0	86.3	123	223	223	223	186	0	0	**1453**

(c-O)

October Input

Hours	Load in kW	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum
Lights	100	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	8
Fans	90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Audio	25	0	0	0	0	0	0	0.75	0.75	0	0	0	0	0	0	0	0	0.75	1	1	1	1	0.75	0	0	7
Video	90	0	0	0	0	0	0	0.75	0.75	0	0	0	0	0	0	0	0	0.75	1	1	1	1	0.75	0	0	7
Mobile Phones	16	0	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0	0.5	0.5	0.5	0.5	0	0	0	3

(d-I)

October Output

Hours	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum in kWh
Lights	0	0	0	0	100	100	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	0	0	**800**
Fans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Audio	0	0	0	0	0	0	18.8	18.8	0	0	0	0	0	0	0	0	18.8	25	25	25	25	18.8	0	0	**175**
Video	0	0	0	0	0	0	67.5	67.5	0	0	0	0	0	0	0	0	67.5	90	90	90	90	67.5	0	0	**630**
Mobile Phones	0	0	0	0	0	0	8	8	0	0	0	0	0	0	0	0	0	8	8	8	8	0	0	0	**48**
TOTAL	0	0	0	0	100	100	94.3	94.3	0	0	0	0	0	0	0	0	186	223	223	223	223	186	0	0	**1653**

(d-O)

Table 2 - Diversification of Revised Residential Loads (inputs and Outputs) in Wh, (a-I) Input for January, (a-O) Output for January, (b-I) Input for April, (b-O) Output for April, (c-I) Input for July, (c-O) Output for July, (d-I) Input for October, (d-O) Output for October

Figure 1 shows the load profile for the revised residential loads, which is very consistent throughout the year with the peaks at around 223kW. The peak is primarily guided by the use of TV and audio devices that remain unchanged throughout the year.

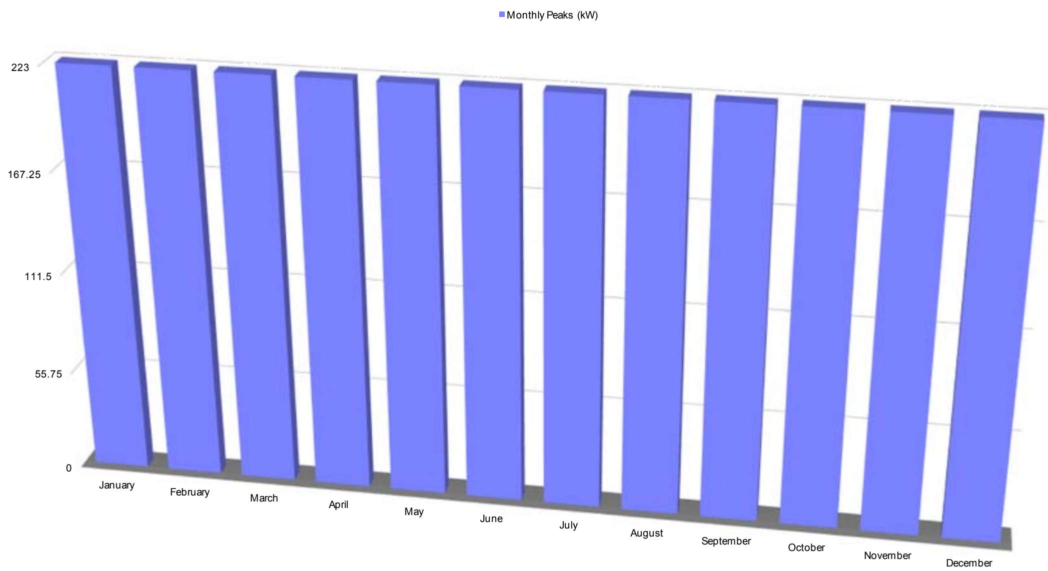


Figure 1 - Monthly Peaks for Revised Residential Loads

Figures 2 (a) to (d) show the load distribution during one day in each of the months of January, April, July and October, representing each season. The loads are representative of the evening peak consumption at around 225kW and the morning peak consumption at around 100 kW. Residential customers do not have access to power from 9 am till 5 pm.

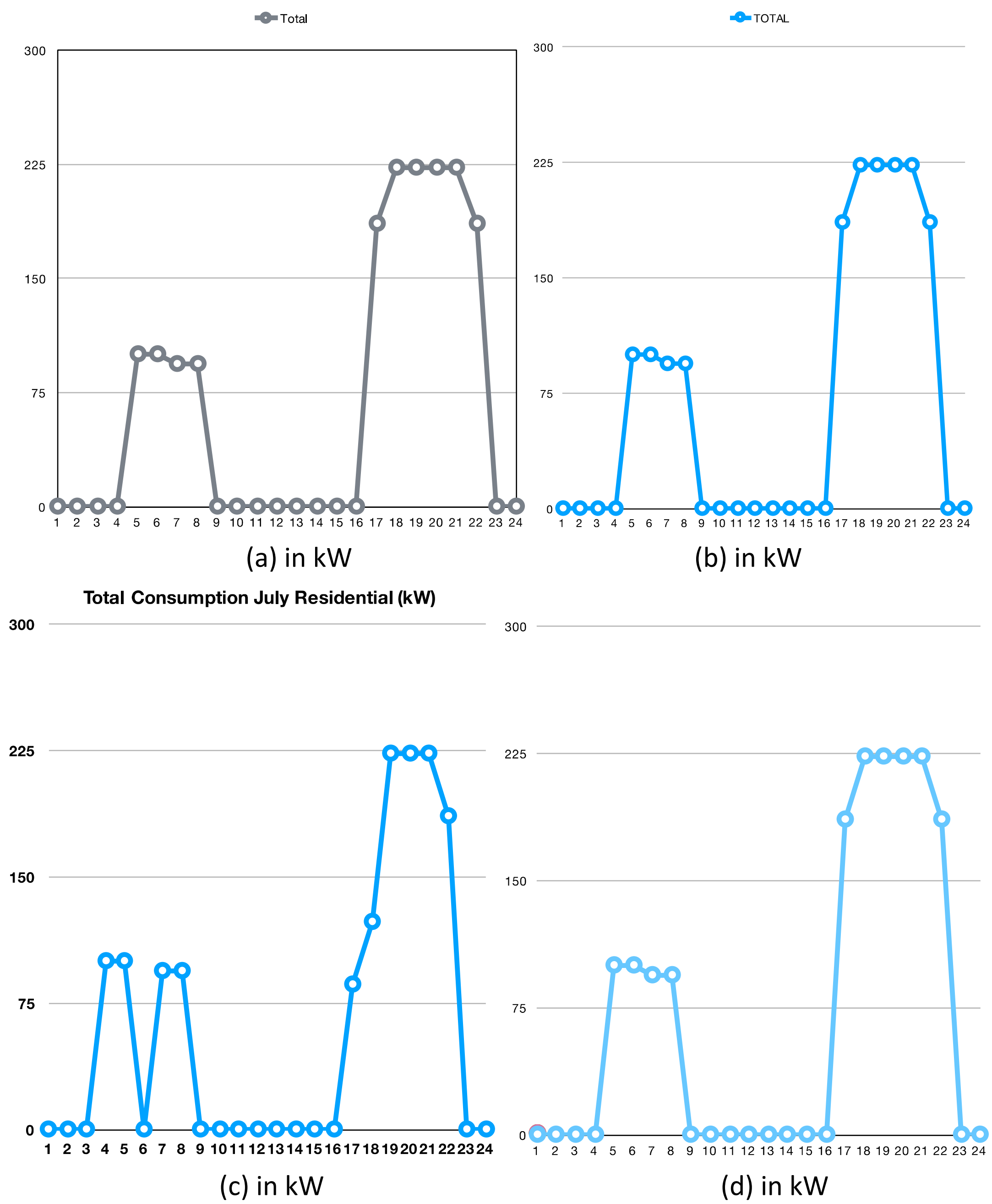


Figure 2: Revised Residential Load Profile for the Month of (a) January, (b) April, (c) July, (d) October

5.2 Commercial Load Assessment

The businesses in the cluster of villages include flour mills, phone towers, fruit/vegetable processing plants, tailor shops, grocery shops and some bicycle and motorcycle repair shops. Throughout the cluster of villages, 203 are present, out of which most businesses are located in Qalandar Khil village (49 businesses) and Turkman villages (47 businesses), with other villages following, including Jafar Khil village (30 businesses), Qala e Beland (30 businesses), Ghulam Shah (26 businesses) and Beg Muhammad Khil (21 businesses). Business loads in quantities are provided in Table 4.

The total load range on a per village basis are estimated at around 56.5 kW (Qala e Beland) and 231.5 kW (Qalandar Khil). The total power demand for the complete cluster of villages is estimated at around 849.1 kW.

The irrigation pumps are typically located in remote areas, mostly away from residential as well as commercial areas. Hence supporting them involves significant additional reticulation and connection costs. We recommend that irrigation pumps be remotely powered and as such removed from the business load profile. Eliminating the irrigation pumps as a load will change the load configuration so that the total load range on a per village basis are estimated at around 41.5 kW (Qala e Beland) and 181.5 kW (Qalandar Khil). The total power demand for the complete cluster of villages is estimated at around 619.1 kW.

The flour mills require significant amount of energy to operate. They are typically seasonal businesses, with 3-4 months (August to November) being their high season and the remainder of the year low season. During the low season, they operate only sporadically as and when needed. Some interviewed flour mill operators informed us that at times they do not operate their mill for more than a week. Additionally, these mills use diesel-engines to run a belt that mechanically power the system. Hence, they would have to convert their mills to electric mills, in order to benefit from the utility's power. We, therefore, recommend that the flour mills also be eliminated from consideration. By eliminating the four mills, the total load is reduced to 45.7 kW, ranging from 5.7 kW (Beg Mohammad Khail) to 10.7 kW (Turkman).

The energy required by the commercial entities are described in table 3 below, which is a reflection of the number of days in a year and the number of hours in day, when these businesses are in operation.

Commercial Data

		Qalandar Khail		Beg Muhammad Khail		Ghulam Shah		Jafar Khil		Turkman		Qala-e-Beland										
	Loads (kW)	Qty	Qty*Load (kW)	Qty	Qty*Load (kW)	Qty	Qty*Load (kW)	Qty	Qty*Load (kW)	Qty	Qty*Load (kW)	Qty	Qty*Load (kW)		Total Qty	Total kW	Hours	Total kWh/ Day	Days/ Year	kWh/Year		
Irrigation Pump	0	10	0	8	0	5	0	0	0	20	0	3	0		46.00	0.00	0.00	0.00	182.50	0.00		
Flour Mill	0	10	0	2	0	9	0	7.00	0.00	4.00	0.00	2.00	0.00		34.00	0.00	0.00	0.00	273.75	0.00		
Telephone Tower	1.5	1	1.5	0	0	0	0	0.00	0.00	0.00	0.00	1.00	1.50		2.00	3.00	24.00	72.00	365.00	26,280.00		
Grape Drying	0	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	121.67	0.00		
Metal Work	1	2	2	2	2	2	2	2.00	2.00	2.00	2.00	2.00	2.00		12.00	12.00	4.00	48.00	273.75	13,140.00		
Fruit/Veg processing	0	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	182.50	0.00		
Tailoring Unit	1	6	6	1	1	1	1	6.00	6.00	1.00	1.00	2.00	2.00		17.00	17.00	9.50	161.50	365.00	58,947.50		
Shops	0.1	20	2	8	0.8	8	0.8	15.00	1.50	20.00	2.00	20.00	2.00		91.00	9.10	10.50	95.55	365.00	34,875.75		
Oil Pump	0	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	6.00	0.00	365.00	0.00		
Hotels/Restaurants	0	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	8.00	0.00	365.00	0.00		
Other Commercial (Barber)	0	0	0	0	0	1	0	0.00	0.00	0.00	0.00	0.00	0.00		1.00	0.00	8.00	0.00	365.00	0.00		
	3.60	49.00	11.50	21.00	3.80	26.00	3.80	30.00	9.50	47.00	5.00	30.00	7.50			41.10		377.05		133,243.25		
																					133,243.25	kWh/Year
																				GHI * 365	1825	
																				kW-DC	73.01	

Table 3: Load and Energy Configuration for Commercial Loads

Accordingly, the amount of energy required to fulfill the demand generated by the commercial customers will be in the range of 112,350 kWh per year. This would mean that a Solar PV plant of approximately 73 kW will generate enough energy to support the demands of the commercial facilities.

The load profiles are prepared based on the seasonal requirements using the following input and output tables for each of the four seasons. In detail, the same profile has been created for every month of the year, depending on circumstances of the respective month.

In all of these cases (see table 4), we have used load and diversification factors of 1, with the exception of metal works, which in reality are mostly tire shops or motorcycle repair shops that operate their equipment only when the customer walks in (as described in Section 6 of Appendix III – Design Methodology) to cater to worst case scenario, because we lack credible historic data or reliable customer input to enable sound engineering calculations.

January Input

Hours	Load in kW	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum
Irrigation Pump	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Flour Mill	0	0	0	0	0	0	0	0	0	0	0	0.2	0.2	0.2	0.2	0.2	0	0	0	0	0	0	0	0	0	1
Telephone Tower	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	24
Grape Drying	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Metal Work	12	0	0	0	0	0	0	0	0	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0	0	0	0	0	0	0	4
Fruit/Veg processing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tailoring Unit	17	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	9
Shops	9.1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	10
Oil Pump	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	6
Hotels/Restaurants	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	8
Other Commercial (Barber)	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	8

(a-I)

January Output

Hours	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum in kWh
Irrigation Pump	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Flour Mill	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Telephone Tower	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	**72**
Grape Drying	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Metal Work	0	0	0	0	0	0	0	0	0	6	6	6	6	6	6	6	6	0	0	0	0	0	0	0	**48**
Fruit/Veg processing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Tailoring Unit	0	0	0	0	0	0	0	0	0	17	17	17	17	17	17	17	17	17	0	0	0	0	0	0	**153**
Shops	0	0	0	0	0	0	0	0	0	9	9	9	9	9	9	9	9	9	9	0	0	0	0	0	**91**
Oil Pump	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Hotels/Restaurants	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Other Commercial (Barber)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TOTAL	3	3	3	3	3	3	3	3	3	35	35	35	35	35	35	35	35	29	12	3	3	3	3	3	**364**

(a-O)

April Input

Hours	Load in kW	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum
Irrigation Pump	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	**6**
Flour Mill	0	0	0	0	0	0	0	0	0	0	0	0.2	0.2	0.2	0.2	0.2	0	0	0	0	0	0	0	0	0	**1**
Telephone Tower	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**24**
Grape Drying	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Metal Work	12	0	0	0	0	0	0	0	0	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0	0	0	0	0	0	0	**4**
Fruit/Veg processing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Tailoring Unit	17	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	**9**
Shops	9.1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	**10**
Oil Pump	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	**6**
Hotels/Restaurants	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	**8**
Other Commercial (Barber)	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	**8**

(b-I)

April Output

Hours	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum in kWh
Irrigation Pump	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Flour Mill	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Telephone Tower	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	**72**
Grape Drying	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Metal Work	0	0	0	0	0	0	0	0	0	6	6	6	6	6	6	6	6	0	0	0	0	0	0	0	**48**
Fruit/Veg processing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Tailoring Unit	0	0	0	0	0	0	0	0	0	17	17	17	17	17	17	17	17	17	0	0	0	0	0	0	**153**
Shops	0	0	0	0	0	0	0	0	0	9	9	9	9	9	9	9	9	9	9	0	0	0	0	0	**91**
Oil Pump	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Hotels/Restaurants	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Other Commercial (Barber)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TOTAL	3	3	3	3	3	3	3	3	3	35	35	35	35	35	35	35	35	29	12	3	3	3	3	3	**364**

(b-O)

July Input

Hours	Load in kW	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum
Irrigation Pump	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	6
Flour Mill	0	0	0	0	0	0	0	0	0	0	0	0.2	0.2	0.2	0.2	0.2	0	0	0	0	0	0	0	0	0	1
Telephone Tower	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	24
Grape Drying	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Metal Work	12	0	0	0	0	0	0	0	0	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0	0	0	0	0	0	0	4
Fruit/Veg processing	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	12
Tailoring Unit	17	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	10
Shops	9.1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	11
Oil Pump	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	6
Hotels/Restaurants	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	8
Other Commercial (Barber)	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	8

(c-I)

July Output

Hours	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum in kWh
Irrigation Pump	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Flour Mill	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Telephone Tower	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	72
Grape Drying	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Metal Work	0	0	0	0	0	0	0	0	0	6	6	6	6	6	6	6	6	0	0	0	0	0	0	0	48
Fruit/Veg processing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tailoring Unit	0	0	0	0	0	0	0	0	0	17	17	17	17	17	17	17	17	17	17	0	0	0	0	0	170
Shops	0	0	0	0	0	0	0	0	0	9	9	9	9	9	9	9	9	9	9	9	0	0	0	0	100.1
Oil Pump	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hotels/Restaurants	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Commercial (Barber)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	3	3	3	3	3	3	3	3	3	35	35	35	35	35	35	35	35	29	29	12	3	3	3	3	390.1

(c-O)

October Input

Hours	Load in kW	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum
Irrigation Pump	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	6
Flour Mill	0	0	0	0	0	0	0	0	0	0	0	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0	0	0	0	0	0	0	2
Telephone Tower	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	24
Grape Drying	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	12
Metal Work	12	0	0	0	0	0	0	0	0	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0	0	0	0	0	0	0	4
Fruit/Veg processing	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	12
Tailoring Unit	17	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	9
Shops	9.1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	10
Oil Pump	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	6
Hotels/Restaurants	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	8
Other Commercial (Barber)	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	8

(d-I)

October Output

Hours	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum in kWh
Irrigation Pump	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Flour Mill	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Telephone Tower	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	**72**
Grape Drying	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Metal Work	0	0	0	0	0	0	0	0	0	6	6	6	6	6	6	6	6	0	0	0	0	0	0	0	**48**
Fruit/Veg processing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Tailoring Unit	0	0	0	0	0	0	0	0	0	17	17	17	17	17	17	17	17	17	0	0	0	0	0	0	**153**
Shops	0	0	0	0	0	0	0	0	0	9	9	9	9	9	9	9	9	9	9	0	0	0	0	0	**91**
Oil Pump	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Hotels/Restaurants	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Other Commercial (Barber)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TOTAL	3	3	3	3	3	3	3	3	3	35	35	35	35	35	35	35	35	29	12	3	3	3	3	3	**364**

(d-O)

Table 4: Diversification of Commercial Loads (inputs and Outputs) in Wh, (a-I) Input for January, (a-O) Output for January, (b-I) Input for April, (b-O) Output for April, (c-I) Input for July, (c-O) Output for July, (d-I) Input for October, (d-O) Output for October

Based on the load demands of the commercial/industrial customers, there is an expected peak power requirement of around 35 kW throughout the year with no significant seasonal variations. This can be seen in Figure 3 below. The assumption is that all businesses will operate year-round at full capacity. Once the system has been in operation for about 6-months to a year, we will be able to better understand the behavior of commercial customers and can make necessary adjustments to further meet the realities on the ground.

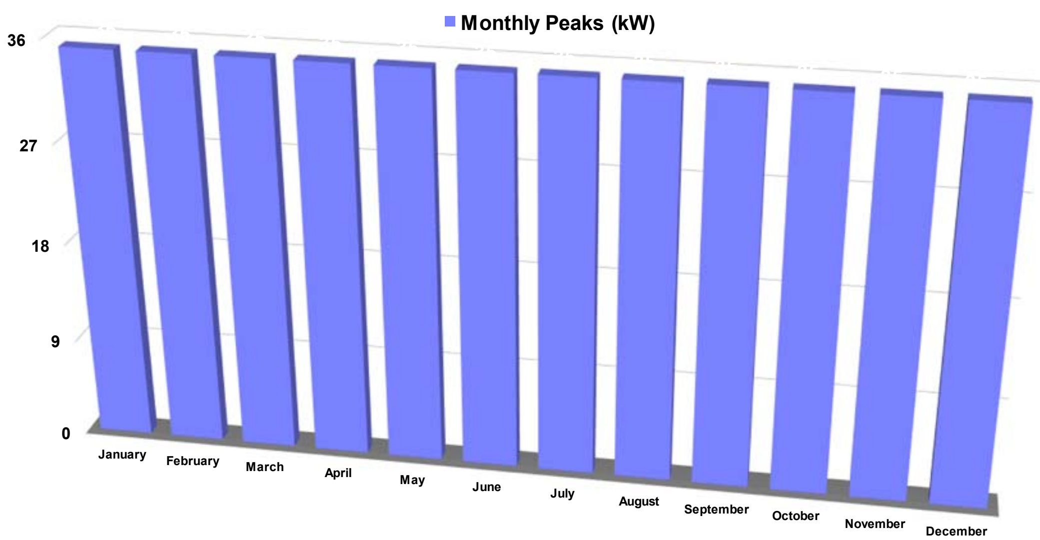


Figure 3: Monthly Peaks for Commercial and Industrial Loads

Figure 4 shows the load profile for the Commercial and Industrial (C&I) customers during the month of September. The load curve represents the average of load for a particular hour over the whole month. The load profile shows that during 24-hour period of a day, the C&I customers use the electricity during the day time (between 9 am and 5 pm). Also, most of the C&I businesses close down in the evening, hence, bringing the load close to zero (about 3kW for Telephone tower).

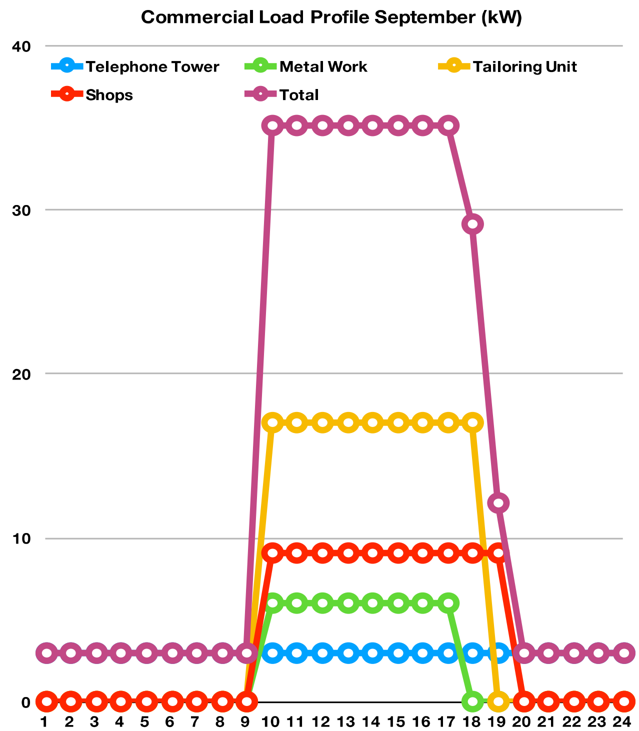


Figure 4: Commercial and Industrial Load profile for the month of September. All other months are identical

5.3 Institutional Load Assessment

There are not many government institutions in the cluster of villages. Altogether only one hospital (10 beds), three schools, three police posts and 44 mosques (main and local), a Darul Hafaaz and one other government agency are located in the cluster of villages. The exact numbers are shown in Table 5.

The power consumption of these institutions is fairly reasonable at around 25.26 kW. Except for the school, the other institutions require power both during the day time and at night time.

According to the survey results the amount of energy required to fulfill the demand generated by the institutional customers will be around 124,350 kWh per year. This would mean an approximately 68 kW Solar PV plant will generate enough energy to support the demands of the institutional facilities.

Institute Data

		Qalandar Khail		Beg Muhammad Khail		Ghulam Shah		Jafar Khil		Turkman		Qala-e-Beland							
	Loads (kW)	Qty	Qty*Load (kW)	Qty	Qty*Load (kW)	Qty	Qty*Load (kW)	Qty	Qty*Load (kW)	Qty	Qty*Load (kW)	Qty	Qty*Load (kW)	Total Qty	Total kW	Hours	Total kWh/ Day	Days/ Year	kWh/Year
Hospitals	9.99	1	9.99	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	1.00	9.99	24.00	239.76	365.00	87,512.40
Schools	1.645	1	1.645	0	0	0	0	0.00	0.00	1.00	1.65	1.00	1.65	3.00	4.94	6.00	29.61	273.75	8,105.74
Police Station	0.309	1	0.309	0	0	0	0	0.00	0.00	1.00	0.31	1.00	0.31	3.00	0.93	24.00	22.25	365.00	8,120.52
Main Mosque	0.31	2	0.62	2	0.62	1	0.31	1.00	0.31	1.00	0.31	1.00	0.31	8.00	2.48	6.00	14.88	365.00	5,431.20
Small/Local Mosque	0.18	6	1.08	5	0.9	6	1.08	7.00	1.26	8.00	1.44	4.00	0.72	36.00	6.48	6.00	38.88	365.00	14,191.20
Darul Hafaaz	0.45	0	0	0	0	0	0	0.00	0.00	1.00	0.45	0.00	0.00	1.00	0.45	6.00	2.70	365.00	985.50
Other Govt Offices	1	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.00	0.00	365.00	0.00
	13.88	11.00	13.64	7.00	1.52	7.00	1.39	8.00	1.57	12.00	4.15	7.00	2.98		25.26		348.08		124,346.56

	124,346.56	kWh/Year
GHI * 365	1825	
kW-DC	68.14	

Table 5: Load and Energy Configuration for Institutional Loads

The load profiles are prepared based on the seasonal requirements using the following input and output tables for each of the four seasons (Table 6). In detail, the same profile has been created for every month of the year, depending on the respective circumstances.

In all of these cases, we have used load and diversification factors of 1 (as described in Section 6 of Appendix III – Design Methodology) to cater to worst case scenario, because we lack credible historic data or reliable customer input to enable sound engineering calculations.

January Input

Hours	Load in kW	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum
Hospitals	9.99	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	24
Schools	4.94	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Police Station	0.93	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	24
Main Mosques	2.48	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	6
Small/Local Mosques	6.48	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	6
Darul Hafaaz	0.45	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	8
Other Govt Offices	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	8

(a-I)

January Output

Hours	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum in kWh
Hospitals	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	239.76
Schools	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Police Station	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	22.32
Main Mosques	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	2	2	2	2	0	0	0	0	0	14.88
Small/Local Mosques	0	0	0	0	6	6	0	0	0	0	0	0	0	0	0	6	6	6	6	0	0	0	0	0	38.88
Darul Hafaaz	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.6
Other Govt Offices	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	11	11	11	11	20	20	11	11	11	11	11	11	11	11	11	20	20	20	20	11	11	11	11	11	319.44

(a-O)

April Input

Hours	Load in kW	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum
Hospitals	9.99	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	24
Schools	4.94	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	6
Police Station	0.93	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	24
Main Mosques	2.48	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	6
Small/Local Mosques	6.48	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	6
Darul Hafaaz	0.45	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	8
Other Govt Offices	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	8

(b-I)

April Output

Hours	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum in kWh
Hospitals	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	239.8
Schools	0	0	0	0	0	0	0	5	5	5	5	5	5	0	0	0	0	0	0	0	0	0	0	0	29.64
Police Station	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	22.32
Main Mosques	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	2	2	2	2	0	0	0	0	0	14.88
Small/Local Mosques	0	0	0	0	6	6	0	0	0	0	0	0	0	0	0	6	6	6	6	0	0	0	0	0	38.88
Darul Hafaaz	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.6
Other Govt Offices	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	11	11	11	11	20	20	11	16	16	16	16	16	16	11	11	20	20	20	20	11	11	11	11	11	349.1

(b-O)

July Input

Hours	Load in kW	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum
Hospitals	9.99	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	24
Schools	4.94	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	6
Police Station	0.93	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	24
Main Mosques	2.48	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	6
Small/Local Mosques	6.48	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	6
Darul Hafaaz	0.45	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	8
Other Govt Offices	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	8

(c-I)

July Output

Hours	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum in kWh
Hospitals	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	239.76
Schools	0	0	0	0	0	0	0	5	5	5	5	5	5	0	0	0	0	0	0	0	0	0	0	0	29.64
Police Station	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	22.32
Main Mosques	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	2	0	0	0	14.88
Small/Local Mosques	0	0	0	6	6	0	0	0	0	0	0	0	0	0	0	0	0	6	6	6	6	0	0	0	38.88
Darul Hafaaz	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.6
Other Govt Offices	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	11	11	11	20	20	11	11	16	16	16	16	16	16	11	11	11	11	20	20	20	20	11	11	11	349.08

(c-O)

October Input

Hours	Load in kW	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum
Hospitals	9.99	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	24
Schools	4.94	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	6
Police Station	0.93	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	24
Main Mosques	2.48	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	6
Small/Local Mosques	6.48	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	6
Darul Hafaaz	0.45	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	8
Other Govt Offices	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	8

(d-I)

October Output

Hours	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum in kWh
Hospitals	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	239.76
Schools	0	0	0	0	0	0	0	5	5	5	5	5	5	0	0	0	0	0	0	0	0	0	0	0	29.64
Police Station	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	22.32
Main Mosques	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	2	2	2	2	0	0	0	0	0	14.88
Small/Local Mosques	0	0	0	0	6	6	0	0	0	0	0	0	0	0	0	6	6	6	6	0	0	0	0	0	38.88
Darul Hafaaz	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.6
Other Govt Offices	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	11	11	11	11	20	20	11	16	16	16	16	16	16	11	11	20	20	20	20	11	11	11	11	11	349.08

(d-O)

Table 6: Diversification of Institutional Loads (inputs and Outputs) in Wh, (a-I) Input for January, (a-O) Output for January, (b-I) Input for April, (b-O) Output for April, (c-I) Input for July, (c-O) Output for July, (d-I) Input for October, (d-O) Output for October

The load profile for the institutional loads is very consistent throughout the months of October to April with the peaks at around 20.3kW. During the months of May through September the peak goes down to around 19.9 kW. This reduction in loads is primarily due to the lighting loads at the mosques that are less due to longer days and shorter nights.

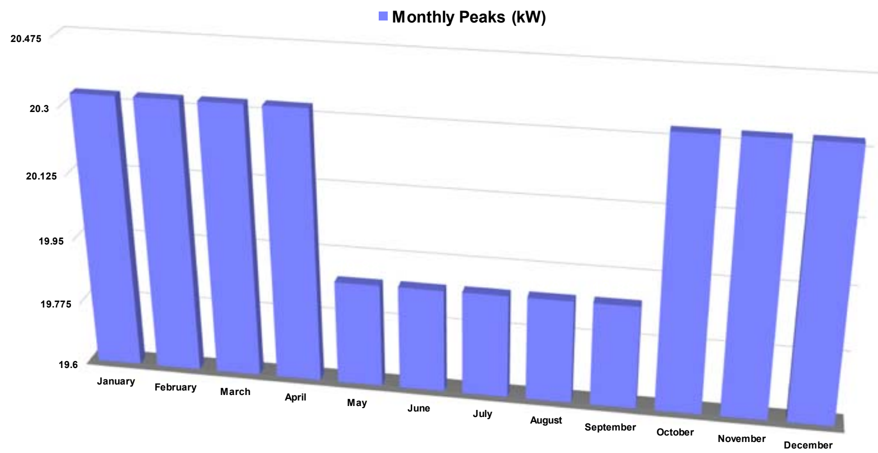
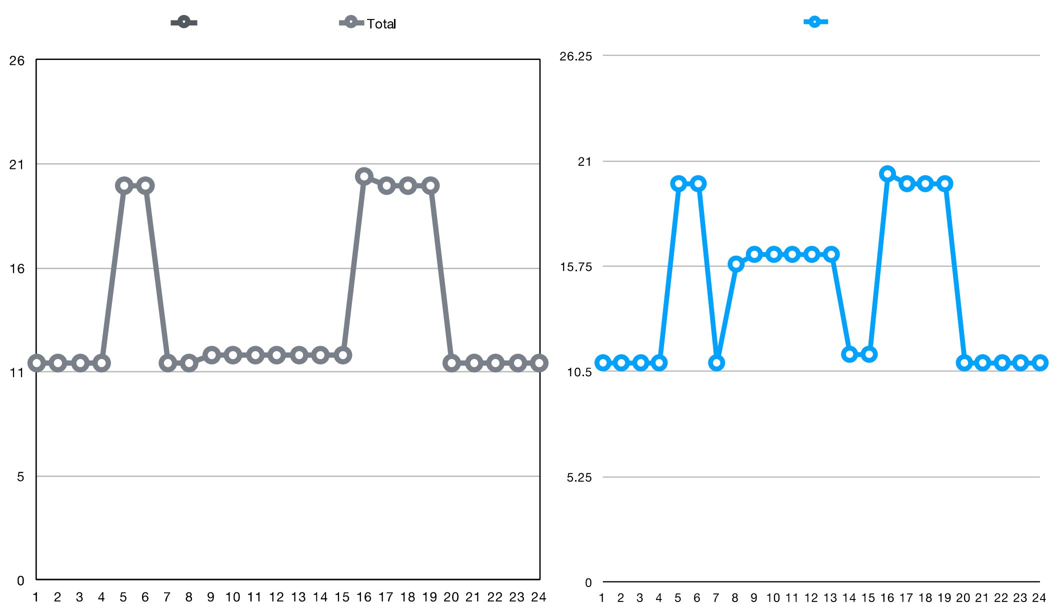
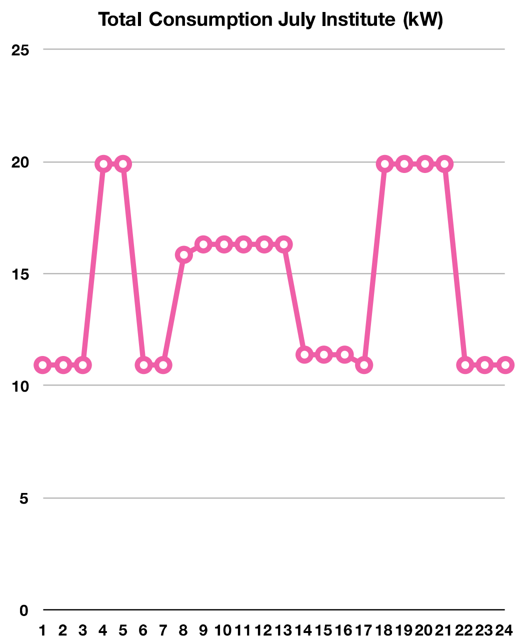


Figure 5: Monthly Peaks for Institutional Loads

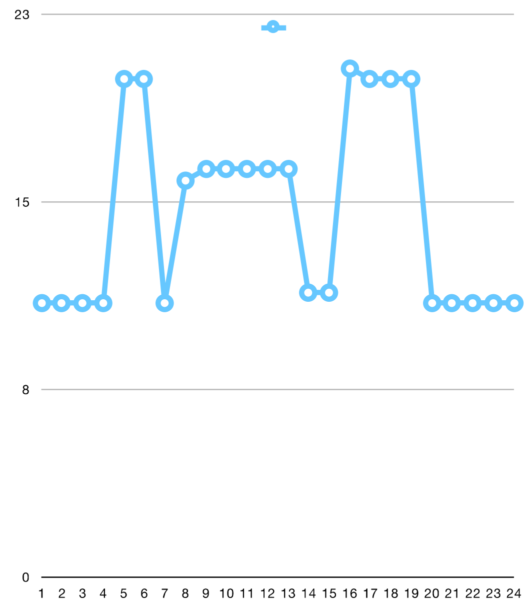
Figure 6 shows the institutional load profile for four seasons. As it can be seen that the total consumption during the month of January defers form the rest of the months in terms of total consumption in kW. The rest of the seasons have higher consumption rate than January and gives as a brief load operation on when these institutes load consumption is increased.



(a) for January in kW (b) For April in kW



(c) For July in kW



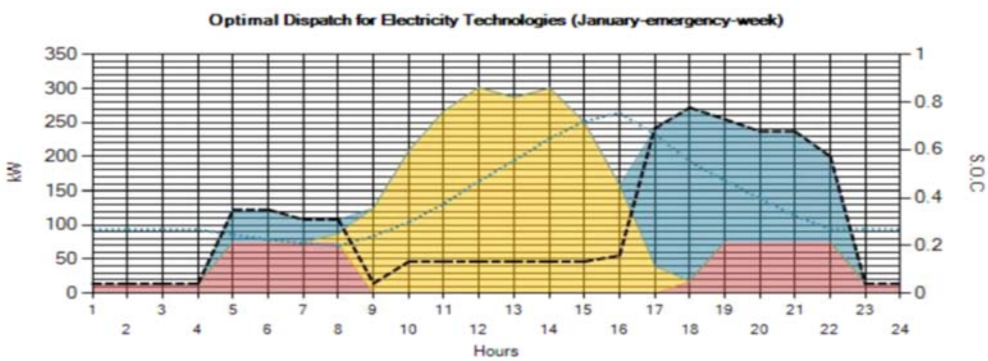
(d) for October in kW

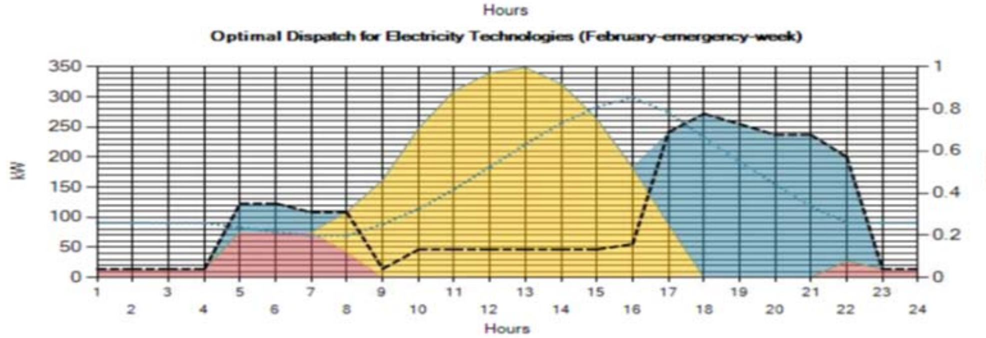
Figure 6: Institutional Load profile for the month of (a) January, (b) April, (c) July, (d) October

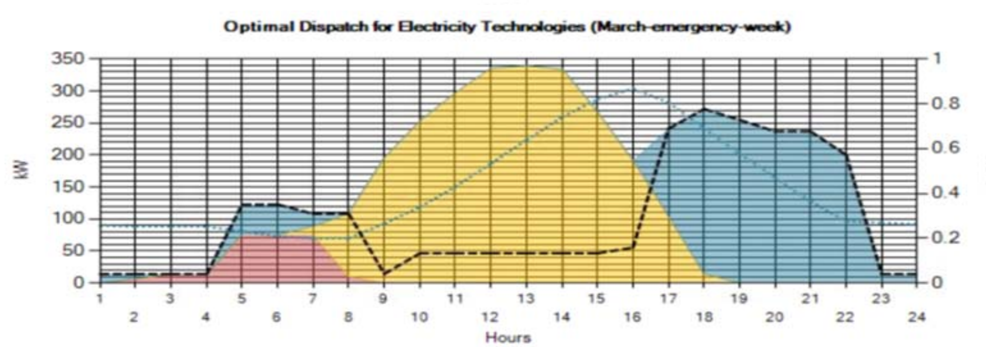
As seen in the previous chapters, the load profile and the peak load of the different kind of loads, namely, residential, commercial and institutional, is completely different. As the centralized mini-grid will support all types of loads, it is necessary to create a cumulative load profile. The cumulative load profile will represent the size and nature of the load that the mini-grid will be required to serve. The next chapter calculates and discusses the overall power demand for the cluster of these 6 villages.

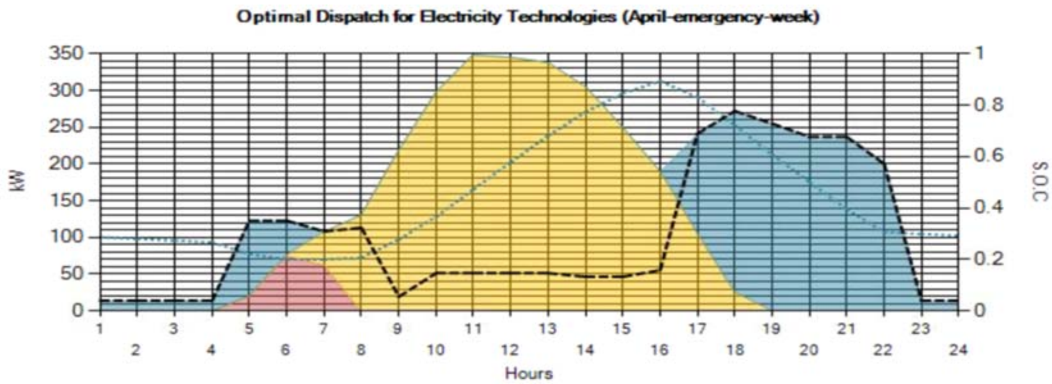
6. SYSTEM SIZING

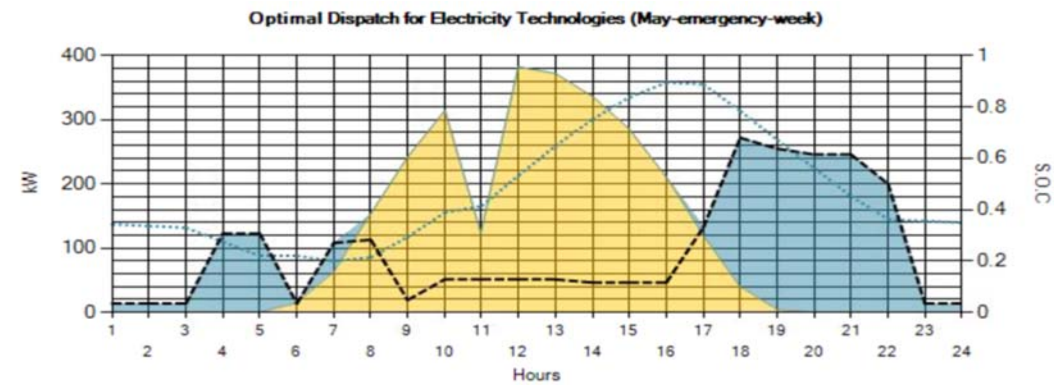
The mini-grid has been designed for 600kW Solar PV with a 2500kWh BESS and a 75kW diesel generator can ascertain a stable operation of the mini-grid. The mini-grid can completely support the loads for about 6 months of the year with 100% solar based generation but will need some amount of diesel in order to support all the loads for the remaining 6 months of the year. Figure 7, shows the charging and discharging curve for the mini-grid; it can be seen that in the months of January, February, March, April, November and December there is a need for diesel generator to operate in order to support the loads for a few hours. This can be achieved with a 75kW diesel generator. Also, the mini-grid will need diesel generator for providing back up power on the days that there won't be enough solar irradiation to generate the required energy. The total amount of diesel required to support a peak load of approximately 272kW will be around 275kW. If we are assuming that a 75kW diesel generator will be required for the regular operation of the mini-grid then it is proposed that another 300kW generator be present for back up operational support.

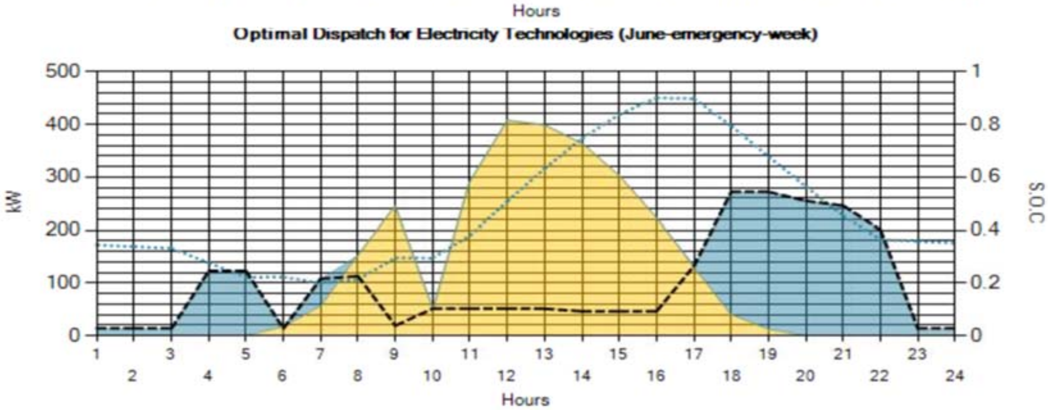


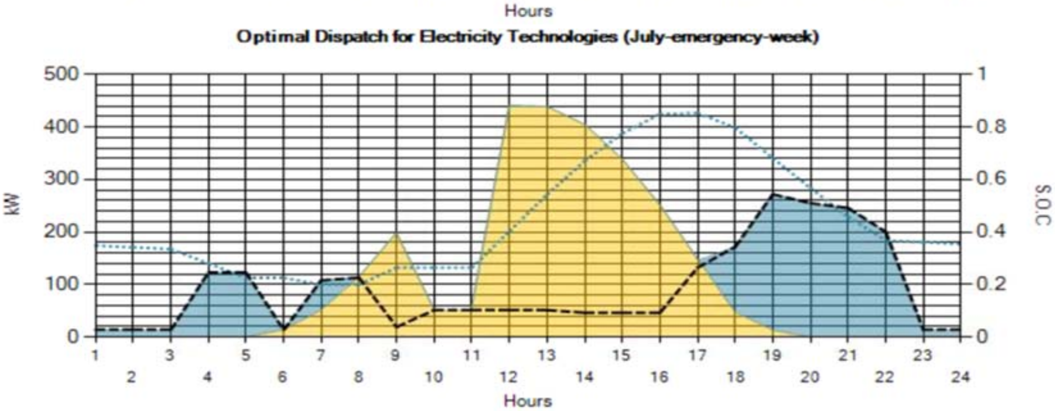


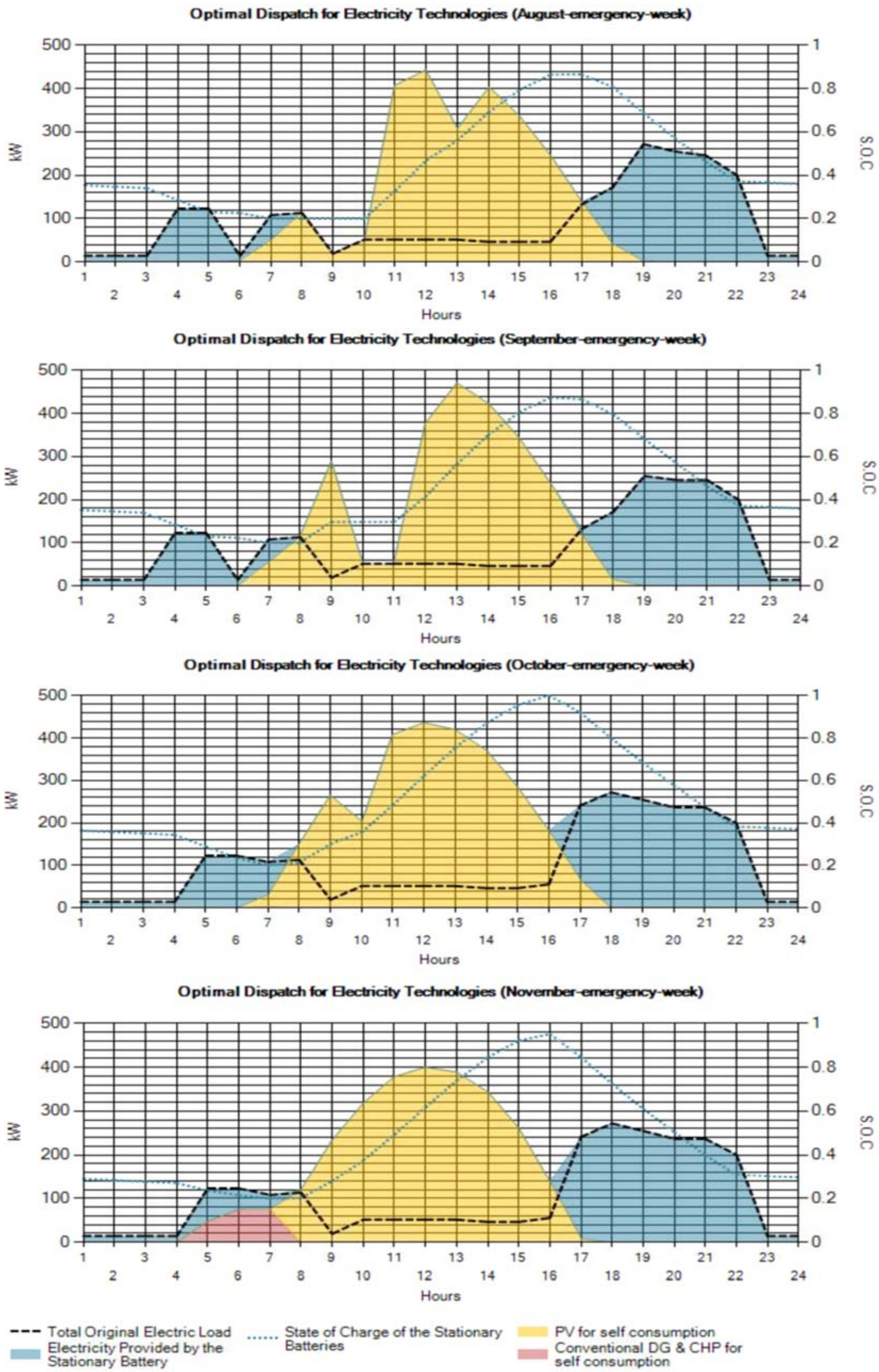



Optimal Dispatch for Electricity Technologies (April-emergency-week)
kW
S.O.C
Hours


Optimal Dispatch for Electricity Technologies (May-emergency-week)
kW
S.O.C
Hours


Optimal Dispatch for Electricity Technologies (June-emergency-week)
kW
S.O.C
Hours


Optimal Dispatch for Electricity Technologies (July-emergency-week)
kW
S.O.C
Hours


Optimal Dispatch for Electricity Technologies (August-emergency-week)
Optimal Dispatch for Electricity Technologies (September-emergency-week)
Optimal Dispatch for Electricity Technologies (October-emergency-week)
Optimal Dispatch for Electricity Technologies (November-emergency-week)
kW
S.O.C
Hours
Total Original Electric Load
Electricity Provided by the Stationary Battery
State of Charge of the Stationary Batteries
PV for self consumption
Conventional DG & CHP for self consumption

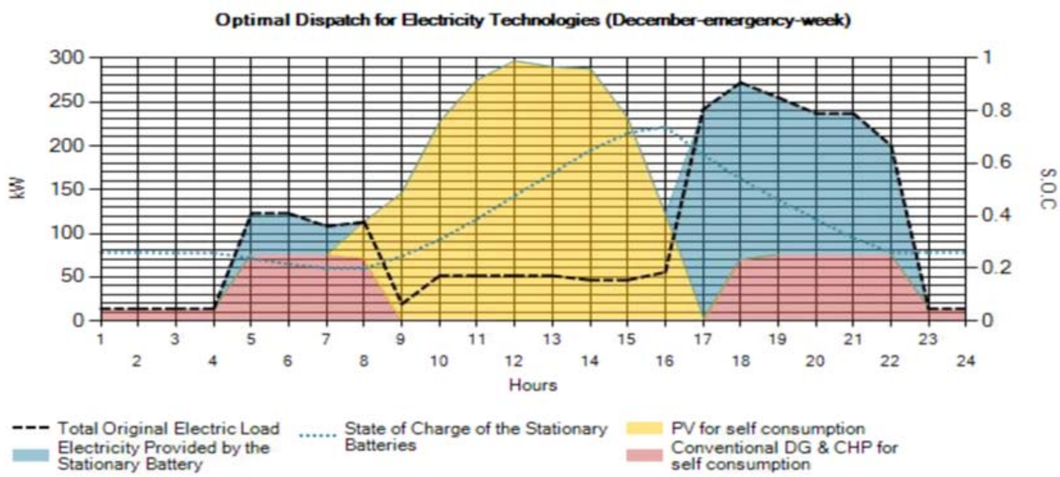


Figure 7: Optimal Charging and dispatch schedule for 600kW-dc Solar PV and 2500kWh BESS mini-grid.

In calculating the system size and the associated BESS, the design assumes a round-trip efficiency of 83% for the BESS (Lux Research – Press release on Li-Ion Cost edge for Stationary Energy Storage)[1], which translates to slightly smaller system size than other types of batteries.

For the estimated load profile created for Parwan, a mini-grid with a solar PV generator of about **600kW-dc** with a **2,500kWh** of battery storage is expected to operate with an estimated diesel cost of about **$15k per year** for a **75kW** diesel generator. Since the peak load is expected to be about 272kW, the system is proposed to have multiple diesel generators (300kW + 75kW) with a combined generation capacity of about 275kW. Having multiple generators will add redundancy to the backup system and reduce the need for operating one large generator, hence having a more efficient operation. Table 7 shows some basic calculations associated with the discussed system. The second column gives an estimate of the average monthly loads. Column 3 give the estimate of the energy that will be generated by the 600kW-dc solar system. Column 4 shows the energy generated from PV that will be used to support the loads. Column 5 gives an estimate of the surplus energy available from the PV system. Column 6 gives an estimate of the amount of energy supplied by the diesel generator. It should be noted that the amount of "Energy Supplied by Diesel" is not a simple difference between the "Average monthly Loads" and "Energy Supplied by Solar PV", rather a much higher number. The reason being that out of the estimated "Average Monthly Loads" not all of it is daytime load. DER-CAM does a detailed hour-by-hour calculation to estimate the amount of load that would directly be served by the solar production during the daytime and also the amount of energy that will be needed to charge the batteries, which will support the loads at night. Because of the charging

1 http://www.luxresearchinc.com/news-and-events/press-releases/read/li-ion-retains-cost-edge-stationary-energy-storage

and discharging efficiencies of the battery (roundtrip efficiency of about 90% x 90% = 81%), the amount of energy used to charge the batteries and then support the loads causes a higher amount of energy supplied by diesel. Column 7 gives an estimate of the Loss of Load Probability in absence of an operating 75kW diesel generator.

	Average Monthly Loads (MWh)	Energy Supplied by Solar PV (MWh)	Energy Used (MWh)	Surplus Energy (MWh)	Energy Supplied by Diesel (MWh)	Loss of Load Probability (LoLP)
January	72.43	60.48	60.48	0.00	21.73	30%
February	65.42	65.16	65.16	0.00	10.60	16%
March	72.43	75.77	75.77	0.00	8.37	12%
April	70.98	78.03	78.03	0.00	4.72	7%
May	70.25	90.26	82.49	7.77	0.00	0%
June	68.77	91.84	80.70	11.14	0.00	0%
July	67.96	102.72	79.46	23.26	0.00	0%
August	67.96	101.06	79.67	21.39	0.00	0%
September	64.98	103.59	76.45	27.15	0.00	0%
October	73.35	91.85	87.28	4.58	0.10	0%
November	70.98	77.79	77.79	0.00	5.91	8%
December	73.35	59.62	59.62	0.00	23.22	32%
	838.85	**998.18**	**902.89**	**95.29**	**74.65**	**8.75%**

Table 7: Calculations for a 600kW-dc PV System with a 2,500kWh BESS

Percentage of Loads supported by Diesel generation over a 1-year period 8.75%

Table 8 provides a detailed calculation on the amount and cost of diesel needed to produce the energy needed to support the 600kW-dc mini-grid.

Size of Diesel Generator (kW)	Hours of Operation per month	Fuel Consumption per hour (Gallon)	Total Fuel Consumed (liters)	Diesel Cost per liter	Total Diesel Cost	Cost of Energy by diesel ($/kWh)
75.00	289.79	6.10	6691.49	$0.65	$4,349.47	$0.20
75.00	141.36	6.10	3264.03	$0.65	$2,121.62	$0.20
75.00	111.55	6.10	2575.91	$0.65	$1,674.34	$0.20
75.00	62.95	6.10	1453.62	$0.65	$944.86	$0.20
75.00	0.00	6.10	0.00	$0.65	$0.00	$0.00
75.00	0.00	6.10	0.00	$0.65	$0.00	$0.00
75.00	0.00	6.10	0.00	$0.65	$0.00	$0.00
75.00	0.00	6.10	0.00	$0.65	$0.00	$0.00
75.00	0.00	6.10	0.00	$0.65	$0.00	$0.00
75.00	1.27	6.10	29.30	$0.65	$19.05	$0.20
75.00	78.77	6.10	1818.92	$0.65	$1,182.30	$0.20
75.00	309.64	6.10	7150.00	$0.65	$4,647.50	$0.20
	995.34		**22,983.29**		**$14,939.14**	

Table 8: Amount & Cost of Diesel needed for a 600kW-DC solar based mini-grid using a 75kW diesel generator

The design of electrical distribution system of the mini-grid emphasizes reliability. The building blocks of reliability are redundant electrical supplies, reliable feeders, multiple feeder paths, control system simplicity and reduction of possible human error. One of the design criteria is that the system should be able to operate without connection to the utility supply, in island mode.

The system has been designed for direct power supply during the day time to businesses and institutions, while night time power is provided to institutions, some businesses and the residential customers. The night-time power is provided by the Battery Energy Storage System (BESS), which can cater only to one night of relevant load. In order to increase the autonomy of the system to multiple days, both the PV system as well as the BESS will need to be significantly increased in size, which involve significant cost. So, in order to cater to multiple cloudy days, when solar radiation is low but the loads are still active, two diesel generator sets with a combined capacity of approximately 275kW will be installed and operated. A 75kW diesel generator will cover the power shortage during the months of January to April and November to December. One or both diesel generators will, however, be on standby for cloudy days to provide power.

The diesel generators will be configured in such a manner that while in operation, they will provide power to the commercial, institutional and/or residential customers, while at the same time charging the BESS. Once the BESS is fully charged, the generator will be shut off and the BESS will ensure power to the customers. Thus, the operating cost of the diesel generators will be maintained at a minimum rate and the overall system cost will be at controllable levels. Details of the design and configuration of the diesel generator system are part of the detailed project design and will not be addressed at this stage.

7. SYSTEM DESIGN

The Parwan mini-grid is based on the electricity being supplied by Solar PV + Battery Energy Storage System (BESS) and use of Diesel Generator as back up source of energy when PV/Battery output is not adequate.

7.1 System Sizing

Load: 275kW Peak Load
PV: 600kW-dc/500kW-ac
BESS: 2500kWh
Diesel: 300kW + 75kW
Grid-Tied Transformer: 500kVA

7.2 Configuration

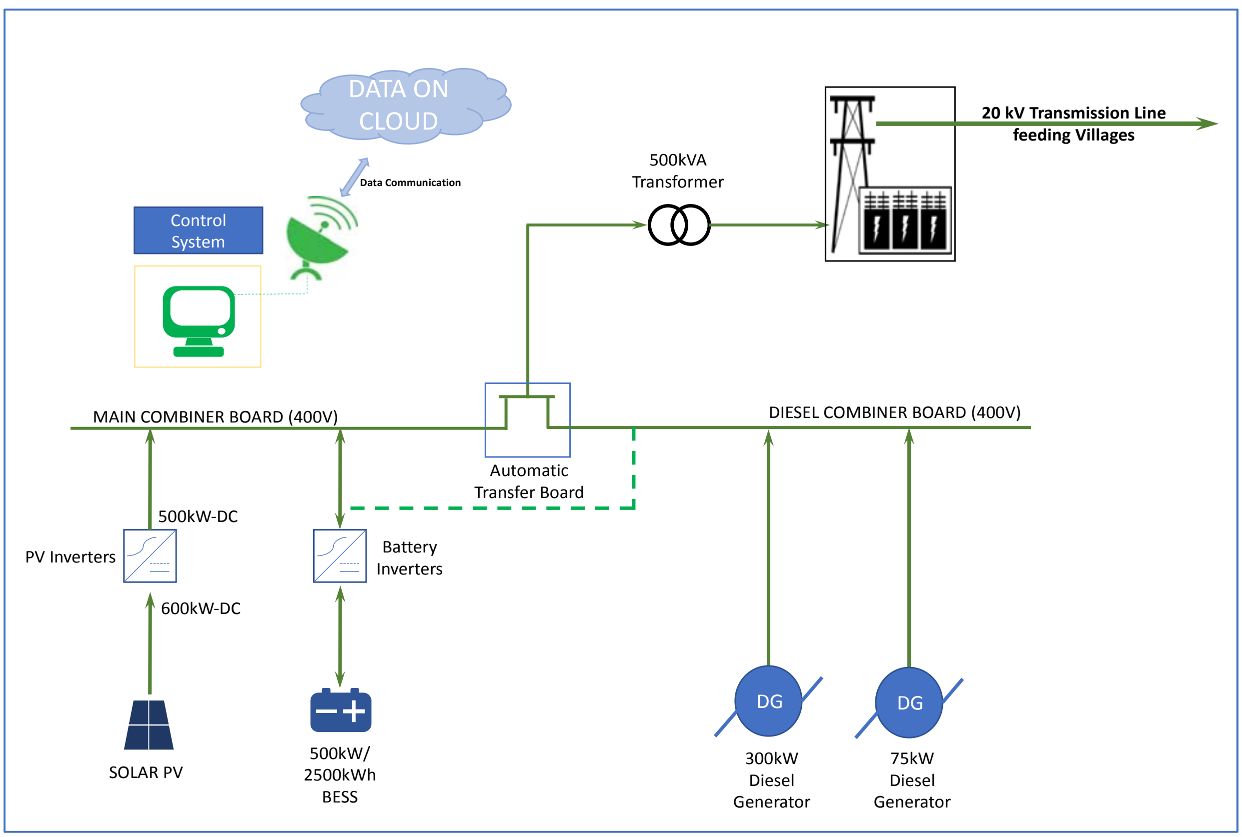


Figure 8: Block Diagram

7.3 Simplified One-Line

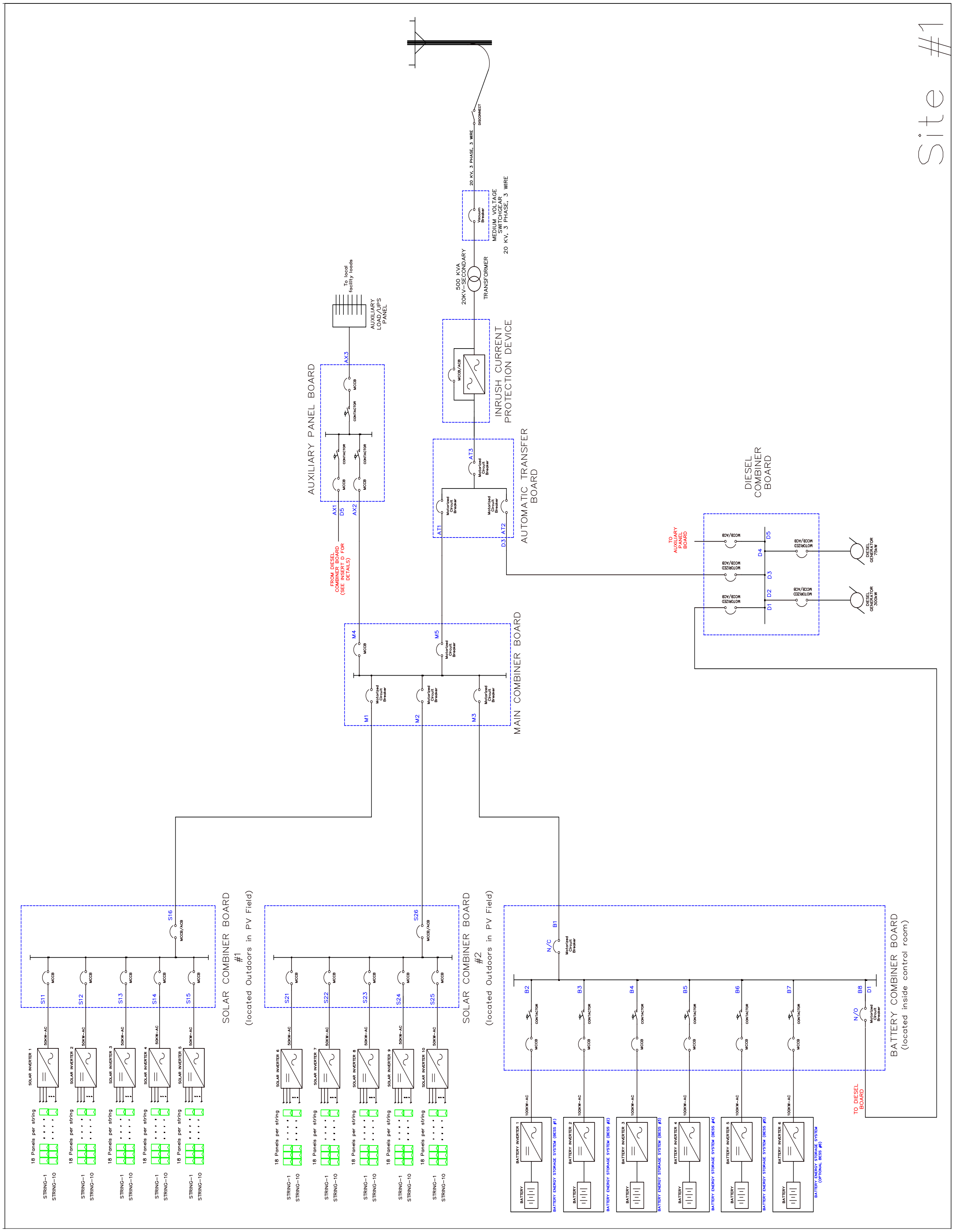


Figure 9: One-Line Diagram

7.4 Operation Logic

The high-level operating logic is the following:

1. As there is no utility, BESS will provide the master voltage and frequency. Solar inverters will follow this reference. System is started with BESS setting up the master voltage and frequency.
2. During day time when solar PV output is high enough, solar PV will be used to support the loads and simultaneously charge the BESS. BESS when sufficiently charged will also act as a buffer to manage short term solar variability.
3. In the evening, as the production from Solar PV starts declining, BESS starts discharging and the PV/BESS combination supports the load. Upon sunset PV inverters get switched OFF while BESS continues to support the load. This operation is carried out by the Automatic Transfer Panel, which is able to manage complex interactions between the various sources, including the PV, the BESS and the Diesel Generators. This operation is carried out by the SCADA and the PV/BESS inverters are able to follow the logic.
4. During the course of evening and night, BESS will support the loads without any PV. When the State of Charge (SOC) of the BESS drops to a predefined set point, the BESS inverters get switched OFF and the system transitions automatically to diesel operation. For a very short period of time (< 5 minutes) the diesel and BESS will operate in parallel in order to make sure that there is no interruption during the switch over from BESS to diesel. PV inverters will continue to remain OFF.
5. 75kW diesel generator unit will start first in case the load is below 50 KW and will continue to power the load until load exceeds 75KW. At this point the 300 KW generator starts automatically and the load gets transferred from the 75 KW unit to the 300 KW unit. There will be a very short period of parallel operation between both the diesel generators to avoid any interruption in the supply during this process. However, in case load at the end of step 4 above is higher than 75KW, the 300KW unit starts straight away skipping the 75KW generator operation.
6. In the morning, as the sun comes up, PV starts charging the BESS while diesel generator supports the load. This continues until output from solar PV is high enough to support the load (see step 7).
7. When the output from PV is high enough to support the load, diesel units get switched OFF and Solar PV takes over supporting the load while charging the BESS. The transition from diesel to PV+BESS is done with momentary paralleling in order to make sure that the transition from Diesel from PV is smooth and without interruption.
8. Load management to limit the load to the generation (to be done by reticulation system supplier). The SCADA system can be accessed via internet to check the actual PV production. They should also check the meteorological department forecast

(cloudy/sunny) to make a day ahead planning. Battery will handle any short-term variability.

9. During days with extended cloud overcast, diesel will continue to support the grid till PV output is high enough to support the load. Solar production during this time will be used to charge the BESS.
10. Emergency operation: During normal operation batteries are charged solely by solar PV. However, in the event of an emergency when batteries SOC level drops to a very low value, it is possible to use the diesel generators to provide emergency charging power to the batteries. PV inverters will be OFF during this operation. Diesel generator will act as the master during this operation and battery inverters will follow this reference signal.
11. Control system provided by the BESS supplier together with SCADA system should manage this operation logic and provide charge/discharge set points to BESS inverters and on/off commands for PV and diesel for optimum performance.

8. PV ARRAY DESIGN

8.1 Codes and Standards

8.1.1 Qualification Standards for PV Modules

- **IEC 61215:** International test standard for crystalline silicon terrestrial photovoltaic (PV) modules. Design qualification and type approval. Not a certification program.
- **IEC 61646:** International test standard for thin-film terrestrial photovoltaic (PV) modules. Design qualification and type approval. Not a certification program.
- **IEC 62108:** International test standard for concentrator modules/assemblies. Design qualification and type approval. Not a certification program.
- **IEEE 1262-1995:** Recommended practice for qualification of crystalline and thin -film PV modules. A test standard; not a certification program. Discontinued after the introduction of IEC 61646.
- **ANSI/UL 1703-2004**, Standard for Safety for Flat-Plate Photovoltaic Modules and Panels
- **ASTM WK25362**, Practice for Photovoltaic Module Reliability Assessment
- **IEC-TC82** IEC Technical Committee (IEC-TC82) Solar photovoltaic energy systems
- **UL1703** for Flat-Plate PV Modules and Panels. Comply with NEC, OSHA and NFPA.
- **UL1741** for Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources
- **UL 2703** – Rack Mounting System & Clamping Device for Flat-Plate PV Modules & Panels
- **UL 1699,** for Arc-Fault Circuit-Interrupters
- **UL 1699B,** AC AFCIs
- ASTM PV standards **E44.09** for PV Electric Power Conversion
- **IEC61215, IEC61730, IEC 62804 (PID FREE)**
- **IEC 62716** (Ammonia Test)
- **IEC 61730** Electrical and Mechanical Safety
- **IEC 61701** (Salt Spray Test)
- **IEC 60364-4-41** Protection Against Electric Shock
- **TS EN 13501-5** (Ignitability Test)
- Quality Certificates: **ISO 9001:2015, ISO 14001:2015, OHSAS 18001:2007**
- **PID Test 1000V**
- **Other applicable standards**

8.1.2 Qualification Standards for Inverters

- **UL 1741**
- **Surge Testing ANSI 62.41 and IEEE 1547-2003**

- **Protection IEC 62109-1/2**
- **IEC 61727**
- **IEC 62116**
- **Other applicable standards**

8.2 Design and Sizing

Based on the load profile created for the six villages, the Parwan mini-grid (Latitude: 34.99°N and Longitude: 69.28°E) will have to support an average load of approximately 95.76kW with a peak load of 271.98kW. The amount of energy to be generated over a period of 1-year is estimated to be around 838.85MWh. The solar energy produced during the day time will be used to support the loads and also to charge the batteries. Diesel generator(s) will be used to provide supplemental energy in case the solar PV is not able to provide enough energy required to support the loads.

The proposed Parwan mini-grid will rely mainly on solar PV based renewable energy generation to support the loads. The panels are proposed to be installed at a 35° tilt at an Azimuth of 0° (South-facing). The micro-grid modeling software DER-CAM is utilized to conduct the sizing of the mini-grid at Parwan based on the load profile. The load profile provides an estimate of the energy required by the loads on an hour-by-hour basis for one full year, thus, providing 8760 data points for a period of one-year. DER-CAM takes the Solar Insolation data and the load data for one year and provides the best sizing option for solar, battery and diesel resources optimized for the least operating cost.

Based on the load profile, the Parwan mini-grid is proposed to have a PV array providing 600kW-dc of solar generation that would provide approximately 500kW-ac power. The system is proposed to have 10 string inverters of 50kW-ac output each in order to achieve the 500kW-ac output. The mini-grid will also have 2500kWh of Battery Energy Storage System (BESS) and diesel generators that can support a peak load of 300kW.

The total land area required for the Parwan mini-grid generation site is approximately 16,000m^2.

8.3 PV Layout

The PV field at the Parwan location has a total of 1800 panels mounted on an adjustable tilt racking system. The maximum tilt for the panels will be at 35° at an Azimuth of 0° (south facing). There is a total of 10 rows of ground mount structures with each row consisting of two sets of panels mounted in portrait mode. One of the most important thing to calculate is the appropriate inter-row spacing in order to avoid shading of panels. First, let us calculate the approximate height of the mounted panels. As it can be seen in Figure 10, the length of each panel is approximately 1960 mm and if two panels are mounted in portrait mode then the total length is 3945mm. For Parwan site, if the maximum tilt we are considering is 35°, then the height of the mounting structure at the highest point will be: 3945*Sin 35°=2262.76mm

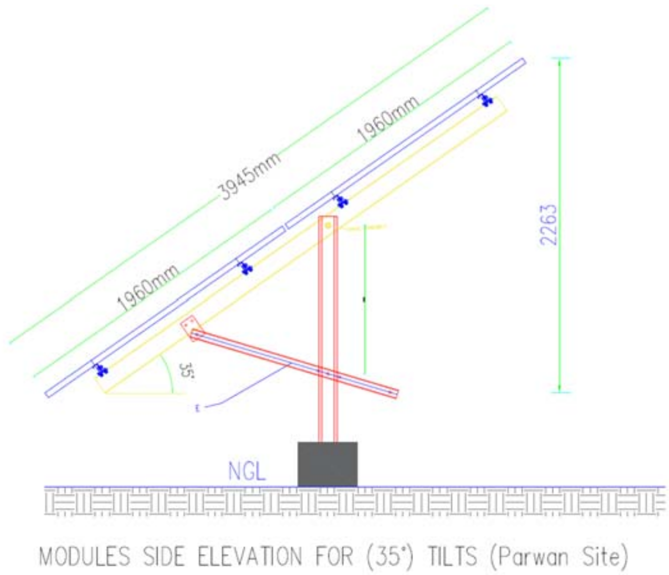


Figure 10: Solar Panel mounting in portrait mode

8.3.1 Tilt Angle Analysis

Following numbers from NREL's PV-Watts shows the annual energy production for different tilts angles: (see attached PV Watts reports for the different scenarios).

Panel Tilt Angle	Annual Average Solar Radiation (kWh/m²/day)	Annual AC Energy produced (kWh)
7 Degree	5.62	952,559
12 Degree	5.78	978,393
20 Degree	5.95	1,006,848
30 Degree	**6.03**	**1,020,357**
35 Degree	6.01	1,018,160
40 Degree	5.96	1,009,965

If fixed tilt angle is used, we recommend 30 Degrees because it has the maximum amount of energy produced over the whole year, namely 1,020,357 kWh.

Using variable tilt angles with three tilts at three seasons, we record an increased annual output of 2.72% for total of 27,703 kWh, which translates to additional revenue of $3,601 per annum at tariff rate of $0.13 per kWh and total of $90,034 over the 25 year life span of the system (see table below).

Tilt Angle	**Month**	**Output in kWh**
12 deg	May	106,620
	June	109,352
	July	113,602
	August	106,700
30 deg	March	79,107
	April	87,280
	September	98,432
	October	92,336
35 Deg	November	79,657
	December	61,221
	January	63,222
	February	50,531
Total Output		**1,048,060**
Output at 30 Deg. Only		1,020,357
Increased Output		**27,703**
Anticipated tariff		$0.13
Annual Additional Revenue		**$ 3,601.39**
System's Lifespan		25
Saving over Lifespan		**$ 90,034.75**

8.3.2 Inter Row Spacing

The inter row spacing is calculated based on the 35° panel tilt and the Solar Azimuth Angle and the Solar Altitude Angle for winter Solstice day (Dec 21st). Since the sunrises and sunset times on winter solstice day are approximately 7 am and 5 pm respectively, for maximum production during a day the inter-row spacing can be calculated for 8 am and/or 4 pm. When the solar system is in the grid connected mode it is a common practice to calculate the inter-row spacing based on the sun position for 9 am and 3 pm but in case of a micro grid it is essential to get the maximum energy generation from the system. The maximum row separation distance is calculated based on the height of the row and the sun location.

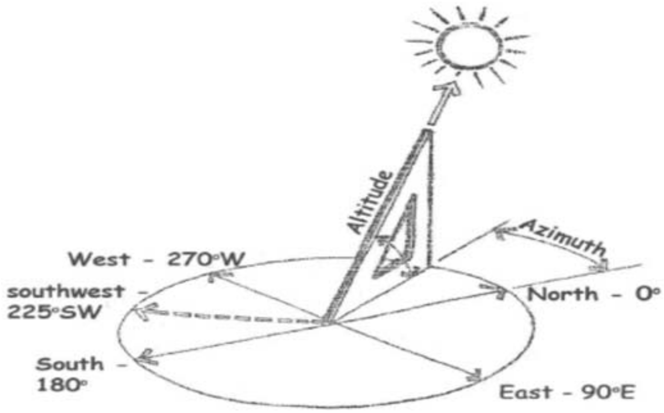


Figure 11: Calculation of Inter-Row Spacing

The minimum row spacing has to be more than the length of the shadow, L ,as seen in Fig. 11.

$$L = H \times Cos\ \psi / Tan\ \alpha$$

Where, H is the height of the row, ψ is the azimuth angle between solar azimuth and array azimuth (in degrees) and α is the solar altitude angle (in degrees). The value of Solar Azimuth and Solar Altitude angles can be estimated from Figure 12 showing the Sun Path Chart for a location at 35°N.

Case #1: Inter-row spacing for 9 am and 3 pm

If the height of the row is considered to be 2263mm, the value of solar azimuth angle to be 42° (at 9 am on Dec 21st) and solar altitude angle to be 18° (at 9 am on Dec 21st), then the maximum row separation is calculated to be 5175mm (17 feet).

Case #2: Inter-row spacing for 8 am and 4 pm

If the height of the row is considered to be 2263mm, the value of solar azimuth angle to be 52° (at 8 am on Dec 21st) and solar altitude angle to be 8° (at 8 am on Dec 21st), then the maximum row separation is calculated to be 9912mm (32.5 feet)

Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
December	0	0	0	0	0.0	0.0	0.0	87.9	305.0	474.5	572.2	618.4	604.0	599.5	484.4	255.1	5.9	0.0	0.0	0	0	0	0	0

Table 9: Global Effective Horizontal Irradiance Data (GH-Effective) for a South Facing - 35 degree Tilt

Based on the above table we can see that for the Parwan location there is good irradiation available between 9 am and 3 pm. So, for the islanded mode of operation for the micro grid, we recommend the inter-row spacing to be at least (6000mm). As the inter-row spacing increases, the production will also increase but considering the irradiation data available we recommend a minimum of (6000mm) of inter-row spacing.

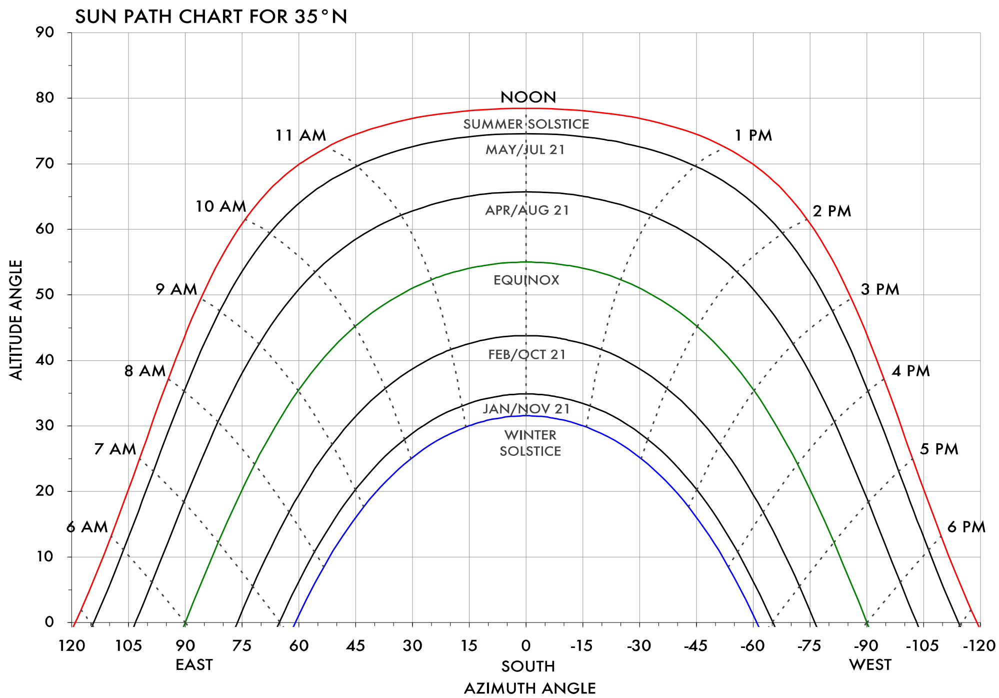


Figure 12: Sun Path Chart for Kandahar Location

8.3.3 Inter Row Spacing Analysis

As the inter-row spacing is reduced, the total annual energy production is reduced due to shading of panels, especially during the early morning and late afternoon hours. The inter-row spacing can be reduced and the ground coverage ratio (GCR) be lowered but the effect is a net loss in total energy produced.

The following table gives the annual energy generation data for different inter-row spacing models for the Parwan solar plant. The data has been generated by Helioscope Simulation using 30 Degrees tilt angle as the baseline.

Inter-row Spacing	Annual AC Energy produced (GWh)	kWh/kW
10 feet (3m)	1.084 GWh	1,797.00
12 feet (3.7m)	1.088 GWh	1,803.90
17 feet (5.2m)	1.096 GWh	1,814.80
18 feet (5.5m)	1.099 GWh	1,823.10
20 feet (6 meters)	**1.100 GWh**	**1,824.60**

The land size and annual energy production is optimized by selecting the inter-row spacing after which further increase does not provide any significant increase in production. The table shows that, at a tilt angle of 30 Degrees, 17 feet (5.2 meters) inter-row spacing will enable the generation of 1,096 GWh of energy, while at inter row spacing of 20 feet (6 meters), 1.100 GWh of energy is produced. This translates to an increase of 4,000 kWh per year or a total of 100,000 kWh for the lifespan of the system. At a tariff rate of $0.13 per kWh, the additional production at 6 meters will translate to additional income of $520 per year for total of $13,000 for the life span of the system. This is shown in the table below:

Inter-Row Spacing	Output in GWh
17 feet	1.096
20 Feet	1.1
Difference in GWh per year	0.004
Difference in kWh per year	4,000
Difference in kWh per Life span of 25 years	100,000.00
Tariff	$0.13
Total additional Income/Year	$520
Total Income over Life span of 25 years	$13,000.00

By using inter-row spacing of 20 feet (6.0 meters), compared to 17 feet (5.2 meters), the total area saved will amount 759 square meters or about 0.38 Jerib.

Row space for 17 Ft (5.2 meters)	5.175	meters
Row space for 20Ft (6 meters)	6	meters
Difference	0.825	meters
Length of row	92	meters
Number of rows	10	
Total Land area saved	759	m2
Total Land Area Saved	0.3795	Jerib
Cost per Jerib	$10,000.000	
	$3,795	
Additional financial benefit due to ~20 ft row spacing	$9,205.00	

8.3.4 Solar Panels

The primary component common to all Solar PV systems is the PV array. An array consists of individual PV modules that are electrically connected to produce a desired voltage, current and power output. Modules and arrays produce DC power, which can be used to charge batteries or can be converted to AC power by inverters to power AC loads.

The voltage of PV modules varies with temperature, and the current varies proportionately to the solar irradiance, so the power output is always varying.

8.3.5 I-V Curve

The current-voltage (I-V) characteristic is the basic electrical output profile of a PV module. The I-V characteristic represents all possible current-voltage operating points and power output for a given PV module at a specified condition of incident solar radiation and cell temperature. Certain points on I-V curves are used to rate module performance and are the basis for the electrical design of the PV array. The parameters include Open-circuit voltage (V_{OC}), short-circuit current (I_{SC}), maximum power voltage (V_{MP}), maximum power current (I_{MP}) and maximum power (P_{MP}). It is important to note that the I-V curve changes with cell temperature and irradiance, and that I-V parameters have meaning only when these conditions are specified.

The V_{OC} is the maximum voltage on an I-V curve and is the operating point for the PV array under infinite load or open-circuit condition and no current output. The V_{OC} is used to determine the maximum circuit voltage for modules and arrays. Increasing temperature reduces the V_{OC} for crystalline silicon solar cells.

The I_{SC} is the maximum current on an I-V curve and is the operating point for a PV device under no load condition and no voltage output. The I_{SC} is used to determine maximum circuit design currents for modules and arrays and is significantly affected by varying solar irradiance.

8.3.6 Temperature Coefficient

A temperature coefficient is the rate of change in voltage, current and power output from a PV module due to changing cell temperature. Temperature coefficient can be expressed as a unit (absolute) change or percentage (relative) change per degree of temperature change. Typically, the temperature coefficient for Silicon is negative, meaning that the voltage reduces with increase in the cell temperature.

Refer to technical specifications for detailed specs of the PV panels.

8.4 PV Inverters

Battery based inverters are used in stand-alone PV systems and operate directly from battery banks as their input source. Most battery-based inverters are bi-directional and include in-built battery chargers.

8.4.1 Maximum Power Point Tracking (MPPT)

The operating point at which the PV array produces its maximum power output lies between its open-circuit and short-circuit condition, when the device is electrically loaded with some finite resistance. The maximum power point (P_{MP}) is the operating point on the I-V curve where the product of current and voltage is at its maximum. The voltage and current output from an array can vary with temperature, irradiance, and load. Various combinations of these factors produce power output anywhere between the maximum rated power level and zero. For any combination of temperature and irradiance, there is a maximum possible power output that corresponds to a certain voltage and current. A maximum power point tracker is a device or circuit that uses electronics to continually adjust the load on a PV device under changing temperature and irradiance conditions to keep it operating at it maximum power point.

Refer to technical specifications for detailed specs for PV panels.

8.5 PV Strings

The PV string sizing discussed here is based on the use of 335W, 72-cell polycrystalline PV module. Each inverter has the ability to have 10 PV strings as input. Based on the allowed input for the inverters and the voltage and current ratings for the solar panels, each solar string will have 18 solar panels connected in series. This will allow approximately 6kW-dc output from each PV string. 10 such strings (of 18 panels in each string) will be connected to one PV inverter. Each inverter will have an output of 50kW-ac and outputs from 5 inverters will be connected to a combiner panel. Total of 2 combiner panels will combine the output from all the 10 inverters. The details of the solar panels, inverters and combiner panel are provided in the drawing set.

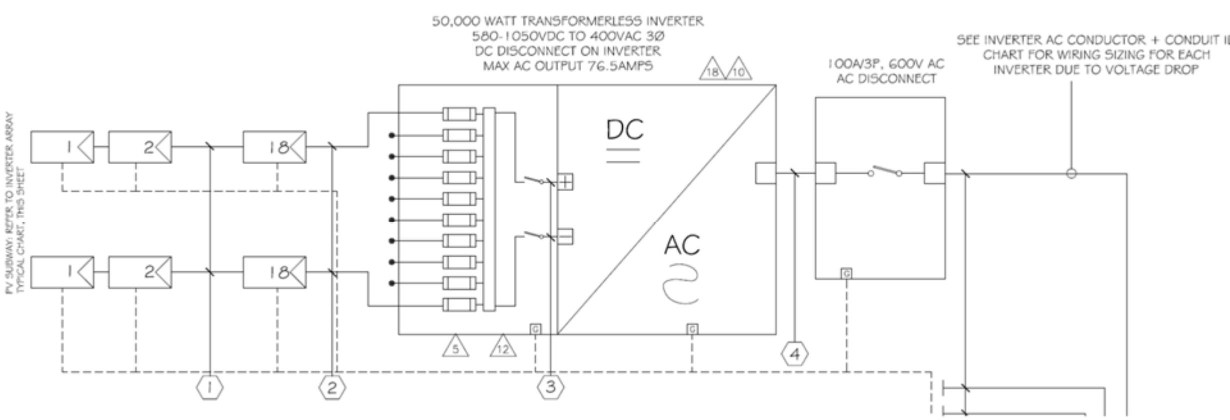


Figure 13: String of 18 PV panels and 10 such strings connected to one PV inverter.

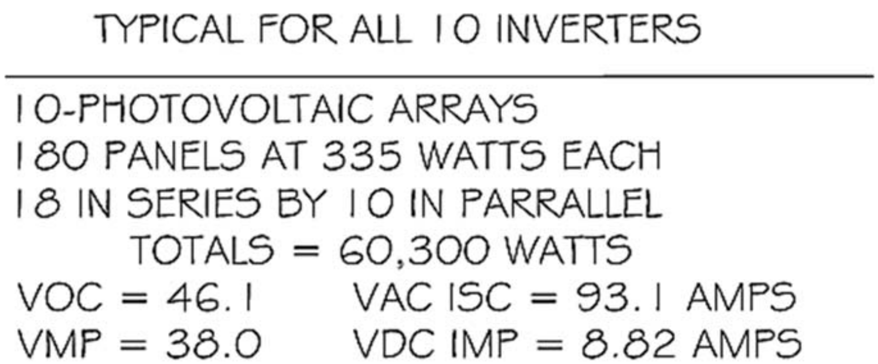


Figure 14: Specification of strings and PV inverter

8.5.1 Breaker Sizing

The Breaker size is calculated based on the capacity of each feeder, its continuous maximums current, and the design fault level. Once the breaker size is identified, the wiring size can be calculated/derived.

For each feeder, the continuous maximum current is taken from the PV inverter data sheet, the battery inverter or the diesel generator, depending on which equipment's data is needed.

The design fault calculation is provided in section 12.2.1 for each type of equipment. This section also includes the formulae used to calculate the faults.

As per the National Electrical Code (NEC) article 240, the breakers are sized at least 20% more than the maximum inerter current and the breaker interruption capacity has to be more than the fault current.

The following tables provide the breaker sizing for each of the source and feeder type:

Feeder Name	Max. Current (A)	Max. Current x 125% (NEC 690.8) (A)	Rated Voltage (V)	Max. LV Fault Level (A)	Breaker Rating Continious * (A)	Breaker Interrupting Capacity* (A)	Max. Voltage drop for cable selection	Cable Size- Cu (mm2)
Feeder from Inverter A	76.5	95.63	400	21189	100	40000	3%	4x 1-core 55mm2 cable and 1x 1-core 25mm2 cable
Feeder from Inverter B	76.5	95.63	400	21189	100	40000	3%	4x 1-core 55mm2 cable and 1x 1-core 25mm2 cable
Feeder from Inverter C	76.5	95.63	400	21189	100	40000	3%	4x 1-core 55mm2 cable and 1x 1-core 25mm2 cable
Feeder from Inverter D	76.5	95.63	400	21189	100	40000	3%	4x 1-core 55mm2 cable and 1x 1-core 25mm2 cable
Feeder from Inverter E	76.5	95.63	400	21189	100	40000	3%	4x 1-core 55mm2 cable and 1x 1-core 25mm2 cable
Ouput from Combiner Board to Main Combiner Board	382.5	478.13	400	21189	No Breaker	N/A	3%	8 x 1-Core 130mm2 cable and 2x 1-Core 55mm2

Table 10: Wire and Breaker Sizing for AC Combiner Board #1

Feeder Name	Max. Current (A)	Max. Current x 125% (NEC 690.8)(A)	Rated Voltage (V)	Max. LV Fault Level (A)	Breaker Rating Continious * (A)	Breaker Interrupting Capacity* (A)	Max. Voltage drop for cable selection	Cable Size- Cu (mm2)
Feeder from Inverter F	76.5	95.63	400	21189	100	40000	3%	4x 1-core 55mm2 cable and 1x 1-core 25mm2 cable
Feeder from Inverter G	76.5	95.63	400	21189	100	40000	3%	4x 1-core 55mm2 cable and 1x 1-core 25mm2 cable
Feeder from Inverter H	76.5	95.63	400	21189	100	40000	3%	4x 1-core 55mm2 cable and 1x 1-core 25mm2 cable
Feeder from Inverter I	76.5	95.63	400	21189	100	40000	3%	4x 1-core 55mm2 cable and 1x 1-core 25mm2 cable
Feeder from Inverter J	76.5	95.63	400	21189	100	40000	3%	4x 1-core 55mm2 cable and 1x 1-core 25mm2 cable
Ouput from Combiner Board to Main Combiner Board	382.5	478.13	400	21189	No Breaker	N/A	3%	8 x 1-Core 150mm2 cable and 2x 1-Core 55mm2

Table 11: Wire and Breaker Sizing for AC Combiner Board #2

Feeder Name	Max. Current (A)	Max. Current x 125% (NEC 690.8)(A)	Rated Voltage (V)	Max. LV Fault Level (A)	Breaker Rating Continious (A)	Breaker Interrupting Capacity (A)	Max. Voltage drop for cable selection	Cable Size- Cu (mm2)
Feeder from Inverter 1	144	180.00	400	21189	200	40000	3%	4 x 1-Core 120mm2 cable and 1X 1-Core 25mm2
Feeder from Inverter 2	144	180.00	400	21189	200	40000	3%	4 x 1-Core 120mm2 cable and 1X 1-Core 25mm2
Feeder from Inverter 3	144	180.00	400	21189	200	40000	3%	4 x 1-Core 120mm2 cable and 1X 1-Core 25mm2
Feeder from Inverter 4	144	180.00	400	21189	200	40000	3%	4 x 1-Core 120mm2 cable and 1X 1-Core 25mm2
Feeder from Inverter 5	144	180.00	400	21189	200	40000	3%	4 x 1-Core 120mm2 cable and 1X 1-Core 25mm2
Spare Feeder 1	144	180.00	400	21189	200	40000	3%	4 x 1-Core 120mm2 cable and 1X 1-Core 25mm2
Spare Feeder 2	144	180.00	400	21189	200	40000	3%	4 x 1-Core 120mm2 cable and 1X 1-Core 25mm2
Ouput from BESS Combiner Board to Main Combiner Board	1008	1260.00	400	21189	1300	50000	3%	12 x 1-Core 300mm2 cable and 4x 1-Core 120mm2
Ouput from Diesel Combiner Board to BESS Combiner Board	433	541.25	400	21189	550	40000	3%	8 x 1-Core 150mm2 cable and 2x 1-Core 55mm2

Table 12: Wire and Breaker Sizing for Battery Combiner Board

Feeder Name	Max. Current (A)	Max. Current x 125% (NEC 690.8)(A)	Rated Voltage (V)	Max. LV Fault Level (A)	Breaker Rating Continious (A)	Breaker Interrupting Capacity (A)	Max. Voltage drop for cable selection	Cable Size- Cu (mm2)
Ouput from PV Combiner Board #1 to Main Combiner Board	382.5	478.13	400	21189	500	40000	3%	8 x 1-Core 130mm2 cable and 2x 1-Core 55mm2
Ouput from PV Combiner Board #1 to Main Combiner Board	382.5	478.13	400	21189	500	40000	3%	8 x 1-Core 150mm2 cable and 2x 1-Core 55mm2
Ouput from BESS Combiner Board to Main Combiner Board	1008	1260.00	400	21189	1300	50000	3%	12 x 1-Core 300mm2 cable and 4x 1-Core 120mm2
Ouput from Main Combiner Board to Auto Transfer Panel	721.71	902.14	400	21189	1000	50000	3%	12 x 1-Core 200mm2 cable and 3x 1-Core 95mm2
Ouput from Main Combiner Board to Auxiliary Panel Board	165	206.25	400	21189	200	40000	3%	4 x 1-Core 120mm2 cable and 1x 1-Core 25mm2

Table 13: Wire and Breaker Sizing for Main Combiner Board

Feeder Name	Max. Current (A)	Max. Current x 125% (NEC 690.8)(A)	Rated Voltage (V)	Max. LV Fault Level (A)	Breaker Rating Continious (A)	Breaker Interrupting Capacity (A)	Max. Voltage drop for cable selection	Cable Size- Cu (mm2)
Incoming from Main Combiner Board to Auto Transfer Panel	721.71	902.14	400	21189	1000	50000	3%	12 x 1-Core 200mm2 cable and 3x 1-Core 95mm2
Incoming from Diesel Combiner Board to Auto Transfer Panel	433	541.25	400	21189	550	40000	3%	8 x 1-Core 150mm2 cable and 2x 1-Core 55mm2
Ouput from Auto Transfer Panel to Inrush Current Device	721.71	902.14	400	21189	1000	50000	3%	12 x 1-Core 200mm2 cable and 3x 1-Core 95mm2

Table 14: Wire and Breaker Sizing for Auto Transfer Panel

Feeder Name	Max. Current (A)	Max. Current x 125% (NEC 690.8)(A)	Rated Voltage (V)	Max. LV Fault Level (A)	Breaker Rating Continious (A)	Breaker Interrupting Capacity (A)	Max. Voltage drop for cable selection	Cable Size- Cu (mm2)
Ouput from 300kW Diesel Generator to Diesel Combiner Board	433.00	541.25	400	21189	550	40000	3%	8 x 1-Core 150mm2 cable and 2x 1-Core 55mm2
Ouput from 75kW Diesel Generator to Diesel Combiner Board	108.25	135.31	400	21189	150	40000	3%	4 x 1-Core 55mm2 cable and 1x 1-Core 25mm2
Ouput from Diesel Combiner Board to BESS combiner Board	433.00	541.25	400	21189	550	40000	3%	8 x 1-Core 150mm2 cable and 2x 1-Core 55mm2
Ouput from Diesel Combiner Board to Auto Transfer Panel	433.00	541.25	400	21189	550	40000	3%	8 x 1-Core 150mm2 cable and 2x 1-Core 55mm2
Ouput from Diesel Combiner Board to Auxiliary Panel Board	165.00	206.25	400	21189	200	40000	3%	4 x 1-Core 120mm2 cable and 1x 1-Core 25mm2

Table 15: Wire and Breaker Sizing for Diesel Combiner Board

8.5.2 Sample Wire Sizing Calculations

The wire sizing calculation varies from equipment to equipment due to the type; here we are showing one example for reference. The AC wire run from the Solar Inverter to the AC combiner panel would be calculated as follows:

Number for further calculations of Max circuit current:
76.5 Amps x 125% (NEC 690.8) = **95.625 Amps.**

We also take into account any de-rating combiner panel would be calculated as follows:

The Maximum Amperage output rating (on equipment cut sheet is **76.5 Amps.**)
If we calculate the same number, then it is:
50,000 watts/400V=125amps/1.732=**72.2 Amps**

Since, according to the equipment specification sheet, the equipment supports a max current output of 76.5 amps, we will take that factors for ambient temp NEC 2014 Table

310.15(B)(2)(a), which in this case is 1.00, so no changes. The other factor would be for more than 3 current carrying conductors in a single conduit NEC 2014 table 310.15(B)(3)(a). Which again for this is 100% as we don't have any more than 3 current carrying conductors per conduit run.

Using NEC 2014 Table 310.15 (B) (16) wire size would be **#3** (25mm^2) that has a amperage rating of **100amp** in the 75deg table and 115amp in 90 deg table.

Then, we apply voltage drop:

$$VD = 0.5 \times I \times R$$

$$VD = 0.5 \times I \times 2 \times L \times R / 1000.$$

Where;

VD = Voltage Drop in Volts.

I = Wire Current in Amperes.

R = Wire Resistance in Ohms (Ω) [Ω/km or] or (Ω/kft).

L = wire distance in meters or feet.

That gets us to the 1/0 (50mm^2**)** conductor size. There is a chart that is involved with the wire resistance in ohms or a calculation for that, but we use a program that holds all of that data for the voltage drop. Due to system being an off-grid setup we designed for a 1% VD. So, here we propose a conductor size of **50 mm^2.**

SYMBOL	CIRCUIT	IMAX (AMPS)	SETS	MATERIAL	INSULATION	RACEWAY	SIZE (mm2)	QTY	CONDUCTOR	MAX. 1 WAY LENGTH (m)	VOLTAGE DROP (1%)	OPERATING VOLTAGE (V)
1	PV MODULE WIRING (INTEGRATED BY MANUFACTURER)	11.64	1	CU	2K PV	FREE AIR	4	1	DC+	1	0.02%	620
							4	1	DC-			
							4	1	G			
2	PV HOME RUN WIRING	11.64	1	CU	2K PV	FREE AIR	4	1	DC+	45.72	1.12%	620
							4	1	DC-			
							4	1	G			
3	PV DC OUTPUT CURCUIT	90 (MAX)	1	CU	MANUF.	INTG.	MANUF.	1	DC+	0.5	N/A	620
							MANUF.	1	DC-			
							MANUF.	1	G			
4	INVERTER OUTPUT CIRCUIT (SHORT RUN)	76.5	1	CU	THWN-2	53mm EMT	55	3	L	1	0.012%	400
							55	1	N			
							25	1	G			
5	INVERTER OUTPUT CIRCUIT (LONG RUN)	76.5	1	CU	THWN-2	53mm EMT/IMC/PVC	55	3	L	81.38	1.09%	400
							55	1	N			
							25	1	G			
6	AC FEEDER FROM AC COMBINER 1	612	3	CU	THWN-2	(3) 78mm EMT/IMC/PVC	150	3	L	86.56	1.08%	400
							150	1	N			
							55	1	G			
7	AC FEEDER FROM AC COMBINER 2	612	3	CU	THWN-2	(3) 78mm EMT/IMC/PVC	150	3	L	71.32	0.89%	400
							150	1	N			
							55	1	G			

8	BATTERY AC OUTPUT CIRCUIT	144	1	CU	THWN-2	63mm EMT/IMC/PVC	120	3	L	22.86	0.29%	400
							120	1	N			
							25	1	G			
9	BATTERY COMBINER PANEL OUTPUT	1,440	4	CU	THWN-2	(4) 91mm EMT/IMC	240	3	L	10	0.10%	400
							240	1	N			
							120	1	G			
10	GENERATOR COMBINER TO BATTERY COMBINER	614	3	CU	THWN-2	(3) 63mm EMT/IMC	150	3	L	10	0.11%	400
							150	1	N			
							55	1	G			
11	GENERATOR COMBINER TO TRANSFER SWITCH	614	3	CU	THWN-2	(3) 63mm EMT/IMC	150	3	L	10	0.11%	400
							150	1	N			
							55	1	G			
12	TRANSFER SWITCH FROM MAIN COMBINER PANEL	1354	3	CU	THWN-2	(3) 91mm EMT/IMC	354.7	3	L	10	0.13%	400
							354.7	1	N			
							120	1	G			
13	AUX PANEL FROM MAIN COMBINER PANEL	165	1	CU	THWN-2	63mm EMT/IMC	120	3	L	10	0.13%	400
							120	1	N			
							25	1	G			
14	AUX PANEL FROM GENERATOR COMBINER	165	1	CU	THWN-2	63mm EMT/IMC	120	3	L	10	0.13%	400
							120	1	N			
							25	1	G			
15	425KW GENERATOR TO GENERATOR COMBINER	614	3	CU	THWN-2	(3) 63mm EMT/IMC/PVC	150	3	L	31.61	0.41%	400
							150	1	N			
							55	1	G			
16	75KW GENERATOR TO GENERATOR COMBINER	108.25	1	CU	THWN-2	53mm EMT/IMC/PVC	55	3	L	31.61	0.14%	400
							55	1	N			
							25	1	G			

Table16: Conductor Sizing

Conductor and Raceway Schedule												
SYMBOL	CIRCUIT	IMAX (AMPS)	SETS	MATERIAL	INSULATION	RACEWAY	SIZE (mm2)	QTY	CONDUCTOR	MAX. 1 WAY LENGTH (m)	VOLTAGE DROP (1%)	OPERATING VOLTAGE (V)
1	AUTOMATIC TRANSFER PANEL TO INRUSH CURRENT DEVICE	1354	3	CU	THWN-2	(3) 91mm EMT/IMC	354.7	3	L	10	<1%	400
							354.7	1	N			
							120	1	G			
2	INRUSH CURRENT DEVICE TO TRANSFORMER	1354	3	CU	THWN-2	(3) 91mm EMT/IMC	354.7	3	L	20	<2%	400
							354.7	1	N			
							120	1	G			
3	TRANSFORMER TO MV SWITCHGEAR	600	1	CU	THWN-2	(4) 91mm EMT/IMC	240	3	L	20	<1%	20000
							240	1	N			
							120	1	G			
4	MV SWITCHGEAR TO TRANSMISSION	600	1	CU	THWN-2	(4) 91mm EMT/IMC	240	3	L	30	<1%	20000
							240	1	N			
							120	1	G			

Table 17: Conductor and Raceway Schedule for Automatic Transfer Switch

CONDUCTOR AND RACEWAY SCHEDULE – AC COMBINER 1												
SYMBOL	CIRCUIT	IMAX (AMPS)	SETS	MATERIAL	INSULATION	RACEWAY	SIZE (MM2)	QTY	CONDUCTOR	MAX. 1 WAY LENGTH (M)	VOLTAGE DROP (1%)	OPERATION VOLTAGE (V)
A	INVERTER OUTPUT CIRCUIT (LONG RUN)	76.5	1	CU	THWN–2	35mm EMT/PVC	26.67 26.67 16	3 1 1	L N G	13.72	0.37%	400
B	INVERTER OUTPUT CIRCUIT (LONG RUN)	76.5	1	CU	THWN–2	35mm EMT/PVC	26.67 26.67 16	3 1 1	L N G	1.83	0.05%	400
C	INVERTER OUTPUT CIRCUIT (LONG RUN)	76.5	1	CU	THWN–2	35mm EMT/PVC	26.67 26.67 16	3 1 1	L N G	23.47	0.63%	400
D	INVERTER OUTPUT CIRCUIT (LONG RUN)	76.5	1	CU	THWN–2	35mm EMT/PVC	26.67 26.67 16	3 1 1	L N G	39.32	1.05%	400
E	INVERTER OUTPUT CIRCUIT (LONG RUN)	76.5	1	CU	THWN–2	35mm EMT/PVC	35 35 25	3 1 1	L N G	47.85	1.02%	400
F	INVERTER OUTPUT CIRCUIT (LONG RUN)	76.5	1	CU	THWN–2	41mm EMT/PVC	50 50 25	3 1 1	L N G	55.47	0.93%	400
G	INVERTER OUTPUT CIRCUIT (LONG RUN)	76.5	1	CU	THWN–2	53mm EMT/PVC	55 55 25	3 1 1	L N G	64.62	0.86%	400
H	INVERTER OUTPUT CIRCUIT (LONG RUN)	76.5	1	CU	THWN–2	53mm EMT/PVC	70 70 25	3 1 1	L N G	81.38	0.86%	400

CONDUCTOR AND RACEWAY SCHEDULE – AC COMBINER 2												
SYMBOL	CIRCUIT	IMAX (AMPS)	SETS	MATERIAL	INSULATION	RACEWAY	SIZE (MM2)	QTY	CONDUCTOR	MAX. 1 WAY LENGTH (M)	VOLTAGE DROP (1%)	OPERATION VOLTAGE (V)
I	INVERTER OUTPUT CIRCUIT (LONG RUN)	76.5	1	CU	THWN–2	35mm EMT/PVC	26.67 26.67 16	3 1 1	L N G	37.49	1.00%	400
J	INVERTER OUTPUT CIRCUIT (LONG RUN)	76.5	1	CU	THWN–2	35mm EMT/PVC	26.67 26.67 16	3 1 1	L N G	18.90	0.51%	400
K	INVERTER OUTPUT CIRCUIT (LONG RUN)	76.5	1	CU	THWN–2	35mm EMT/PVC	26.67 26.67 16	3 1 1	L N G	9.45	0.25%	400
L	INVERTER OUTPUT CIRCUIT (LONG RUN)	76.5	1	CU	THWN–2	35mm EMT/PVC	26.67 26.67 16	3 1 1	L N G	9.14	0.24%	400
M	INVERTER OUTPUT CIRCUIT (LONG RUN)	76.5	1	CU	THWN–2	35mm EMT/PVC	26.67 26.67 16	3 1 1	L N G	27.43	0.73%	400
N	INVERTER OUTPUT CIRCUIT (LONG RUN)	76.5	1	CU	THWN–2	41mm EMT/PVC	35 35 25	3 1 1	L N G	42.98	0.91%	400
O	INVERTER OUTPUT CIRCUIT (LONG RUN)	76.5	1	CU	THWN–2	41mm EMT/PVC	50 50 25	3 1 1	L N G	58.52	0.99%	400
P	INVERTER OUTPUT CIRCUIT (LONG RUN)	76.5	1	CU	THWN–2	53mm EMT/PVC	55 55 25	3 1 1	L N G	67.06	0.90%	400

Table 18: Conductor and Raceway Schedule for - AC Combiner 1 & 2

Wire/cable sizes are calculated using applicable software. Cable software does not print out any calculations. It simply suggests the wire/cable size based on current, voltage drop allowed and distance. This is pretty standard. We cannot get the calculation logic used by the software company. Breaker size has to be at least 20% more than the max inverter current. Breaker interruption capacity has to be more than the fault current.

8.5.3 Grounding

Grounding provides a path for fault current or lightning surges to flow through to protect people and equipment from electric shock hazards. Number of Earthing Electrode and Earthing Resistance depends on the resistivity of soil and time for fault current to pass through (1 sec). If we divide the area for earthing required by the area of one earth plate gives the number of earth pits required. There is no general rule to calculate the exact number of earth pits and size of earthing strip, but discharging of leakage current is certainly dependent on the cross-section area of the material so for any equipment the earth strip size is calculated on the current to be carried by that strip. For most of the electrical equipment like transformer, diesel generator set etc., the general concept is to have 4 number of earth pits. 2 no's for body earthing with 2 separate strips with the pits shorted and 2 no's for Neutral with 2 separate strips with the pits shorted. The strip connected should be capable to carry at least the neutral current, which means a strip of GI 25x3mm should be enough to carry the current and for body a strip of 25×3 will do the needful. Normally we can consider the strip size that is generally used as standards.

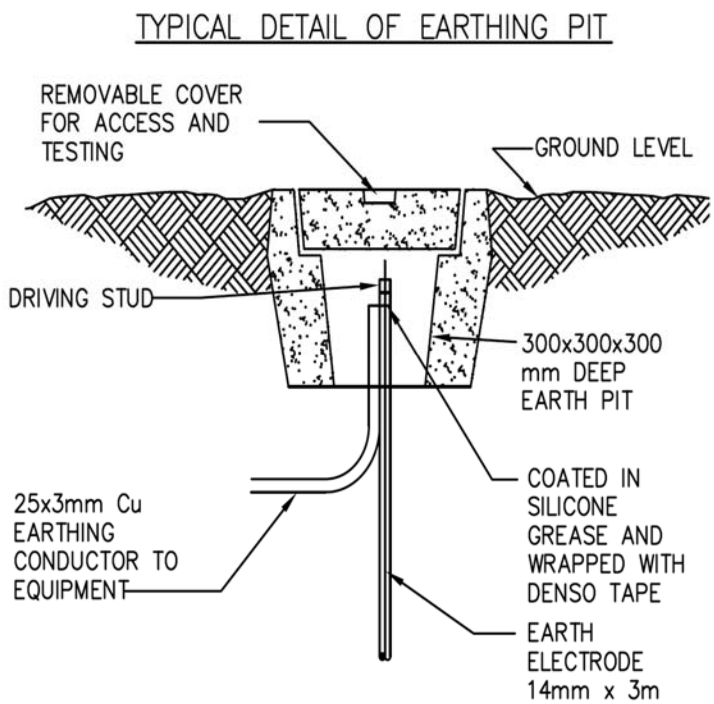


Figure 15: Typical Design for Earthing Pit and Earthing conductor

The grounding shall be prepared as per the required test. It may need additional grounding rods, underground cable loops or ground well. The Contractor shall apply all requirements to achieve the final test for all grounding systems for this mini-grid solar power plant.

8.5.4 Equipment Grounding Conductor (EGC)

PV modules mounted to metal racks are effectively grounded when the module frames are secured to and in electrical contact with the rack, and the rack is grounded. However, since the integrity of the electrical contact between the module frames and mounting structure cannot always be assured, individual module frames are connected together with equipment grounding conductors (EGC). This can be accomplished with a few continuous runs of bare conductor that are secured to each module with a special connector, or with many short bonding jumpers between adjacent modules.

When ground-fault protection is used, PV circuit equipment grounding conductors are sized in accordance with Article 250, which establishes the minimum size for equipment grounding conductors based on the overcurrent protection rating in the circuit. NEC table 250.122 is used for sizing. For example, if the PV output circuit overcurrent protection device is 60 A, then a 10 AWG equipment grounding conductor is required.

8.5.5 Grounding Electrode Conductor (GEC)

A grounding electrode is a conductor rod, plate, or wire buried in the ground to provide a low-resistance connection to the earth. NEC 690.47 establishes requirements for grounding electrodes used for PV systems. Most PV systems involve both AC and DC systems, and they are considered two separate systems according to NEC article 690 since the DC grounded conductor is not directly connected to the AC grounded conductor. The size of equipment grounding conductors are shown with the associated wire runs in Table 16, 17 and 18.

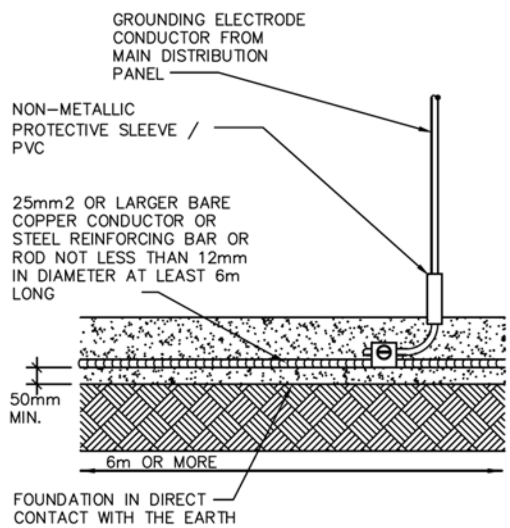


Figure 16: Grounding Electrode Conductor sizing details

8.5.6 Ground Fault Protection

Ground Fault is the undesirable situation where the current flows through grounding conductors. Ground Fault Protection is mentioned in NEC 690.5 and is not required for ground mounted arrays.

8.5.7 Lightning Protection

Because PV arrays are not mounted on elevated structures, many PV systems are protected from potential lightning that can cause severe damage. Lightning protection system requirements are covered briefly in Article 250 and more extensively in NFPA 780 (Standard for the Installation of Lightning Protection Systems). Lightning protection systems consist of a low-impedance network of air terminals (lightning rods) connected to a special grounding electrode system and not connected to the DC or array electrode conductors. The lightning protections is covered in detail in the section covering poles and reticulation systems.

8.5.8 Monitoring

PV systems consist of different components to transfer energy. Measuring the electrical parameters at certain intervals can help gather more information about system operating status and alert users to possible problems. Measuring the output of the system is essential for production-based financial incentives. The traditional monitoring method entails simply comparing actual energy generation to that predicted from the simulation software. The advantage of this approach is simplicity, affordability, and reliability. There are multiple levels at which a PV system can be monitored; they can be classified as:

8.5.9 Inverter Monitoring

Inverter-level AC and DC monitoring offers insights into an inverter's status, given the strategic location of the inverter to monitor the performance of the PV system. Most inverter manufacturers embed their devices with monitoring functionality.

8.6 Solar Combiner Board #1

The Solar Combiner Board #1 is proposed to be installed in the PV field that would combine the inputs from 5 inverters (Inverters A to E). A total of two combiner boards are proposed. The sizing and specifications of both the combiner boards is exactly similar. Each combiner board is a 3-phase, 400V, 600A panel. The details of the Solar Combiner Board #1 is discussed in Chapter 6: Low-Voltage Combiner Boards.

8.7 Solar Combiner Board #2

The solar combiner board#2 is proposed to be installed in the PV field that would combine the inputs from 5 inverters (Inverters F to J). This combiner board is a 3-ph, 400V, 600A panel. The details of Solar Combiner Board#2 are discussed in Chapter 6: Low-Voltage Combiner Boards.

8.8 Weather Station

Two (2) weather stations shall be installed to provide adequate meteorological data to evaluate system performance.

One weather station shall be located at control room building and the other located in the field. The station shall essentially include sensors for the following parameters:

Standard Pyranometer

- Irradiations at Tilt Plane in W/m^2.
- Insolation at Plane of Array in Wh/m^2
- Global irradiation in W/m^2.
- Global Insolation in Wh/m^2
- Cell temperature in °C.
- Environment temperature in °C.
- Humidity sensor

Dedicated pyronometers shall be used for measurement of global irradiation on tilted plane of array and global horizontal irradiation.

Refer to technical specifications for detailed specs for Weather Station.

Air temperature sensor specifications:

- Range -40°C to +70°C
- Resolution 0.1
- Accuracy ± 0.3°C at 20°C
- Sampling Rate 1 Hz
- Units °C, °F, °K

PV module temperature sensor specifications:

- Measurement range: -20 TO 100°C
- Sensor type: platinum resistance wire
- Electrical output: PT100
- Cable 3 mt, connection with 3 conductors
- Mounting: tape (included)

All weather stations will be integrated in the SCADA system. Weather stations located on the field will be provided with data logger capable of collecting the data points with capability of recording and storing environmental data without AC power for two (2) days. Both the weather station and the data logger will be tamper proof.

8.9 Additional Requirements

All the material and works must be in accordance with the most advance practice for this type of equipment. Other than specified hereafter all the materials and realized works will be in accordance with latest edition of the IEC recommendations.

The delivery and the equipment in it shall be designed to meet the requirements of the following codes and standards: International Electrotechnical Commission (IEC) / National Electrical Code (NEC).

The design, materials, manufacturing, transportation, inspection, tests and packaging of the equipment and systems supplied shall be carried out as per International practices.

8.10 Exceptions to this Specification

Any proposal for deviation from this Specification and all other documents and drawings referenced in this Specification, shall be clearly written, in a complete and explicit way.
The form shall be signed and submitted for approval to Employer. Contractor shall not proceed with implementation of any deviation that has not been previously indicated and has not been approved in writing by Employer.

8.11 Guarantees

The Contractor shall guarantee all characteristic required. The Contractor shall present and supervise all the guarantee tests.

The Contractor shall guarantee that the supplied equipment, material, or part thereof shall follow the specifications hereto and shall be unused products, free from any defects in design, material or workmanship. Spare parts furnished shall be identical or equivalent to original parts (spare parts are quoted as optional).

The warranty period must be twelve months from the date of commissioning (provisional plant acceptance) or 24 months from the date pf delivery whichever is earlier.
This warranty implies that the Contractor shall repair, or replace if necessary, all the elements damaged during this period.

8.12 Document Discrepancy

In case of discrepancy between the documents included in this Specification, the following order of priority shall prevail:

- Applicable legislation only if more restrictive criteria are not established in the Data Sheets Requisition or Specification.
- Data Sheets.
- Technical Specification.

- Other specifications and standards of the project.
- International Codes and Standards.

8.13 Spare Parts

Two detailed spare parts lists shall be included. One list will include all recommended spare parts for commissioning and the other list with recommended spare part for ten (10) year operation. Both lists will include:

- Spare part description
- Quantity
- Unit Price

Furthermore, two-year operation spare parts list will include a recommended planning for equipment replacement (operation hours).

8.14 Bill of Quantities

Refer to the Bill of Quantity which will be separately attached in the design package.

9. BESS DESIGN

9.1 Justification For Containerized BESS

Battery energy storage systems based on Li ion batteries are supplied by companies like SAFT, Samsung, LG Chem, TESLA etc. These are normally supplied by the manufacturers as factory assembled and tested units complete with sub systems for thermal management, cooling, battery management, fire protection etc. Hence many of the manufacturers supply these preassembled units as building blocks (e.g. units of 500kWh) fully assembled, wired and tested in e-houses or containers. A big advantage with this arrangement is the ability to procure fully assembled and tested units with manufacturer's warranty for the assembled unit.

An alternative approach is to assemble the entire battery system on racks within building. This is typically done for large installations where multi-level arrangements may be necessary due to space constraint. In this case either the manufacturer designs and assembles the battery unit at site or a specialized assembler/system integrator will come on board once the actual products have been ordered and shipped to the site to integrate them into one fully functional system. This will include rack work, wiring, provision of battery management system, thermal management, cooling systems, fire protection and testing. As this involves a significant amount of onsite work, manufacturers do not prefer that and do it only for very large installations.

Another option is to procure the battery cells from manufacturers and recruit the services of a certified battery assemblers to assemble the batteries and associated components onsite. In this case battery assemblers provide the design and do the assembly work. One must then negotiate with manufacturers about how the warranty for the assembled unit is handled. Manufacturer may guarantee cells/battery packs but may not guarantee the system. This may come from the assemblers. The main question will then be about the financial risks if the assembler does not have the financial credibility to provide these guarantees.

Between the above, we would suggest a manufacturer assembled, fully tested and guaranteed containerized/e-house version for an installation like this case. This would make sure that a fully assembled, tested and guaranteed system at competitive prices is provided. For small and medium size systems, this will be more cost effective than onsite assembly work due to standardization of design, volume manufacturing, less engineering and onsite work. We do not have accurate figures for comparison but for small and medium size systems getting a preassembled and tested unit may be 10% to 20% more cost effective than onsite assembly. For a 2500kWh system this would mean a saving of about $150K in capital costs plus the comfort of a fully guaranteed system.

In addition to the fully assembled battery unit, BESS system also includes inverters, Power conditioning unit, and a site controller. These are normally manufactured by inverter manufacturers. However, as they must work as an integrated system it is normal to buy the entire BESS (assembled battery system, inverters and site controllers) from one vendor – the BESS supplier. For small installations like this, the site controller functionality is enhanced to cover the microgrid/mini grid functionalities. In this case BESS supplier also performs and takes over the role of system integrator.

In terms of cost, the containerized BESS system costs about US$xxx per kWh, which translates to around $x,xxx,xxx for a 2,500 kWh BESS as is required in Parwan.

For a similar sized BESS assembled on site, using US and European products, the following costs may incur:

- Li-Ion Battery: $xxx/kWh x 2500 kWh = $x,xxx,xxx
- Racking and other accessories, including AC systems, etc.: $xx,xxx
- Construction of additional space for the BESS: $xx,xxx
- Costs for isolating each 500kWh from the next since any thermal mishaps will destroy the whole system: $xx,xxx
- Cost of testing and commissioning the assembly: $xx,xxx
- Battery Inverters: 6 x 100 kW @ $xx,xxx x 6 = $xxx,xxx
- Provision of site controller & integration with other components: $xx,xxx

TOTAL Cost: $x,xxx,xxx

So, the containerized BESS system offers a gross financial benefit of US$ 95,000. However, taking into consideration unreliable warranty, possible system defects, possible inadequate system controls and integration, possible reduced round-trip efficiency, possibly shorter life cycle and reliability of service, the net cost effect of an onsite assembled Li-Ion BESS system may be in the range of excess of $250,000-350,000 more than a containerized system. In other words, the onsite assembled BESS system may be around 20% more expensive than a containerized BESS system.

In addition to that, the onsite assembled system has the disadvantage of not having a single point of responsibility that will assume full responsibility for the sound operation of the system and offer credible guarantee over the life span of the BESS system. The Battery manufacturer may offer its own warranty, while the inverter manufacturer and other component manufacturers may offer their respective warranties. However, this complex system does not have a single source that offers warranties to the user.

Furthermore, assembly design and work by certified assemblers in a country such as Afghanistan, where highly skilled workforce in the area of solar power systems and electric installations is a rarity, the situation of maintaining or honoring any type of warranties may prove to be a difficult task altogether.

Other disadvantages of an onsite assembled system are the round-trip-efficiency of the battery that may be affected by less than ideal BESS design.

On the other hand, a containerized BESS system will have all components already integrated into it, so that the efficiency, reliability and life span of the system will be maximized. Furthermore, the integrated components will be the responsibility of a single integrator that in this case will be the BESS supplier, who will assume responsibility for all components and will provide all controls so that we can be assured of a fully functional system. As a matter of fact, the complete package from BESS supplier will include battery containers, battery management system, inverters, controls system and system integration.

Today, many manufacturers are available in Europe, Korea, Japan, China and other parts of the world, that are making the containerized BESS into a competitive product with choices of suppliers. Being scalable also allows for expansion of the BESS at any time. As a matter of fact, today's technology for Li-Ion batteries relies almost exclusively on containerized BESS for utility scale system of this size.

Such containerized systems are built in compliance with international standards for outdoor applications, so that they are weather proof, humidity tolerant, suitable for summer heat and winter cold, fitted with adequate grounding, lightning protection and other related safety and operational standards. Only thus are the manufacturers able to offer up to ten years warranty on their products.

Furthermore, containers can be relocated to a different site and used in case of arrival of grid connection to the site. Users can be fully trained in operation, maintenance and repair of containerized BESS. Energy smoothing through standard system design can ensure that charging and discharging sequence is optimized. As an additional caveat, in such systems, shipping and installation is also less problematic and ensures system reliability.

A system designer has a choice of designing a utility scale PV with an AC coupling or a DC coupling system.

We have chosen to design the system as AC-coupled. This means that the PV outputs are converted on site from DC to AC power and then transmitted the control room, where it is reconverted to DC power to charge the BESS system. For this purpose, one-directional inverters are used in the PV array field and bi-directional inverters are used in the control room to charge the BESS.

We suggested an AC coupled design for the solar and BESS system for following reasons:

- Enables use of standard solar PV and BESS inverters
- Modular design - Easy to add more solar or BESS in future
- Provides ability to charge BESS from other sources – e.g. diesel
- Allows flexibility in locating BESS. No need to locate it close to solar PV
- Enables use of staring inverters for PV and central inverters for BESS

A DC-coupled system would transport DC power from the inverter over long distances and then connect everything on the DC side, which is then converted to AC power at a one-directional inverters. The components needed for DC coupling of utility scale systems are manufactured by only a handful of manufacturers and are fairly expensive, rendering DC coupled systems very rare, if at all found. This is why in this design, an AC coupled system is used.

Recommendation:

We strongly recommend the use of a containerized pre-assembled, pre-certified, pre-integrated and pre-optimized system that costs less than an onsite assembled system by more than $95,000 to acquire. However, the effective net economic disadvantage, taking into consideration factors such as unreliable warranty, possible system defects, possible inadequate system controls and integration, possible reduced round-trip efficiency, possibly shorter life cycle and reliability of service, will be in the range of $250,000 to $350,000 or around 20%.

9.2 Codes and Standards

IEEE 1547 Interconnection of Distributed generation
UL 1741 requirements cover inverters, converters, charge controllers, and interconnection system equipment.
IEC 62477-1 Power Electronics Converter System
IEC 61000-6-2,4 Electromagnetic Compatibility
IEC 61850 Remote Communication
UL 1642, IEC 62619 Cell Safety
IEC 60950 Module Safety
IEC 61508 Container Safety
IEC 62040-2 EMC (Cat C1 and C3)
IP33, ISO668, ISO12944 Level C51 – Container Specifications

IEC 60721 Environment (dust, chemical, wind, fire exposure, etc)
ISO9001, ISO14000 Quality Management and Environmental Management
Other Applicable standards

9.3 Design and Sizing

Based on the estimated load profile created for Parwan, a mini-grid with a solar PV generator of about 600kW-dc with a 2,500kWh of battery storage and a 75+300kW diesel generator for backup power is proposed. Please refer to preliminary design document for details.

9.4 Configuration

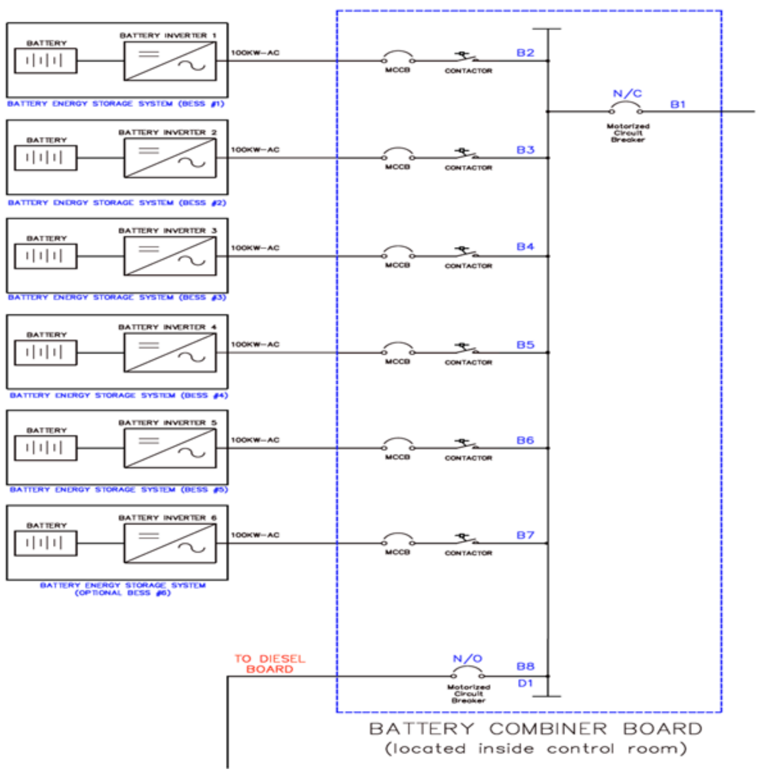


Figure 17: BESS Configuration

9.5 General Conditions

We recommend a manufacturer assembled, fully tested and guaranteed containerized/e-house version for an installation like the Kandahar mini-grid. This would make sure that a fully assembled, tested and guaranteed system at competitive price is provided. BESS is provided as a complete solution from the manufacturer in ready to install containers integrating Battery Management System (BMS), thermal management and safety management. In the containerized system, safety is priority with a consistent approach embracing cell, module, string and container designs. The BMS and thermal management system should be provided to ensure highest energy efficiency, availability, maintainability and life time.

In addition to the fully assembled battery unit, BESS system will also include inverters (Power conditioning unit) and a site controller (BESS control system). For small installations like this, the site controller functionality is enhanced to cover the microgrid/mini grid functionalities. In this case BESS supplier can also perform and take over the role of system integrator.

The complete package from BESS supplier will include battery containers, battery management system, inverters, controls system and system integration. The BESS configuration includes battery, inverters, control system and combiner board. The exact configuration of the BESS will eventually depend on the supplier of the BESS. The general layout will have batteries installed in a container and the number of containers will be determined by the supplier. For the Parwan mini-grid the requirement is to have battery with a storage capacity of 2500kWh. It is common to have about 500kWh installed in a single 20’x8’ shipping container. With that assumption the Parwan mini-grid will require about 5 battery containers. Again, depending upon the BESS supplier, the inverters, control equipment and/or combiner boards might either be available in separate containers or may have to be installed in the equipment room.

Key Features:

- Latest generation of Li-Ion technology
- Advanced industrial design offering highest safety and robustness
- 20 years design life
- Sophisticated battery management for enhanced operability
- Monitoring and Control of voltage and temperature at cell level
- Real time supervision of charge and discharge current limits
- Real time indication of State of Charge (SOC)
- Balancing of SOC between cells and strings
- Alarms and fault management
- Indication of State of health (SOH)
- Advanced thermal management system based on air conditioning unit and controllable fans
- High cooling efficiency
- Safety management system with smoke detection, fire suppression system and alarms
- Quick and cost-effective installation with containers delivered – plug and play- ex factory due to ready to deploy solution

- Easy system integration
- Scalable configuration
- Safety driven design guarantees safe behavior in case of abuse usage or cell thermal runaway
- Auxiliary power supply 400AC for HVAC, FSS and lighting and 24V DC for electronics and fans.

Refer to technical specifications for detailed specs of the BESS.

9.6 Battery Inverters

Application: the inverter has to be suitable for grid forming and grid following modes of operation. During Mini-grid operation the inverters will set the voltage and frequency for PV inverters to follow.

- It should be possible to parallel all the battery inverters in both grid-forming and grid-following modes.
- It should be possible to charge and discharge batteries while it is in grid-forming mode.
- Black start functionality required
- Short-term (<5min) paralleling between battery and diesel is required

Refer to technical specifications for detailed specs of the Battery Inverters.

9.7 BESS Control System

- BESS control system will provide On/Off commands and set-points (voltage, frequency, active power, reactive power) for the solar and battery inverters based on load, weather forecast and operating status of PV, batteries and diesel.
- BESS control system will implement the mini-grid operations logic jointly with the SCADA system. Communication between test control system and SCADA shall be through MODBUS TCP/IP.

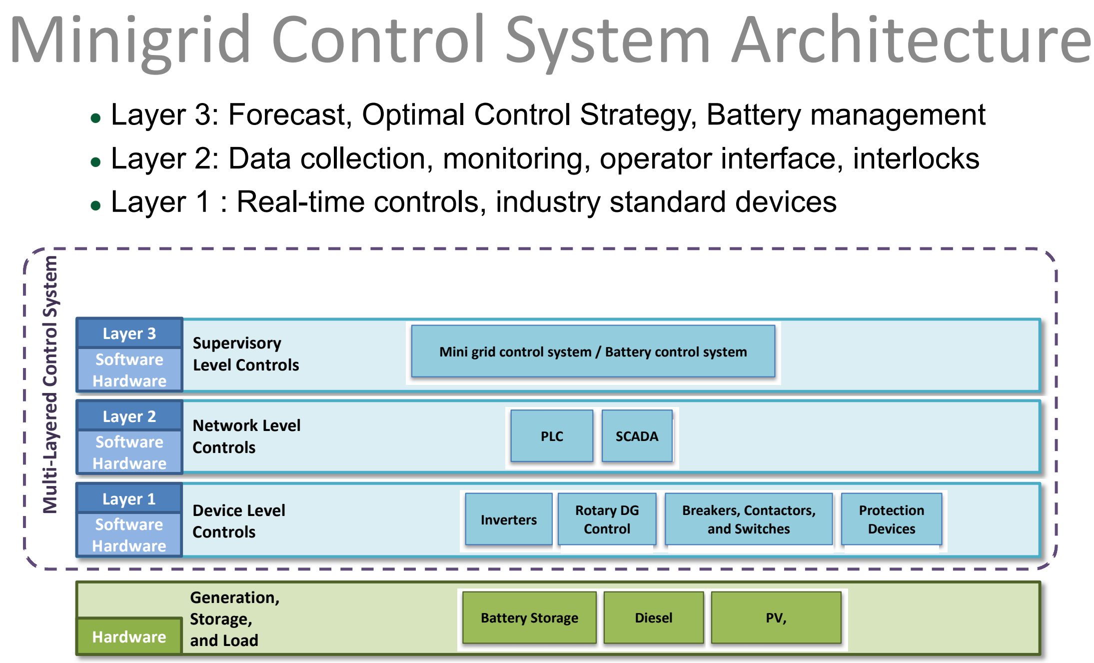


Figure 18: MiniGrid Control System Architecture

The Purpose of a PV-inverter is to convert DC power to Ac power and feed the power system. In a typical solar application with battery backup, the battery system is equipment with a charge regulator that ensures that the state of charge of the Battery is within the desired and required parameters. In a large-scale utility application, the BESS has its own bi-directional inverters that supply the AC power from the PV system's Main Combiner Board to the Battery system as a converted DC power and then transfers the charge from the BESS to the Main Control Board after converting it to AC Power.

Battery based inverter/chargers are bi-directional in nature, including both a battery charger and an inverter. They require a battery to operate. Battery-based inverter/chargers may be grid-interactive, standalone grid-tied or off-grid, depending on their UL rating and design. The primary benefit of inverter/chargers is that they provide for continuous operation of critical loads irrespective of the presence or condition of the grid. UL1741 requires the grid-tied generation source to stop generating power in the event of a grid outage. This de-powering is known as anti-islanding, as opposed to 'islanding' which is defined as generating power to power a location in the event of a grid outage. Therefore, UL1741 grid-tie inverters will not generate power in the event of a grid outage, so a user will experience an outage irrespective of the availability solar harvest. Battery-based inverter/chargers will power the critical loads in the event of a grid outage, but will do so in a manner to not create the islanding condition. Further, UL1741 inverter/chargers may be rated as either interactive or standalone. The former export excess power to the grid, while the latter do not–by rating and by definition. In all instances, the battery based inverter/charger manages energy between the array and the grid while keeping the batteries charged. They monitor battery status and regulate how the batteries are charged.

Battery control system doubling up as Mini-grid control system shall perform the following

- Monitor BESS internal systems, inverters, battery state of charge, loads and generation (PV, battery, diesel) etc.
- Prepare day ahead forecast of load and PV generation and schedule operation of BESS and diesel generation
- Provide control strategy for optimized Mini-grid operation
  - Automatic starting of diesel generation
  - On/Off commands and operation set points for diesel generation
  - Commands and control for synchronous operation of diesel units
  - Diesel generation ramp and ramp down commands and set points
  - BESS inverter on/off commands
  - Battery rate of charge/discharge set points
  - Battery ramp up and ramp down commands and set points
  - Commands and control for synchronous operation of battery and diesel
  - Managing the load transition from battery to diesel and from diesel to PV+BESS combination. The idea it to ramp down output from one unit while ramping up the other unit for a smooth bump-less transition
  - PV curtailment if needed
  - On/off commands for PV inverters
  - Black start
- Battery control system will communicate with field devices through the Plant controller unit of the SCADA system

9.8 Systems Integration

- BESS supplier shall also play the role of a system integrator and provide system integration services
- The system integrator must integrate the PV, BESS, Diesel and the controlling devices with the battery control system and SCADA as part of commissioning work to form a functioning Mini Grid that can work both in grid connected and islanded modes.

9.9 BESS Combiner Board

The current designed configuration has 5 containers of 500kWh each with a bi-directional battery inverter of 100kW. Each inverter is 100kW, 400V, 50Hz, 3-phase, 4 wire. The output from the 5 inverters is connected to a battery combiner panel. The BESS combiner panel is a 1500A, 400V, 3-phase 4-wire panel with a total of 9 feeders. The Details for the Battery Combiner board is discussed in Chapter 6: Low-Voltage Combiner Boards.

9.10 Additional Requirements

All the material and works must be in accordance with the most advance practice for this type of equipment. Other than specified hereafter all the materials and realized works will be in accordance with latest edition of the IEC recommendations.

The delivery and the equipment in it shall be designed to meet the requirements of the following codes and standards: International Electrotechnical Commission (IEC) / National Electrical Code (NEC).

The design, materials, manufacturing, transportation, inspection, tests and packaging of the equipment and systems supplied shall be carried out as per International practices.

9.11 Exceptions to this Specification

Any proposal for deviation from this Specification and all other documents and drawings referenced in this Specification, shall be clearly written, in a complete and explicit way.
The form shall be signed and submitted for approval to Employer. Contractor shall not proceed with implementation of any deviation that has not been previously indicated and has not been approved in writing by Employer.

9.12 Guarantees

The Contractor shall guarantee all characteristic required. The Contractor shall present and supervise all the guarantee tests.

The Contractor shall guarantee that the supplied equipment, material, or part thereof shall follow the specifications hereto and shall be unused products, free from any defects in design, material or workmanship. Spare parts furnished shall be identical or equivalent to original parts (spare parts are quoted as optional).

The warranty period must be twelve months from the date of commissioning (provisional plant acceptance) or 24 months from the date pf delivery whichever is earlier.
This warranty implies that the Contractor shall repair, or replace if necessary, all the elements damaged during this period.

9.13 Document Discrepancy

In case of discrepancy between the documents included in this Specification, the following order of priority shall prevail:

- Applicable legislation only if more restrictive criteria are not established in the Data Sheets Requisition or Specification.
- Data Sheets.
- Technical Specification.
- Other specifications and standards of the project.
- International Codes and Standards.

9.14 Documentation and Drawings

The system supplier has to provide the following drawings and documents:

1. Detailed Single-Line Diagram
2. Detailed Three-Line Diagrams
3. Wiring diagrams
4. Assembly/shop floor drawings
5. General arrangement drawings
6. Foundation plan
7. Installation manual
8. Operating and troubleshooting manual
9. Software details for the control system
10. Test Certificates (Factory tests and Type test)

9.15 Factory Acceptance Tests

- All factory tests as per IEC or NEC
- Standard Visual, Mechanical and Electrical Factory Acceptance tests and inspections to be performed
- Details on standard Factory Acceptance Test to be provided by the manufacturer/assembler of the Battery Energy Storage System
- Option for factory inspection and witness test

9.16 Spare Parts

Two detailed spare parts lists shall be included. One list will include all recommended spare parts for commissioning and the other list with recommended spare part for ten (10) year operation. Both lists will include:

- Spare part description
- Quantity
- Unit Price

Furthermore, two-year operation spare parts list will include a recommended planning for equipment replacement (operation hours).

9.17 Bill of Quantities

Refer to the Bill of Quantity which will be separately attached in the design package.

10. LOW VOLTAGE SWITCH BOARDS

10.1 Codes and Standards

The delivery and the equipment in Low-Voltage Switchgear shall be designed to meet the requirements of the following codes and standards:

- **IEC 61439-1 and IEC 61439-2** testing is to be accomplished successfully in compliance with
- **IEC 61439-3** Distribution Boards
- **IEC / TR 61641** Test verification under arc fault conditions in accordance with
- **IEC 60529** Degree of protection
- **IEC 60364-4-41** Protection against electric shock (safety class) in acc. with
- **IEC 62271-202** factory-assembled stations described in
- **IEC 61439-2** mounting designs for switchgear
- **IEC 60364-7-729** The minimum dimensions for operating and Maintenance gangways according to
- The minimum clearances between switchboards and obstacle as specified by the manufacturer must be observed.
- **IEC 61439-1** Environmental conditions
- **IEC 61439-1 and -3** Rated Diversity Factor for switchgear in accordance with
- **IEC 61439-1 and IEC 61439-6** Busbar Trunking System
- **IEC 60364-1** Personal Safety
- **IEC 60947-2** Circuit Breakers
- **IEC 60364-4-41** Residual Current Devices
- **IEC 60947-2** circuit-breakers with fault current protection in accordance with
- **IEC 62606** Arc-fault detection devices (AFDD) are specified in IEC 62606
- **IEC 60947-2** Low-voltage circuit breakers
- **IEC 60898-1** Miniature circuit-breaker in accordance with
- **IEC 60947-1** The standard basis for low-voltage switching devices in general is
- **Other applicable standard**

10.2 Solar Combiner Board #1

The solar combiner boards are proposed to be installed in the PV field that would combine the inputs from 5 inverters each. A total of two combiner boards are proposed. The sizing and specifications of both the combiner boards is exactly similar.

Each combiner board is a 3-phase, 400V, 600A panel. Maximum Short Circuit current happens when it is grid connected and fed by the utility, nevertheless, the impedance (5%) of the 500kVA transformer limit this to maximum 10000kVA (which is less than 15kA at 400V). The low voltage combiner boards are designed for a minimum of 36kA which is more than adequate.

Since each inverter has a maximum AC output of 76.5A, the incoming feeders from the inverters have a Molded Case Circuit Breaker (MCCB) with a 100A rating. Each MCCB must have inbuilt overcurrent and short-circuit protection. Each MCCB must have the capability to be capability to interact with the SCADA system and communicate its operating status (communicate whether it is On or Off via SCADA). The outgoing feeder from the Solar combiner board must have a motorized circuit breaker rated for 600A.

By combining the AC outputs from 5 inverters, a higher gauge cable can be used thus reducing the losses. The Solar combiner board #1 has the following key specifications.

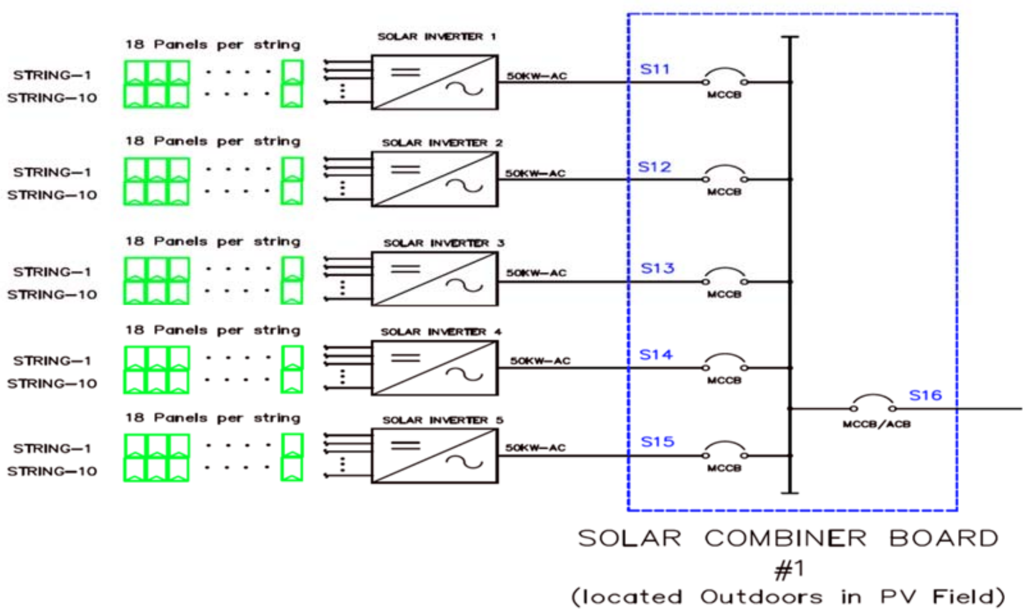


Figure 19: Simplified drawing showing the connection for Solar Panels, Inverters and Combiner Panel#1

Refer to technical specifications for detailed specs for Combiner Panel#1.

10.3 Solar Combiner Board #2

The Solar Combiner board #2 is a 3-phase, 400V, 600A panel. Since each inverter has a maximum AC output of 76.5A, the incoming feeders from the inverters have a Molded Case Circuit Breaker (MCCB) of a 100A rating.

Maximum Short Circuit current happens when it is grid connected and fed by the utility, nevertheless, the impedance (5%) of the 500kVA transformer limit this to maximum 10000kVA (which is less than 15kA at 400V). The low voltage boards are designed for a minimum of 36kA which is more than adequate.

Each MCCB must have inbuilt overcurrent and short-circuit protection. Each MCCB must have the capability to be capability to interact with the SCADA system and communicate its operating status (communicate whether it is On or Off via SCADA). The outgoing feeder from the Solar combiner board must have a motorized circuit breaker rated for 600A.
By combining the AC outputs from 5 inverters, a higher gauge cable can be used thus reducing the losses. The Solar combiner board #2 has the following key specifications.

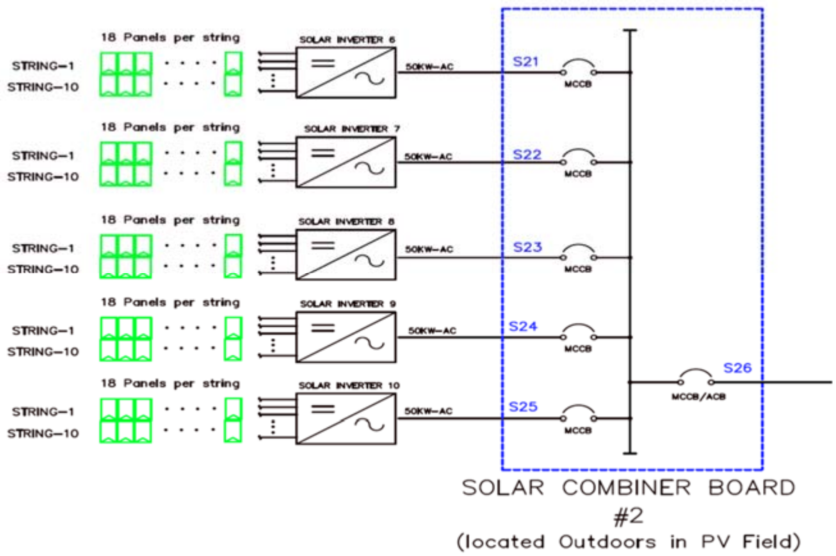


Figure 20: Simplified drawing showing the connection for Solar Panels, Inverters and Combiner Panel#2

Refer to technical specifications for detailed specs for Combiner Panel#2.

10.4 Battery Energy Storage System (BESS) Combiner Board

The current designed configuration has 5 containers of 500kWh each with a bi-directional battery inverter of 100kW. Each inverter is 100kW, 400V, 50Hz, 3-phase, 4 wire. The output from the 5 inverters is connected to a battery combiner panel. Each combiner board is a 3-phase, 1500V, 600A panel. Maximum Short Circuit current happens when it is grid connected and fed by the utility, nevertheless, the impedance (5%) of the 500kVA transformer limit this to maximum 10000kVA (which is less than 15kA at 400V). The low voltage boards are designed for a minimum of 36kA which is more than adequate.

The BESS combiner panel is a 1500A, 400V, 3-phase 4-wire panel with a total of 9 feeders. 5 feeders are connected to the 5 battery inverters and have a Molded Case Circuit Breaker (MCCB) of a 200A rating and a contactor for protection. Each MCCB must have inbuilt overcurrent and short-circuit protection. Each MCCB must have the capability to interact with the SCADA system and communicate its operating status (communicate whether it is On or Off via SCADA). The opening and closing of each contactor will be controlled via commands sent by SCADA.

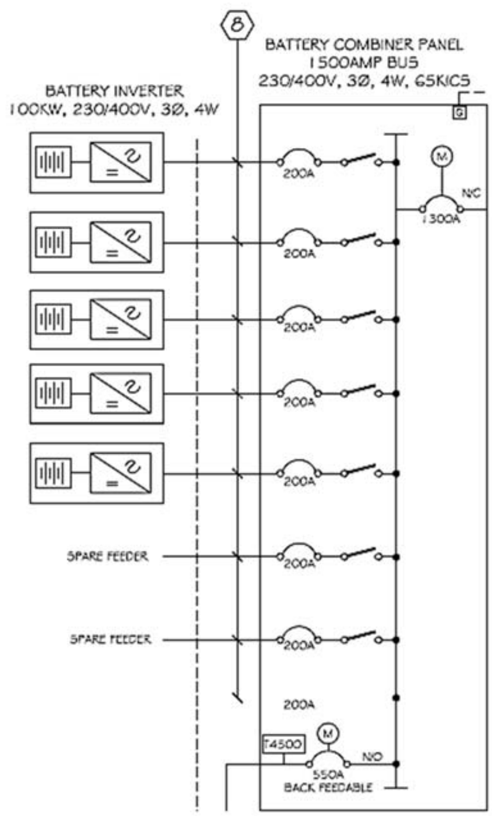


Figure 21: Battery Combiner Panel/Board details

Maximum Short Circuit current happens when it is grid connected and fed by the utility, nevertheless, the impedance (5%) of the 500kVA transformer limit this to maximum 10000kVA (which is less than 15kA at 400V). The low voltage boards are designed for a minimum of 65kA which is more than adequate.

The outgoing feeder from the *BESS Combiner Board* to the *Main Combiner Board* is normally-closed and the charging of the batteries takes place through the power flow from the *Solar Combiner Boards* (both 1 and 2) to the *Main Combiner Board* and from there to the *BESS combiner Board.* This main feeder is rated for 1300A and has a motorized breaker for controlling the operations that receives the operation command from SCADA.

One feeder on the BESS combiner board is connected to the diesel board and is normally-open. This feeder is only used in case of emergency when the charge level of batteries is lower than the acceptable level. In this scenario, the main output feeder from the *BESS Combiner Board* to the *Main Combiner Board* will be opened, the feeder from the *Diesel Combiner Board* will be closed and the batteries will be charged from the diesel generator. The feeder to the *Diesel Combiner Board* is rated for 550A and has a motorized breaker for controlling the operations that receives the operation command from SCADA.

The BESS combiner board is provided with spare feeders that may be used in case the number of battery containers are more than 5.

Refer to technical specifications for detailed specs for BESS Combiner Board.

10.5 Diesel Combiner Board

The *Diesel Generator Combiner Board* is a 400V, 800A, 3-phase, 4-wire panel board. The diesel combiner board has two incoming feeders from two different diesel generators, namely, a 300kW generator and a 75kW generator. The 300kW and 75kW generators are connected to the combiner board through a 500A and a 150A motorized circuit breaker, respectively. Generator protection with auto-synchronizer is used with the two diesel generators to make sure that their operation is synchronized. Both the breakers must have inbuilt overcurrent and short-circuit protection. Each combiner board is a 3-phase, 400V, 800A panel. Maximum Short Circuit current happens when it is grid connected and fed by the utility, nevertheless, the impedance (5%) of the 500kVA transformer limit this to maximum 10000kVA (which is less than 15kA at 400V). The low voltage boards are designed for a minimum of 36kA which is more than adequate.

Each breaker must have the capability to interact with the SCADA system and should be able to execute On/OFF switching through SCADA commands. The operation logic is such that the 75kW diesel generator unit will start first, in case the load is below 75 KW and will continue to power the load until load exceeds 75KW. At this point the 300 KW generator starts automatically and the load gets transferred from the 75 KW unit to the 300 KW unit. There will be a small amount of time of parallel operation of the two diesel generators. However, in case the initial load is detected to be higher than 75KW, the 300KW unit starts straight away skipping the 75KW generator operation.

There are three outgoing feeders from the diesel combiner board. The main output feeder from the *Diesel Combiner Board* connects to the *Automatic Transfer Board* and provides power to the mini-grid when the energy available from the PV+BESS is not enough to support the loads. This feeder has a motorized 550A circuit breaker and receives the ON/OFF operational command from SCADA. At the time when the grid loads are supported by the operation of diesel generator, the Auxiliary Panel serving the local building loads also receives power from the diesel combiner board. This takes place through the fourth feeder on the diesel combiner board through a 200A MCCB.

The fifth feeder from the *Diesel Combiner board* connects to the *BESS Combiner board* and has a 550A motorized circuit breaker. This feeder is used to synchronize the diesel generators to the BESS; this is achieved through an Auto-Synchronizer (similar to T4500). At the time of transfer from BESS to diesel generator the feeder between diesel and BESS is used to synchronize the sources and synchronize diesel to BESS. This allows a smooth transition from BESS to diesel and the same logic is used when the source needs to be switched from diesel to PV+BESS. The operation logic does not call for continuous parallel operation of the BESS and the generator. Typically, the BESS supports the load and the generator kicks in when the BESS state of charge drops to a pre-set value. At this point generator is paralleled with the BESS for a very short time (less than a few minutes) and load is transferred from BESS to the generator. The purpose is to minimize interruptions during this transition. BESS is disconnected from the bus after this transition. The Minigrid control system/SCADA will have the logic to monitor the BESS state of charge and start, synchronize and stop the generators.

10.5.1 Reverse Power Flow Issues

Reverse power flow typically happens during parallel operation of generators when one of the generators is faulty or prime mover is not in operation resulting in the generator operating as a motor. We think reverse power relays are not needed in this case for following reasons:

- The operation logic does not call for continuous parallel operation of generators. We will only have momentary paralleling (less than a few minutes) to minimize interruptions during transitions.
- The probability of one of the generators failing during the few minutes of parallel operation is extremely low justifying the investment in reverse power schemes.
- Reverse power schemes can be implemented in future if continuous parallel operation is required in future

Similarly, remedial measures for limiting circulating currents in the common neutral which bonds the wye connections of the generating sources are also not required as the generators will be in parallel operation only momentarily (less than few minutes).

Because of the above additional elaborations, we have decided to revise our statement on reverse power flow issue as follows:

“The operation logic does not call for continuous parallel operation of generators. We will only have momentary paralleling (less than a few minutes) to minimize interruptions during transitions. The synchronization mechanism will ensure that generators are working at the time of synchronization. As the parallel operation is limited to just during transitions we feel that the risk of reverse power flow is negligible.”

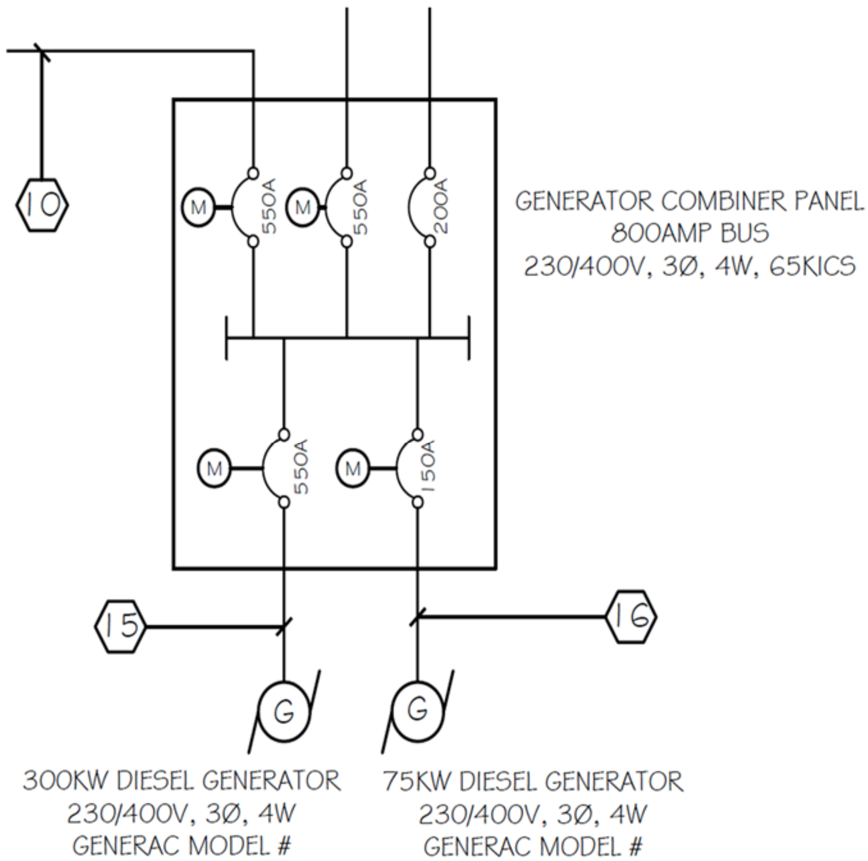


Figure 22: Simplified drawing showing the connection for the Diesel Combiner Board

Refer to technical specifications for detailed specs for Diesel Combiner Board.

10.6 Main Combiner Board

The main combiner board is a 3000A panel that combines the feed from the two solar combiner boards and the feed from the BESS combiner board. The output from this panel is connected to the Automatic Transfer switch and serves as main feeder providing the feed from the PV+BESS system. A 400A Auxiliary Panel also gets the feed from the Main combiner panel to serve the local loads including all the lighting, HVAC, etc. loads.

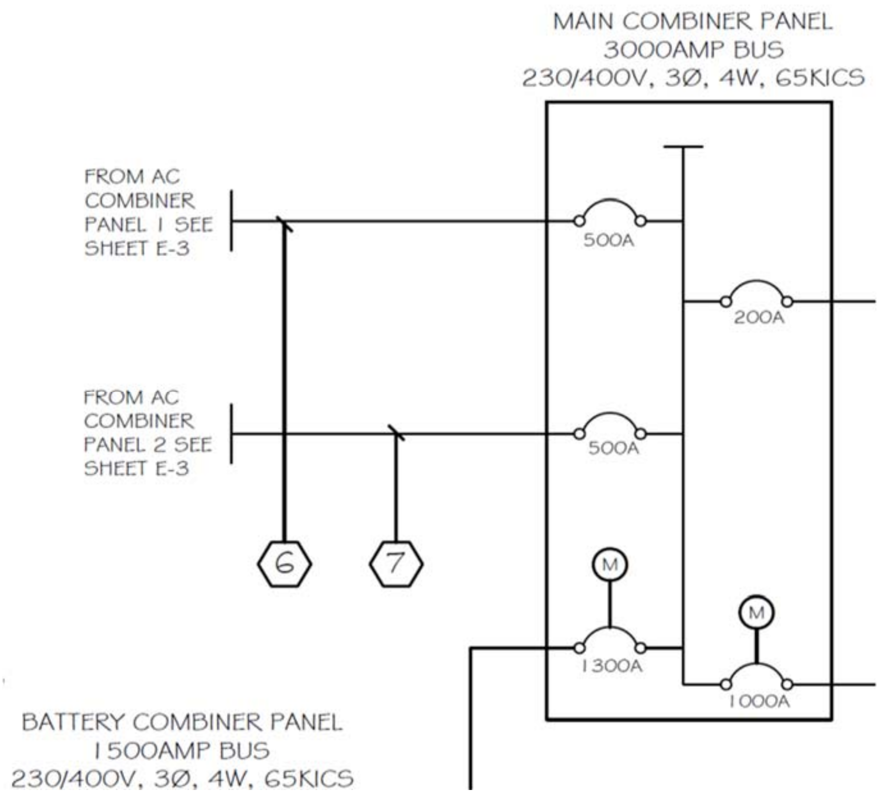


Figure 23 Main Combiner Panel

Refer to technical specifications for detailed specs for Main Combiner Board.

10.7 Automatic Transfer Board

A transfer switch allows an electrical system to be quickly and safely switched from primary power source to an alternate power source to keep critical loads operating without interruption.

The transfer board is used with PV system in off-grid situation where an alternate power from diesel generator is relied upon when insolation is low, or the PV system cannot charge the batteries. Automatic transfer board continually monitors the primary power source (PV+Battery); when the voltage falls below a certain level, the switch automatically starts a power transfer, such as sending electronic signal to the diesel generator to initiate its start-up sequence. When SCADA detects proper voltage and frequency on the alternate source, it completes the transfer. The transfer board is programmed in such a way that the transfer happens without an interruption in the power supply. In order to achieve smooth transition, each transfer occurs with a very short term paralleling of the distributed generation resources (<5 min).The switching will also manage an automatic and controlled transfer back to the primary power when it becomes available again.

In all cases, the primary power source must be completely disconnected from the electrical system before the alternate power source is connected. This prevents the power from back-feeding into the primary system but results in a short power interruption. Depending on the system the interruption may last from a fraction of a second to several seconds.

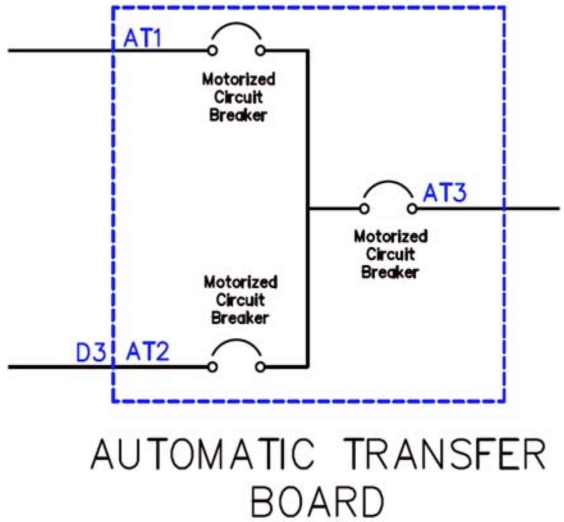


Figure 24: Automatic Transfer Panel

Refer to technical specifications for detailed specs for Automatic Transfer Board.

10.8 Inrush Current Limiting Device

The inrush current limiting device is the ideal soft-starting solution for medium and low voltage transformers. The sophisticated control ensures the elimination of the magnetizing inrush current, thus, eliminates nuisance tripping as well as dynamic shock to the transformer windings. The starter can be supplied with options such as Line and Bypass vacuum contactors or circuit breakers, connect switches, main and control protection fuses, transformer protection relay, etc.

Refer to technical specifications for detailed specs for Inrush Current.

10.9 Auxiliary Panel Board

The Auxiliary Panel board is the panel board that would supply power to all the local loads. These would include all the lighting, HVAC, control equipment, etc. loads at the facility and around the power plant. The auxiliary panel has two different input feeders that will be interlocked and only one feeder will feed the panel at any point in time. The Auxiliary panel will get the energy feed from the main combiner panel when the mini-grid is served by the Solar+BESS system. During the mini-grid operation when the loads are served by the Diesel generators, the feeder from the main combiner panel will disconnect and the feeder from the Diesel combiner panel will connect to provide the power to the Auxiliary panel. The local panel will also have an Uninterruptable Power Supply (UPS) that would support all critical local loads during the period of switching or the period of emergency when there is not power supply.

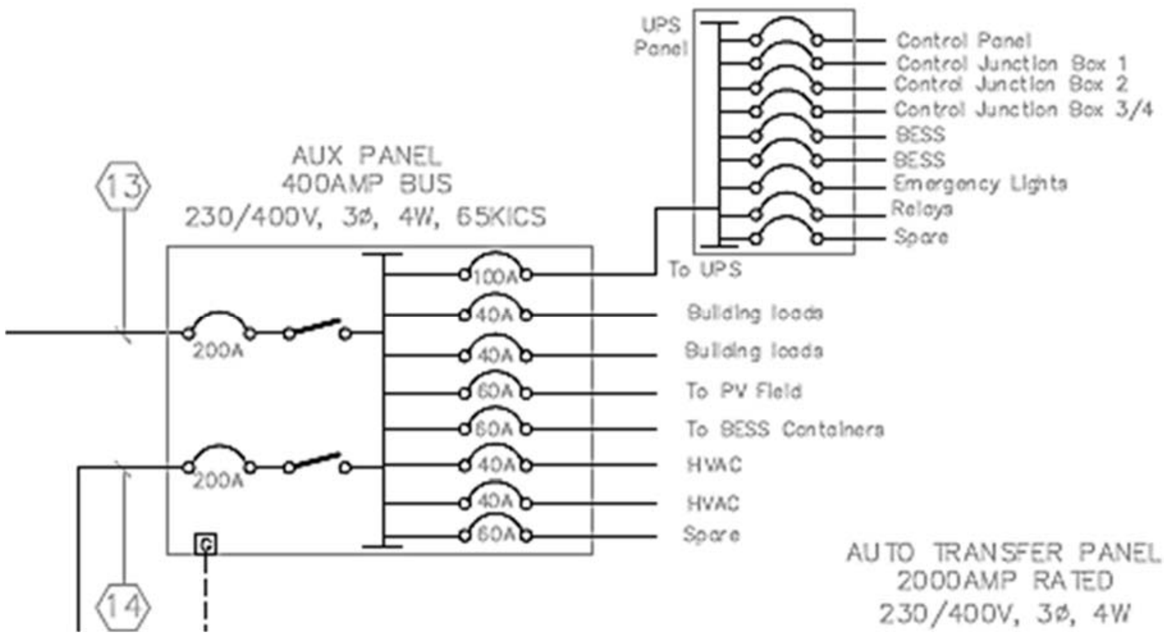


Figure 25: Auxiliary Panel

Refer to technical specifications for detailed specs for Auxiliary Panel.

10.10 Uninterruptable Power Supply

An uninterruptable power supply (UPS) is a battery based system that includes all the additional power conditioning equipment, such as inverters, chargers, to make a complete self-sustained power source. In the standby mode, the UPS keeps its batteries at full state of charge from the available power. When there is a loss of power, an automatic transfer circuit isolates critical loads from the main supply and supplies AC power inverted from the DC power from the battery. The UPS power will be used to back up computers, security systems, lights, power required for the control systems and other critical loads in event of power loss. The UPS supports the critical operation of the control boxes, server, relays, RIO boxes, etc. requiring 6.67kVA supply. Details of the SCADA system is shared in Chapter 14 on SCADA Layout and specifications. The size of the UPS battery back determines the magnitude and duration of critical loads operation.

10.11 Additional Requirements

All the material and works must be in accordance with the most advance practice for this type of equipment. Other than specified hereafter all the materials and realized works will be in accordance with latest edition of the IEC recommendations.

The delivery and the equipment in it shall be designed to meet the requirements of the following codes and standards: International Electro-technical Commission (IEC)/National Electrical Code (NEC).The design, materials, manufacturing, transportation, inspection, tests and packaging of the equipment and systems supplied shall be carried out as per International practices.

10.12 Exceptions to this Specification

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10.13 Guarantees

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The warranty period must be twelve months from the date of commissioning (provisional plant acceptance) or 24 months from the date pf delivery whichever is earlier.
This warranty implies that the Contractor shall repair, or replace if necessary, all the elements damaged during this period.

10.14 Document Discrepancy

In case of discrepancy between the documents included in this Specification, the following order of priority shall prevail:

- Applicable legislation only if more restrictive criteria are not established in the Data Sheets Requisition or Specification.
- Data Sheets.
- Technical Specification.
- Other specifications and standards of the project.
- International Codes and Standards.

10.15 Documentation and Drawings

The system supplier has to provide the following drawings and documents:

1. Detailed Single-Line Diagram
2. Detailed Three-Line Diagrams
3. Wiring diagrams
4. Assembly/shop floor drawings
5. General arrangement drawings
6. Foundation plan
7. Installation manual
8. Operating and troubleshooting manual
9. Software details for the control system
10. Interface details for communication
11. Test Certificates (Factory tests and Type test)

10.16 Factory Acceptance Tests

- All factory tests as per IEC or NEC
- Visual/Mechanical Inspections
    - General Visual and Mechanical Inspections
        - Check the layout of fitted components
        - Check the overall dimension of switchboard, size of busbars, cables and earthing conductors and location of feeder entry point.
        - Check and verify the brand, model, and circuit identification of components installed such as breakers, current transformers, fuses, ammeters, voltmeters, power meters and protection relays
        - Check overall paint work, door locking device, door gasket, door hinges, door cut-out holes
        - Check the busbar and cable tightening, the marking, busbar clearance, base angle bar and plinth

        - Check the labels, name plate and phase identification
    - Moisture and Corona Inspections
    - Wiring and Bolted Connection Checks
    - General Wiring Checks
    - Moving Parts and Interlocks
    - Insulators and Barrier Checks
- Electrical Tests
    - Bolted Connection Electrical Tests
    - Insulation Electrical Tests
    - Dielectric Withstand Tests
    - Control Wiring Electrical Tests
    - Instrument Transformers
    - Circuit Breakers and Switches
    - Control Power Transfer Scheme
    - Metering Electrical Tests
    - Current Injection Tests
    - System Function Test
    - Cubicle Heaters
    - Surge Arresters
    - Dual-Source Phasing Check
- Option for factory inspection and witness test

10.17 Spare Parts

Two detailed spare parts lists shall be included. One list will include all recommended spare parts for commissioning and the other list with recommended spare part for ten (10) year operation. Both lists will include:

- Spare part description
- Quantity
- Unit Price

Furthermore, two-year operation spare parts list will include a recommended planning for equipment replacement (operation hours).

10.18 Bill of Quantities

Refer to the Bill of Quantity which will be separately attached in the design package.

11. DIESEL GENERATOR

11.1 Codes and Standards

- **IEC 60034** Rotating Electrical Machines
- **IEC 60085** Thermal Evaluation and Classification of Electrical Insulation
- **IEC 60529** Degrees of Protection provided by Enclosures (IP Code)
- **ISO 10816** Specification for Mechanical Performance: Vibration
- **ISO 3046** Specification for Reciprocating Internal Combustion Engines
- **SI 426** European Commission (dangerous substances) (Classification, packing, labelling, and Notification of Regulations 1992.
- **CIMAC** Congress International des Machines a Combustion
- **ISO 9000** Recommendations for Diesel Engine Acceptance Tests Quality assurance
- **Other applicable standards**

11.2 Design and Sizing

Since the peak load is expected to be about 275kW, the system is proposed to have multiple diesel generators (300kW + 75kW). Having multiple generators will add redundancy to the backup system and reduce the need for operating one large generator all the time, hence having a more efficient operation.

11.2.1 Operation Mode for Diesel Generator

During the course of the day, PV + BESS will support the loads. During evenings and nights, BESS will support the loads without any PV. When the State of Charge (SOC) of the BESS drops to a predefined set point, the BESS inverters get switched OFF and the system transitions automatically to diesel operation. The 75kW diesel generator unit will start first in case the load is below 75 KW and will continue to power the load until load exceeds 75KW. At this point the 300 KW generator starts automatically and the load gets transferred from the 75 KW unit to the 300 KW unit.

11.2.2 Charging Battery by Diesel Generator

At times during the operation of the generator it might be operating at less than 100% of its operating capacity. The diesel combiner board has a feeder that is connected to the BESS combiner board. This allows for the diesel generator to charge the batteries in case

- The charge in the battery is too late for safe operation, and/or

- In the scenario when some load needs to be added to the diesel generator so that the diesel operates efficiently and in a stable manner.

11.3 Configuration

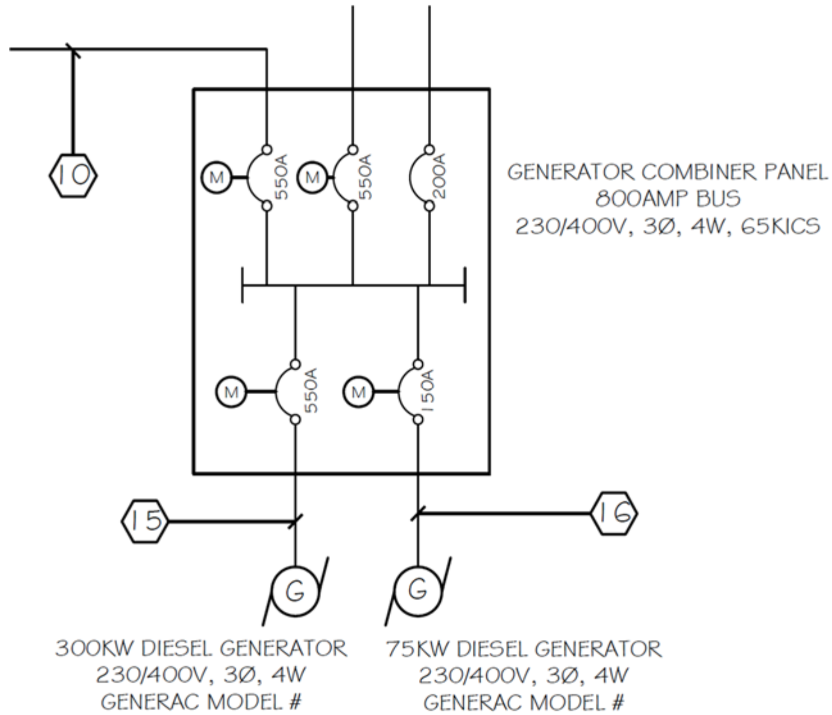

Figure 26: Diesel Combiner Board Configuration

The configuration of diesel generators proposed for the Parwan mini-grid is to have two diesel generators of 300 and 75 kW capacity connected to the diesel combiner board. The operation of the diesel generators will mostly be individual and only in some situations there will be parallel operation of the two diesel generators needed for a very short period of time. This parallel operation will be to make sure that there is no interruption in the power supply.

Refer to technical specifications for detailed specs for Diesel Generators.

11.4 Diesel Combiner Board

The *Diesel Generator Combiner Board* is a 400V, 800A, 3-phase, 4-wire panel board. The diesel combiner board has two incoming feeders from two different diesel generators, namely, a 300kW generator and a 75kW generator. The 300kW and 75kW generators are connected to the combiner board through a 550A and a 150A motorized circuit breaker, respectively. The details about the Diesel Combiner Board is presented in Chapter 6: LV Combiner Boards.

11.5 Working, Design and Construction of a Diesel Engine

In diesel engines, exceedingly compressed air and ignition fuel are fused together to generate the mechanical energy, which is later converted to electrical energy. The air is taken in from the atmosphere and is subjected to high compression. This process heats up the engine, and when diesel fuel is injected, due to high temperatures and pressure the fuel ignites.

In case of a diesel engine, air is taken in separately and diesel is injected separately via injectors, this leads to a better air-fuel compression ratio because only the air is compressed in this scenario. Depending on the mode of operation the diesel engines can be classified into 2-cycle or 4-cycle engines.

11.5.1 Generator

- The governor of the generator regulates the speed of the engine in accordance with the ISO 8528 Part-1 Class3.
- The voltage regulation is to be maintained constant at 0.5% from no-load to full load settings.
- The random fluctuations in the voltage during operation should be within 0.5% during normal operation
- The random fluctuations in the frequency should be within 0.25% during normal operation of the generator
- The radio frequency emissions should comply with the military and IEC standards
- The Electromagnetic compatibility should be in accordance with EN61000-6-4/EN61000-6-2
- The generator should be enclosed in a sound attenuated canopy

11.5.2 Engine

- The engine should be a 4 stroke, turbocharged diesel engine.
- The bore diameter of the cylinder should be about 5.5 inches and the piston should travel 6 inches
- The volume of the cylinders in the engine should be 855 cubic inches and the cylinder block should be made of cast iron
- A battery of approx. 100 amp/hr is to be used and the battery charging alternator should be able to provide 55 amps.
- 24 V negative earth supply is required for starting motor and engine operation

- A direct injection type fuel system is to be used with the fuel filter having spin on filter with water separator
- The engine should be able to operate at ambient temperatures of 50° C

11.5.3 Alternator

- A brushless, 4- pole, revolving field type machine is to be used
- The stator winding pitch parameter is to be maintained at 2/3rd pitch for all the 4-wire applications
- A single bearing, flexible disc arrangement is to be used while attaching the alternator to an engine
- Low voltage insulation i.e. the class H type is to be utilized. This insulation should be able to withstand the temperatures up to 150°C
- The phase connections follow the phasor rotation of A, B, C where A leading B leading C by 120° in counter clockwise direction
- Direct drive centrifugal blower fan is to be used for cooling during operation
- The total harmonic distortion of the sine wave should be less than 1.5% during no-load and less than 5% for non-distorting balanced linear load
- The Telephone Influence Factor (TIF) which is a measure of interference of power-line harmonics with telephone lines should be less than 50 as per NEMA guidelines
- The total harmonic factor should be less than 2%

11.5.4 Available Voltages

The available voltage range varies depending on the type of connection between the two conductors.
For a line-to-line connection, at 50 Hz, the available voltages should be 190, 200, 220, 380, 400, 416, 440, 480
For a line-neutral connection, at 50 Hz, the available voltage range should be 110, 115, 127, 220, 230, 240, 254, 277

11.5.5 Fuel Tank and Fuel consumption

- An 800-900 L (250L for the smaller generator) base fuel tank should be equipped with the diesel generator
- While operating in prime mode, the consumption should be in the range of 70-76 L/hr (20L/hr for the smaller generator)

- While operating in standby mode, the consumption should be in the range of 80-84 L/hr (22-25L/hr for the smaller generator)

11.5.6 Control System

- The engine should be equipped with a control panel, which should be able to regulate the voltage, control the governor action, engine protection, etc.
- The inbuilt control panel should be able to start the generator locally or via a remote signal
- The control panel should consist of LED indicators pertaining to various diesel generator parameters like running mode, oil level, engine temperatures, common warnings, failure conditions, etc.
- The generator should be equipped with an emergency stop switch
- The control system should be equipped with basic engine protection equipment

A control panel should have options to enable enhancements or better capabilities like paralleling option, security keys, additional input and output models, etc.

11.6 Additional Requirements

All the material and works must be in accordance with the most advance practice for this type of equipment. Other than specified hereafter all the materials and realized works will be in accordance with latest edition of the IEC recommendations.

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11.7 Exceptions to this Specification

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11.9 Document Discrepancy

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- Data Sheets.
- Technical Specification.
- Other specifications and standards of the project.
- International Codes and Standards.

11.10 Documentations and Drawings

- Detailed Single-Line Diagram
- Detailed Three-Line Diagrams
- Wiring diagrams
- Assembly/shop floor drawings
- General arrangement drawings
- Foundation plan
- Installation manual
- Operating and troubleshooting manual
- Software details for the control system
- Interface details for communication
- Test Certificates (Factory tests and Type test)

11.11 Factory Acceptance Tests

- Factory tests as per IEC or NEC
- Testing of the impact load acceptance
    a. demonstrate that the response of the generator to load meets the specified limits of
        i. Rated voltage,
        ii. Frequency, and
        iii. Recovery time.
    b. Monitor the transient graphs for voltage and frequency in real time.
- Test the full functionality of the generator
    a. Simulate the protection alarms and shutdowns to test the operation and safety of generator set,
- Perform load-proving test.
    a. Demonstrate the capability of generator to continuously carry rated load for a period of time, depending on the required continuous or standby ratings.
    b. Key parameter readings to be taken at regular intervals specific to the requirements.

11.12 Spare Parts

Two detailed spare parts lists shall be included. One list will include all recommended spare parts for commissioning and the other list with recommended spare part for ten (10) year operation. Both lists will include:

- Spare part description
- Quantity
- Unit Price

Furthermore, two-year operation spare parts list will include a recommended planning for equipment replacement (operation hours).

11.13 Bill of Quantity

Refer to the Bill of Quantity which will be separately attached in the design package.

12. TRANSFORMER

12.1 Codes and Standards

The transformers shall be designed, manufactured and tested according to the following Standards:

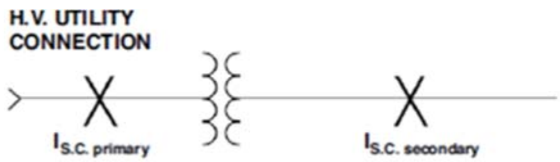
- **IEC 60044-1, -2, -3** Current Transformers for protection; Instrument transformers.
- **IEC 60060** High voltage test techniques.
- **IEC 60071** Insulation co-ordination.
- **IEC 60076, -11** Power transformers; Operating Temperatures
- **IEC 61936-1** Spatial requirements, Site Installation
- **IEC 60137** Bushings for alternating voltages above 1000 V.
- **IEC 60233** Test on hollow insulators for use in electrical equipment.
- **IEC 60551** Determination of transformer and reactor sound level.
- **IEC 60722** Guide to the lightning impulse and switching impulse testing.
- **IEC 62271-105** Switch-dis-connectors
- **IEC 60909-0** Short circuit calculations
- **Other applicable standards**

12.2 Design and Sizing

A 500kVA step up transformer will be used to step up the system voltage from 400V three-phase to 20kV. The secondary voltage of 20kV is selected due the prospect of connecting the mini-grid to the main utility transmission line in the future. The Parwan mini-grid has three sources of energy supply, namely, solar PV, BESS and diesel. All the supply systems are designed to supply power at 400V, 3-phase, 50Hz. Based on the estimated load profile, the mini-grid will have a peak load of about 275kW. It is expected that as the villages are exposed to the option of having reliable electricity, the consumption of electricity would increase over the coming years. Keeping that in mind a 500kVA transformer is proposed for the Parwan site.

12.2.1 Fault Level Calculations

The following table contains faults in two steps – theoretical max with infinite fault level of the utility and the real max with 20KA fault level. Also fault level can be stated in MVA and kA. In the following table, the MVA fault is shown first and then the KA fault. Calculations are based on following formula:



Step A. Calculate the "f" factor ($I_{S.C.\ primary}$ known)

3Ø Transformer ($I_{S.C.\ primary}$ and $I_{S.C.\ secondary}$ are 3Ø fault values)

$$f = \frac{I_{S.C.\ primary} \times V_{primary} \times 1.73\ (\%Z)}{100{,}000 \times kVA_{\ transformer}}$$

1Ø Transformer ($I_{S.C.\ primary}$ and $I_{S.C.\ secondary}$ are 1Ø fault values: $I_{S.C.\ secondary}$ is L-L)

$$f = \frac{I_{S.C.\ primary} \times V_{primary} \times (\%Z)}{100{,}000 \times kVA_{\ transformer}}$$

Step B. Calculate "M" (multiplier).

$$M = \frac{1}{1+f}$$

Step C. Calculate the short-circuit current at the secondary of the transformer. (See Note under Step 3 of "Basic Point-to-Point Calculation Procedure".)

$$I_{S.C.\ secondary} = \frac{V_{primary}}{V_{secondary}} \times M \times I_{S.C.\ primary}$$

Fault from utility			
Utility Fault current	20000	A	
Utility voltage	20000	V	
Fault MVA	692.8	MVA	
Transformer Rating	500	KVA	
Transformer Impedance	5	%	
Transformer Fault Level	10	MVA	
System Fault	9.86	MVA	
System Fault Current at 400V	14228.80	Amps	
Fault generated by Battery			
Battery/Inverter capacity	500	KW	
Rated Current at 400V	721.71	A	
Max Current	1443.42	A	
Fault level	1.00	MVA	

Fault generated by Diesel			
Diesel capacity	300	KW	
Power Factor	0.8		
Rated current at 400V	541.28	A	
Reactance	0.15		
Fault current	3608.55	A	
Fault level	2.5	MVA	
Total Fault level from Battery and Diesel	3.5	MVA	
Fault level from Utility	9.86	MVA	
Design fault level at 400V	9.86	MVA	the higher of the two
Design fault level at 20KV	692.8	MVA	

Table 19: Fault Level Calculation

12.3 Configuration

The proposed configuration of the step-up transformer is recommended to be a Star-Star configuration. The alternate configuration can be a Delta on the utility side, as is a common practice in Afghanistan.

12.3.1 Star-Star configuration

Some of the advantages of having a Star configuration on the utility side are:

- Solid grounding can be achieved with a Star configuration,
- With the Star configuration any fault in the MV line is easy to detect
- Insulation level can be phase to earth
- Low transient voltage stress

The disadvantages of a star-star configuration are

- Any ground fault will result on system tripping, and
- The system will have high fault currents and thermal stress.

12.3.2 Star-Delta configuration

The advantages of having a Star-Delta configuration (with delta on the utility side) are:

- The system will not trip during any transient faults
- Low fault current and low thermal stress

The disadvantages of a star-delta configuration are

- The system needs high insulation level – line to line
- High transient voltage stress
- The system needs additional equipment to detect faults

Note- In either of the system configuration, the step-down transformers for loads can be delta on the 20 KV side and star on the 400V side.

Refer to technical specifications for detailed specs for Transformer.

12.4 Additional Requirements

All the material and works must be in accordance with the most advance practice for this type of equipment. Other than specified hereafter all the materials and realized works will be in accordance with latest edition of the IEC recommendations.

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- Assembly/shop floor drawings
- General arrangement drawings
- Foundation plan
- Installation manual
- Operating and troubleshooting manual
- Software details for the control system
- Interface details for communication
- Test Certificates (Factory tests and Type test)

12.9 Factory Acceptance Tests

- All factory tests as per IEC or NEC
- For details check ANSI/IEEE Standard C57.12.90
- List of Tests
    - No-Load Losses

  - No-Load Excitation Current
  - Load Losses and Impedance Voltage
  - Dielectric Tests
  - Switching Impulse Test
  - Lightning Impulse Test
  - Partial Discharge Test
  - Insulation Power Factor
  - Insulation Resistance
  - Noise Measurement
  - Temperature Rise (Heat Run)
- Measurement of voltage ratio and check for vector relationship,
- Measurement of winding resistance,
- Measurement of insulation resistance,
- Measurement of short circuit impedance and load loss,
- Measurement of no load losses and current, Induced overvoltage withstand test,
- separate source voltage withstand test,
- visual and dimensional check as per approved GA drawing ,
- Oil B.D.V. test

12.10 Type Tests

- Temperature rise test,
- short circuit test,
- Impulse test,
- Determination of transient (Impulse) voltage transfer characteristics,

1. Noise level test,
2. Zero phase sequence impedance test
3. capacitance tan delta test, S.R.F.A test,
4. Pressure and vacuum test on transformer tank,
5. Magnetic balance test

- Option for factory inspection and witness test

12.11 Spare Parts

Two detailed spare parts lists shall be included. One list will include all recommended spare parts for commissioning and the other list with recommended spare part for ten (10) year operation. Both lists will include:

- Spare part description

- Quantity
- Unit Price

Furthermore, two-year operation spare parts list will include a recommended planning for equipment replacement (operation hours).

12.12 Bill of Quantities

Refer to the Bill of Quantity which will be separately attached in the design package.

13. MEDIUM VOLTAGE SWITCHGEAR/ GRID CONNECTION SOLUTION

13.1 Codes and Standards

The delivery and the equipment in Medium-Voltage Switchgear shall be designed to meet the requirements of the following codes and standards:

- **IEC 60298** HV Metal-Enclosed Switchgear and Controlgear.
- **IEC 60056** HV Alternating-Current Circuit Breakers.
- **IEC 60129** AC Disconnectors (Isolators) and Earthing Switches.
- **IEC 60044** Instrument Transformers.
- **IEC 60282** HV Fuses.
- **IEC 60071** Insulation Coordination.
- **IEC 60060** HV Test Techniques.
- **IEC 60529** Classification of Degrees of Protection Provided by Enclosures.
- **IEC 60694** Common Clauses for HV Switchgear and Control Gear Standards.
- **lEC 60099** Surge arresters.
- **lEC 60358** Surge Capacitor.
- **IEC 62271-200 IEC 62271-200** AC metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV
- **Other applicable standards**

The temperature rise of any part of the switchgear and control gear at an ambient air temperature not exceeding 40°C shall not exceed the temperature-rise limits specified in the appropriate standard, **IEC 62271-100** and **IEC 62271-1**.

The electrical life of the circuit breaker shall conform to **IEC 62271-100 class E2**, no maintenance of the circuit breaker interrupting parts for the life of the circuit breaker and only minimal maintenance of the other parts. As a minimum, the circuit breaker shall have not less than 20.000 make-break operations at full load without any maintenance or replacement of parts being necessary.

13.2 Design and Sizing

The Medium voltage switchgear is designed based on the generation capacity and load. We have selected a 20kA 600A grid-tie switchgear. The fault level of the utility is assumed to be

20kA. The switchgear is complete with synchronization capability that can be used in future when there is grid available.

A visible disconnect and a set of lightning arrestors have to be installed on the first pole as part of the reticulation system.

13.3 Configuration

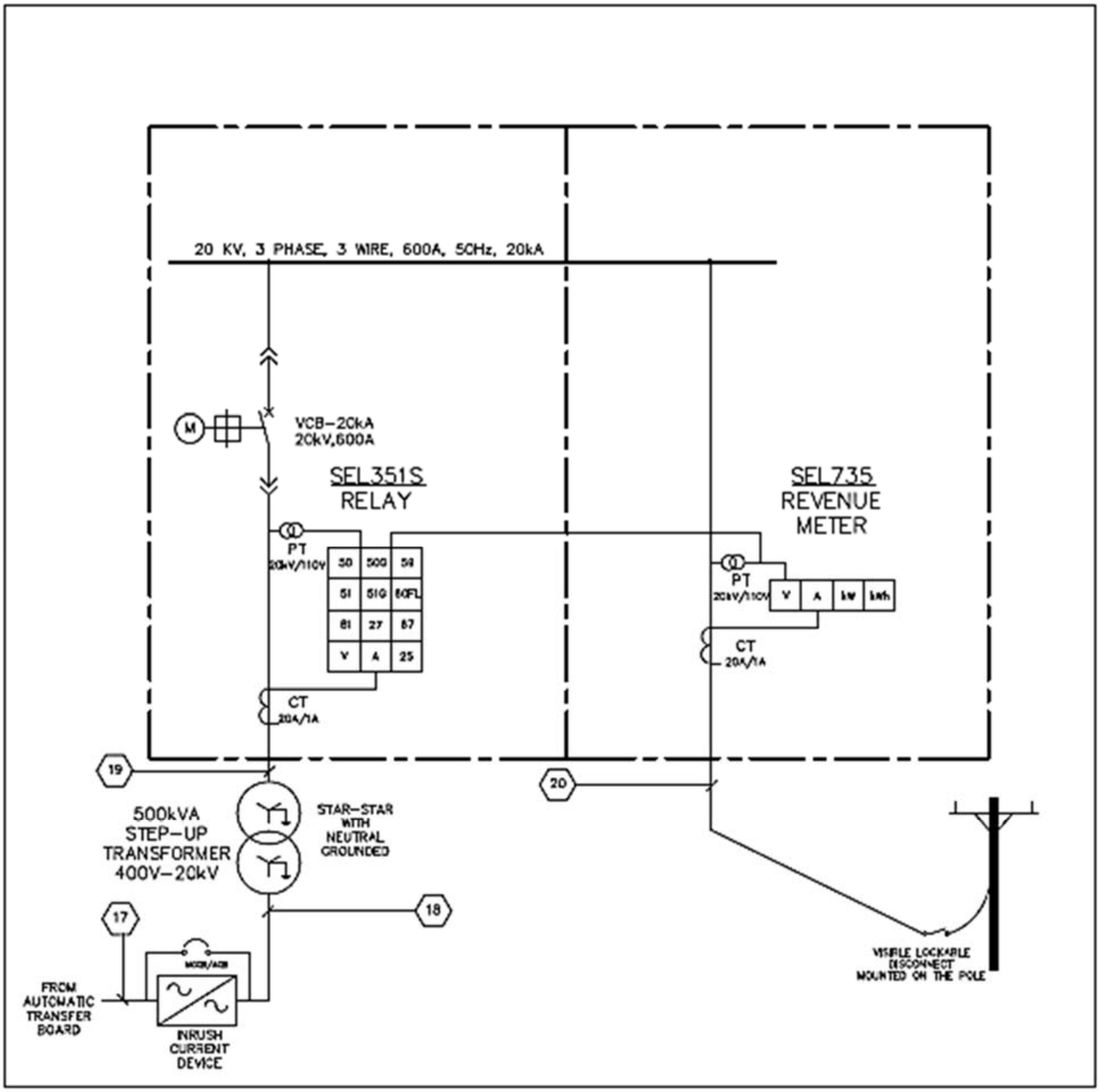

Figure 27: Medium Voltage switchgear details

Refer to technical specifications for detailed specs for Medium Voltage Switchgear

13.4 Total LV/MV Length

The total transmission routes for LV and MV are 16,223 meter. The following amount of cables are needed for both LV and MV routes:

- The total length of cable required for LV is 13,817 meter
- The total length of cables required for MV is 8253 meter

13.5 Additional Requirements

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The Contractor shall guarantee all characteristic required. The Contractor shall present and supervise all the guarantee tests. The Contractor shall guarantee that the supplied equipment, material, or part thereof shall follow the specifications hereto and shall be unused products, free from any defects in design, material or workmanship. Spare parts furnished shall be identical or equivalent to original parts (spare parts are quoted as optional).

The warranty period must be twelve months from the date of commissioning (provisional plant acceptance) or 24 months from the date pf delivery whichever is earlier.
This warranty implies that the Contractor shall repair, or replace if necessary, all the elements damaged during this period.

13.8 Document Discrepancy

In case of discrepancy between the documents included in this Specification, the following order of priority shall prevail:

- Applicable legislation only if more restrictive criteria are not established in the Data Sheets Requisition or Specification.
- Data Sheets.
- Technical Specification.
- Other specifications and standards of the project.
- International Codes and Standards.

13.9 Documentation and Drawings

The system supplier has to provide the following drawings and documents:

- Detailed Single-Line Diagram
- Detailed Three-Line Diagrams
- Wiring diagrams
- Assembly/shop floor drawings
- General arrangement drawings
- Foundation plan
- Installation manual
- Operating and troubleshooting manual
- Software details for the control system
- Interface details for communication
- Test Certificates (Factory tests and Type test)

13.10 Factory Acceptance Tests

- All factory tests as per IEC or NEC
- MV switchgear shall be thoroughly tested at the factory to assure that there are no electrical or mechanical defects. Tests shall be conducted as per UL, ANSI and CSA Standards.
- Thoroughly test the switchgear at the factory with the circuit breakers in the connected position in their cubicles. The factory tests shall be in accordance with IEEE C37.09 and shall include the following tests:
    - Design Tests
    - Production Tests

13.10.1 Physical Inspection

1. Verify that the drawings and other project-specific documentations are correct, and make sure that the order number, customer name, and project name are consistent on all documents.
2. Verify component certifications, as required.
3. Verify that the product meets all applicable engineering and workmanship standards and specifications.
   - Verify paint quality.
   - Verify that all components are present, not damaged, and are correctly installed.
   - Verify structural integrity.
4. Verify that warning nameplates and isolation barriers are present to protect personnel and equipment.
   - Check for appropriate warning labels and nameplates to advise personnel of possible hazards.
   - Check that appropriate barriers are in place to isolate all medium voltage compartments. Barriers are to ensure that personnel cannot touch live medium voltage in a cell that is otherwise de-energized.
5. Verify that bus and bus connections have proper clearance, creepage, phasing, and torque.
   - Visually check to verify electrical clearances, creepage allowances, and bend radii.
6. Check the tightness of all control and power wires.
   - All hardware connections are torqued to standards and all crimps are proper.
   - Check for cross-threaded hardware.
7. Verify the mechanical interlocks.
   - Verify the operation of any isolation switches, mechanical interlocks & door interlocks.

13.10.2 Electrical

1. Functional checks are performed wherever possible; otherwise, inspection and continuity checks are made.
   - Continuity checks are performed on all parts of the control circuit that cannot be verified by cycling the equipment.
   - Trace or continuity checks are performed on all power wiring.
   - Verify the control wiring is identical to the electrical schematics.
2. A “HI-POT” dielectric withstand test is performed on all buswork and power cables from phase-to-phase and phase-to-ground (except solid-state components, low voltage controls, and instrument transformers). The voltage level that is used for this test depends on the nominal AC voltage of the product
3. Component devices are functionally operated in circuits as shown on electrical diagrams or as called for by specific test instructions.
   - Calibration of printed circuit boards according to specifications.
   - I/O checks
   - Programmable devices

4. Instruments, meters, protective devices, and associated controls are functionally tested by applying the specified control signals, current/ voltages. Multi-function protective relays and like devices are not programmed – these types of devices are only functionally tested.
5. The product must function in accordance with the electrical diagram.

a. Medium voltage starters are inspected for the following:
- Electrical interlocking
- Overload protection and ground fault, if applicable

b. Medium voltage Smart Motor Controllers (SMCs) are inspected for the following:
- Electrical interlocking
- Motor protection and ground fault
- Motor start tests at rated voltage
- Motor stop tests (if applicable) at rated voltage

c. The following tests are performed on MV drives, as applicable:
- Control power failure test
- Rectifier gating checks
- Inverter gating checks
- Machine converter tests
- Load tests
- Power module failure tests
- Transformer over-temperature tests
- Cooling fan failure tests
- Remote control tests

Drives are accelerated to the test facility's nominal frequency of the motor, under load, and then decelerated to 10Hz. This cycle may be repeated continuously for up to 0.5 hour. Drives are tested under constant load at the nominal frequency of the test motor.

13.11 Spare Parts

Two detailed spare parts lists shall be included. One list will include all recommended spare parts for commissioning and the other list with recommended spare part for ten (10) year operation. Both lists will include:
- Spare part description
- Quantity
- Unit Price

Furthermore, two-year operation spare parts list will include a recommended planning for equipment replacement (operation hours).

13.12 Bill of Quantities

Refer to the Bill of Quantity which will be separately attached in the design package.

14. SCADA LAYOUT AND SPECIFICATIONS

14.1 SCADA Layout

SCADA layout document includes,

a. Overview of SCADA system for Microgrid application.
b. Detailed system block diagram shall be provided.

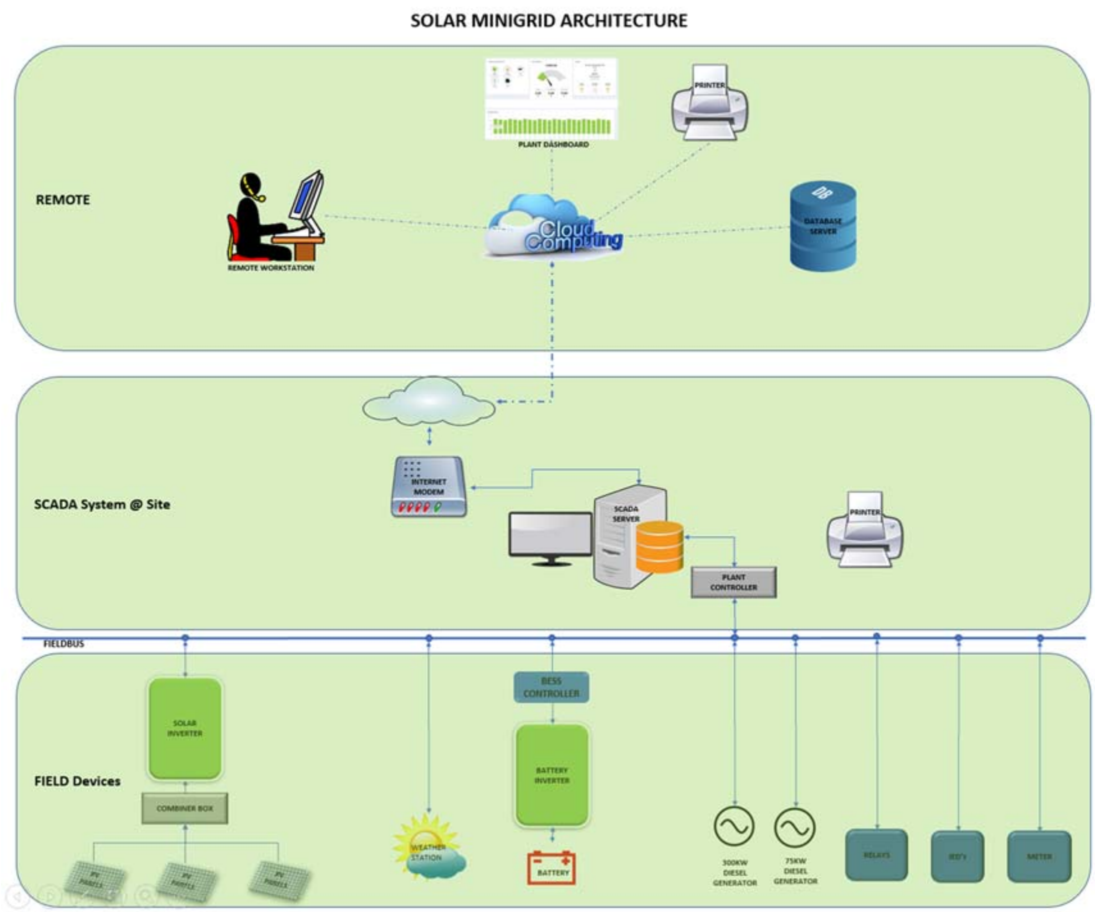


Figure 28: SCADA Architecture

Figure 28 represents overall SCADA architecture. SCADA vendor shall consider this for detailed design. SCADA vendor is responsible for providing minimum functionalities represented in the Figure 28.

a. PLANT CONTROLLER.
    i. PLC
        1. Necessary communication ports (Profibus / Profinet)
b. SCADA Server

1. Industrial Grade Box PC
2. 24” Monitor

ii. SCADA Software
1. User friendly GUI
2. Trends
3. Historian
4. Alarms
5. Multiple Protocol capability

iii. Printer (Laser)

c. Ethernet Switch with necessary copper and FO
d. All are enclosed in the enclosure.
e. Cloud
i. Remote cloud computing functionality to be provided as an optional
ii. SCADA shall be capable of remotely monitored (Offsite)
iii. Remote maintenance workstation shall be provided
iv. Long Term Historian shall be provided.

14.2 SCADA System Architecture

System architecture document consists of the following:

a. Network architecture.
b. Communication Protocol details
c. Communication Media (Ethernet / RS-485 / RS-232. Copper / Fiber)
d. Communication flow diagram
e. Hardware components (PLC, Servers, Media Converters, Ethernet Switches)
f. Software (Application Software for PLC, SCADA)

14.3 SCADA Data Flow Diagram

Data Flow diagram consists of list of data points from each system. Shall reflect how data is managed, monitored and controlled. Data log details.

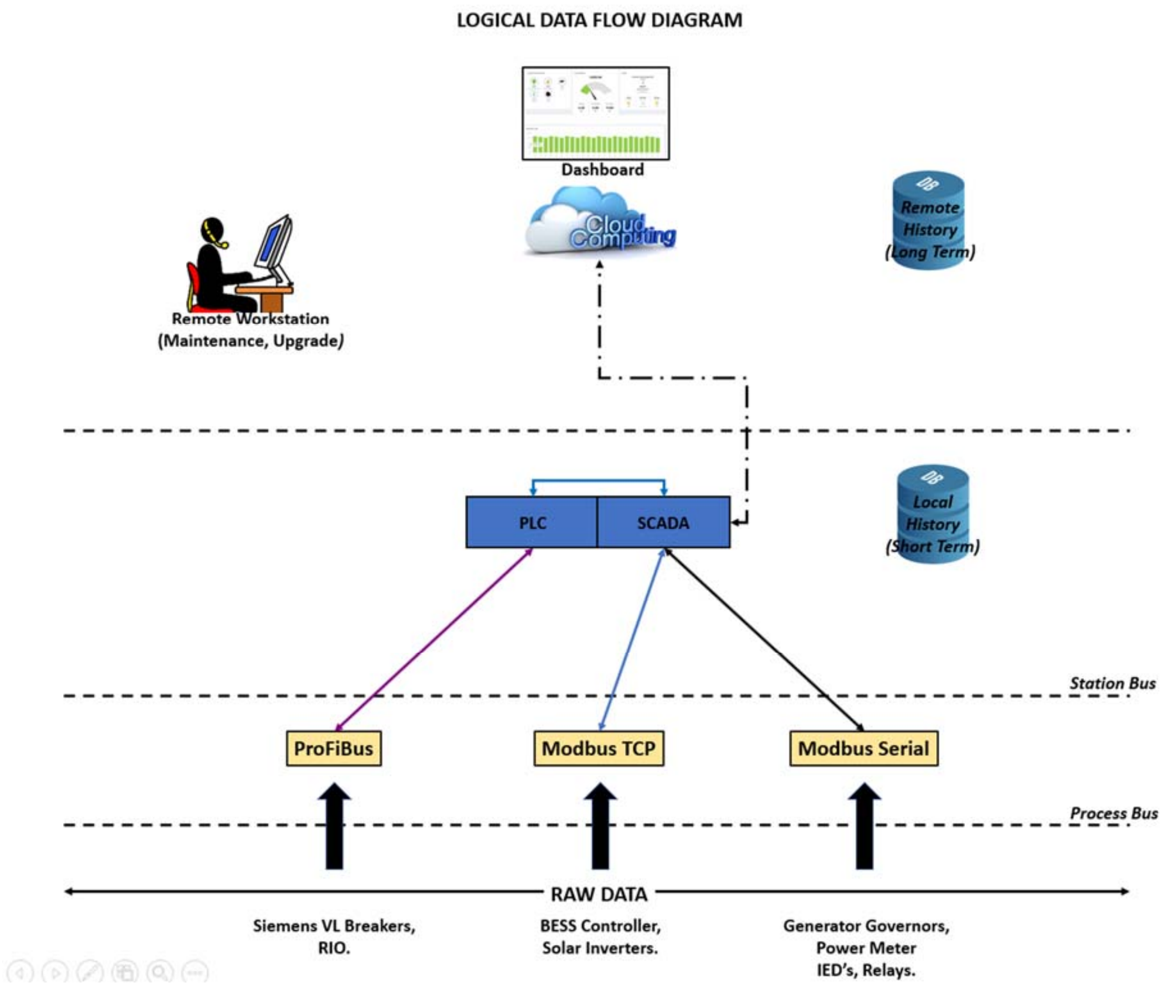


Figure 29: DATA Flow Diagram

Above Figure (29) represents Data Flow diagram for SCADA system.

AC Combiners, Battery Combiner, MV Switchgear, Main Combiner and Automatic Transfer Boards are equipped with VL Breakers with COM20 (Profibus) module. SCADA shall monitor and control these breakers. MV Switchgear has Power meter, SCADA shall read all power meter parameters.

BESS Controller monitor and control Battery Inverters. SCADA shall communicate to BESS Controller through Modbus.

Solar Inverters have Modbus TCP communication. SCADA system shall monitor and control Solar Inverter through Modbus TCP. All RIO are on Profibus / ProfNet nodes to SCADA system.

14.4 SCADA Hardware Design and Layout

Vendor shall provide, detailed SCADA enclosure design. Consists of

a. Bill of Material
b. Layout drawing.
    i. Mechanical (Dimensions, gross weight etc.).
    ii. Environmental properties of the system.
    iii. Mounting arrangement
    iv. Thermal Management
    v. General Arrangement drawing

14.5 SCADA Server, Workstation and Monitoring System

Provide detailed specification of

i. Servers
    a. Box PC
ii. Workstations
    a. Desktop / Laptop
iii. Layout drawings

14.6 SCADA Communication and Network Architecture

Vendor shall provide detailed communication architecture diagram.

a. Detailed drawing of communication network Architecture diagram
b. Communication components
    vi. Media Convertors
    vii. Ethernet Switches
    viii. Network type (Copper / Fiber / Wireless)
    ix. Hardwired I/O details
    x. Shall provide type of connectors
    xi. Calculation of attenuation

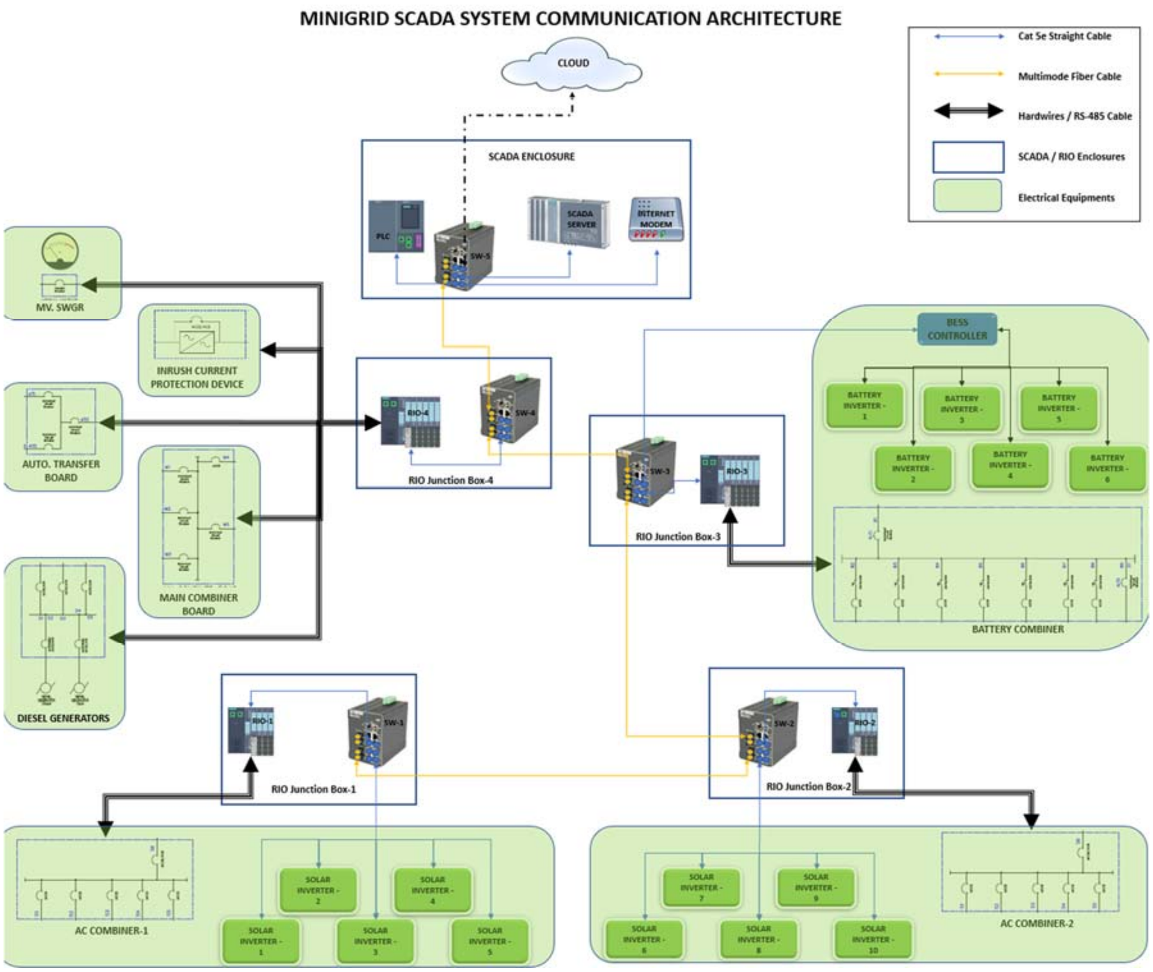


Figure 30: SCADA Communication Architecture

Above Figure (30) represents communication Architecture of Mini Grid SCADA system.

a. Solar Inverters
    i. Modbus TCP Communication
b. AC Combiners
    i. Capable of Profibus Communication
c. RIO Junction Boxes (4 Numbers)
    i. RIO Module with Profibus Communication Module
    ii. OLM for ProFiBus
    iii. Ethernet Switch
d. SCADA Enclosure
    i. SCADA Server PC
    ii. Master PLC
    iii. Ethernet Switch
    iv. Internet Modem.

14.7 SCADA Functional Specifications

14.7.1 Functionality

Following are minimum functionality to be provided by SCADA vendors.

- All hardware equipment shall have minimum 10 years replacement support.
- Software update service to be provided minimum of 2 years
- ANSI standard electrical schematics (AUTOCAD) shall be provided for
    - Electrical Schematics
    - Communication Network Diagram
- SCADA GUI as per ANSI standards
- SCADA vendor shall provide all necessary hardware and software to meet the requirements in the following sections. Prior approval is required if there is a deviation.
- SCADA system shall be consists of PLC and HMI software.
- Standalone PLC and SCADA with multiple communication protocol capability are necessary. Including Profibus, Profinet, Modbus RTU, Modbus TCP and CANBUS.
- Vendor is providing necessary gateways, media converters if necessary.
- RIO junction boxes shall be outdoor enclosures for AC combiners.
- Communication media between Main PLC and RIO shall be Fiber Optic. Vendor shall provide necessary FO cable and connector details.
- All DI/DO are 24 VDC, interposing relays to be provided control circuits.
- Site will provide 230VAC (single phase) max 60 Amps as an incoming power. Vendor shall provide necessary Power Supply units in the system.

14.7.2 Preferred Manufacturers

a) PLC
- Provide Ethernet Communications
- Provide Profinet Communications
- Provide Profibus Communications

b) RIO
- Power Supply (230VAC / 24VDC)
- Provide Profinet Communications
- Provide Profibus Communications
- OLM
- Digital Inputs (24VDC)
- Ethernet Switch

c) SCADA HMI Software
  - Provide Ethernet Communication
  - Server Client Architecture
  - Remote Monitoring and Control Functionality
  - Data Logging
  - Alarm Management
  - Historical Data
  - Trending
  - Faceplate / Library functionality
  - User Administration

d) Cloud / Remote Monitoring (Optional)
  - Remote Data Logging
  - Long term historian
  - Remote Support workstation
  - Data Analytics
  - Dashboard.

14.7.3 Field Equipment

Mini Grid SCADA system shall be designed to perform following functions.

- Minigrid devices
- Solar Inverters
- AC Combiners
- Battery system
  - BESS Controller
  - Battery Inverters
  - Batteries
- Battery Combiners
- Diesel Generators
  - Generator Controller
  - Diesel Combiner
- Automatic Transfer Board
- Inrush Current Protection Device
- MV Switchgear
  - Power Meter
- Auxiliary Panel Board
- Weather Station.

SCADA vendor shall provide complete system which will monitor and control all above field equipment.

1. Solar Inverters
   There are 10 solar inverters in the system. Group of 5. SCADA shall monitor and control all inverters parameters through Modbus TCP communication. SCADA system shall monitor alarm / events and reports to operators through email / SMS.
2. AC Combiners
   There are two AC combiners, consists of VL breakers (Without metering function). With Profibus COM20 module. SCADA shall monitor and control AC combiners.
3. Battery system.
   Battery system consists of Batteries, Battery Inverters and BESS controller. BESS controller controls battery inverters. SCADA shall communicate to BESS controller for monitoring and controlling charge and discharge commands through Modbus TCP. If Modbus RTU is provided by BESS controller, SCADA vendor shall provide necessary gateways. SCADA shall also monitor BESS controller for any alarms / events and reports to operator.
4. Battery Combiners.
   Battery combiner, consists of VL breakers (Without metering function). With Profibus COM20 module. SCADA shall monitor and control Battery combiners.
5. Diesel Generators.
   There are two generators. (300kW and 75kW). Each Diesel Generator consists of Generator Controller. SCADA shall issue Start / Stop commands to Generator Controllers through Modbus TCP. Vendor shall provide necessary gateway if required. SCADA monitors status of generators. Diesel generator has Diesel Combiner. Equipped with VL breakers (Without Metering function). SCADA shall monitor and control combiner breakers through Profibus communication channel. SCADA system shall report alarms / events to operator.
6. Automatic Transfer Board.
   Consists of VL breakers (Without metering function). With Profibus COM20 module. SCADA shall monitor and control Automatic Transfer Board.
7. Inrush Current Protection Device.
   SCADA system shall monitor and control this equipment.
8. MV Switchgear.
   Consists of VL breakers (With metering function). With Profibus COM20 module. SCADA shall monitor meter data from VL breaker. Also controls. MV Switchgear equipped with Power Meter. SCADA shall monitor all power meter data through Modbus TCP. Necessary gateway to be provided by vendor.

9. Auxiliary Panel Board
   Consists of VL breakers (Without metering function). With Profibus COM20 module. SCADA shall monitor and control VL Breakers.
10. Weather Station.
    SCADA system shall monitor weather station and records data. Weather station shall be communicated through Modbus TCP. Necessary gateway to be provided by SCADA vendor if required.

14.8 Design and Functions

1. Introduction
   SCADA system shall monitor and control all connected devices. Provide alarm notifications for immediate assistance of the plant status.
   - Dashboards for visualization of data
   - Communication status of devices
   - Alarm and Event for smooth pant operation
   - Realtime Data of plant
2. Monitoring Functions.
   The following capabilities shall be implemented into SCADA system.
   - Realtime data: System shall be implemented to see real time data from each connected device.
   - Alarm / Event Notification: Shall be capable of alerting operator any critical alarms through email and SMS.
   - System Efficiency: SCADA shall have analytics to display system efficiency.
3. Online Configuration:
   SCADA system shall be upgraded without interrupting the system. Any changes / modification to system can be implemented white system is online / running.
4. Navigation:
   Navigation Structure shall be shown in the left part of the screen in a logical tree view to provide a quick and friendly access to following screens. It must be organized using folders for proper navigation:
   - General: Linked to “General View” display.
   - Weather Stations: Linked to “Weather Station View” display.
   - Inverters: Linked to “Inverters View” display.
   - BESS: Linked to “Battery System Views” display
   - Generators: Linked to “Generator System Views” display
   - General Communication: Linked to the “General Communication View” display.

- Medium Voltage: Folder containing access to specific art of the Medium Voltage.
- Alarms and Events (A&E): Folder containing the following A&E groups. Alarm and events are shown in an additional Tab.

5. Access Control:
   In order to provide a secured access to the system, the login process should be implemented with following roles:
   - Administrator has all privileges. This role can be grant to another user and could create users with any role. There is no restriction in the data or configuration access to this role.
   - Engineer can change signal database structure and create or modify trends, menus and displays.
   - Operator can see data and set orders but is not allowed to change any database parameter.
   - View only can see data and trends (default user at login).
6. Parameters to be monitored:
   Any device subjected to be monitored shall be connected to the SCADA system and relevant signals sampled, registered and displayed on the correspondent SCADA screen as required by the Employer in order to provide adequate Plant information for trouble shouting, commissioning and plant operation.
   Sampling timing must be implemented according to the variance of the variable.
   Variable records shall be shown as instantaneous values or cumulated values at selected intervals selected by the user.
   The following variables, parameters and signals are just an example. The SCADA system shall not only restrict to them if more signals are available and convenient for monitoring and reporting purposes:
   a. General View

      The General View of the Control System allows the operator to get an overview of the whole plant.
   b. Energy Counter

      The following data is obtained from the tariff meter located at the electric room by MODBUS Communication (or similar).
      - Total Energy: Total amount of energy in kWh.
      - Energy Day: Total amount of energy produced in the current day in kWh.
      - Output Power: Instant output power in kW.
   c. Inverter Stations

The following data is gathered from individual meters located at each MV incomer.

- Total Energy. Total amount of energy produced measured from the meter in kWh.
- Energy Day: Total amount of energy produced in the current day for all energy meters in kWh.
- Output Power: Output power from all energy meters in kW.

d. Weather Stations

Tilt Irradiation. Irradiation measured at the POA pyranometer in W/m2.

- Average of the cells located at tilt plane considering the following method:
- Only the available cells or equipment are considering for this calculation.
- If no cell or equipment is available, the value is set to null and appears as "Non-Available".
- If weather station is present and available, its cells are considered for this calculation.

Global Horizontal Irradiation. Global irradiation measured in W/m2 by the horizontal pyranometer.

- Average of the pyranometers considering the following method:
- Only the available pyranometer or equipment is considered for this calculation.
- If no pyranometer or equipment is available, the value is set to null and appears as "Non-Available".
- If weather station is present, its pyranometer is considered for this calculation.

Environment temperature. External temperature measured in ºC.

- Average of the meters considering the following method:
- Only the available meters or equipment is considered for this calculation.
- If no meter or equipment is available, the value is set to null and appears as "Non-Available".
- If weather station is present, its meter is considered for this calculation.

Cell temperature. Tilt Cell temperature measured in ºC.

- Average of the temperature cell meters considering the following method:
- Only the available meters or equipment are considered for this calculation.

- If no meter or equipment is available, the value is set to null and appears as “Non-Available”.
- If weather station is present, its meters are considered for this calculation.

Weather Stations View

The weather Stations View provides the values from radiation and temperature sensors from the Stations present in the plant. The communication status with all of them could also be checked using this display.

e. Input Status.

Communication Status: Alarm flag to indicate the communication status with the Weather Station. The alarm symbol will turn red when the Control System is not able to connect to the equipment and green when the communication is working.

f. Input Values.

- Fixed Radiation. Value of radiation for the current day from the pyranometer cell at horizontal plane of the weather station in in Wh/m2.
- Tilt Radiation. Value of radiation for the current day from the tilt calibrated cell 1 of the weather station in Wh/m2.
- Global Irradiation. Value of irradiation from the pyranometer of the weather station at horizontal plane in W/m2.
- Global Radiation. Value of radiation for the current day from the pyranometer of the weather station at horizontal plane in Wh/m2.
- Cell Temperature. Value from the cell temperature probe of the weather station in ºC.
- Ambient Temperature. Value from the external temperature probe of the weather station in ºC.

g. Inverters View

The inverters View provides some values of all plant inverters as well as an indication of general alarm.

Input Status.

- Inverter Communication Status. This flag indicates the inverter communication status. The led symbol will turn red when there is a communication alarm and green when the communication success.
- Inverter General Fault. This flag indicates any inverter fault. The led symbol will turn red when there is a fault in the inverter and green when the inverter is working properly.

Input Values.

- Output Power. Output power from inverter in kW.
- Energy Day. Total day amount of energy from inverter in kWh.

h. Medium Voltage Views

MV plant information will be shown trough the following types of views.

- MV View. The Medium Voltage View shows the single line diagram of the Medium Voltage system of the plant including the actual breaker status.

i. Inverter stations general view

The General View of the inverter stations (IS) provides an overview of this part of the plant including all combiner boxes (CNs) connected to the IS. The information displayed of the CNs includes last value read and status.
This view is particularly useful to verify the communication status with the CNs. Also, to check if there is any anomaly in the CN, the status of the breaker or an overvoltage fault.
Input Values

- Combiner Current. The sum of all string currents in A.
- Combiner Voltage. The average of measuring equipment voltage in V. Only available equipment is considered for this calculation.
- IS Tilt Irradiation. The value from the calibrated cell of the weather station located in the IS area in W/m2.
- IS Global Irradiation. The value from the pyranometer of the weather station located in the IS area in W/m2.
- IS Cell Temperature. The value from the cell temperature meter of the weather station located in the IS area in ºC.
- IS External Temperature. The value from the external temperature meter of the weather station located in the IS area in ºC.
- Inverter Energy Total. Total amount of energy in kWh.
- Inverter Energy Day. Total amount of energy day in kWh.
- Inverter Output Power. The current active output power in kW.
- DC Meter Energy Total. Total amount of energy in kWh.
- DC Meter Energy Day. Total amount of energy day in kWh.
- DC Meter Output Power. The current active output power in kW.
- Energy Meter Energy Total. Total amount of energy in kWh.
- Energy Meter Energy Day. Total amount of energy day in kWh.
- Energy Meter Output Power. The current active output power in kW.

j. Calculations.
    - IS Energy Total. The sum of all IS energy meters total energy in kWh.
    - IS Energy Day. The sum of all IS energy meters daily energy in kWh.
    - IS Output Power. The sum of all IS energy meters active output power in kW
k. Trends screen

    Trends views aim to trace Plant behavior during a time frame using a chart utility provided by the Control System SCADA.
    Following are typical trend views:

    - Inverters. Including one trend per inverter containing the following measures:
        - Output Energy in kWh.
        - Performance ratio trend of each inverter Kwh output
        - Input Active Power in kW.
        - Input Voltage in V.
        - Input Current in A.
        - Output Active Power in kW.
        - Reactive Power in kVAr.
        - Output Voltage in V.
        - Output Current in A
        - Power factor
        - Daily load profiles,
        - Diversity factors,
        - Load factors,
        - Capacity factors
        - Internal Temperature.
    - Weather Station. Including one trend per equipment with the following measures:
        - Irradiations at Tilt Plane in W/m2.
        - Insolation at Plane of Array in Wh/m2
        - Cell temperature in ºC.
        - Environment temperature in ºC.
        - Global irradiation in W/m2.
        - Global Insolation in Wh/m2
    - Generation Meter:
        - Total generation in Kwh. o Total AC Power in Kw. o AC voltage.
        - AC Current.
        - AC frequency.

14.9 RIO Junction Box Specifications

There are four junction boxes required. Two junction boxes are installed in outdoor environment near AC combiners. Two are installed indoor. One closer to BESS Controller and another closer to other switchgears.

Purpose of the RIO junction box is to create distributed architecture. Connect and communicate to distributed field devices. Minimize hardwires running from devices to main controller. Typical junction box consists of following components.

1. Enclosure (Two Outdoor and Two Indoor)
2. Power Supply (230VAC / 24VDC)
3. Interface Module with Profibus
    a. Profibus is used for communication to VL Breaker COM20 (or similar)
        i. Daisy chain configuration shall be implemented for all Profibus slave devices.
4. Digital Input (24 VDC) (8 DI's) for future expansion
5. Digital Output Modules (24 VDC) (8 DO's) for future expansion
6. OLM module (Profibus copper to Fiber). For connecting to Main Controller.
    a. All RIO's are connected to Main controller through Fiber Optic media.
7. Industrial grade ethernet switch with wide operating temperature
    a. Ethernet switch with minimum 6 copper and two multimode Fiber ST ports.
    b. Capable of Modbus TCP protocol
    c. Copper ports are connected to Solar Inverters, BESS controller, Generator Controller for Modbus TCP communication
    d. Fiber ports are used for communication to SCADA system.

Note:

1. All cables between RIO junction boxes and Main PLC / SCADA enclosure shall be multimode fiber.
2. All VL breakers to RIO junction box shall be Profibus two wire cable
3. All Solar Inverters to Ethernet Switch are Cat5e ethernet cable
4. Generator controller to Ethernet switch. Vendor shall provide Modbus RTU to Modbus TCP gateway.
5. Power meter at MV Switchgear to Ethernet switch. Vendor shall provide Modbus RTU to Modbus TCP gateway
6. BESS controller to Ethernet Switch. Vendor shall provide Modbus RTU to Modbus TCP gateway
7. Profibus OLM with two fiber ports shall be installed in each RIO junction box.

14.10 Scope of Work

SCADA vendor/supplier shall provide the following:

- PLC based plant controller
- SCADA hardware
- Communication cables
- RIO Junction box
- Programming of Junction Box, PLC controller and SCADA.
- Documentation
- Onsite commissioning
- System integration support to BESS system vendor

15. CIVIL DESIGNS WITH CALCULATIONS, INCLUDING ROADS, WALKWAYS AND FLOOD CONTROLS

15.1 List of Codes and Technical Criteria

The following codes and technical criteria and those referenced therein shall be required for this project.

References within each reference below shall be required and adhered to. If there is conflict in the criteria the most stringent requirement shall be applied. This list is not exhaustive and is not necessarily complete. The publications to be taken into consideration shall be those of the most recent editions.

ACI 318	Building Code Requirements for Structural Concrete (latest edition), American Concrete Institute
ACI 530/ASCE 5/TMS 402	Building Code Requirements for Masonry Structures (latest edition)
AISC 360	Specification for Structural Steel Buildings (latest edition), American Institute of Steel Construction
ASCE 7	Minimum Design Loads for Buildings and Other Structures (latest edition)
ASTM	American Society for Testing and Materials
ASTM-D-1586	Standard Test Method for Standard Penetration Test
ASTM-D-5299	Standard Guide for Decommissioning Ground Water Wells
AWS D1.1	Structural Welding Code – Steel (latest edition), American Welding Society
BS 7671	British Standards Requirements for Electrical Installations (IEE Wiring regulations, 17th Edition)
EIA ANSI/TIA/EIA-607	(1994) Commercial Building Grounding/Bonding Requirement Standard
IBC	International Building Codes, 2009 edition (and its referenced codes including those inset below)
IEEE C2	National Electrical Safety Code (NESC), latest edition
IMC	International Mechanical Code, latest edition
IPC	International Plumbing Code, latest edition

Fire Protection and Life Safety:

NFPA 1	General Fire Protection, latest edition
NFPA 10	Portable Fire Extinguishers, latest edition
NFPA 72	National Fire Alarm Code, latest edition
NFPA 80	Fire Rated Doors and Windows, latest edition
NFPA 101	Life Safety Code, latest edition
ANSI TIA/EIA 607-A	Commercial Building Grounding (Earthing) and Bonding Requirements for Telecommunications, (latest edition)
ANSI TIA/EIA 607-A	Commercial Building Grounding (Earthing) and Bonding Requirements for Telecommunications, (latest edition)

USACE-AED Design Requirements:
In addition, technical criteria provided in USACE-AED Design Requirements (most recent version) shall be required for use in design and construction specifications as indicated in the following documents.

The following design criteria shall be used:
AED Design Requirements – Voltage Drop Calculations Process, latest version
AED Design Requirements - Site Layout Guidance, latest version
AED Design Requirements - Well Pumps & Well Design/Specifications, latest version
AED Design Requirements – Water Tank and Water Distribution Systems, latest version
AED Design Requirements - Booster Pumps, latest version
AED Design Requirements – Chlorinators, latest version
AED Design Requirements - Hydro-Pneumatic Tanks, latest version
AED Design Requirements - Jockey Pumps, latest version
AED Design Requirements - Water Tanks, latest version
AED Design Requirements – Hydrology, latest version
AED Design Requirements - Sanitary Sewer and Septic Systems, latest version
AED Design Requirements - Grease Trap, latest version
AED Design Requirements - Oil-Water Separator, latest version
AED Design Requirements – Geotechnical Investigations for USACE Projects, latest version

All codes listed are used as a design guide. Other standards may apply.

15.2 Building System Descriptions

15.2.1 Architectural Components

Codes:

- 2003 International Building Code (IBC)
- UNIFORM BUIDLING CODE (UBC)
- NeuFert 2006 (Architecture Design Data)
- Force Protection: D regulation UFC-4-010-01, 31 July 2002
- Architect standards 6th Edition
- National Fire Protection Association (NFPA 101): Life Safety Plan Only
- Local building codes: there are no known applicable local building codes for this project.
- Other applicable standards

All Building Major Construction Components:

Office building	Concrete structure with Brick wall
Power house	Equipment room Brick wall with RCC columns and RCC ceiling system
	Open yard for containerized battery and inverters
	And steel canopy for generator, fuel tank and transformer shade
Guard Room	Brick wall with RCC columns and RCC ceiling system
Water tank /Towers	Brick wall and RCC ceiling system for the guard room

15.2.2 Plumbing

Codes:

- International Plumbing Code
- Uniform Plumbing Code
- American Society of heating, Refrigerating, and air Conditioning Engineers (ASHRAE) handbooks
- American society of mechanical Engineers
- American society of testing and materials
- American welding society

Materials:

- Domestic water pipe **Polyvinyl Chloride per ASTM D 1784 and 1785 50psi hydrostatic test.**
- Waste and vent PVC ASTM D2665
- Hot Water 90 Degrees C

15.2.3 Electrical

Codes:

- National fire protection association, NFPA 70 (national Electrical Code, 2002)
- National Fire Protection Association Life Safety Code NFPA 101
- Illuminating Engineering society of North America (IES)

Power Distribution Design Loads:

- Each electrical panel shall have a short circuit withstand rating of 65kA ISC/0.5 Sec.
- Voltage drop for branch circuit home runs shall not exceed 2% and 3% for main feeder and total 5%.
- A ground grid system is provided as indicated in the drawings.
- See drawings for electrical load calculations.

Lighting Design:

- Fluorescent lighting is provided as per calculation based on the lux required. Switches are provided to control the lighting for all rooms.
- Emergency/egress lighting is provided only as required by NFPA 101.
- Lighting is seismically braced.
- Exterior building mounted security lighting is provided.
- Lighting levels meet the following:
    - General office Space 400 Lux
    - Dining room 200 Lux
    - Sleeping room 300 Lux
    - Meeting room 300 Lux
    - Living Quarters 300 Lux
    - Hall 300 Lux
    - Kitchen 500 Lux
    - Storage 200 Lux
    - Maintenance/Repair room 400 Lux
    - Lobbies 150 Lux
    - Lounges 150 Lux
    - Mechanical & Electrical rooms 200 Lux
    - Toilets 200 Lux
    - Exterior lighting 5 Lux

Outdoor Area and Street Lighting is not Provided, building exterior light are enough for exterior lightings around the buildings.

15.2.4 Mechanical criteria

Outdoor Design Conditions:

Summer	36 C (97° F) db and 23.8° C (75° F) WB.
Winter	-5.00 C db
Range of DB	Summer 36
Average Extreme wind"	40 km/h (25mph)
Winter heating	all areas should be maintained at 20° C (68° F) db.

Ventilation:

Office	37 CMH/m^2 with ceiling fans
Mechanical/Electrical rooms	Mechanical ventilation sufficient to remove heat to 42° C (100 ° F)
Toilet and Wash Area	Min 37 CMH/m2 (2 CFM/Ft^2) or 85 CMH per water closet, whichever is greater.

Air Intakes:
Size for maximum velocity of 2.5 m/s (500 fpm) through the free area.

Filtration:
Weatherproof louvers with a bird screen.

Seismic:
Meet requirements of IBC 2000 for ductwork, equipment, and piping.

Codes:

- American society of heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) Handbooks American society of mechanical Engineers
- American society for testing and materials
- American welding society
- Sheet metal and Air conditioning contractor's national association
- Underwriter's laboratories (UL)

15.3 Office Building

15.3.1 Architectural Layout

The office space is design for 6 staff, working during the day to operate the plant.
Interior space consists of following rooms.

Office room-1	=	10sqm
Officer room-2	=	12sqm
Hall/lobby	=	15sqm
Kitchen	=	12sqm
Meeting/dining RM	=	15sqm
Sleeping room	=	20sqm
Toilets#1	=	4sqm
Toilet#2	=	4sqm

First floor Consist of 2 High officer rooms, one junior officer room, one hall for waiting area and meeting and dining room, one sleeping room and two toilets.

Building size:

This is one story building which have rectangular shape.

Total net area	=	150sqm
Gross area	=	171sqm

Code Reference Information:

2003 IBC – International Building Code

Occupancy Type:

IBC (chap 3) Barracks, Group (R)

Occupancy separation (Table 302.3.2)

Construction Type:

IBC (601) Type A 11

Allowable Area:

IBC (Table 503)	=	$111m^2$
Actual Area	=	$171m^2$

Minimum Number of Exits Required:

IBC (Table 1018.1) 2 exits (building G.B) Occupants <1-500 < occupants Exist provided = 2 (Complies)

Maximum Exit Travel Distance Limit:

IBC (Table 1018.2) 100 feet	=	30.4m
Actual travel maximum distance to exit	=	11m (Complies)

15.4 Site Development

Final Adjustment to grading and utility connections are performed on-site.

15.4.1 Utilities

Water:
Building connections are taken to 1.5 meters beyond the building; from that point they are connected to main water distribution system.

Sanitary Sewer:
Building connection are taken to 1.5 meters beyond the building; from that point they are connected to the septic tank and then connected to drain field or leach field.

15.4.2 Architectural Components

Exterior Materials:

- Walls: 350mm brick masonry wall plastered and painted. The total width becomes 400mm for insulation.
- Doors and frames: steel, painted.
- Windows: PVC fixed insect screen.
- Roofing: 130mm RCC slab with insulation.

Interior Materials:

- Floor covering: Sealed concrete.
- Walls: under beam 350mm Burnt Brick Masonry plastered and painted.
- Walls: under slab as partition wall 15mm
- Doors and frames: steel, painted and PVC door for wet areas.
- Safety Equipment: fire extinguishers provided.
- Signage: Exit signs provided

15.4.3 Structural Systems

Office building is class –I frame system of RCC beams and columns, the walls are not bearing, it is used as partition inside the building and weather proof outside the building. Ring beam is provided at ground surface level to provide sufficient strength for the building frame, Minimum steel areas based on ACI code -318-08 are provided.
All other building is the same system as above mentioned.

- The Flat roof system is a RCC Slab painted with local insulation and bituminous liquid waterproofing on top, plaster at the bottom, applied immediately after the slab.
- The exterior finish of the structures is mortar plaster applied immediately after installation mesh over insulations boards over brick wall. The 50mm thick insulation board is fasten by plaster mesh 1mm thick @ 25mm opening size by 150mm long , and Ø12mm expansion PVC Bolt into wall, The bolt shall be installed 4-6 per sqm area of wall and on edges as necessary.
- The interior walls finish is plaster, applied immediately after the completion brick masonry wall.
- In wet areas (kitchen, toilet and showers): the interior low partition walls brick masonry with plaster and ceramic tile all up to 1.2 m, floors are ceramic tile.
- Other floors are painted concrete.
- All components listed in the design Criteria are contractor Furnished/Contractor installed unless otherwise noted. Furniture, Equipment, are not part of this contract, and are in the drawings to show how we met the requirements for number of occupants, cup boards and other wood board in kitchen is part of the contract.

15.4.4 Mechanical Systems

Plumping Design:
System demands are established in accordance with listed applicable codes and standards.
All new plumbing fixtures are at commercial or industrial grade as appropriate

Sanitary Drainage System:
The sanitary drainage system consists of regular waste systems. All piping systems are provided with clean out located as required. The proposed regular waste system consists of

Waste and vent piping to all plumbing fixtures. All drainage connections are drained by gravity through soil waste stacks and the house drains to site sanitary sewer. All piping is PVC

Domestic Water System:
The building domestic water supply is connected to the network main water supply system. Domestic water system shall include double check backflow prevention, and building water distribution to all plumbing fixtures and water heater. Drinking fountains are provided. All piping is schedule 25 galvanized or schedule PPR PVC or PVC. Water heaters are solar water heater.

Mechanical Design:
Ceiling fans and fire wood heaters with vent through roof are provided in all rooms.

Toilet and kitchen are exhausted. Make – up air is transferred from outside through filtered louvers.

- Heating is provided for personal comfort in dining, sleeping and other common areas via wood fired local heater, vent is provided for and heater will be installed by customer.
- Ceiling fans are provided for air in sleeping areas and offices.
- Calculations for heating and ventilation loads have been made based on brick walls and insulated roofs and wall, R=20 for walls and R=30 for roof.
- Domestic water is heated via electric water heaters. Water heaters are located in inside the wet areas depending or their numbers and size.
- Fire alarm, stand-alone smoke detector is provided.
- Fire extinguisher is provide as required by code, 1/100sqm

Indoor Design Conditions:

Office Building	Heating only in the office 20^{o} C (68^{o} F) by fire wood heaters Ceiling fans only in the offices for summer ventilation
Toilet/Shower Areas	Exhaust fans at ventilation rate of 2 cfm/sf or 37 CMH/M^{M} No heating.
Guard Room	Heating only 20^{o} C (68^{o} F) by fire wood stove. Ceiling fans for summer ventilation.
Guard Tower	Heating only 20^{o} C (68^{o} F) by fire wood stove Ceiling fans for summer ventilation

Outdoor Air Ventilation Rate:

Office and Sleeping Areas	Windows plus ceiling fan ventilation 37 CMH/M^{2} of floor area or 85
Toilet and Wash Areas	CMH/WC, whichever is larger 19CMH/M^{2} for kitchen

15.4.5 Electrical Systems

Power Distribution Design Loads:
Electric outlets are provided. See Design Calculation for load calculation and design analysis.

Lighting Design:

- Fluorescent lighting is provided, water proof light is provided in wet location.
- Switches are provided to control lighting in all rooms.
- Egress lighting is provided
- Lighting is seismically braced.
- See Design Calculation for lighting calculations.

Grounding:
A ground grid system is provided as indicated in the drawings.

15.5 Powerhouse Building

This building has three parts

- **Part one**: is for equipment room and storage
- **Part two**: is for containerized battery yard
- **Part three**: is for generators, fuel tank and transformers canopy

15.5.1 Architectural Layout

Part one - Total gross Area	=	279.3sqm
Part two - Total gross Area	=	342sqm
Part three - Total gross Area	=	138.7sqm
Shape	=	Regular Rectangular Shape.
No of floor	=	1 floor
Structure	=	Steel canopy structure over steel pipe column and metal truss and GI roof.
Total floor area	=	123.95sqm

The facility consists of following rooms:

a. Space for two Generators, one 425kW and 75kW, 7.65mx6.7m
b. Space for one fuel tank Ø2.5m, 5m length, Space Room 6.7mx4.5m
c. Space for two step transformer, MV breakers, MTS and MDB, 6.35mx6.7m
d. Space for storages and equipment rooms

Code Reference Information:
2003 IBC – International Code Building

Occupancy Type:

- IBC (chap 3) Power House- not classified in any specific occupancy –group U Incidental

- Generator Room (N/A) = group U
- Occupancy separation (Table 302.3.2) no requirement.

Construction Type:
BC (601) Type IIB

Allowable Area:
IBC (Table 503) = Following spacing in between equipment not less than 70cm
Actual provided space = 100cm (complies)

Minimum Number of Exits Required:
IBC (Table 1018.2 = 1 exits (building G.R U) Occupants <50 Travel Distance < 22,8m
Exits Provided = 3 (Complies)

Maximum Exit Travel Distance Limit:
IBC (Table 1015.1) = 22.86 meter
Actual travel maximum distance to exit = 6.7m (Complies)

Site Development:
Final adjustments to grading and utility connections are performed on-site.

15.5.2 Utilities

Water:
Not used.

Sanitary Sewer:
Not used.

15.5.3 Architectural Components

Exterior Materials:

- Walls: chain link fence for generator, fuel tank and transformer, 350mm thick brick masonry for control room
- Doors and frames: chain link fence gates for generator, fuel tank and transformer, steel double door for equipment room
- Windows: PVC window for equipment room
- Roofing: Steel structure canopy for generator, fuel tank and transformer
- Fuel tank: containment concrete wall 1m high all around

Interior Materials:

- Floor covering: Sealed concrete.
- Walls: chain link fence for generator, fuel tank and transformer, 350mm thick brick masonry for control room
- Ceilings: Steel structure canopy for generator, fuel tank and transformer, concrete slab for equipment room
- Doors and frames: Steel door
- Safety Equipment: One fire extinguisher provided.
- Signage: not used.

15.5.4 Structural Systems

The building is a single story rectangular building with no walls around and steel roof structure supported by pipe column, design for snow, wind and other loads
Isolated footing is provided for each column.

Control Room and Storage Areas Structures:
Part of the facilities is for equipment room, the building is a single story rectangular building with 350mm thick bearing Brick masonry walls with RCC columns at each corner. The building is designed as wall bearing with RCC frame.

The RCC Columns is designed to bear the load and to limit the eccentricity between the center of stiffness and the current center of mass and reduce the major twisting effects on the building. The roof consists of 130mm thick RCC slab supported by the bearing walls and RCC columns.
The foundation of this building is square footing foundation for columns and continuous foundation for wall type 800mm below finished floor level perimeter ground beam according to design. Minimum steel area as per ACI code is provided for columns, ring beam, top beam and foundation footings.

The containerized batteries are place on open yard and place on open area on concrete pads.

15.5.5 Mechanical Systems

Mechanical Design:

- Fuel piping is provided to supply fuel from fuel to generators, black steel welded type is considered supply pipe is Ø20mm and return pipe Ø20mm to fuel tank.

- The fuel pipe is directly connected to generator fuel pump and discharge pipe is back connected to fuel tank.

Sanitary Drainage System:
Not used

Domestic Water System:
Not used

15.5.6 Electrical Systems

Power Distribution Design Loads:
Electric outlets are provided. See Design Calculation for load calculations and design analysis.

Lighting Design:
- Fluorescent dust proof G type lighting fixture is provided.
- Switches are provided to control lighting in all rooms.
- Egress lighting is provided
- Lighting is seismically braced.
- See Design Calculation for lighting calculations.

Grounding:
A ground grid system is provided as indicated in the drawings.

Communications:
Not used

15.6 Guard Room

15.6.1 Architectural Layout

The room consists of one room and a toilet.
Total Floor Area of the Room **=** 18.25 m2

Code Reference Information:
2003 IBC – International Code Building

Occupancy Type:
- IBC (chap. 3) Guard Room –not classified in any specific occupancy- Group U
- Guard Room (N/A) = group U

- Occupancy separation (table 302. 3.2): No requirements

Construction Type:

IBC (table 601)	Type ll B

Allowable Area:

IBC (Table 503)	=	18qsm
Actual area	=	20sqm (Complies)

Minimum Number of Exits Required:

IBC (Table 1018.2)	=	1 exit (Building Group U. occupants <50, travel distance < 22.8m)
Exits Provided	=	1 (Complies)

Maximum Exit Travel Distance Limit:

IBC (table 1015.1)	=	91.44 meters
Actual maximum travel distance to exit	=	3.5 meters (complies)

Site Development:

Final adjustments to grading and utility connections are performed on-site.

15.6.2 Utilities

Water:

Building connections are taken to 1.5 meters beyond the building; from that point they are connected to main water distribution system.

Sanitary Sewer:

Building connections are taken to 1.5 meters beyond the building; from that point they are connected to main water distribution system.

15.6.3 Architectural Components

Exterior Materials:

Walls: 350mm brick masonry wall with plaster surface, painted.

Doors and frames: steel door, painted.

Windows: PVC, with metal sill and screen.

Roofing: 130mm RCC slab and local insulation and Tar sheet final surface aggregate.

Interior Material:

Floor coverings: Sealed concrete.

Walls: 250mm

Ceilings: 130mm RCC slab with plaster, painted.
Safety Equipment: one fire extinguishers provided.
Signage: Not Used

15.6.4 Structural Systems

The building is a single story rectangular building with 350mm thick bearing Brick masonry walls with RCC columns at each corner. The building is designed as wall bearing with RCC frame.

The RCC Columns is designed to bear the load and to limit the eccentricity between the center of stiffness and the current center of mass and reduce the major twisting effects on the building. The roof consists of 130mm thick RCC slab supported by the bearing walls and RCC columns.

The foundation of this building is square footing foundation for columns and continuous foundation for wall type 800mm below finished floor level perimeter ground beam according to design

Minimum steel area as per ACI code is provided for columns, ring beam, top beam and foundation footings.

15.6.5 Mechanical Systems

Mechanical Design:
Wooden heaters are provided for heating and ceiling fan for ventilation.

Plumbing Design:
System demands are established in accordance with listed applicable codes and standards.
All new plumbing fixtures are at commercial or industrial grade as appropriate

Sanitary Drainage System:
The sanitary drainage system consists of regular waste systems. All piping systems are provided with cleanout located as required. The proposed regular waste system consists of waste and vent piping to all plumbing fixtures. All drainage connections are drained by gravity through soil waste stacks and the house drains to site sanitary sewer. All piping is PVC

Domestic Water System:
The building domestic water supply is connected to the compound's main water supply system. Domestic water system shall include double check backflow prevention, and building water

distribution to all plumbing fixtures and water heater. Drinking fountains are provided. All piping is schedule 25 PVC. Water heaters are electric

15.6.6 Electrical

Power Distribution Design Loads:
Electric outlets are provided. See Design Calculation for load calculations and design analysis.

Lighting Design:

- Fluorescent lighting is provided.
- Switches are provided to control lighting.
- Lighting is seismically braced.
- See Design Calculation for lighting calculations.

Grounding:
A ground grid system is provided as indicated in the drawings.

Communications:
The communication system is not required in this contract.

15.7 Water Tower and Water Tank Structure

15.7.1 Architectural Layout

The tower has 7m height and 3m height of tank, total height of 10m

Water Tank Capacity:
Total inner volume = 30 m^3

Code Reference Information:
2003 IBC – International Code Building

Occupancy Type:

- IBC (chap. 3) water tank tower – not classified in any specific occupancy - Group U
- Water tank tower (N/A) = group U
- Occupancy separation (table 302. 3.2): No requirements

Construction Type:
IBC (table 601) Type ll B

Site Development:
Final adjustments to grading and utility connections are performed on-site.

15.7.2 Utilities

Water
Water is connected to water tank above tower from water well and then distribution to building.

Sanitary Sewer
NA

15.7.3 Architectural Components

Exterior Material:
Walls: NA
Doors and frames: NA
Windows: NA
Roofing: RCC SLAB 15CM thick.

Interior Material:
Floor coverings: Sealed concrete.
Walls: 350mm RCC
Ceilings: 150mm RCC slab with plaster, painted.
Safety Equipment: NA.
Signage: Not Used

15.7.4 Structural Systems

The Tower facility is a 7m high above ground and 3m is water tank height, total height for the facilities is 10m. The tower is located on high area which has 6m for down facilities. The structure is concrete with 6 RCC columns at each corner. The building is designed RCC frame.

The RCC Columns is designed to bear the load and to limit the eccentricity between the center of stiffness and the current center of mass and reduce the major twisting effects on the building. The roof consists of 150mm thick RCC slab supported by the bearing walls and RCC columns. The foundation of this building is mat foundation for columns 800mm below finished floor level perimeter ground beam according to design
Minimum steel area as per ACI code is provided for columns, ring beam, top beam and foundation footings.

15.7.5 Mechanical Systems

Mechanical Design:
N/A

Plumbing Design:
Over flow, inlet, out let, drain and other piping is provided for the water tanks

Sanitary Drainage System:
N/A

Domestic Water System:
N/A

15.7.6 Electrical

Power Distribution Design Loads:
Electric outlets are provided. See Design Calculation for load calculations and design analysis.

Lighting Design:

- Flood light is provided on 4 faces.
- Lighting is seismically braced.
- See Design Calculation for lighting calculations.

Grounding:
A ground rod is provided as indicated in the drawings.

15.8 Civil Standards and Codes

The Civil Works shall comply as a minimum with International Standards ISO, IEE, DIN, BS Standards (International Standards Organization: European Norm: EN; German Standards: DIN; British Standards: BS; American Standard: ASM).

Works of any nature, not specifically mentioned in the Contract, however necessary for the Works subject of this Contract, shall be executed as per state of the art.

Where there is conflict between this General Specification and the relevant Norm, the Specifications shall take precedence.

Materials supplied and work performed shall comply with these Standards and regulations as a minimum. If other Standards are used, the Standards shall be equal or superior to those specified and full details of the difference shall be supplied to the Engineer if requested.

When standards are referred to, the edition shall be the current at the time of issue of tender documents, together with any amendments issued to that date. In case any standard is superseded, the later relevant standard shall be adhered to.

If requested by the Engineer, the Contractor shall supply at his own expense one copy of any standard, which is applicable to the contract.

System of Units:
The International System of Units (SI) applies to all aspects of the project.

Loading and Structural Design Standards:
For civil structural design, the following codes and standards have been used for determining the design loads and calculating required dimension of the sections:

- IS 1893: 1970 Criteria for earthquake resistant design of structures
- BS 8110: 1985 Structural Use of Concrete
- BS 8007: 1987 Design of Reinforced Concrete Structures for Retaining Aqueous Liquids
- BS 4466: 1987 Specification for Bending Dimension and Scheduling of Reinforcement for Concrete
- BS 6031: 1981 Code of Practice for Earthquakes.

15.9 Concrete

The structural concrete shall comply with the general specifications and the construction drawings. For the analysis purpose, the following values were adopted:

Unit Weight:

Reinforced concrete	=	25 kN/m³
Plain concrete	=	24 kN/m³

Characteristic Strength:

C15	=	15Mpa
C25	=	25Mpa
Concrete		ASTM C 39 and ACI 318; f''_c = 25 MPa (3625 psi) minimum specified compressive strength @ 28 days
Water-cement ratio	=	0.45 (maximum)
Steel Reinforcement Deformed bar		ASTM A 615 (ASTM A 706 for weldable rebar); f_y= 420 MPa (60 ksi) yield strength

Welded Wire Fabric	ASTM A 185
Non-Shrink Grout	35 MPa (5000 psi) min compressive strength at 28 days, ASTM C827
Mortar	ASTM C 270; Cement-Lime Type S, minimum 12.4 MPa (1800 psi) average compressive strength at 28 days
Grout	ASTM C 476; minimum 14 MPa (2,000 psi) compressive strength @ 28 days
Stone Masonry	f_{st}=300 kg/cm^2 (4350 psi) required for general walls foundation

The design concrete strength is derived from the characteristic strength multiplied by a coefficient 0.67 which is a material partial safety factor. The material partial safety factor (0.67 = 1/1.5, where 1.5 is material partial safety factor) in flexure and axial load takes account of differences between and laboratory values, local conditions and inaccuracies.

15.10 Metal Canopy and Steel Structure

15.10.1 Steel Structure

Plates, Shapes & Bars	ASTM A 36; F_y = 250 MPa (36 ksi) minimum yield strength
Hollow Sections	ASTM A 500, Grade B; F_y = 318 MPa (46 ksi) minimum yield Strength
High Strength Bolts	ASTM A 325
Standard Bolts	ASTM A 307
Anchor Bolts	ASTM F 1554; Grade 36 steel
Welding	AWS D1.1 (American Welding Society)
Welding Electrodes	E70XX
Sheets	ASTM A 653; Grade 340 (50), Class Z275 (G90) for galvanized coating:

15.10.2 Welding (for Canopy)

All major load bearing steel members shall be pre-engineered structural steel manufactured by a reputable foreign steel firm according to ASTM and AWS requirements.
For minor structural members of small steel structures (tanks, sheds, stairs.), the following shall apply. As there are no established testing labs and procedures in Afghanistan, we used an additional 2.0 safety factor to account for Afghanistan welders' deficiencies and inability to

conduct proper testing. We used 500 $kg.cm^2$ for f_y permissible instead of 1000 kg/cm^2 allowed by AWS D1.1-98. We substituted testing with visual inspection by at least 10 year experienced afghan welder.

15.10.3 Reinforcement steel

The reinforcement design is based on the following specifications

- Complies with the requirements of BS 8110
- TMT steel having ultimate tensile strength of 420 MPa (Fe 420).

The reinforcement steel also uses a material partial safety factor of 1.15.

Minimum Bend Diameter:
All reinforcement shall be bent at cold temperatures. Hooks are calculated at follows:

- A 180° bend plus an extension of at least 4db (diameter of bar) but not less than 64.00 mm
- A 90° bend plus an extension of at least 12db or
- Ties and stirrups either 90° or 135° bend plus an extension of at least 6db but not less than 64 mm.

The following minimum bending diameters should be used

Table 20: Minimum bending diameter

#	Bar Size	Minimum Diameter of Bend
1	#3 through #8	6 d_b
2	#9, #10 and # 11	8 d_b
3	#14 and #18	10 d_b

Clear Cover of Concrete Structures:
Minimum concrete cover of reinforced concrete is compiled in Table 21.

Table 21: Clear cover of concrete structures

#	Description	Minimum Cover (mm)
1	Concrete cast against & permanently exposed to earth	75.00
2	Concrete exposed to earth or weather	
	#6 through#18 bars	50.00
	#5 and smaller bars	35.00
3	Concrete not exposed to weather or in contact with	

	ground	
Slabs, walls	#14 and #18 bars	35.00
	#11 and smaller bars	2000
Beams, Columns	Primary reinforcement, Ties, Stirrups	40.00
NOTE: Until unless otherwise mentioned, 75mm thick C15 concrete shall be used for blinding • For footings • For columns • For beams • For slab/staircase		

Reinforcement Spacing:
Reinforcement spacing of the main longitudinal bars can also be controlled by size of aggregate. The minimum spacing required is compiled in Table 22.

Table 22: Minimum bending diameter

#	Description	Minimum Spacing
1	Clear distance between Bars in a layer	d_b or 25.0 mm
2	Two or more Layers in parallel, distance between layers	25 mm
3	In column clear distance between bars	$1.5d_b$ or 40.0 mm
4	In walls and slabs, primary reinforcement shall be spaced farther than 3 time thickness of wall or slab	460.0 mm

Reinforcement Spacing of Ties:
Compression members shall be enclosed by lateral bars such as:

#3 in size for longitudinal bars #10 and less
#4 in size for longitudinal bars #11, #14, #18

Vertical Spacing of ties shall not exceed the following:

16 multiply by diameter of longitudinal bars
48 multiply by diameter of ties bars
48 multiply by least dimension of the compression members
Compression reinforcement in beams shall be enclosed with ties satisfying the size and spacing as discussed above.

Minimum Reinforcement:

Area of longitudinal reinforcement for compression members shall not be less than 0.01 nor more than 0.08 times the gross area of the section.

At any section of flexural member where positive reinforcement is required by analysis, the ratio provided shall not be less than $200/f_y$.

Minimum reinforcement shall be provided at least of the following ratios of reinforcement area to gross concrete area but not less than 0.0014.

- Where grade 40 or 50 deformed bars are used 0.0020
- Where grade 60 deformed bars are used 0.0018

15.10.4 Adopted Soil Parameters

The following values were adopted for the properties of soil during foundation design:

Unit weight of dry soil	=	18 kN/m^3
Unit weight of saturated soil	=	21 kN/m^3
Unit weight of submerged soil	=	11.2 kN/m^3
Angle of repose for the soil	=	30^o-35^o (based on soil properties)
Allowable bearing pressure	=	96 kN/m^2

Other parameters:

Modulus of elasticity for C15/C25	=	19,365/25,000 MPa
Poisson's ratio	=	0.25
Coefficient of thermal expansion	=	0.00001 per °C.

Foundation:

Allowable bearing pressures: 0.75 kg/sq cm based on the technical requirements listed in soil report. However, we designed the footing based on AMERCAN CONCRETE INSTITUDE (ACI), 318 Strength Design 318-08

15.10.5 Loads

Reference used for USACE project in Afghanistan.

Wind Loads:

Basis ASCE 7-98

Basic Wind Speed = 80 mph (122Km/hr)

Exposure category "C" (Open Terrain)

Importance Factors 1w = 1.0

W =Ce*Cq*qs*Lw		
Exposure factor Ce =	1.06	for exposure Category C , Open Terrain
and Cq =	0.8	
qs for wind speed 122 KM/PH =	0.08	t/m2

Table 23: is used to determine wind load

Seismic Loads:
Basis 2010 IBC Section 1614 “Earthquake loads- general”
Ss = 2.29g

S1 =0.869g

Group “1”

Site Class “D”

Importance Factor 1 = 1.0

Fa = 1.0 (table 1615.1 (1))

Fv = 1.5

Sms = Fa Sa (2.29g)

Sds = 2/3 Sms (1.1g)

Sm1= Fv S1 (1.5g)

SD1 = 2/3 Sm1 (1.0g)

Seismic Use Groups for all buildings is (l), no true hospitals or schools or buildings with over 300 occupants are anticipated. See table 1604.5, seismic design category based on short period response table 1616.3 (1)

Seismic design category = E (Based on footnote a.)
Section 1616.6.3 (if the structures have period T < 0.5sec, Sds & Sd1 need not be based on a value of Ss> 1.5g and S1>.6g) therefore Sds =1.0g and Sd1=0.4g
Table 1617.6 is used to determine R = 2 1/2, Q=2. Cant. Column system max ht. <35’. Walls act as nonbearing for all buildings except in Generator room and Well house
Cs =.156g based on EQ 16-35 therefore V_{base} = Cs (w) EQ 16-34

For Components:
Out of wall for design, the RCC frame themselves is controlled by section 1620.1.7 EQ 16-63 Fp =0.41 Sds therefore F_p =0.4*(1.0)*1*W_w

The following Calculation is used for frame system (Special RCC frames)	
Response Modification coefficient R	6.5
System Over strength factor Ω	2.5

$C_S = S_{DS}/(R/I_E)$, Equation 16-35	0.15385
V_{base} = CS*(Weight of the structure) , Equation 16-35	0.15*W

Table 24: Is used to determine design coefficients and factors for relevant building System

Vertical loading:

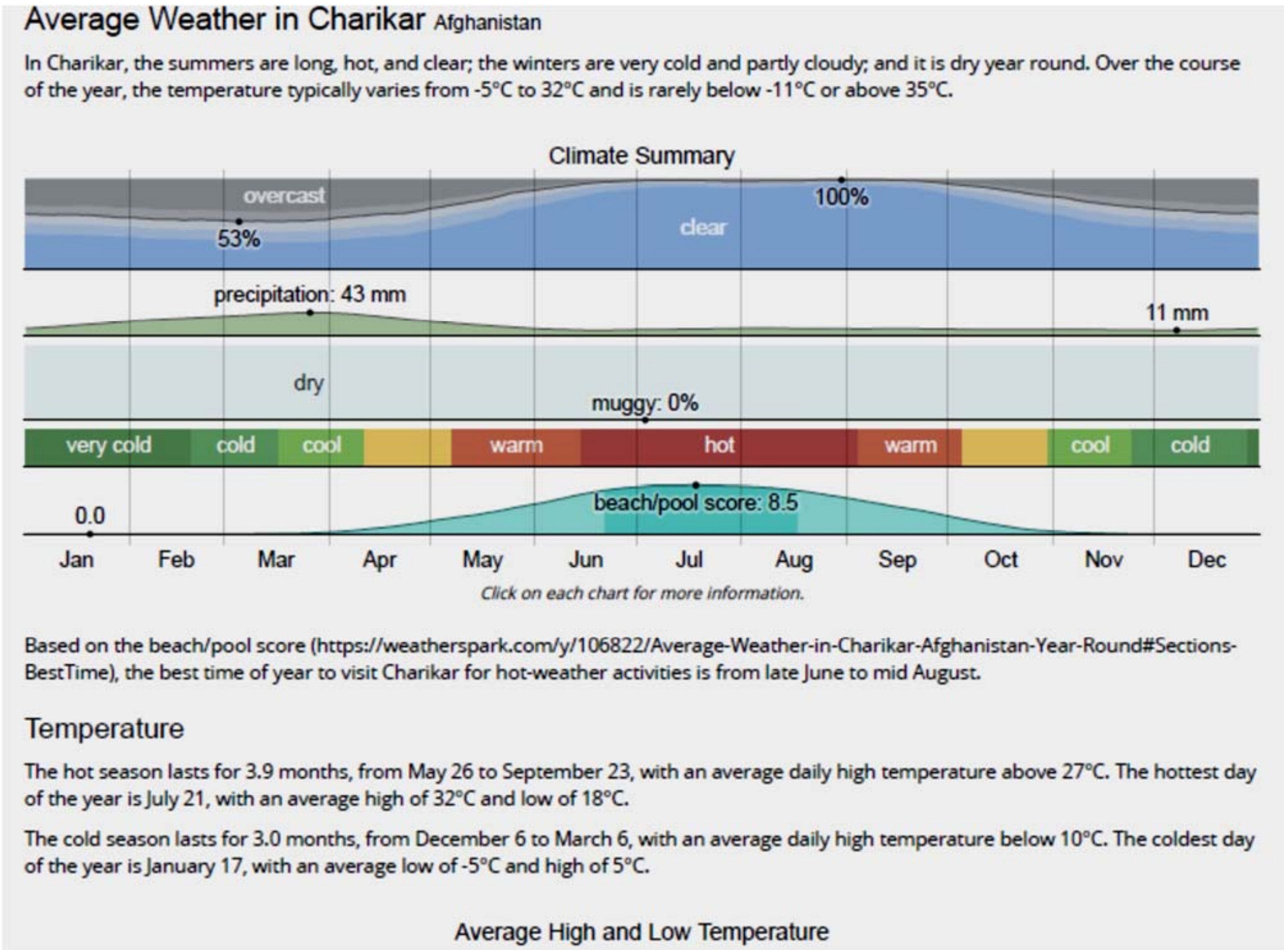
Snow loading	=	200 kg/sq/ meter
Roof live load	=	200 kg/sq meter
Office live load	=	350 kg/sq meter
Barracks live load	=	195 kg/sq meter
Ground floor live load 490	=	kg/sq meter
Corridors live load	=	490 kg/sq/ meter
Mechanical room live load	=	735 kg/sq/ meter
Storage area live load	=	612 Kg/sq meter

Geotechnical investigation – the geotechnical investigation analysis for the site is completed. The report recommends the site for building construction and the bearing is in the range of 0.75-1.2 Kg/cm2. The test results for the borings are submitted with design submittal.

16. SITE FACILITIES

16.1 Hydrology/Weather Kandahar – Site Storm Water Management

The project location as show is near to Charikar, the rainfall intensity estimated from the following tables. The indoor design for heating and cooling found based on outside weather conditions. The outside condition is found in the following figures .



Average Weather in Charikar Afghanistan

In Charikar, the summers are long, hot, and clear; the winters are very cold and partly cloudy; and it is dry year round. Over the course of the year, the temperature typically varies from -5°C to 32°C and is rarely below -11°C or above 35°C.

Based on the beach/pool score (https://weatherspark.com/y/106822/Average-Weather-in-Charikar-Afghanistan-Year-Round#Sections-BestTime), the best time of year to visit Charikar for hot-weather activities is from late June to mid August.

Temperature

The hot season lasts for 3.9 months, from May 26 to September 23, with an average daily high temperature above 27°C. The hottest day of the year is July 21, with an average high of 32°C and low of 18°C.

The cold season lasts for 3.0 months, from December 6 to March 6, with an average daily high temperature below 10°C. The coldest day of the year is January 17, with an average low of -5°C and high of 5°C.

Average High and Low Temperature

Figure 31: Weather Study in Charikar

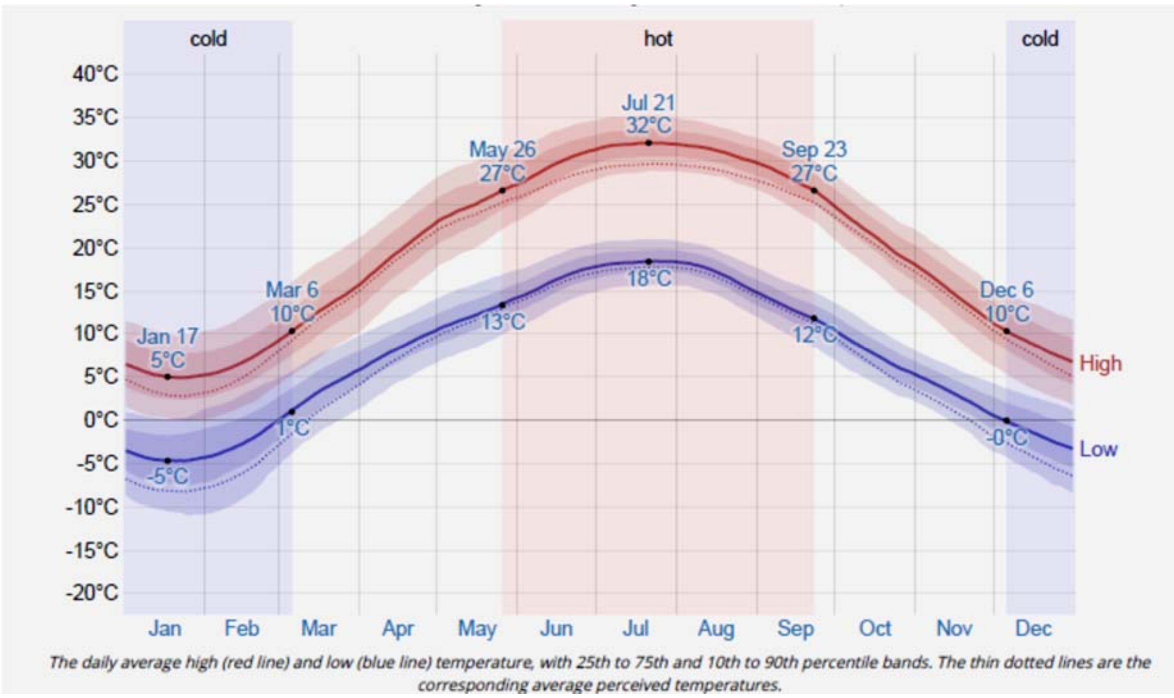


Figure 32: Anual Average Temperature Study for Parwan

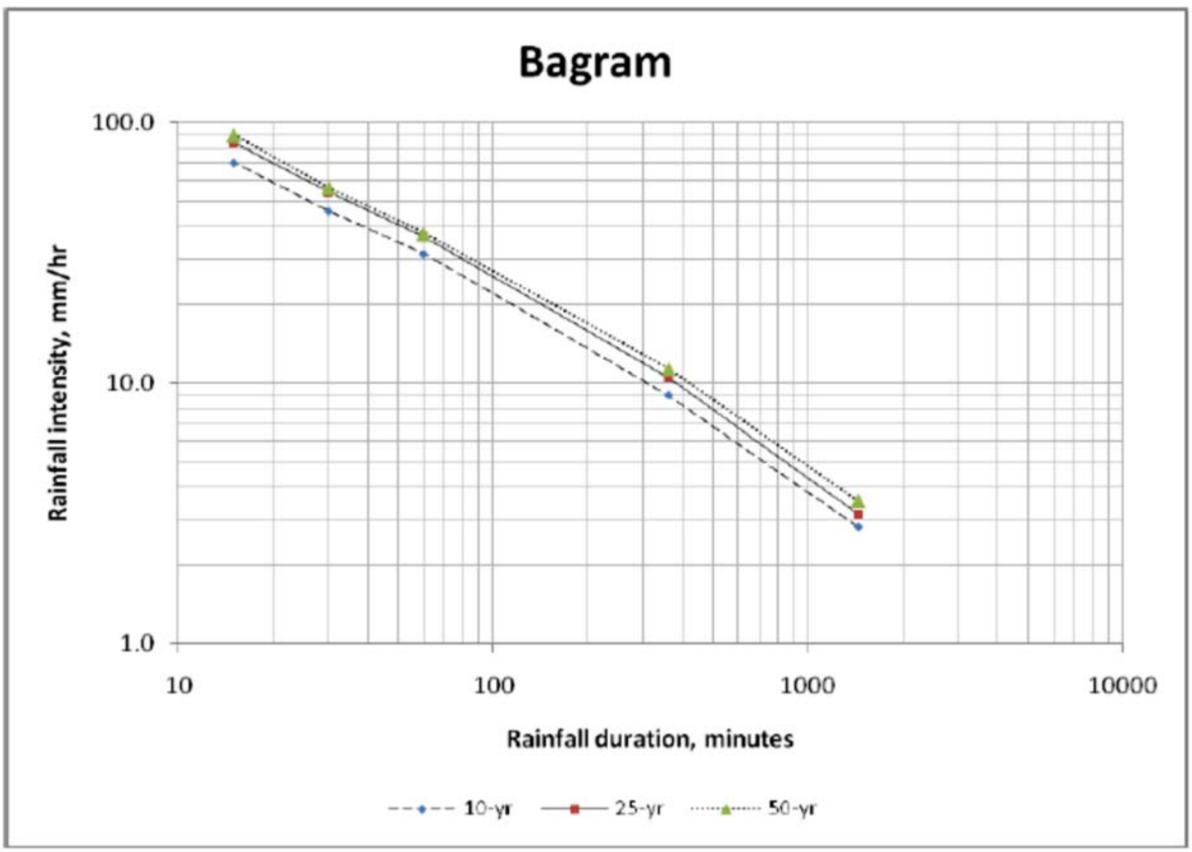


Figure 33: Rain intensity chart

The site is divided in basin and area slope to trench and runoff water is estimated based on ground surface materials than the trench size is estimated. Open V type trenches are considered which are the most cost effective, easy for construction and good for water flow. Two type trenches are considered earth channel for low slope up to 0.5% and stone patching surface trenches are considered for high slope above 0.5% to control erosion on trenches sides. The storm water is calculated based on the above table and site trenches and culverts are provided as per natural slope and required at site. Drainage plan is provided showing finished floor of building and slope and grade the site to trenches that no rain water will be standing on site.

16.2 Security Fence and Gate

Security fence is provided around power house facilities and panel yards selected site, the total area is 21,500m2 as indicated in drawings.

Foundation stone wall is provided under Fence to prevent excavating under fence by mates, dogs or steeling the panel form site. The stone wall is 80cm in ground and 40cm above grade level to prevent flooding into the site as well. Fence post is fixe on stone wall. Fence gate is provided at entrance 3.5m wide and 2.4m high.

16.3 Roads and parking space

Concrete surface road, parking and walkway are considered to prevent dust for Panels.
The ADT is not much but concrete surface is good to control dust on sites.
The road layer considered as follows:

- Sub graded natural ground compacted to 90%
- Sub base course 150mm layer compacted to 95%
- Base course 150mm compacted to 98%

Concrete walk way is considered to control dust control. Walkway layer consist of sub graded compacted to 90% base course compacted to 98% and 10cm concrete 20Mpa

16.4 Mounting frame for PV Panels

Metal frame for PV panel is provided as unit base; each unit has space for 18 PVC panels and has four posts in ground. Each unit is set side by side to provide a uniform row for PV panels. The frame structure includes vertical columns, rafters, purlins and other component which are provided for fixing the panel. The frame can be adjusted to different tilt angles for different seasons. Details of angles and tilts are given in the drawings. Cold farm frame have been used in the frame structure and all nuts and bolts are standards. The concrete foundations are provided for each post.

The frame, designed, withstand all the natural calamity/forces such as wind load, quake load and other vertical loads of panels. The calculation is provided for the frame are done manually as well as by software.

16.5 Site Lighting System

Site lighting is provided in the perimeter fence line on the pole at 7m height. The lights are directed to perimeter line only and the purpose of lighting is to control and guard the site perimeter for the compound. The lights are controlled and switched on and off from the Guard. Underground PVC conduits Ø50mm pipe and cables are provided for each light fixtures mounted on the pole. Two circuits (one in the lift and one in the right) are provided which cover the whole site perimeter light fixtures. Total of 8 Poles and 16 light fixtures are provided. The pole will be constructed from steel pipe 100mm at the bottom and 75mm at the top. Two lights and two cameras will be installed in each pole.

The light fixture is LED 4000K 230V, Rated luminous flux: 3866lm, Rated input power: 40W, Luminaries efficacy: 84lm/W, Electronic ballast 120÷240V 50Hz. Cable insertion place is provided at base of the pole. The cables are run from inside the pole pipe to the fixture point. The lighting pole calculation is provided to withstand all natural calamity/forces.

16.6 Sewer System and Leach Field

Gravity sewer line is provided for office building and guard room toilets. All sewer line flown by gravity to septic tank and then connected to leach field. Excess water will flow to leach field and will be absorbed. Septic materials will need low maintenance once a year. Leach field will not affect any nearby wells or water facilities. This is the most economic system for septic system implemented by USACE in most of their projects and they are working very well. The septic tank design and calculation provided. Refer to the calculation sheets for more information.

Sanitary Sewer laterals run from the new buildings by gravity to the new sanitary sewer collection system constructed as part of this project. Because of the small number of occupants, the sanitary sewer collection system is mainly 100mm PVC pipes. The sanitary sewer collection system has been designed for 80% of the water usage of 10 person compounds, using 155 Lit per day per person, and having a peaking factor of 1.5 times the average daily flow. Manholes and/or cleanouts are provided as indicated at each change in direction of the new sewer lateral line. We have no manholes that are spaced more than 120m.

The septic tank is considered for waste water which is connected to the leach field. The septic is sized for 10 individuals for the duration of two days. The leach field is designed for 10 individuals, assuming 80% of 155 lit of water per head per day; the scope determine the size of the leach field as indicated in drawing. Size of septic tank and leach field is calculated - refer the calculations. The leach field is a good system for treatment of sewerage system disposal and it is used by USACE in some of its projects. It can work for long times. Some are still working but few are blocked due to large amount of waste or improper construction. The design is based on design requirement attached in design standard package.

16.7 CCTV and Video Security System

Site Video and Camera system are provided to for site surveillance, security check, control of theft and other security issues through perimeter fence and other parts of the compound. The cameras are installed at the light pole along the perimeter fence. A total of 16 cameras are provided and installed. Each camera has the capacity to observe/see up to 50m and the site distance is around 40m.

16.8 Concrete Pad

Concrete pads are provided for containerized Battery Energy Storage System, the transformers, generators and the fuel tanks. The pads are all interior pads and there are no isolated exterior pads. All the pads are supported and jointed with grade slab. The BESS, the fuel tank and generators have same loading and weight therefore only one type is calculated and te transformer is less in weight and it is calculates separately. The pad consist of 150mm grade slab and then 100-150mm additional concrete poured over grade slab. The overall thickness of pad is 25cm and the grade slab is 15cm with reinforcement bars.

16.9 Fuel Tank

Steel sheet fuel tank is considered for fueling generators. The fuel tank is sized based on the fuel consumption for 6 months for the two generators. The generators are not running all the time. They are operating in coordination with PV panels. The tank can hold 25000 Liter fuel which is enough for 6 months as calculated in DPR report. The fuel tank is designed round type shape to have the best strength against collapsing. The circular tanks are the most cost effective with strong strengths against fuel and other forces. The tank is supported by steel saddle and saddle is anchored in the concrete. The calculation is provided for all sheeting, anchors and pad and the slab foundation. The tank is inside the canopy with containment wall around to hold leakage fuel during leakage of tank. The containment is sufficient to hold all fuel in the tank. A sump and valve is provided for cleaning purpose and flow of water out of the containment. The valves shall be closed all the time and shall be opened as/when required.

16.10 Master plan

Building Connections – Land scope and building connection based on usage is considered, comfortable design and setting facilities location are considered in site layout plan. The site utilities are connected to the buildings as required. This includes connection to the water main, sanitary sewer collection system, and electrical service.

Land Disturbance Limits –the sites is not in rectangular shape, the total area is 20000m2 ranges. The site-specific topography will determine the direction of storm water flow.

16.11 Survey and topographic plan

Site survey is performed and topo plan is included in drawing showing all exist feature at site as indicated. The survey plan for distribution system also shows all roads and exist culverts and houses.

16.12 Site grading

Site grading is considered to slope the site as per natural slope and drain water from site and the finish floor elevation for building and other facilities is considered above 40cm above grade that shall prevent flooding during flooding.

16.13 Site drainage

Storm Drains and culverts – the design utilities surface runoff features through grading plan that will be developed based on site specific plans. We expect to construct trenches and culverts to drain surface flood water out compound, the site will be graded and culvert will be constructed at natural slop direction. Tow kind of culverts are considered. The PVC pipe culverts design for closed areas within the compound to collect water from closed area to main culvert and main culvert are designed of stone masonry to drain the storm water out of the compound.

16.14 Water distribution system

The water is being provided to each building and to solar panel from the water distribution system. The solar panel needs washing on a time basis which needs water to wash the dirt. The distribution system consists of network around building, piping inside building and reservoir water tanks. The one-day demand is calculated as 20000Lit for domestic demand and washing, therefore 27000 Lit is provided, and the water storage tanks are located on 4m high concrete water tower structure. The water storage tanks are connected with water pump and well pump. Water tower is provided to provide pressure to all fixtures. The tank provides water as down fed system to the building fewer amounts of head lose. Sufficient pressure is provided to all fixtures including showers.

The water will be pumped from the new water well to water storage tank. The one day water demand including washing is stored in the water tanks. The water tanks are connected with compound network. Each building which needs water is connected with network distribution system. The new water well, new water pump will be located in the bore well. The well is located on high elevation, While the septic tank is located at the low elevation, furthest point from the well and water tank. The water distribution network is 25-50 mm PVC or PPR pipes running to the buildings for the water usage of max 6 individuals, using 150 Lit per day per person, having a peaking factor of 1.5 times the average daily flow, as we assumed the office will work in one shifts around the clock. Water lines are PVC pressure rated pipe. Blow Valves are provided at low elevation and air valve are provided at high elevation as required, also other valves are provided to isolated buildings from the water distribution piping system.

Washing panel, paths or spraying garden stand up tapes are provided in the main network system. Hose bib tapes are provided, 25 mm stands up pipe at 1.2m elevation is provided to supply sufficient water for washing panels, paths spraying gardens and etc. total of xx stands up tape including. 1 stands up tape are also provided for Guard rooms.

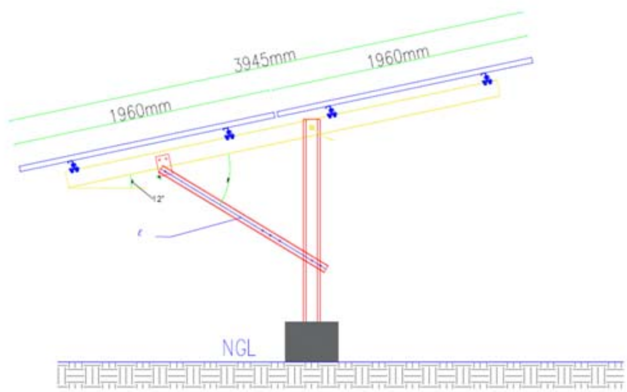
16.15 Public Lightings

The public lighting design is provided in the main roads near main shopping areas and crowded places where people have walking during the night. The light fixture is mounted on the concrete poles at 4-5 m height from ground level and is fed from nearest meter box at the pole with auto photocell switch on the fixture. The lighting fixture's spacing is 120m at the site which can be provided more than 5 lux lighting illumination which is required as per NEC code. NEC Code recommends 5 lux for street lights. LED fixture with 100w power consumption and luminosity of 13200 lm is selected which can provide sufficient luminosity for the roads. There may be flood light installed in front of the shops and houses' gates by individual households and shop owners as well which can help to increase the light illumination during the night time.

Substation lighting is provided by projector type LED light fixture with 50W power and luminosity of 2400 lm which can provide sufficient illumination for the transformer and its surrounding areas. 10lux illumination is provided as per NEC Code. Two light fixtures per substation is provided to light up all direction and the projectors are also movable that can be adjusted to direct lights at specific locations as required. The street type light fixtures are big and need 1m spacing in front and may touch with MV wires. Therefore, the projector type LED lights are selected for substations.

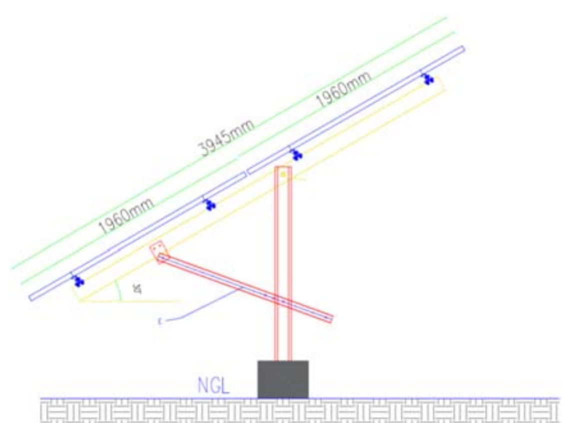
17. MECHANICAL DESIGNS OF RACKING SYSTEMS, INCLUDING ALL CALCULATIONS

The pole mounts will be made of steel with a concrete foundation and associated racking system. The racking system is installed on the poles. Every set of four poles will carry 20 solar panels. A row of solar panels and rows are sized in line with the PV park layout and the string size. Steel structures are made of galvanized steel protected against corrosion for up to 50 years. The structures shall be tilted at three angles for three seasons, in line with the drawings.



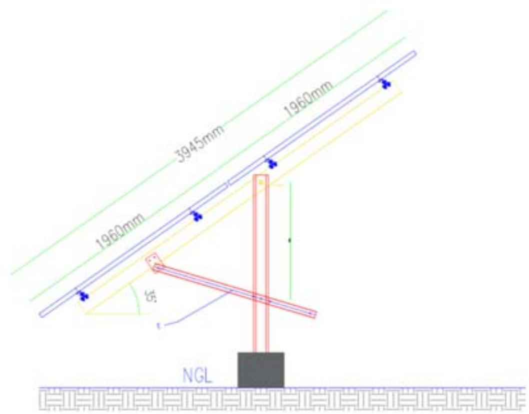
MODULES SIDE ELEVATION FOR (12°) TILTS (Parwan Site)

(a-I)



MODULES SIDE ELEVATION FOR 30°) TILTS (Parwan Site)

(a-II)



(a-III)

Figure 34: Module side elevation for tilts (a-I) 12°, (a-II) 30°, (a-III) 35°

17.1 Codes and Standards

Manufacture and installation of steel works shall be as indicated in drawings and specs. Where there is a conflict between various regulations, codes and standards and the priority of those documents is not spelled out in this specification the contractor should request for clarification in writing from the Engineer.

All regulations, codes and standards referred to in this specification refer to the latest editions of those regulations, codes and standards unless otherwise approved by the Engineer.

S.N.	Code/ Regulation	Description
1	ANSI/API Spec 2B	Specification for Fabricated Structural Steel Pipe
7	ASTM A312	Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes
12	ASTM F593	Standard Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs
13	ASTM F594	Standard Specification for Stainless Steel Nuts
14	AWS D1.1	Structural Welding Code Steel (2008)
15	IS 2062	Steel for General Structural Purpose
16	IS 10748	Hot-rolled Steel Strip for Welded Tubes and Pipes
17	ISO 630	Structural steels -- Plates, wide flats, bars, sections and profiles
18	ISO 898	Mechanical Properties of Fasteners
19	ISO 1461	Hot Dip Galvanized Coatings on Fabricated Iron and Steel Articles.
20	ISO 3506	Mechanical Properties of Corrosion-Resistant Stainless Steel Fasteners

Table 25: Applicable External Specifications, Codes and Standards

17.2 Structural Materials

For valves and pipelines, the manufacture shall conform to use of steel and polymer in accordance with the following guideline as shown in table 26.

Table 26: Material specifications for Steel Equipment & Structures

S.N.	Material Type	Equipment or Structure	Steel Grade
1	Stainless Steel	Fasteners and Anchor Bolts	ASTM F593/F594 Alloy Grade-A
2	Hot Rolled Steel	Plates Structural and Flat Bars	ASTM A36, Grade 60
3	Hot Rolled Steel	Penstock pipe, easily weldable	IS:2062, ASTM A106
4	Cold Rolled Steel	Shafting for tandem lifts Radial gate pins.	ASTM A108, Grade 1045
5	Ductile Iron	Bearings and Rollers	ASTM A536 Grade 60-40-18

17.2.1 Bolted Connections

Bolts, nuts and washers and other demountable fastenings of all galvanized parts and also Aluminium alloy parts shall be in stainless steel to the appropriate DIN Standard and shall remain unpainted. P.T.F.E. washers shall be flatted beneath bolt-head and washer when fastening galvanized and aluminium alloy parts.

All nuts shall be secured by pre-stressing, lock or counter nuts or similar methods. Spring washers are not allowed in structural members. Washers shall be used at both bolt head and nut. No welding is allowed on either item as galvanizing must remain intact. Bolts shall not be reused. Pre-stressing tolls shall be applied when utilizing torque stress techniques. The grease shall be non-corrosive and must not contain sulphur.

All holes for bolted connections up to 18 mm shall be approximately 1mm larger than the bolts used. For bolts above 18 mm the holes shall be 1.5 mm larger unless otherwise specified.

Bolts heads and nuts shall rest squarely against the base material, and bolts shall be a length that will extend entirely through and up to a maximum of 6mm beyond the nuts.

Bolts with pre-installed tension control may be used subject to Engineer’s approval.

17.2.2 Bolts in Shear and Tension Connections

Bolts in structural members from 12 mm and above shall be pre-stressed to 50% of yield strength unless otherwise specified by the Engineer. Bolts in joints exposed to wave loads shall be pre-stressed to 75%of yield strength.

17.2.3 Friction Grip Connections

Bolts shall be pre-stressed and documented as specified on design drawings or as approved by the Engineer. Enlarging of holes for high stress bolts shall be by reaming only. Holes shall be clean-cut without torn or ragged edges. Outside burrs resulting from drilling or reaming operations shall be removed with a tool making a 2 mm bevel. All holes shall be drilled and reamed as necessary prior to application of protective coating.

17.2.4 Hand Railing

Unless otherwise specified all rails shall be fabricated from 32 mm bore galvanized medium weight steel tube. Hand railing shall be provided along every edge of all metalwork and concrete walkways, stairs or accessible open areas where the drop beyond the edge exceeds 700 mm. Hand railing shall consist of Standards at regular intervals not exceeding 1.5 m, and two rails. The upper rail shall be 1.0 m above the adjacent finished floor level, and 900 mm above the nosing line on stairways. The lowest rail shall be midway between floor and upper rail. The hand railing fixing and anchorages shall be designed to withstand a continuous horizontal load at the top rail of 750 N/m. Hand railing shall be flush jointed. Hand railing terminating against a wall shall have a suitable wall fixing.

Where required ladders, stairways or other openings shall be guarded on three sides by hand railing conforming to the requirements stated above. Access to the ladders or openings shall be guarded by two removable galvanized hanging chains secured to eyes at top and middle levels. Hand railing shall be of uniform appearance and manufacture.

17.2.5 Module mounting structure

The array mounting systems and overall installation must meet all applicable local building codes, and shall have attachment points, which are consistent with the module manufacturer's installation instructions, and the requirements of ANSI/ASCE 7-98.

The array support structure shall be fabricated using corrosion resistant GI (40 mm x 40 mm x 5 mm) or anodized aluminum or equivalent metal sections. Minimum thickness of galvanization shall be 80 microns. Array support structure fabricated from alternate material shall have equivalent degree of protection The Contractor shall submit respective certificates from an approved laboratory latest at commissioning.

Array mounting hardware supplied for this installation shall be compatible with the site considerations and environment. Special attention shall be paid to minimize the risk from exposed fasteners, sharp edges, and potential damage to the modules or support structure.

Corrosion resistance and durability of the mechanical hardware is emphasized. All materials shall be selected to avoid corrosion and degradation. The use of any wood or plastic components is strongly discouraged.

These are high profile, publicly visible installations, and the aesthetics of the overall installations are extremely important. To create a uniform appearance of the array, spacing between individual modules and panels shall be kept to a minimum, and the overall layout keeping in consistency with the overall architectural features of the buildings and properties. As much as possible, all mechanical hardware, conduit, junction boxes and other equipment shall be concealed beneath and/or behind the array, and all other electrical work performed neatly and as inconspicuously as possible.

The array layout shall be consistent with the electrical ordering (and labeling) of source circuits in the array combiner boxes. Ease of access for array troubleshooting and maintenance is provided by allowing access to the back of the array for module junction box servicing, and removal/replacement of individual source circuits (panels) and modules if necessary.

The support structure shall be free from corrosion when installed; array support structure welded joints and fasteners shall be adequately treated to resist corrosion.

PV modules shall be secured to support structure using screw fasteners and/or metal clamps. Module fasteners/clamps shall be adequately treated to resist corrosion.

The support structure shall withstand wind loading of up to 150 km/h and operating environmental conditions for a period of minimum 25 years.

The junction boxes shall be of IP54 (for outdoor) as per IEC 529.

The mounting structures are fixed in reinforced concrete foundations, designed to withstand all loads including weight, wind, snow, and earthquake. The Contractor shall design the foundations and propose standard mounting structures and shall submit the documents including structural analyses, drawings, plans, etc. to the Employer for approval.

18. RETICULATION SYSTEM

18.1 Codes and Standards

1. American National Standards Institute – ANSI

2. ASTM International - ASTM
   - ASTM D92 Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester
   - ASTM D445 Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (the Calculation of Dynamic Viscosity)
   - ASTM D664 Standard Test Method for Acid Number of Petroleum Products by Potentiometric Titration
   - ASTM D877 Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids using Disk Electrodes
   - ASTM D923 Standard Practices for Sampling Electrical Insulating Liquids
   - ASTM D924 Standard Test Method for Dissipation Factor (or Power Factor) and Relative Permittivity (Dielectric Constant) of Electrical Insulating Liquids
   - ASTM D971 Standard Test Method for Interfacial Tension of Oil against Water by the Ring Method
   - ASTM D974 Standard Test Method for Acid and Base Number by Color-Indicator Titration
   - ASTM D1298 Standard Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
   - ASTM D1500 Standard Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)
   - ASTM D1524 Standard Test Method for Visual Examination of Used Electrical Insulating Oils of Petroleum Origin in the Field
   - ASTM D1533 Standard Test Methods for Water in Insulating Liquids by Coulometric Karl Fischer Titration
   - ASTM D1816 Standard Test Method for Dielectric Breakdown Voltage of Insulating Oils of Petroleum Origin Using VDE Electrodes
   - ASTM D2029 Standard Test Methods for Water Vapor Content of Electrical Insulating Gases by Measurement of Dew Point
   - ASTM D2129 Standard Test Method for Color of Clear Electrical Insulating Liquids (Platinum-Cobalt Scale)
   - ASTM D2284 Standard Test Method of Acidity of Sulfur Hexafluoride

- ASTM D2285 Standard Test Method for Interfacial Tension of Electrical Insulating Oils of Petroleum Origin against Water by the Drop-Weight Method
- ASTM D2477 Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Insulating Gases at Commercial Power Frequencies
- ASTM D2685 Standard Test Method for Air and Carbon Tetrafluoride in Sulfur Hexafluoride by Gas Chromatography
- ASTM D2759 Standard Practice for Sampling Gas from a Transformer under Positive Pressure
- ASTM D3284 Standard Test Method for Combustible Gases in the Gas Space of Electrical Apparatus Using Portable Meters
- ASTM D3612 Standard Test Method for Analysis of Gases Dissolved in Electrical Insulating Oil by Gas Chromatography
- ASTM D3613 Standard Practice for Sampling Electrical Insulating Oils for Gas Analysis and Determination of Water Content
- Other applicable standards

3. Association of Edison Illuminating Companies - AEIC

4. Canadian Standards Association - CSA

5. Electrical Apparatus Service Association - EASA
ANSI/EASA AR100 Recommended Practice for the Repair of Rotating Electrical Apparatus

6. Institute of Electrical and Electronic Engineers - IEEE

- ANSI/IEEE C2 National Electrical Safety Code
- ANSI/IEEE C37 Compilation Guides and Standards for Circuit Breakers, Switchgear, Relays, Substations, and Fuses
- ANSI/IEEE C57 Compilation Distribution, Power, and Regulating Transformers
- ANSI/IEEE C62 Compilation Surge Protection
- ANSI/IEEE C93.1 Requirements for Power-Line Carrier Coupling Capacitors and Coupling Capacitor Voltage Transformers (CCVT)
- ANSI/IEEE 43 IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery
- ANSI/IEEE 48 IEEE Standard Test Procedures and Requirements for Alternating Current Cable Terminations 2.5 kV through 765 kV

- IEEE 81 IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System Part I: Normal Measurements
- ANSI/IEEE 81.2 IEEE Guide for Measurement of Impedance and Safety Characteristics of Large, Extended or Interconnected Grounding Systems
- ANSI/IEEE 95 IEEE Recommended Practice for Insulation Testing of Large AC Rotating Machinery with High Direct Voltage
- IEEE 100 The Authoritative Dictionary of IEEE Standards Terms
- IEEE 141 IEEE Recommended Practice for Electrical Power Distribution for Industrial Plants (IEEE Red Book)
- ANSI/IEEE 142 IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (IEEE Green Book)
- ANSI/IEEE 241 IEEE Recommended Practice for Electric Power Systems in Commercial Buildings (Gray Book)
- ANSI/IEEE 242 IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (Buff Book)
- ANSI/NETA ATS-2009 IEEE 386 IEEE Standard for Separable Insulated Connectors System for Power Distribution Systems above 600 V
- ANSI/IEEE 399 IEEE Recommended Practice for Power Systems Analysis (Brown Book)
- ANSI/IEEE 400 IEEE Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems
- ANSI/IEEE 400.2 IEEE Guide for Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF)
- ANSI/IEEE 421.3 IEEE Standard for High-Potential-Test Requirements for Excitation Systems for Synchronous Machines
- ANSI/IEEE 446 IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications (Orange Book)
- ANSI/IEEE 450 IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications
- ANSI/IEEE 493 IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems (Gold Book)
- ANSI/IEEE 519 IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems
- ANSI/IEEE 602 IEEE Recommended Practice for Electric Systems in Health Care Facilities (White Book)
- ANSI/IEEE 637 IEEE Guide for the Reclamation of Insulating Oil and Criteria for Its Use IEEE 644 Procedures for Measurement of Power Frequency Electric and Magnetic Fields from AC Power Lines

- ANSI/IEEE 739 IEEE Recommended Practice for Energy Management in Commercial and Industrial Facilities (Bronze Book)
- ANSI/IEEE 902 IEEE Guide for Maintenance, Operation and Safety of Industrial and Commercial Power Systems (Yellow Book)
- IEEE 1015 IEEE Recommended Practice for Applying Low-Voltage Circuit Breakers Used in Industrial and Commercial Power Systems (Blue Book)
- IEEE 1100 IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment (Emerald Book)
- ANSI/NETA ATS-2009 ANSI/IEEE 1106 IEEE Recommended Practice for Maintenance, Testing, and Replacement of Nickel-Cadmium Batteries for Stationary Applications
- ANSI/IEEE 1159 IEEE Recommended Practice on Monitoring Electrical Power Quality
- ANSI/IEEE 1188 IEEE Recommended Practice for Maintenance, Testing, and Replacement of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Applications
- IEEE 1584 IEEE Guide for Arc-Flash Hazard Calculations
- Other applicable standards

7. Insulated Cable Engineers Association – ICEA

- ANSI/ICEA S-93-639/NEMA WC 74 5-46 kV Shielded Power Cable for Use in the Transmission and Distribution of Electric Energy
- ANSI/ICEA S-94-649 Standard for Concentric Neutral Cables Rated 5,000-46,000 Volts
- ANSI/ICEA S-97-682 Standard for Utility Shielded Power Cables Rated 5,000-46,000 Volts
- Other applicable standards

8. International Electrical Testing Association –

- NETA ANSI/NETA ETT Standard for Certification of Electrical Testing Technicians
- ANSI/NETA MTS 7.2.1.1 Standard for Electrical Maintenance Testing of Dry-Type Transformers
- ANSI/NETA MTS 7.2.1.2 Standard for Electrical Maintenance Testing of Liquid-Filled Transformers
- NETA MTS Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems
- Other applicable standards

9. National Electrical Manufacturers Association - NEMA

- NEMA AB4 Guidelines for Inspection and Preventive Maintenance of Molded-Case Circuit Breakers Used in Commercial and Industrial Applications
- ANSI/NEMA 84.1 Electrical Power Systems and Equipment Voltage Ratings (60 Hz)
- NEMA MG1 Motors and Generators
- Other applicable standards

10. National Fire Protection Association - NFPA

- ANSI/NFPA 70 National Electrical Code
- ANSI/NFPA 70B Recommended Practice for Electric Equipment Maintenance
- ANSI/NFPA 70E Standard for Electrical Safety in the Workplace ANSI/NFPA 99 Standard for Healthcare Facilities
- ANSI/NFPA 101 Life Safety Code ANSI/NFPA 110 Emergency and Standby Power Systems
- ANSI/NFPA 780 Installation of Lightning Protection Systems
- Other applicable standards

11. Occupational Safety and Health Administration - OSHA

12. State and local codes and ordinances

13. Underwriters Laboratories, Inc. - UL

18.2 Transmission and Distribution System

The transmission line conveys the power from the power house to the villages. It consists of a 20kV conductor line installed on both, concrete poles ranging from 9 to 12 m height and respective sub-stations in each village. The average span is 60 m, maximum span should not exceed 80 m.

The distribution networks (0.4 kV LV network) connect the consumers with the sub-stations via ABC cables fixed on 9 m concrete poles. Average span is 50 m while maximum span shall not exceed 60 m. Clearance shall be provided according to National or international Standard.

Service lines of at minimum 4x4mm^2 to 4x16mm^2 based on distance from main service lead from the 0.4 kV distribution network to the consumers premises where house connection boxes including short circuit fuses and RCBOs are installed.

Split pre-paid electronic meter are considered at the consumers premises and in public meter boxes to allow pre-payment and to protect meters against manipulation. The proposed pre-paid metering system are described in section 19.

All transformer stations (main and all step-down or substations) are equipped with separate earthing systems for MV and LV voltage. In addition, LV earthing is required at each meter box or consumer and at each dead end of feeder and at every 10^{th} pole.

The system lay-out is based on the daily load pattern as compiled drawing and one line diagram. The number and type of consumers per village is compiled in Table, transformer capacity per village in Table.

The maximum capacity includes margins for technical losses (3-4%) and for future expansion (10%) extra load is considered. The technical losses include energy losses in transformers and cables. The transformer have two type of losses, winding losses which is independent of loads and other is loading losses which depends on loads. Cable losses are due to loading which depends on size of the cable and the flow of current through it. All losses are calculated and reported in details. However, at present, losses will decrease as 200w per family are used instead of 1000w per family.

NEC code and other parameters suggest considering 25% future loads but as per site analysis, population growth of 10% is considered for this project.

The load flow and short circuit analyses (single and three-phase) are considered in calculation, sizing of breakers, MCB and conductor/cable sizes and verification of maximum voltage drops and power losses will be based on calculation and not more 4%.

The mechanical and electrical design of the T&D network is optimized with respect to cost and quality.

Site LV Electrical Distribution- Electrical power is distributed in underground PVC duct banks to meter boxes at various locations on the site.

Voltage drop

The voltage drop is calculated by ETAP software based on IEC standard and IEEE Guidelines. The Maximum voltage drop is not more than 8% in total and the allowance in main service line is 4-5% and 1-3% in branch lines and circuits.

The total transmission routes for LV and MV are 16,223 meter. The following amount of cables are needed for both LV and MV routes:

- The total length of cable required for LV is 13,817 meter
- The total length of cables required for MV is 8253 meter

The element of distribution system are as follows:

18.3 Power Poles

Concrete power poles are provided for MV and LV distribution, 4 type of pole is considered in design as follow:

P1- is normal concrete power pole, 12m high and used for MV lines, while it is able to carry LV line as well under MV lines. This pole design is stipulated for tension load of 400kg at top

P2- is secure concrete power poles, 12m high and used for MV line, while it can carry LV lines as well. P2 poles are stronger than P1 and used in places where it faces higher strain or potential external harm, such as near corners or near roads etc. This pole is design for tension load of 800kg at the top.

P3 - is normal concrete pole used for LV lines, it can carry one to two or more LV circuits and used only for LV lines. This pole is designed for tension load of 300kg at the top

P4 - is 15m concrete pole used for crossing over fuel tank station or main roads, to ensure adequate clearance. This pole is design for tension load of 1100kg at the top.

Pole calculation and analysis is provided to check if the applied loads are in line with this project. The supported structure such as pole top cable structure, distribution panel structure, transformer structure and fuse and surge arrester structure are analyzed and calculated to check if it can withstand the applied loads. Due to the calculation, changes have been made and the final design and drawing are corrected and submitted.

The foundation of poles is based on soil condition (soil bearing pressure of 0.75kg/cm2) and change in direction at different angles. The foundation is simple stone and earth backfill at straight line, with no concrete foundation (only stone and soil can be used). At 0-6 degrees, concrete foundation is required and at 6-30 degrees, type 2 foundations is required, while at 30-90 degrees, guy wire will be used.

Where there is no place to install a guy wire, a tension pole is considered to be used instead, a tension pole for P2 with total allowable loads of 800kg at top and concrete foundation, calculation have been performed to check if the P2 can work, calculation show that tension is less than 800kg and P2 is good in such cases and used at site.

18.4 Reticulation and Household Connection System

The power supplied to the households is fixed at around 200 Watt, which would imply that the wiring from the households to the meters and from the meters to the transformer and to the to the power plant would have to be sized accordingly. However, in designing the reticulation system, we deferred to the national standards for rural electrification, which assumes between 1-2.5 kW power per household, with diversity factor of 80% at the transformer level. Thus, the wiring is sized somewhat larger than at 200 Watt per household. The additional cost is justified as follows:

1) The lifespan of the PV plant is 25 years, while the life span of the reticulation system is significantly more at close to 50-years. During this time frame, the villages are expected to receive grid connection, given the fact that they are located around 10 km from the provincial capital of Charikar. Hence, it makes sense to size the system with a clear understanding of the future grid connection.
2) The commercial, institutional and residential customers are typically on the same overhead wiring system. Whereas the residential loads are limited to 200 Watt, commercial and institutional loads are not limited. If the designed wiring size were to be set for 200 Watt residential customers, commercial and institutional customers would need to be connected through alternative wiring system, which would double the overhead wiring costs.
3) There is always a likelihood that one neighbor will settle for a 200 Watt connection, while another neighbor, connected to the same meter will want to receive a 1 kW connection. If the power produced in the plant allows for such connectivity and the customer is willing to pay for power, the mini-grid would set the metering for the desired output. This would require that the sizing of the system is able to transmit the minimum of 1 kW power.

In view of these circumstances, the complete reticulation system design was based on 1 kW residential load.

The surveyed load demand is in excess of 1 kW per household. Due to supply limitations, the actual connected power for the interim period will be at 200 Watts for low income households and more than 200 Watts for affluent households, should sufficient power be available. Additionally, the system is within 3.5 km of the grid system, which in the reasonably foreseeable future will also be able to connect to the PV utility system. This implies that in foreseeable future, the supply of power will be significantly in excess of 200 Watts. This requires that the transmission and household connection system should be sufficiently sized to meet this future demand and supply. This also translates to the World Bank's Multi-Tier Framework tiers 3 and 4, which should be a long-term objective of the design. As such the household connections have been sized for 1 kW, which is in line with normal practice in Afghanistan.

Power connection to house and businesses are through step down transformers, LV distribution and meter boxes. Total of 8 transformers are considered based on location and concentration of house and shops and other connection to masque and etc. For each transformer surge arrester and fuse cut off is provided to increase protection for the system. The transformer is distributed based on the bellow table (27) and as indicated in the site plan.

Name of Village	Estimated No of HH	No of Business	Substation & transformers	Size of Substation (KVA)	MCB (A)	MB9	MB6
Qala-e- Baland	234	30	TR#1	315	500	28	3
Turkman	300	47	TR#2	400	630	34	9
Ghulam Shah	180	9	TR#3	250	400	21	3
Ghulam Shah	120	8	TR#4	200	300	13	7
Ghulam Shah	50	9	TR#5	200	300	4	6
Qalander khail	550	49	TR#6	500	800	68	2
Beg Muhd Khail	207	21	TR#7	315	500	25	1
Ghulam Shah	320	30	TR#8	400	630	36	4
Total	1961	203	8			229	35

Table 27: Transformer and Substations

The transformers are located at the proper location to provided direction to all routes and roads. The LV circuits from each transformer is distributed in all routes and the maximum distance is 800m and the minimum is 250m. Based on the load and distance, the double lines are also considered. Voltage drop is calculated in both MV and LV lines.

18.5 LV Distribution

LV distribution is from Transformer to meter boxes, the longest LV line is around 400-800m and shortest is about 100m. In most of LV overhead lines, two line are considered to minimize the voltage drop and ensure cost affective distributions. The LV distribution is on concrete pole with 9m height in total height of 7.5m from the ground. The LV lines are connected to meter boxes located at poles and also at pad far from pole. Most of the meter boxes are located at poles but some are located far from poles based on location of houses. Some meter boxes are located 80m, 120m, 150m and 200m far from pole connected with underground Copper 4-core cable in PVC conduits.

ABC aluminum cables size of 25, 35, 50, 70, 95, 120 and 150 mm2 are used in LV distribution. Each LV circuits is control by LV breaker at MDB located under each transformer. The MDB controls each circuit separately and can be used during maintenance.

The distribution is mostly in level surface area with maximum ground slope up to 2%, there is no big slope in distribution site to affect the distribution system for MV and LV lines.

Crossing over road: Crossing over road is critical issue for MV as well as LV lines, in most cases there are loads required at both side of roads and these loads cannot be feed from one side of road since crossing road for many LV lines are not possible therefore in some places where required, a separate circuits branches from circuits are provided in the other side of the road.

18.6 Overhead Line Clearance

Clearance shall be provided according to the National or International Standard. There is no such national standard available and the national utility company accepted to use the 12m pole for MV lines with 1.8m embedded in ground and 9m LV pole with 1.5m embedded in ground. With these poles' heights, the required clearance for both MV and LV as per NESC or other international code are good and is easily obtainable at the site. The clearing are based on the National Electrical Safety Codes on Overhead Line Clearances and they are shown in the table below which is a good clearance at the site.

Using 12m pole for MV lines, which is 10m above the ground, is an acceptable height and has enough clearance for all type of features exist on the ground. Also using 9m pole for LV lines is an acceptable height for all existing features on the ground. Also the distribution area is platen and level with 1-2% slope which will not affect the overhead lines going through a slope.

Clearance for MV lines

Minimum Vertical clearance	Required per Code	Available at Project Site
Ground accessible to pedestrians only	6.5m	9m
open country site	6m	10m
Roads and streets	7m	10m
Fence line	5m	7m
Walls	4m	6m
Building , accessible points , flat roofs upon Power line may stand		
power line above trees	2.5m	3m
Power line above steel structure	3m	NA
Power line above telecommunication lines	2.5m	NA
Horizontal distance from building	2.3m	5M
Exist light or pole	2.3m	NA
Normal span	60m	
Maximum span	90m	
Minimum depth of pole foundation	1.5m	
Minimum horizontal phase to phase separation	0.4m	
LV Lines		
open country site	4m	7.5M
Roads and streets	4.3m	7.5M
Fence line	4.3m	5M
Walls	3m	4M
Allowance for Creep		
ABC cable	600mm	
ACSR	600MM	

All the existing features under the overhead line are met as per the above clearance table. All vertical and horizontal clearance are met at the site as per above table.

18.7 Meter Boxes

The Meter Boxes (MBs) are for use in the low voltage distribution system to achieve simple and cost-effective means of providing single phase and three phase connections to the customers. Meter boxes will be installed at poles from the secondary network to provide service connections to small groups of houses in their vicinity.

18.7.1 Types of Meter Boxes

Two type of meter box are designed for this project. MB9 type is used to house 9 meters for 9 households, while MB6 type is used to house 6 meters for 6 households. Each meter box has main breaker and switch and sub breaker for each meter. The main breaker can off and on based on the routine power connection to house and businesses. RCBO breakers are used for each house connection to protect the system from short circuits and human touch.

18.8 Distribution Construction Materials

The following materials and structure are used in MV and LV distributions. Drawing for each structure in detail is provided. All the items are detailed in MV and LV distribution standards. Appendix –A

MV UNDERGROUD CABLES / ACCESSORIES

C1 MV UNDERGROUND CABLE 12/20kV, N2XS2Y, single core, copper, XLPE
T1 OUTDOOR TERMINATION KIT 20kV, XLPE insulation
T2 INDOOR TERMINATION KIT 20kV, XLPE insulation
J1 STRAIGHT JOINT KIT 20kV, XLPE insulation
C2 SHRINK CAP, XLPE insulation
J3 BRANCH JOINT KIT 20kV, XLPE insulation according to Chapter C

MV COVERED CONDUCTORS & ACCESSORIES

E1 MV COVERED CONDUCTORS
E2 ARC PROTECTION DEVICE
E3 INSULATION PIERCING CONNECTOR
E4 HELICAL (PREFORMED) TIES

LV UNDERGROUD CABLES / ACCESSORIES

C3	LV UNDERGROUND CABLE 0.6kV/1kV, NYCWY, concentric copper conductor
C4	LV UNDERGROUND CABLE 0.6kV1kV, NYY-J, three core
T3	OUTDOOR TERMINATION KIT 0.6/1kV
J2	UNDERGROUND STRAIGHT JOINT- KIT 0.6/1kV
C5	END CAP 0.6/1kV, according to Chapter D (Technical Specification)

OVERHEAD MV CONDUCTOR / ACCESSORIES

C6	ALUMINIUM CONDUCTOR STEEL REINFORCED (ACSR)
S1	COMPRESSION SPLIES, full tension for ACSR
S2	REPAIR SLEEVE, for ACSR conductors
C7	COMPRESION TAP CONNECTOR, Type H
S3	COMPRESSION STIRRUP CONNECTOR for ACSR
C8	HOT LINE CLAMP, for installation on compression stirrups

ABC LV CABLES & ACCESSORIES

C9	ABC CABLES (QUADRUPLEX) 0.6/1V, aluminum conductor
S4	SPIRAL (PIG TAIL) HOOK
N1	NUT HOOK
N2	NUT HOOK (EXTERNAL ANGLE)
C10	DEAD END CLAMP, for non-insulated neutral AAAC with cutting
C11	DEAD END CLAMP, for non-insulated neutral AAAC without cutting
C12	SUSPENSION CLAMP (UP TO 30º)
Y1	YOKE UNIVERSAL
S5	PRE-INSULATED SLEEVES
S6	COMPRESSION SLEEVES (FULL TENSION)
C13	INSULATION PIERCING CONECTOR
C14	SEALING CAP 0.6/1kV

INSULATORS & ACCESSORIES

I1	SUSPENSION INSULATOR, porcelain, ball& socket according to Chapter Q
I2	PIN TYPE INSULATOR, porcelain according to Chapter Q (Tech. Spec.)
C15	WEDGE TYPE TENSION CLAMP
C16	WEDGE TYPE TENSION CLAMP, for ACSR conductor with current loop
B4	BALL CLEVIS
N3	EYE NUT
E1	SOCKET EYE STRAIGHT
P1	POLE TOP PIN

P2 SHORT SHANK PIN
P3 OFFSET POLE TOP PIN
P4 DOUBLE ARMING PLATE

MISCELLANEOUS
A1 SURGE ARRESTER
B1 DOUBLE ARMING BOLT
B2 MACHINE BOLT
B5 BUCKLE FOR STRAPS
C17 COPPER CONDUCTOR
C18 NOT IN USE
C19 GROUND STUD CONNECTOR (SPILT BOLT)
G1 GROUND WIRE MOULDING GUARD
R1 GROUND ROD
S7 STRAP
S8 STRAPS
S9 FACADE SADLES
W1 ROUND WASHER
W2 SQUARE WASHER
W3 SPRING LOCK WASHER

GUY
A2 CONE ANCHOR, concrete
G2 GUY HOOD, ductile iron, hot dip galvanized
G3 GUY END, galvanized steel
G4 TAPERED GUY (GUARD)
N4 THIMBLEYENUT, galvanized steel
R3 THIMBLEYE ANCHOR ROD, galvanized steel
R4 TWINEYE ANCHOR ROD, galvanized steel
S12 SPLIT BOLT, copper to galvanized
W4 GUY WIRE

ASSEMBLIES

AS-01	SINGLE CROSS ARM STEEL (2000 mm)
AS-02	SINGLE CROSS ARM STEEL (3200 mm)
AS-03	DOUBLE CROSS ARM STEEL (2000 mm)
AS-04	DOUBLE CROSS ARM STEEL (3200 mm)
AS-05	SINGLE SUPPORT ON CROSS ARM (TANGENT)
AS-06	DOUBLE SUPPORT ON CROSS ARM (ANGLE)
AS-07	SINGLE SUPPORT ON TOP POLE
AS-08	DOUBLE SUPPORT ON TOP POLE

AS-09	DEAD END ON CROSS ARM
AS-10	DEAD END ON POLE
AS-11	LV-SINGLE SUPPORT
AS-12	LV-SINGLE DEADEND
AS-13	LV-SINGLE DEADEND (existing spiral hook)
AS-14	LV-DOUBLE SUPPORT (angle up to 60º)
AS-15	LV-SINGLE SUPPORT (external angle)

MV STRUCTURES

MV-301C	STRUCTURE M1, ALIGNMENT
MV-302C	STRUCTURE M2, ALIGNMENT, SMALL ANGLE
MV-303C	STRUCTURE M3, TENSION, LARGE ANGLE
MV-304C	STRUCTURE M4, TENSION, BRANCH
MV-305C	STRUCTURE M5, TENSION, DEADEND
MV-306C	STRUCTURE M6, TENSION, SHACKLE
MV-601C	STRUCTURE MM1, ALIGNMENT, DOUBLE CIRCUIT
MV-602C	STRUCTURE MM2, ALIGNMENT, SMALL ANGLE, DOUBLE CIRCUIT
MV-603C	STRUCTURE MM3, TENSION, LARGE ANGLE, DOUBLE CIRCUIT
MV-604C	STRUCTURE MM4, TENSION, BRANCH, DOUBLE CIRCUIT
MV-605C	STRUCTURE MM5, TENSION, DEADEND, DOUBLE CIRCUIT
MV-606C	STRUCTURE MM6, TENSION, SHACKLE, DOUBLE CIRCUIT
TR-01	POLE MOUNTED TRANSFORMER

LV STRUCTURES

LV-101 STRUCTURE L1, ALIGNMENT (angle 0º to 30º)

LV-102 STRUCTURE L2, TENSION, SHACKLE

LV-103 STRUCTURE L3, TENSION, BRANCH

LV-104 STRUCTURE L4, TENSION, SHACKLE & BRANCH

LV-105 STRUCTURE L5, ALIGNMENT, LARGE ANGLE (angle 30º to 60º)

LV-106 STRUCTURE L6, TENSION, RIGHT ANGLE (angle 60º to 90º)

LV-107 STRUCTURE L7, TENSION, DEAD END

TRENCHES

T-001 TRENCHES FOR DIRECT BURIAL CABLES – Low Voltage

T-002 TRENCHES FOR DIRECT BURIAL CABLES – Medium Voltage

T-003 TRENCHES FOR DIRECT BURIAL CABLES – Low & Medium Voltage

T-004 STREET CROSSING IN CONCRETE ENCASED DUCT

T-004.1 STREET CROSSING IN CONCRETE ENCASED DUCT

T-005 STREET CROSSING IN CONDUIT Special case

T-006 STREET CROSSING & SECTIONS

SWITCHING EQUIPMENT

PR-01	RECLOSER WITH BYPASS SWITCH
PR-02	RECLOSER WITHOUT BYPASS SWITCH

PR-03	LOAD BREAK SWITCH
PR-04	SINGLE SUPPORT ON CROSS ARM DISCONNECTING SWITCH
CT-1	MV CABLE TERMINATION TO OVERHEAD LINE FROM TRANSFORMER
CT-2	MV CABLE TERMINATION TO OVERHEAD LINE FROM GRID/ JUNCTION

MISCELLANEOUS

M-001 CONDUIT INSTALLATION

M-002 PAD-MOUNTED FEEDER PILLER & METER BOX

CX-01 CONCRETE TRENCH

CABLES AND CONDUCTORS

C-001 TABLE OF CABLE AND CONDUCTORS ASSIGNATION

C-002 OVERHEAD LINE DESIGN CRITERIA

C-003 WEATHER CASE

C-004 SAG TENSION CALCULATIONS – EXAMPLE

19. LOAD GROWTH SCENARIO

The mini-grid proposed and discussed here will be a definite positive and huge step in the direction of providing the people with reliable and cleaner electricity. The impacts that it will have in the lives of the generations to come will be tremendous. Even though, this mini-grid will be a huge leap in the right direction, this is not the all end of the electricity infrastructure.

As it was discovered during the course of this study, and discussed in this report, the energy produced by a 1MW Solar PV system is not enough to support all the demands and needs of the people of these villages. This is a very good starting point by setting up the infrastructure and reaching the end customer. But, this system provides about 30% of the total energy requirements. As people get more dependent on the reliable electricity they will explore other options of businesses and livelihoods and this will definitely increase the demand for more electricity.

There are multiple ways to expand the reach and impact of this mini-grid. Some of them are discussed below:

- Once the transmission and distribution infrastructure is established, more solar PV and battery energy storage system (BESS) can either be added at the same location or at a different location and tied into the existing infrastructure.
- As the loads and demands at village level increase, smaller decentralized PV+BESS systems can be added at village level and tied into the infrastructure.
- After a stable operation of the mini-grid is established and proven, it can be proposed to tie into the Utility grid. This will allow more and more such mini-grids to be established with a future prospect of interconnecting into the Utility grid. This will reduce the impact of new loads on the Utility grid and will add clean and renewable energy produced purely using solar resources.
- On the commercial front, the proposed 600KW mini-grid cannot support loads like the irrigation pumps. Either completely off-grid irrigation pumps or decentralized solar systems can be setup in order to support clusters of irrigation pumps.
- On the residential front, with the availability of electricity people will be able to use equipment like space heaters, water heaters, iron, etc. to help increase the quality and comfort of their households.

During the system design, we have assumed a relatively higher diversity factor, which slightly increases the designed system size. The system is not expected to provide excess energy and as such the system is not expected to feed the grid but the grid, when in place, will be expected to supplement the power demand within the communities. The system, as designed, will cater to a reduced power supplied to residential customers of 200 Watts per household as compared to a demanded 3.1 kW per household. The power provided to commercial customers have also been limited from demanded 849.1kW to 45.7kW. Additionally, access to residential customers has been limited to 5 pm to 9 am and to commercial customers from 9 am to 5 pm. Thus, the utility has additional 803.4kW of commercial clients as Anchor customers and additional demand by the residential customers, coupled with the potential overlap of power provided to residential, commercial and institutional customers. This by itself will require a system size more than twice the existing system size.

In addition to existing unmet demand that can be part of the demand growth potential over the coming years, we will also face a generic demand growth, which is based on population growth, refugee resettlement from Pakistan and other related factors. Since growth in power because of the beneficiaries' preference cannot be effectively quantified, we have opted to use the population growth as one indicator for the demand growth. According to world Bank's population growth data, Afghanistan's population growth rate is 2.7%, with varying averages since the 1960s. Because of the future evolution of Afghanistan's demographic and recent years' tendencies for reducing population growth, we have selected 2.5% as our estimated population growth rate. Additionally, we have assumed a demand growth of 5% on an annualized basis, which is primarily due to resettlement into the area, start of new businesses and an inherent need to require more energy as the economic condition of the population improves. There is no scientific or experiential value that the designers can use to estimate this growth as such growth are dependent on factors that are specific to the location. There is no data available for the targeted communities and as such the future demand can at best be estimated. At this level, the load growth of 7.5% per annum will be as shown in table 29.

Year	Population	Energy Consumption (kWh/yr)	Energy per capita (kWh/yr)	Growth y/y	Increase in Energy Consumption (kWh)	Estimated amount of Solar PV needed to meet the growth (kW)		
0	12,000	838,853	69.90					
1	12,900	901,767		7.5%	62,914	34.47		
2	13,868	969,399		7.5%	67,633	37.06		
3	14,908	1,042,104		7.5%	72,705	39.84		
4	16,026	1,120,262		7.5%	78,158	42.83		
5	17,228	1,204,282		7.5%	84,020	46.04	200.24	kW of PV
6	18,520	1,294,603		7.5%	90,321	49.49		
7	19,909	1,391,698		7.5%	97,095	53.20		
8	21,402	1,496,076		7.5%	104,377	57.19		
9	23,007	1,608,281		7.5%	112,206	61.48		
10	24,732	1,728,903		7.5%	120,621	66.09	287.46	kW of PV
11	26,587	1,858,570		7.5%	129,668	71.05		
12	28,581	1,997,963		7.5%	139,393	76.38		
13	30,725	2,147,810		7.5%	149,847	82.11		
14	33,029	2,308,896		7.5%	161,086	88.27		
15	35,507	2,482,063		7.5%	173,167	94.89	412.69	kW of PV
16	38,170	2,668,218		7.5%	186,155	102.00		
17	41,032	2,868,334		7.5%	200,116	109.65		
18	44,110	3,083,459		7.5%	215,125	117.88		
19	47,418	3,314,719		7.5%	231,259	126.72		
20	50,974	3,563,323		7.5%	248,604	136.22	592.47	kW of PV
21	54,797	3,830,572		7.5%	267,249	146.44		
22	58,907	4,117,865		7.5%	287,293	157.42		
23	63,325	4,426,705		7.5%	308,840	169.23		
24	68,074	4,758,707		7.5%	332,003	181.92		
25	73,180	5,115,610		7.5%	356,903	195.56	850.57	kW of PV

Table 29: Load profile growth over 25 years

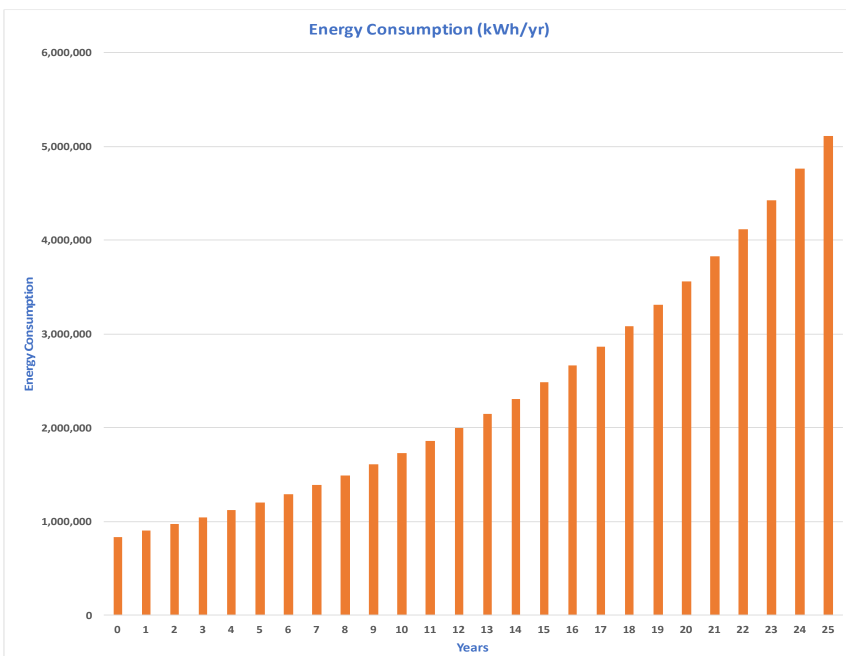


Figure 35: Load profile growth over 25 years

This indicates that after the first five years, 200 kWdc of extra generation will be needed to meet the demand. In the subsequent five years, additional 287 kWdc, 413kWdc, 592kWdc and 851 kWdc respectively will need to be added to the system to ensure that additional demand is met.

20. TARIFF COLLECTION & PAY AS YOU GO SOLUTION

20.1 Tariff Calculation

For the proposed mini-grid configuration, based on the preliminary design, the PV-system costs, reticulation system cost as well as maintenance and operation costs, component replacement costs and other associated cost factors have been taken into consideration. A basic method for calculating the tariff of a solar power project is to use a basic Levelized Cost of Energy (LCoE) approach. A simplified LCoE calculation can be made using the following formula:

$$\mathrm{LCoE} = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

Where,

t: The year of calculation, which varies for every one of the 25 years

n: The whole lifetime of the system, which is 25 years

r: Discount rate of 10%

It: Investment expenditures (CAPEX) in the year t=1,

Mt: Operational and maintenance expenditures in the year t=1 plus (under worst case scenario) additional annual set-aside is considered to cover the cost of replacement of BESS and inverters every ten years. The personnel estimated for a properly functioning system is estimated to be structured as per table below.

Ft: Fuel expenditures, has been included in the O&M cost calculation (Mt). So, Ft=0.

Et: Electricity yield in the year t=1, which translates to 1,456,089 kWh.

20.2 O&M Personnel Requirement

Description	**QTY**	**Months**	**Unit Cost**	**Annual Pay**
Personnel:				
Project Manager & Site Engineer	1	12	$700	$8,400
Admin/Finance Officer	1	12	$450	$5,400
Technicians	3	12	350	$12,600
Service Personnel	4	12	200	$9,600

Table 30: Operation and Maintenance Personnel Requirements

When considering a one-time investment in year one with no further consideration for opportunity cost in the following years, the expected tariff is calculated at US$ 0.53 (equivalent of AFA 37.20) per kWh.

However, a tariff rate of US$ 0.53 (AFA 37.20) per kWh is unreasonable and will, based on the surveyed household payment capability, provide only around 12.10 kWh of power per household per month, which is not sufficient to entice population to pay for power.

The client is willing to possibly subsidize most or all of the CAPEX related to the mini-grid. At a CAPEX of US$0, the LCoE is calculated to be US$0.14 per kWh or equivalent of AFA 9.83 per kWh.

The project owner is, furthermore, evaluating the possibility of subsidizing the cost of replacement of the BESS and the inverter system every ten-years (worst-case scenario), which allows the tariff to further reduce to US$ 0.07 (AFA 5.17) per kWh.

Additionally, it is normal to have a tiered tariff system, charging residential customers a fixed rate and marking up the power to institutional and commercial customers. The utility would be well-advised to initiate such a tiered tariff system.

20.3 General Framework of Pay as You Go (PAYG) Requirement

The typical O&M constraint in rural electrification systems is focused on collection of tariffs and with it, recovering of the investment and financing the operation and maintenance costs of the system.

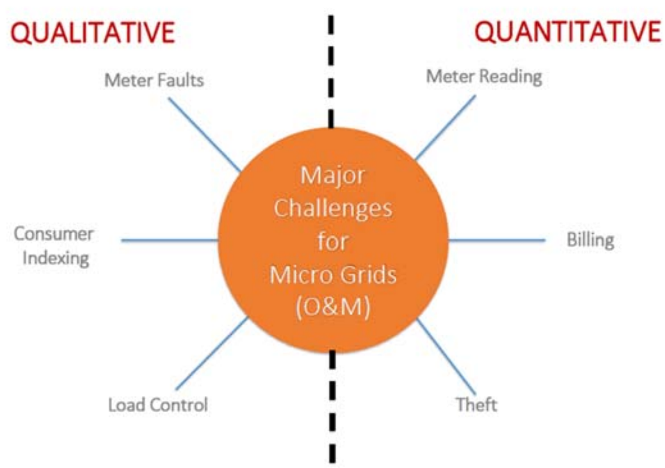


Figure 36: Micro Grid Major Challenges

On the qualitative side, where reliability of the grid becomes a significant consideration, load control, consumer indexing and meter faults are critical.

Load control can make the difference between system overloads and system reliability. The system stipulates that every residential customer will receive about 200 Watts of power up to a total energy consumption of around 1kWh from 5 pm to 9 am. Commercial customers receive power as per their need from 9 am to 5 pm, while institutional customers receive 24 hours of power as needed. The metering system must be able to regulate these variabilities and ensure that the demand side behavior can be effectively controlled and managed, thus minimizing risk of system overload.

Customer indexing help to develop a good understanding of the number of customers is always known, and transformer load analysis can be effectively done before giving new connections, power leakages on the grid is detected in a timely manner and is effectively addressed. Furthermore, customer indexing ensures that consumer mapping data is accurate and that wrong feeder/transformer is not mapped to the wrong meter.
Smart meters, provide integrated, low cost solutions to intelligently manage and organize power distribution throughout a mini-grid.

Meter faults can be avoided by installing reliable digital meters that eliminate incorrect usage/billing, avoids incorrect low line voltage operation and protects against general unreliability of the meter as a whole.

On the quantitative side, where revenue is lost due to incorrect billing, theft of power, inaccurate meter reading and other losses, the reliability and effective use of a sound metering system will avoid lost revenue and ensure a sustainable mini-grid.

Smart meters enable prepaid and postpaid payments for electricity consumption. Wireless, real time, prepaid payment system using cell phones allows consumers to make payments at their doorsteps or in the neighborhood store and monitor their energy consumption. Complete billing system is online and can be changed at any time without replacing meter.

Smart meters enable use of variable pricing, so that the price of power on the meter can be changed depending on demand, time of day, type of customers or even source of generation.

Smart meters also help to minimize theft and facilitate fault detection through the intelligent wireless network formed by the meters, which informs the grid operator of the location of power theft, faults or overload on the distribution lines.

Smart meters automatically shut off when any consumer crosses their load limit. Domestic, agricultural, and commercial consumers can be provided meters with different limits. Online remote monitoring technology allows real time control and monitoring of every meter on the grid.

All meters communicate over RF mesh networks. The wireless network is controlled by a Data Concentrator. The Data Concentrator is intelligently managed by the associated provider operated cloud servers.

The Smart Metering System as recommended in this document includes the Pay-As You-Go (PAYG) system, handheld point of sale systems, etc. Discussions with wireless phone companies will be initiated by the Contractor to ensure that adequate Internet connectivity and networks are provided to facilitate the operation of the system.

20.4 Codes and Standards

Meters must comply with applicable international standards, including:

- IEC 62052-11 standard in combination with IEC 62053-11, 62053-21, 62053-22 and 62053-23 as well as to the European (MID harmonized) standards EN50470-1, EN50470-2 and EN50470-3 and other relevant standards.
- The compliance to these standards must have been done by independent laboratories that have been accredited to ISO 17020/17025. The relevant tests include: mechanical requirements, insulation properties, accuracy requirements, influence quantities, electrical requirements, electromagnetic compatibility, and the effect of climatic environments.
- Other standards may also apply.

Prepayment System must comply with STS standards. The Standard Transfer Specification (“STS”) has become recognized as the only globally accepted open standard for prepayment systems. It is a secure message system ensuring the appropriate encryption key management for protecting the security of prepayment transactions of utilities. STS is centered on the information transferred between a point-of-sale and a pre-payment meter - this includes the manner in which the vending station encodes the token with the information, and the way in which the meter interprets the information. STS provides the facility of generating (e.g. credit transfer) tokens which can only be used by the intended meter, and furthermore in the case of credit tokens, can only be used once in that meter.

The servers and related IT infrastructure must be equipped with accreditations such as VeriSign or equivalent that provide necessary security measures such as firewalls and other VeriSign security measures to prevent unauthorized network access from outside the MDM environment. A changing entrance key prevents automatic “key” generation machines to break into the system.

20.5 Pre-Paid Meter

Split-type compact DIN-Rail mounted Class 1 accuracy single phase electricity meter built in 35mm (or equivalent) international standard housing made of poly-carbonate flame retardant material. The meter adopts Power Line Carrier (PLC) communication between the meter and keypad. Double circuit measurement and relay are also available on request for reinforced tamper prevention.

Refer to technical specifications for detailed specs for metering system.

20.6 Hand-Held Point of Sale Device

The hand-held portable, standalone POS device shall be designed for use over cellular communication networks for the selling of credit for prepayment meters. The device provides on-line vending via the utility's MDMS. PCPOS5000S enables a utility to set up flexible vending points that are fully mobile, cost-effective and automatic communications with the central Utility Vending Database. The unit shall comprise of an external power supply, internal Rechargeable battery, integrated modem, thermal printer for printing the STS token number, swipe card reader, and is designed for stationary use.
FEATURES

- 128*64 LCD Display, 24 keys, menu operation interface, easy operation
- Platen removal mechanism, easy loading paper and maintenance
- Prints SMS message
- Standalone device, no need to connect to PC
- Keeps 50 SMSs in memory
- Sends SMS if required
- Generates calls (hands free)
- Paper: Thermal paper roll, 58mm /2inch wide
- Effective printing area: 48mm
- Character: 12*24 dots
- Number of columns: 32 columns/line
- Printing Head Life: Paper traveling distance 50KM

Refer to technical specifications for detailed specs for hand held point sale device system.

21. OPERATION AND MAINTENANCE PLAN

A utility scale PV system is always faced with different types of maintenance and operation issues. Some key products and system related O&M issues are as follows:

21.1 Critical O&M Issues for PV Power Plant

The contractor will be required to develop a detailed maintenance and operational schedule, which will be approved by the Engineer. The schedule will be based on the actual make and model of panels, inverters and other associated components. The manufacturer recommended O&M schedule will be incorporated into their plan and then approved by the Engineer. The Engineer will also develop a detailed O&M contract, which will be signed with the contractor shortly before the testing and commissioning of the system, and will address all critical issues related to the O&M activities.

The following sub-sections will describe some critical O&M related issues that the contractor will need to address in their O&M plan:

21.1.1 Panel cracking

Different components of PV solar plant may fail during the operation. First, panels might crack, even in the new once, if they have been damaged in the manufacturing process. The micro-cracks are not always obvious, and that’s why the new panels must be inspected and a warranty must be secured. The cracks may lead to the failure of panels or losses of optimal efficiency.

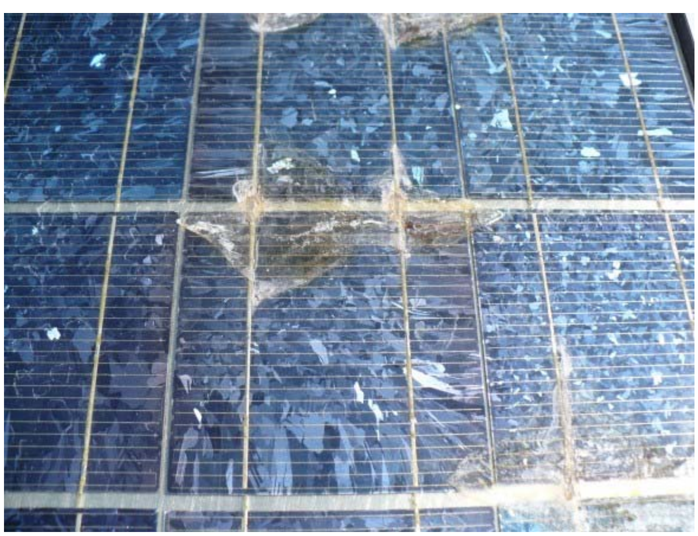


Figure 37: Panel failure due to cracking

21.1.2 Visual discoloration

Visual discoloration is another common defect that reduces the amount of sunlight that penetrates into a solar cell. As a result, solar cells are less exposed to solar irradiation, and generate less energy. The reason it leads to loss of efficiency is because different color panels changes the wavelength of light that can be absorbed. As in the case with panel cracking, not much can be done once the panel became discolored, hence the solar panels must be carefully operated and maintained.

21.1.3 Hotspots

Contrary to the common misleading opinion, solar panels are most efficient when they gain maximum solar irradiance, not maximum temperature. Quite the contrary, high temperatures can actually damage solar panels, leading to the emergence of the hot spots. Hot spots occur when a panel is shaded, damaged, or electrically mismatched and decrease power output. Since solar cells are attached in strings, just one hot spot can lead to multiple cells functioning poorly. To solve this problem, all shading should be negated, and electrical connections should be optimized.

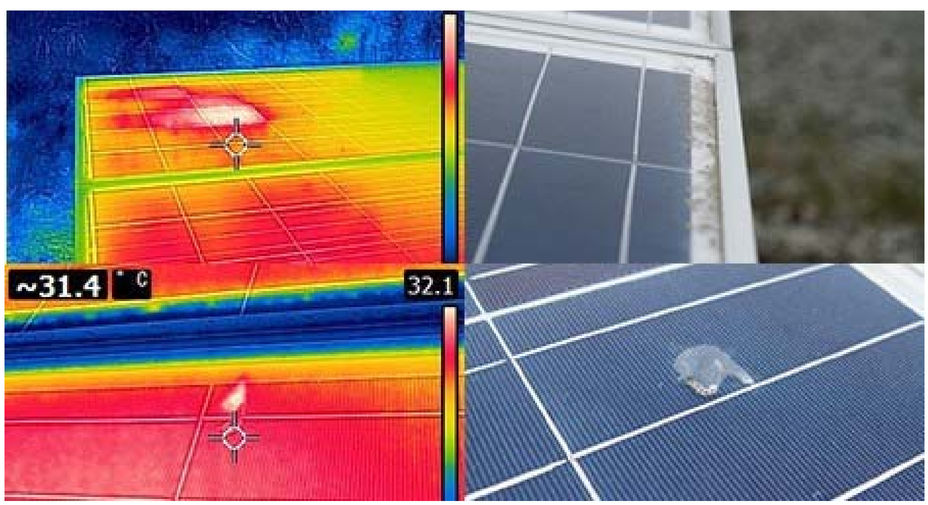


Figure 38: PV Hotpots

21.1.4 Inverters failure

Generally, inverter faults are the most common cause of system downtime in PV power plants. Therefore, the scheduled maintenance of inverters should be treated as a centrally important part of the O&M strategy.

21.1.5 Trackers and Panel Orientation

Panel orientation is an issue for static PV solar systems. It requires due diligence on the consumer’s part to make sure the installer is taking the proper steps necessary to determine an ideal panel orientation. Similarly, tracking systems also require maintenance checks. These checks will be outlined in the manufacturer’s documentation and defined within the warranty conditions. In general, the checks will include inspection for wear and tear on the moving parts, servicing of the motors or actuators, checks on the integrity of the control and power cables, servicing of the gearboxes and ensuring that the levels of lubricating fluids are appropriate. The alignment and positioning of the tracking system should also be checked to ensure that it is functioning optimally. Sensors and controllers should be checked periodically for calibration and alignment.

21.1.6 Structural Integrity

The module mounting assembly, cable conduits and any other structures built for the solar PV power plant should be checked periodically for mechanical integrity and signs of corrosion. This will include an inspection of support structure foundations for evidence of erosion from water run-off.

21.1.7 Weather Conditions (snow, wind, soiling)

Finally, depending on the environmental conditions, the panels must be protected from wind, snow, and soiling (in dusty areas). Regular cleaning and maintenance will be enough in these cases. Solar DAO uses durable crystalline silicon panels that are built of lead-free, optically transparent, anti-reflective glass, which can withstand the tested shot of an ice ball with 35mm diameter at a speed of 30 m/s. Their serviceable life is up to 25 years, with 10 years of guaranteed performance.

Figure 39: Effects of weather condition

21.1.8 Other Issues

Other common unscheduled maintenance requirements include but are not limited to:

- Tightening cable connections that have loosened.
- Replacing blown fuses.
- Repairing lightning damage.
- Repairing equipment damaged by intruders or during module cleaning.
- Rectifying SCADA faults.
- Repairing mounting structure faults.
- Rectifying tracking system faults.

21.2 Maintenance Checklist for Electrical Distribution Systems:

21.2.1 Intrusive LV Switchboards

❒ Check function of all power meters before shutdown.
❒ Check function of lamps and indicators.
❒ Inspect locking devices for signs damage or worn.
❒ Clean thoroughly, vacuum and full visual inspection of exterior and interior of all LV switchboards.
❒ Inspect control wiring, relays, power supply units, timers, etc. where applicable.
❒ Check electronic surge protection is intact where installed.
❒ Verify control circuit fuse rating and continuity.
❒ Check and torque test bolted electrical connections as necessary to specified levels.
❒ ACB maintenance withdrawable or fixed, check contacts, arc chutes secondary injection, etc.
❒ Visual inspection for signs of overheating or deterioration.
❒ Final visual inspection to insure all clear after work completed.
❒ Inspection of all panels for paint work damage and signs of corrosion.
❒ Check battery tripping packs, battery integrity, signs of defects, etc.

21.2.2 Non-Intrusive LV Switchboards

Note: These maintenance procedures require no shutdowns.

❒ Check function of all power meters before shutdown.
❒ Check function of lamps and indicators.
❒ Inspect locking devices for signs damage or worn.
❒ Clean thoroughly, vacuum and full visual inspection of exterior only.

❒ Visual inspections of control wiring, relays, power supply units, timers and fuse carriers.
❒ Check electronic surge protection is intact where installed.
❒ Visual inspection for signs of overheating or deterioration.
❒ Inspection of all panels for paint work damage and signs of corrosion.
❒ Check battery tripping, battery integrity, signs of defects.

21.2.3 ACB Chassis

❒ Rack out ACB.
❒ Clean/ vacuum internal chassis.
❒ Check operation of safety shutters closing.
❒ Check shutter locking devices are intact.
❒ Check operation and position of contacts.
❒ Operate padlocking system.
❒ Grease clusters as necessary.

21.2.4 ACB's

❒ Check general condition of the device.
❒ Clean with diluents Henkel 273471, vacuum ACB.
❒ Check filters clean/vacuum arc-chutes.
❒ Visual check for contact wear.
❒ Check auxiliary wiring insulation.
❒ Check ACB locking devices.
❒ Open/close manually.
❒ Charge the device manually.
❒ Secondary injection with FFT Kit, produce trip curve report.
❒ Check earth fault protection/earth leakage protection.
❒ Grease disconnect contacts as necessary.
❒ MCCB trip test with report.

21.2.5 Busbar & Accessories

❒ Visual inspection all Power bar runs
❒ Check supports
❒ Check alignment, straight runs, joint packs and directional change pieces
❒ Check panel flanges, earth continuity etc.
❒ Thermal image survey of complete runs

21.2.6 Meters

❒ Voltage connections
❒ CT connections
❒ Modbus connections

21.2.7 MCCB checks

❒ Motor operator
❒ Under voltage release
❒ Power supply unit
❒ Control relays
❒ Fuse and fuse holders

21.2.8 PDU

❒ Clean thoroughly exterior and interior PDU switchboards
❒ Check function of all power meters
❒ Verify control circuit fuse rating and continuity
❒ Check function of lamps and indicators
❒ Check and torque test bolted electrical connections as necessary to specified levels
❒ Check all cable connections for tightness and torque terminals
❒ Visual inspection for signs of overheating or deterioration
❒ Inspection of all panels for paint work damage and signs of corrosion
❒ Inspection to insure all clear after work completed before fitting covers
❒ All labeled secure in place

21.2.9 Thermal Imaging Surveys

Thermal imaging is becoming more common within preventive maintenance programs to help detect excess heat in electrical components. It can be carried out while the system is under a full load with no impact to operations.

Thermal imaging technology can detect loose connections, corroded elements, short circuits, overloaded circuits and busway-joint analysis. This non-invasive technique also allows to gather data from a remote location, away from potentially dangerous situations.

21.3 O&M Approaches and Activities

Maintenance can be broken down in two parts:

- **Scheduled maintenance:** Planned in advance and aimed at fault prevention, as well as ensuring that the plant is operated at its optimum level.
- **Unscheduled maintenance:** Carried out in response to failures.

Another way to classify the PV O&M approaches is to break them down into three categories, each with different cost-benefit tradeoffs and risk profiles:

- **Preventative maintenance (PM)** encompasses routine inspection and servicing of equipment — at frequencies determined by equipment type, environmental conditions, and warranty terms in an O&M services agreement — to prevent breakdowns and unnecessary production losses. This approach is becoming increasingly popular because of its perceived ability to lower the probability of unplanned PV system downtime. However, the upfront costs associated with PM programs are moderate and the underlying structure of PM can engender superfluous labor activity if not optimally designed.

- **Corrective or reactive maintenance** addresses equipment repair needs and breakdowns after their occurrence and, as such, is instituted to mitigate unplanned downtime. The historical industry standard, this "break-fi x" method allows for low upfront costs, but also brings with it a higher risk of component failure and accompanying higher costs on the backend (perhaps placing a premium on negotiating extended warranty terms). Though a certain amount of reactive maintenance will likely be necessary over the course of a plant's 20-year lifetime, it can be lessened through more proactive PM and condition-based maintenance (CBM) strategies.

- **Condition-based maintenance (CBM)** uses real-time data to anticipate failures and prioritize maintenance activities and resources. A rising number of third party integrators and turnkey providers are instituting CBM regimes to offer greater O&M efficiency. The increased efficiency, however, comes with a high upfront price tag given communication and monitoring software and hardware requirements. Moreover, the relative novelty of CBM can produce maintenance process challenges caused in part by monitoring equipment malfunction and/or erratic data collection.

Preventative Maintenance (PM) includes the following activities:

- Panel Cleaning

- Water Drainage
- Vegetation Management
- Retro-Commissioning (identifies and solves problems that have developed during the course of the PV system's life.)
- Wildlife Prevention
- Upkeep of Data Acquisition and Monitoring Systems (e.g., electronics, sensors)
- Upkeep of Power Generation System (e.g., Inverter Servicing, BOS Inspection, Tracker Maintenance)
- Site maintenance (e.g., security, road/fence repair, environmental compliance, snow removal, etc.).

Corrective/Reactive Maintenance typically includes:

- On-Site Monitoring
- Non-Critical Reactive Repair (addresses production degradation issues)
- Critical Reactive Repair (high priority, addresses production losses issues)
- Warranty Enforcement

Condition-Based Maintenance (CBM) usually consists in Active Monitoring — Remote and On-Site Options Equipment Replacement (Planned and Unplanned) and Warranty Enforcement (Planned and Unplanned).

21.4 Contracts & Obligations

21.4.1 Key Contractual Provisions (KCP)

KCPs in O&M contracts impact the O&M budgeting considerations and approaches, and typically include:

- **Service-level agreements (SLA)** — specify compliance timeframes for responding to and resolving a range of plant conditions, based on equipment type and issue severity level.
- **Availability or "uptime" guarantees** — define the percentage of time that a system must be fully able to produce electricity. Availability guarantees are typically set at 97–99% per year.
- **Performance ratio and yield guarantees** — stipulate plant performance levels (e.g., a minimum amount of energy delivered) according to measured solar irradiation at a site, based on system design and modeled plant behavior — which can be variable, thus introducing risks. These guarantees account for Force Majeure events and warranty defects.

- **Production guarantees** — state annual plant production levels, independent of weather conditions. Insurance coverage can be used to mitigate weather risk, though it can be an expensive policy to underwrite.
- **Performance incentives** — reward/penalize for plant performance that misses, meets, or exceeds projected production levels.
- **Energy-based contracts** — links plant production (kWh/yr) with O&M service provider revenues so that associated expenses are calibrated according to low (fall/winter) and high (spring/summer) revenue periods.

21.4.2 O&M Contract Contents

The purpose of an O&M contract is to optimize the performance of the plant within established cost parameters. To do this effectively, the O&M contract should clearly set out:

- Services to be carried out by, and obligations of, the contractor.
- Frequency of the services.
- Obligations of the owner.
- Standards, legislation and guidelines with which the contractor must comply.
- Payment structure.
- Performance guarantees and operational targets.
- Methodologies for calculating plant availability and/or performance ratio.
- Methodologies for calculating liquidated damages/ bonus payments in the event of plant under- or over-performance.
- Terms and conditions.
- Legal aspects.
- Insurance requirements and responsibilities.

21.4.3 O&M Contractor Services and Obligations

The O&M contract should list the services to be performed by the contractor, including the following entries:

- Plant monitoring requirements.
- Scheduled maintenance requirements.
- Unscheduled maintenance requirements.
- Agreed targets and/or guarantees (for example, response time or system availability figure) Reporting requirements (including performance, environmental, health and safety, and labor relations reporting).

- The contractor should also be contractually obliged to optimize plant performance. Additionally, it should be stipulated that all maintenance tasks should be performed in such a way that their impact on the productivity of the system is minimized.

21.4.4 O&M Terms of the Contract

The O&M contract will also typically define the terms by which the contractor is to:

- Provide, at intervals, a visual check of the system for visible damage and defects.
- Provide, at intervals, a functional test of the system components.
- Ensure that the required maintenance will be conducted on all components of the system. As a minimum, these activities should be in line with manufacturer recommendations and the conditions of the equipment warranties.
- Provide appropriate cleaning of the modules and the removal of snow (site-specific).
- Make sure that the natural environment of the system is maintained to avoid shading and aid maintenance activities.
- Replace defective system components whose failure is deemed imminent.
- Provide daily (typically during business hours) remote monitoring of the performance of the PV plant to identify when performance drops below set trigger levels.

In an O&M contract, the obligations of the owner/ developer are generally limited to granting the O&M contractor access to the system and all the associated land and access points, obtaining all approvals, licenses and permits necessary for the legal operation of the plant providing the O&M contractor with all relevant documents and information, such as those detailed above, that are necessary for the operational management of the plant.

The cost factors that will be included in the O&M activities are estimated to consist of the following:

- Personnel cost, consisting of
    - One project Manager/site engineer
    - One Admin/Finance Officer
    - Three technicians
    - Four Service personnel
    - Guards and other personnel
- Operational costs include:
    - Fuel for generator based on calculated LoLP
    - Fuel for diesel generators on cloudy days, estimated for 60 days per year
    - Diesel Generator repair and maintenance costs
    - Spare parts for PV Plant and reticulation system.

21.5 Quad Pod Jack for Tilt Angle Adjustment User Manual

This manual describes the operation of this unit. Please read this manual carefully before operations. This manual provides safety and as well as information on operation.

21.5.1 Safety Instructions

1. Before using the unit, read all instructions, the brace channel and all appropriate sections of this manual.
2. To reduce risk of injury, use an assistant while lifting up the unit because of its heavy weight.
3. Do not disassemble the unit. Take it to a qualified service center when service or repair is required.
4. Please strictly follow operation procedure when you want to mount and dismount the quad pod jack from the PV frame.
5. Warning!! Only qualified service persons are able to service this unit. If malfunction occurred, please send this unit back to local dealer or service center for maintenance.

21.5.2 Introductions

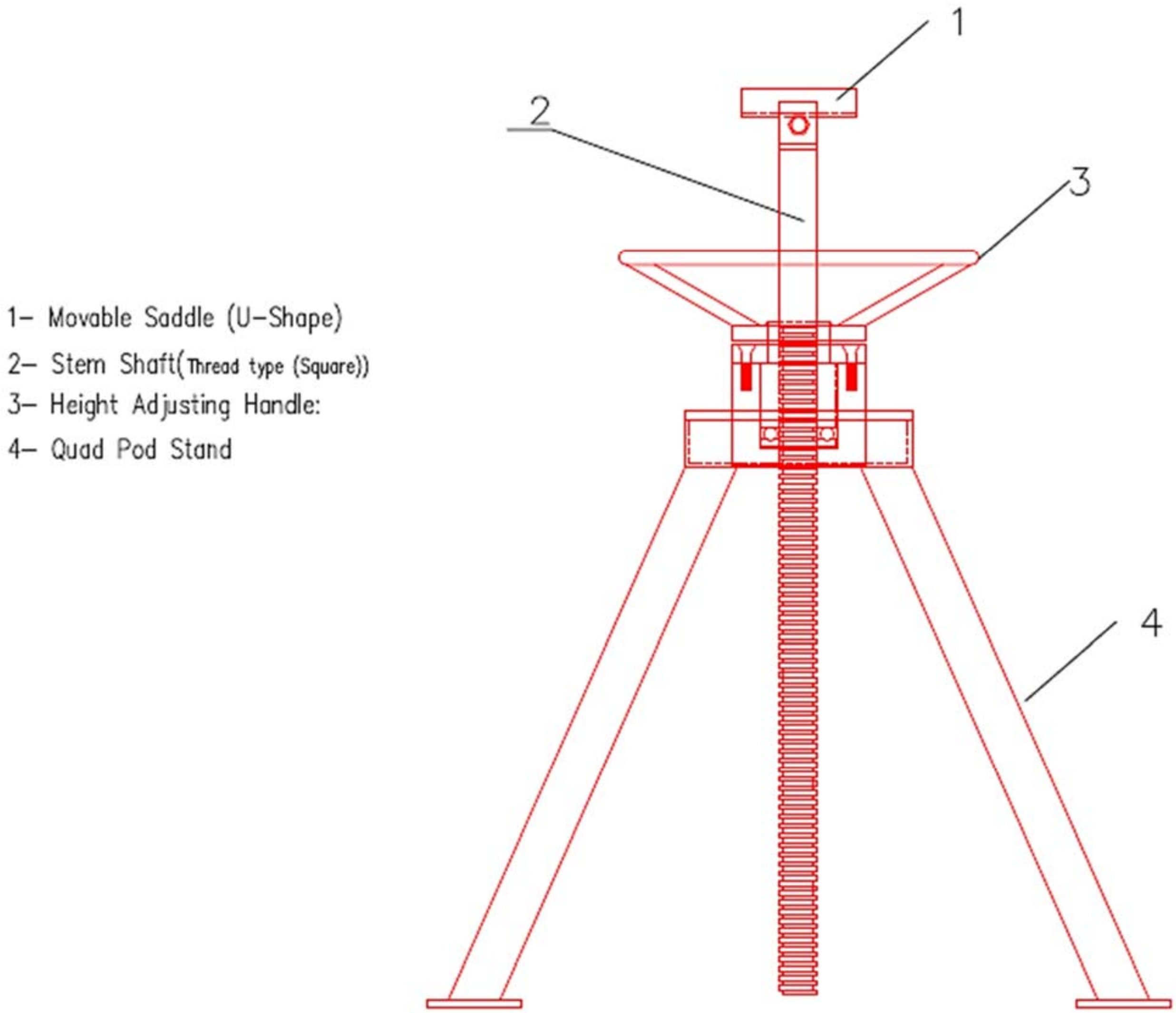
This is a quad pod jack for the adjustment of the PV support structure tilt angles for 7°, 12°, 30°, 35° and 40°. Its movable jack and adjustable brace chamber allows a user to change angles in the most reliable way possible.

Features

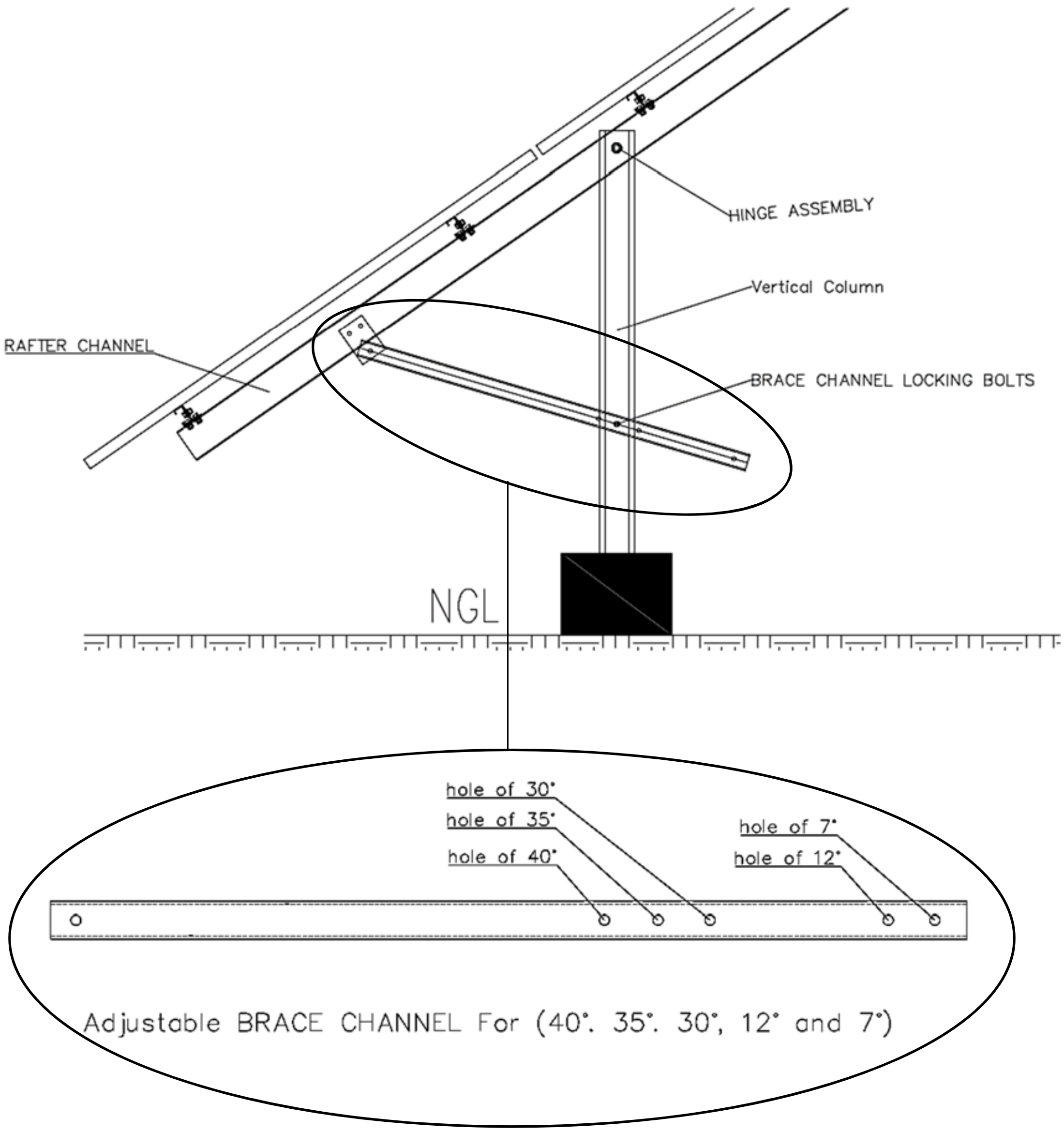
- Adjustable brace channel
- Portable quad pad jack
- Easy to use
- Easy to maintain
- Accessible by a minimum of one operator
- Cost effective device for manual tracking

21.5.3 Product Overview

1. **Quad Pad Jack**



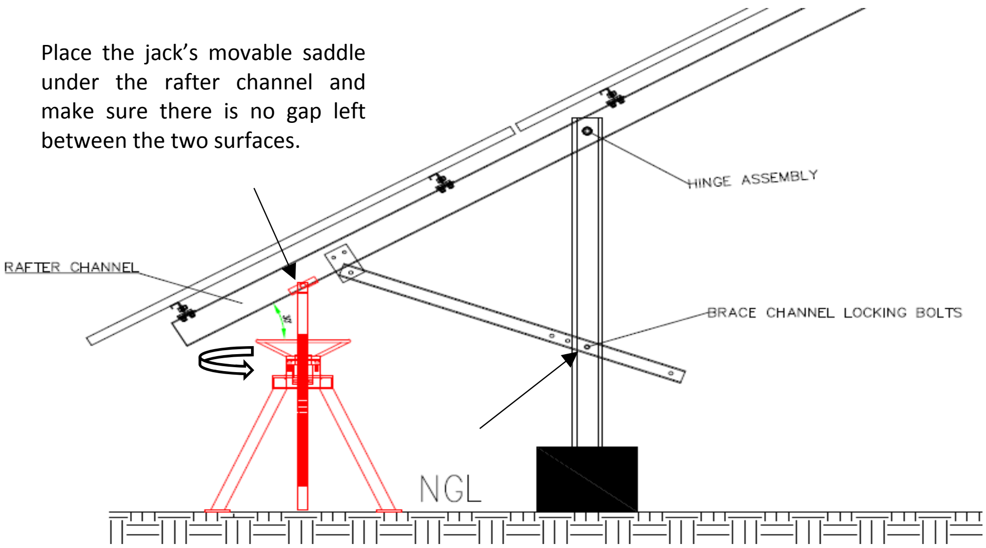
2. **Adjustable Tilt Angle Mechanism**



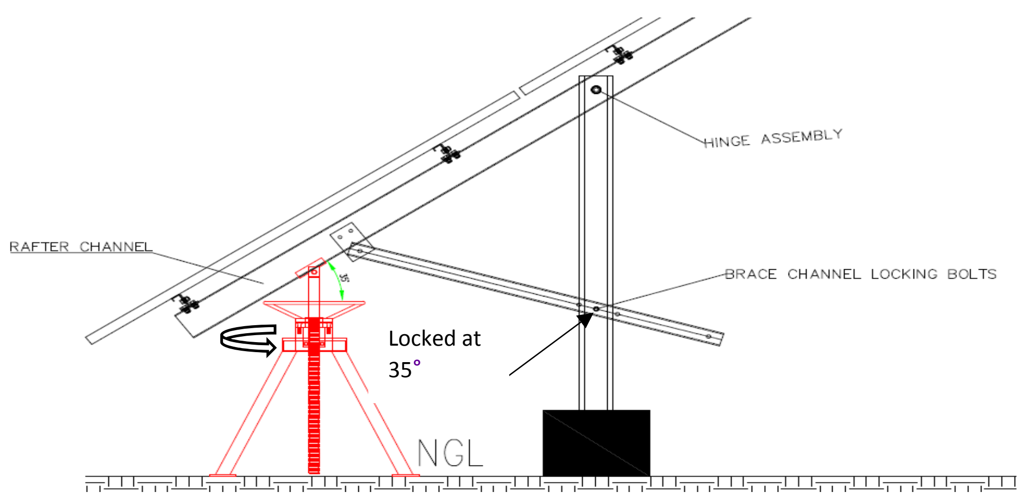
21.5.4 Quad Pad Jack Operation

Changing the Angle

The following illustration shows basic operation for changing the tilt angles. As described above the support structure has the ability to change its tilt angel from a different range of degrees. The illustrated figure shows the tilt angle changed from 30° to 35° tilt.



1. As shown above the brace channel is locked at the 30°, in-order to adjust the tilt to 35° place the quad pad jack under the rafter channel as illustrated in the above figure.
2. After placing the jack's movable saddle firmly under the rafter channel, start undoing the nut and bolt which holds the brace channel at 30°.
3. The brace channel is fixed with a pin at the top end with the rafter channel as shown in the figure, now check for any jams and see if the brace channel moves freely along its own axis.
4. As show in the figure, turn the jack's wheel anti clock wise this will allow the shaft along with the rafter to move downwards. While turning the wheel, with the aid of the second operator (it can be fully operated with a single person, but for a quicker operation two persons are recommended) check if the brace channel's bolt hole for 35° is in position for locking and at this point stop turning the wheel.
5. Once, at the position for locking please tie up the nut and bolt before removing the jack.
6. After the bolt is locked remove the jack and to avoid any jams turn the wheel even further so the shaft is not in contact with the rafter anymore.



22. ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT

During the assessment, a detailed social and environmental assessment of the site and associated reticulation path was carried out in all cluster villages. The assessment established that no social, community, institutional or political structures of the area are negatively impacted by the project. At the same time, the individual and family structures are not negatively impacted by the project. Similarly, community resources such as common spaces, gathering areas, and other similar resources are not negatively impacted. As a matter of fact, the arrival of electricity in the communities, such resources are expected to be enhanced and to better serve the population of the area.

22.1 Noise Pollution

The project is expected to be completed without any significant noise during the construction phase and even less so post construction and during normal operations. However, a back-up generator system will be installed that will operate during prolonged cloudy days and where necessary. These generators will cause some noise pollution. However, they will be installed in a closed space and will be away from residential and commercial neighborhoods close to the main street and surrounded by agricultural land. Hence the effect of the noise on the villages will be minimum. The pollution as affected by the diesel generator fumes is also minimum, taking into consideration the fact that there are not many other sources of pollution in the area. The minimum pollution is also offset by the great benefit of the system to the population and the prosperity of the communities.

22.2 Impact on Water and Air

There will be no negative impact on the quantity and quality of surface or sub-surface water or the soil. Solar power is an environmentally sound technology that uses the abundance of natural sun light to produce electricity. However, where diesel generators will be installed some impact will be noticeable on air. This impact will be minimal, as the generators will operate only during scarce multiple cloudy days and as needed.

22.3 Impact on Forests and Trees

At the project site and throughout the reticulation path, there are no forests, no orchards that will, in any shape or form, be negatively impacted by the project. No trees have to be removed to clear path for the reticulation system, even though some trees branches will need to be clipped to facilitate the passing of the overhead power cables. In addition to that, the designated solar power plant site contains some small saplings that will need to be removed. This impact will be insignificant. Otherwise, no damage will be caused to any natural resources.

22.4 Impact on Agriculture, Flora & Fauna

The cluster of villages that build the project site is mostly agricultural land. Except for the actual site of the solar power plant, which requires that rain-fed agricultural land be de-scoped to an industrial land, there will be no impact on the agricultural land in the cluster of villages. The flora and fauna will not be negatively impacted and grazing land, which is not part of the geography of the cluster villages, will also not be impacted.

22.5 Impact on Historic Heritage

The project site and the surrounding areas, including the reticulation path do not have any historic heritage, archaeological sites or other similar sites. Therefore, there is no impact on these facilities. Access to electricity will enable the population to have ready access to mass media, which in turn enhances the level of awareness of the population towards many aspects of life, including the preservation of cultural heritage and historic structures.

22.6 Impact on Wildlife & Protected Wildlife

The township and neighboring communities, where the project site and the reticulation path are located do not impact any wildlife in any way possible. Protected wildlife is not prevalent on the project site and are therefore not affected by the project.

22.7 Impact on Irrigation Systems

The irrigation system will not be affected by the project, as there are no irrigation channels at the site of the solar power plant. The reticulation path may cross some irrigation channels but do not affect their operation. The only impact on agricultural land will be through de-scoping of 10 jeribs of land from agricultural land to industrial land and the effective construction of the solar power plant. Other than that, the project can only have a positive impact on irrigation systems, by enabling the use of electric powered irrigation pumps to increase the quantity of irrigated land.

22.8 Social Impact

The project may demonstrate some negative impact on the social fabric of the target community, especially as it relates to the neighboring communities. Some of the neighboring communities are located fairly close to the project site, yet they will not have access to the power from the project. This may create resentment against the population of the target villages and may have some negative impact on the social fabric of the area.

As a whole, the project has a net positive impact on the social, natural resources and environmental condition of the target area or at a minimum no negative impacts at all.

ANNEX II – C: THE DETAILED PROJECT REPORT OF THE 1000 KW SOLAR MINIGRID IN KANDAHAR PROVINCE

Detailed Project Report

Design of 1 MW Solar Powered Utility, including Reticulation System for Panjwayee District of Kandahar Province, Afghanistan

August 14th, 2018

Contract #: UNDP/AFG/PS/2018/xxxx

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1. EXECUTIVE SUMMARY

Kandahar province lies about 500 km to the south-west of Kabul and is connected through the Kabul-Herat highway running through Maidan-Wardak, Ghazni and Zabul provinces. Kandahar City is the capital of the province. The project is located in Panjwayee district of Kandahar, which is located about 40 km to the west of Kandahar city. The project site is located at the district center of Panjwayee, which is a small township with neighborhoods and suburbs. The 25 villages/neighborhoods that are part of the project scope are in reality mostly neighborhoods of the city plus some suburban communities. The 25 target communities had previously been organized in 15 Shuras or community development councils. However, these Shuras had been canceled and replacement Shuras had not been established at the time of this assessment. As a result, the assessment team had to put together an ad-hoc team of village elders and insiders to collect the data needed to design this project.

Even though household data has been collected for the 25 communities, commercial and institutional data could not be separated based on villages/neighborhoods as nearly 95% of the commercial institutions are located within one cluster of the commercial district that stretches across multiple neighborhoods. Small mosques are located in almost every community and they have been listed as such.

The population is mostly engaged in agriculture and horticulture but significant commercial activities such as tailoring, flour milling, bicycle and motorcycle repair shops, machine shops, mechanical shops, cosmetic shops, grocery shops and other commercial activities also engage the population. Altogether 516 commercial entities are in operation and their numbers are growing. The target area has two hospitals, two schools, one main police station and 10 police posts, and one main mosque and 67 community mosques, in addition to a district office and a municipal building. About 96% of the households have a single solar panel plus a battery backup to meet their basic need for lighting and phone charging. The average size of a household is about twelve persons, even though some households have as many as 18 members, which signals that multiple households possibly reside within one Qala (housing compound). The target area is not connected to the grid power, even though a 20 KV power line passes about 4 kilometers north of the site of the planned solar power plant and a 110kV grid, which is part of the South Electric Power Systems (SEPS) is expected to pass within two kilometers of the site.

The households in the target area are classified under tier 0 and tier 1 of the World Bank's Multi-Tier Framework. About 5% of the households are classified under tier 0 and have no access to reliable energy and are forced to solely depend on fossil fuels such as firewood, kerosene, propane gas and the like to meet their energy needs. About 95% of the households are classified under tier 1 and have access to a solar panel (less than 100 Watts) and a battery unit, which provides lighting for about four hours during the night time. The energy demand is, therefore, fairly significant and the desire to benefit from other aspects of an electrified dwelling is highly desired.

The overall system size installed in Kandahar is expected to be 1,000 kW solar, with 3.5 MWh of Battery Energy Storage System (BESS) and two diesel generators sets of 450kW and 75kW. Thereby, the 450kW diesel generator will cater to peak demand, while the 75kW diesel generator will ensure continuous power late at night when the BESS has reached its discharge limit and there is no solar radiation to provide power to the customers.

While the residential customers demanded about 1.1 kW power on a 24-hour basis, the project is able to provide only 195 Watts per household from 5 pm until 9 am. All commercial customers, with the exception of irrigation pumps, flour mills and other users with greater than 5kW consumption, who receive no solar power from the utility, receive power as per their need but from 9 am to 5 pm only. Institutional customers receive power as needed on a 24-hour basis.

The solar power plant produces 400 Volt power, which is stepped up with a 750kVA transformer to 20kV, which is then transmitted via overhead lines to the target communities. Altogether 8 transformers will then step down the power and provide electricity to the villagers as well as commercial and institutional customer through about 300 meter boxes, which equipped with 6 to 9 meters. Prepaid metering system with associated components are installed.

The contractor is expected to use existing 100% design documents to construction, install, test, commission, operate and maintain (for 12 months) the utility and collect power fees based on set tariffs.

2. INTRODUCTION

ASERD is a UNDP supported National Afghan Program that supports the Ministry of Rural Rehabilitation and Development (MRRD) to implement rural renewable energy projects. The program design is based on four pillars.

1. Rural energy services: implement renewable energy projects such as mini-grids powered by small hydro power, solar, wind and thermal energy. In electrified villages opportunities will be provided for local business developers, entrepreneurs and SMEs to take advantage of the availability of power.
2. Capacity building and outreach: the energy projects in rural area will also work closely with local MRRD staff and other government entities in order to improve their capacity.
3. Innovative models: the program will seek to use and introduce new delivery models to Afghanistan, ranging from technology choice to financial tools.
4. Rural Energy policy and Regulation: the program will closely coordinate with stakeholders, especially the Ministry of Energy and Water (MEW) in terms of addressing policy and regulation gaps.

UNDP is the owner of the project and will provide the required funding under its Afghanistan Sustainable Energy for Rural Development (ASERD) program.

MRRD
The Ministry of Rural Rehabilitation and Development (MRRD) as the implementing Agency will implement the project.

UNPD Consultant
An entity or individual who will act on behalf UNDP and or MRRD as an owner’s engineer for execution of this contract.

3. GENERAL INFORMATION

Kandahar province lies about 500 km to the south-west of Kabul and is connected through the Kabul-Herat highway running through Maidan-Wardak, Ghazni and Zabul provinces. Kandahar City is the capital of the province. The project is located in Panjwayee district of Kandahar, which is located about 40 km to the west of Kandahar city. The project site is located at the district center of Panjwayee, which is a small township with neighborhoods and suburbs. The 25 villages/neighborhoods that are part of the project scope are in reality mostly neighborhoods of the city plus some suburban communities. The 25 target communities had previously been organized in 15 Shuras or community development councils.

Even though household data has been collected for the 25 communities, commercial and institutional data could not be separated based on villages/neighborhoods as nearly 95% of the commercial institutions are located within one cluster of the commercial district that stretches across multiple neighborhoods. Small mosques are located in almost every community and they have been listed as such.

The location of the township and the surrounding villages can be verified using the following GPS coordinates:

#	Village / CDC	E	N
1	Pump street	733952.350	3492468.048
2	Toryalai Agha street	733747.384	3492482.847
3	Janan Oil street	733514.980	3492959.623
4	Aslam Jan Agha street	733371.807	3492897.742
5	Molla Obaidullah St	733230.709	3492910.402
6	Jami De Sha street	733101.268	3492935.927
7	Hamam street	733333.398	3492357.771
8	Loya Nachara	732662.038	3491921.662
9	Wara Nachara	731900.625	3490930.353
10	Haji Sardar street	734283.705	3491900.207
11	Usmani street	733391.799	3492137.606
12	Doctor Sayyed Agha St.	733591.294	3492469.720
13	Omar street	733773.722	3492223.858
14	Armara Kalai	733923.839	3491798.863
15	Torgi Kalai	733671.756	3490832.298
16	Haji Lalo Kalai	733954.868	3490380.412
17	Charkhab Kalai	733788.205	3489519.525
18	Akbar Kalai	733204.659	3489443.694
19	Dastagiri kalai	732759.821	3489605.064
20	Haji rostam kalai	733880.470	3489047.282
21	Haji Rahmatullah kalai	734637.065	3489894.315
22	Haji shir gul kalai	734084.675	3492098.102
23	Haji Khalifa kalai	734498.106	3492128.132
24	Haji Malem kalai	734794.068	3492008.401
25	Haji Mamor Kalai	735083.163	3491966.210

Table 1: GPS coordinates for all villages

The design and construction of the envisaged PV Mini-grid shall provide safe and sustainable power supply to the connected Consumers.

The one-year operation shall provide on-the-job training to the local operators in operation, maintenance and troubleshooting of the plant and the appertaining distribution network and to the administrative staff in metering, billing, and stock keeping.

UNDP is engaging a capable and qualified Contractor to carry out construction, installation, commissioning, and one-year operation and maintenance (O&M) of a PV hybrid mini grid system of 1,000 kW and associated reticulation in the cluster of 25 villages and neighborhoods in Panjwayee district of Kandahar province Afghanistan. The scope of work includes:

1. Procurement of equipment and supply for the complete PV system including:
    a. The PV panels and associated inverters and related components
    b. SCADA,
    c. Low Voltage Equipment and accessories
    d. Aux boards
    e. Diesel generators and associated controls
    f. Transformer and associated controls
    g. Li-Ion Battery Energy Storage System (BESS) and associated accessories
    h. Medium Voltage equipment and associated accessories
    i. System integration services
2. PV power plant site development including:
    a. Civil layout and design
    b. Buildings design
    c. Details, including
        i. Water supply, including water wells, storage tanks, water supply network
        ii. Plumbing
        iii. Roads, Parking, and Walk Ways
        iv. Electrical wiring
        v. Sewer system including septic tanks and leach fields
        vi. Drainage system for the complete site
        vii. Light Poles and area lighting
        viii. Concrete Pads
        ix. Security Cameras
        x. Fence
        xi. Other related structures and components
3. Manufacture, supply and installation of PV panel structures, including
    a. PV Panel Frames
    b. Poles
    c. Racking systems
    d. Concrete foundation
    e. Other related components
4. Manufacturing, supply and installation of T&D system consisting of:
    a. 20 kV MV network
    b. 20/0.4 kV substations including transformer, protection devices, LV distribution cabinets (seven)

   c. 0.4 kV LV network
   d. Meter boxes,
   e. Service lines
   f. Consumer connections

   Including testing and commissioning

5. Supply, installation and operation of pre-paid metering system and associated cloud-based management of the system throughout the cluster of villages
6. Collection and management of tariffs in collaboration with the local electricity supply board and MRRD/ASERD
7. Supply of spare parts for one years
8. Commissioning of the complete mini-grid.
9. Training of operators and administrative staff
10. Providing warranty over a period of one year after successful commissioning and issuing of Preliminary Acceptance Certificate (PAC)
11. Running the power station for one year starting from issuing of PAC including on-the-job training of operators and administrative staff during this time, monitoring of operation, output, billing and technical and non-technical losses including submission of monthly monitoring reports.

4. SURVEYS AND INVESTIGATIONS

A detailed site assessment was carried out, which yielded the following results:

The population is mostly engaged in agriculture and horticulture but significant commercial activities such as tailoring, flour milling, bicycle and motorcycle repair shops, machine shops, mechanical shops, cosmetic shops, grocery shops and other commercial activities also engage the population. Altogether 516 commercial entities are in operation and their numbers are growing. The target area has two hospitals, two schools, one main police station and 10 police posts, and one main mosque and 67 community mosques, in addition to a district office and a municipal building. About 96% of the households have a single solar panel plus a battery backup to meet their basic need for lighting and phone charging. The average size of a household is about twelve persons, even though some households have as many as 18 members, which signals that multiple households possibly reside within one Qala (housing compound). The target area is not connected to the grid power, even though a 20 KV power line passes about 4 kilometers north of the site of the planned solar power plant and an 110kV grid, which is part of the South Electric Power Systems (SEPS) is expected to pass within two kilometers of the site.

The households in the target area are classified under tier 0 and tier 1 of the World Bank's Multi-Tier Framework. About 5% of the households are classified under tier 0 and have no access to reliable energy and are forced to solely depend on fossil fuels such as firewood, Kerosene, propane gas and the like to meet their energy needs. About 95% of the households are classified under tier 1 and have access to a solar panel (less than 100 Watts) and a battery unit, which provides lighting for about four hours during the night time. The energy demand is, therefore, fairly significant and the desire to benefit from other aspects of an electrified dwelling is highly desired. During the assessment, it was noted that households demanded electricity to the tune of 1.1 kW per households to meet their needs, which demonstrates a high demand for power. Based on the 1.1 kW demand by household members of the community, more than 8,703 MWh of energy will be needed to cover only the residential loads. This can be supported by running a diesel generator, in addition to the 1,000kW solar system, to produce 6,842 MWh of energy at an annual cost of $1.25 million plus regular maintenance and repair costs. In addition, we will need to cover the cost of commercial and institutional loads that are also applicable. This is not supportable by the revenues from the operations of the system and as such not realistic. So, it was decided to reduce the supply of power to the households to a level that would enable the system to be built and operate efficiently. Such a system will be able to offer the households' power from 5 pm to 9 am and will be allocated the equivalent of 195 Watts peak and around 1.07kWh of energy per day per household. This means that even though the demand is there and the ability of the households to pay is almost 1.5 times the power made available to them, they will still only get a peak load of 195 Watts per household, assuming that this will last for their normal needs and its respective duration.

At the business level, the lathe shops, machine shops, flour mills, irrigation pumps and a number of other users are large power consumers across all villages/neighborhoods and will use in excess of 7.5 kW up to 23 kW of power, they will not be catered to. While the irrigation pumps are typically located away from the homes, so that extending the transmission lines to the pumps will be an additional cost burden for the project/the beneficiaries, other large users are located within the bazaars and are easily accessible. However, since the system size is limited to 1 MW, it was decided to remove all commercial loads greater than 7.5 kW (with the exception of ice cream shops) from the load portfolio and include them in the proposed expansion model for the system. The government or the land owners may choose to fund the purchase of decentralized solar powered irrigation pumps and thus minimize their fuel, repair and maintenance costs, use their existing diesel generators or wait for the grid system or possible double sizing of the PV utility to meet their energy demands.

At the institutional level, the hospital and the police posts are the two steady consumers of power with the schools and the mosques catering to spikes at their respective times of the day/night. The 69 main and community mosques cater to the greatest load peaks with total of around 95 kW, which covers the lights plus some additional equipment.

It is also estimated, that the Battery Energy Storage System (BESS) will only cater to one night's power for the community, primarily households, mosques and the hospital and will not be able to be used if there are multiple cloudy days with very limited solar irradiation. As such, a Generator System must be installed that can cater to 425 kW peak load and can be operated, when needed. This can be as a combination of one 75kW diesel generator systems that will operate as and when needed to meet the community's power needs, where the few hours of peak load in excess of 75kW can be supported by the BESS. A 425kW diesel generator, along with the 75kW backup system will ensure that peak loads are fully supported on cloudy days with no BESS available to offset some of energy needed.

The proposed mini-grid is designed to support the commercial loads during day time (9am-5pm), residential loads during nights (5 pm-9 am) and the institutional loads during 24-hours in a day. With this approach, the peak loads can be maintained at around 425kW with a total annual generation of just over 1,700MWh purely from solar production, topped by just under 100 MWh from diesel generation. The system can later be expanded to support increasing load requirements by adding more solar and batteries. The load growth profile, based on a generic population growth rate of 2.5%, shows increase of 105 kW in five years, with additional 119 kW, 134kW, 152kW and 172 kW in the subsequent five years intervals.

5. LOAD IDENTIFICATION/ASSESSMENT

The following load configurations for residential, commercial and institutional customers were identified during the preliminary design:

5.1 Residential Load Assessment

The project will tolerate a Loss of Load Probability (LoLP) of around 10%, which means that the project can cover the cost of diesel as part of the operating costs, if the amount of energy produced by the diesel generation system is around 10% of the overall system output.

After modeling multiple operating scenarios, the most stable system can be achieved by restricting the residential loads to the essential loads, namely, lights, fans, audio & video equipment and cell phone charging. Also, electricity to the residential customers will only be available from 5 pm to 9 am. During the day, the system will completely support the commercial and institutional customers and the remaining energy will be used to charge the batteries. The batteries will support the night time loads and provide stable and reliable electricity.

For the residential customers, a load of approximately 195W will be supported per household. It is necessary to provide electricity to the highest number of households and provide that in a stable and reliable way. Once the system is operational, consumption behavior of the customers will be monitored over the period of several months and/or year, then changes to the system can be proposed. Once a stable and reliable source of electricity is available, the consumption will also go up, so it is essential to provide some scope of expansion for consumption.

Table 2 shows calculation based on 2,081 households served by the mini-grid in a scenario where only Light, Audio, TV/Video, Fan and Mobile Phone charging is provided to each house hold. If high efficiency equipment is used, then the consumption can be reduced to acceptable levels and more consumers can be served. Table 2 shows a total load of 407.36kW for 2081 households, which is about 195W per household.

Residential Loads	# / HH	W/ device	Total Load - All HH (kW)	Duty cycle (hrs)	kWh / Day
Light Bulbs	6	7	87.40	6	524.41
Audio	0.25	10	5.20	6	31.22
TV / Video	0.75	75	117.06	6	702.34
Fan	1	75	156.08	12	1872.90
AC	0.75	100	0.00	0	0.00
Heater	0	500	0.00	0	0.00
Refrigerator	0	250	0.00	0	0.00
Computer	0	150	0.00	0	0.00
Mobile Phone	4	5	41.62	3	124.86
Iron	0	1000	0.00	0	0.00
Water Pump	0	500	0.00	0	0.00
Total		**2672**	**407.36**		**3255.72**

Table 2: Configuration of the Residential Power Demand Based on Wish-list

The load profiles are prepared based on the seasonal requirements using the following input and output tables for three seasons for the Kandahar location, as shown in Table 3 (a) through (c). January represents the data for winter months, April for spring and July for summer months. In detail, the same profile has been created for every month of the year, depending on the circumstances of the respective month.

JANUARY LOAD PROFILE																										
Institutional	**Total Load (kW)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**Sum**
Light Bulbs	87.40	0	0	0	0	0	0.75	0.5	0	0	0	0	0	0	0	0	0	0.75	1	1	1	0.75	0.5	0	0	6.25
Audio	5.20	0	0	0	0	0	0	0.25	0.5	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.5	0.25	0	0	4.5
TV / Video	117.06	0	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0.75	1	1	1	0.75	0.5	0	0	6
Fan	156.08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AC	156.08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heater	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Refrigerator	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Computer	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mobile Phone	41.62	0	0	0	0	0	0	0.75	0.75	0	0	0	0	0	0	0	0	0.5	0.5	0.5	0.5	0.5	0.25	0	0	4.25
Iron	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water Pump	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**563.43**	0	0	0	0	0	0.75	2	1.75	0	0	0	0	0	0	0	0	2.75	3.25	3.25	3.25	2.5	1.5	0	0	

(a-I)

JANUARY LOAD PROFILE																									
Institutional	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**Sum in kWh**
Light Bulbs	0	0	0	0	0	65.6	43.7	0	0	0	0	0	0	0	0	0	65.6	87.4	87.4	87.4	65.6	43.7	0	0	546
Audio	0	0	0	0	0	0	1.3	2.6	0	0	0	0	0	0	0	0	3.9	3.9	3.9	3.9	2.6	1.3	0	0	23.4
TV / Video	0	0	0	0	0	0	58.5	58.5	0	0	0	0	0	0	0	0	87.8	117	117	117	87.8	58.5	0	0	702
Fan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heater	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Refrigerator	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Computer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mobile Phone	0	0	0	0	0	0	31.2	31.2	0	0	0	0	0	0	0	0	20.8	20.8	20.8	20.8	20.8	10.4	0	0	177
Iron	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water Pump																									
Total (kW)	0	0	0	0	0	65.6	135	92.3	0	0	0	0	0	0	0	0	178	229	229	229	177	114	0	0	

(a-O)

APRIL LOAD PROFILE

Institutional	Total Load (kW)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum
Light Bulbs	87.40	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0.75	0	0	4.75
Audio	5.20	0	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.5	0	0	5.25
TV / Video	117.06	0	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0.75	1	1	1	0.75	0.5	0	0	6
Fan	156.08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.25	3.75
AC	156.08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heater	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Refrigerator	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Computer	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mobile Phone	41.62	0	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0.5	0.5	0.5	0.5	0.5	0.5	0	0	4
Iron	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water Pump	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**563.43**	0	0	0	0	0.5	0.5	1.5	1.5	0	0	0	0	0	0	0	0	2.5	2.75	3.75	3.75	3.5	2.75	0.5	0.25	

(b-I)

APRIL LOAD PROFILE

Institutional	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum in kWh
Light Bulbs	0	0	0	0	43.7	43.7	0	0	0	0	0	0	0	0	0	0	0	0	87.4	87.4	87.4	65.6	0	0	415
Audio	0	0	0	0	0	0	2.6	2.6	0	0	0	0	0	0	0	0	3.9	3.9	3.9	3.9	3.9	2.6	0	0	27.3
TV / Video	0	0	0	0	0	0	58.5	58.5	0	0	0	0	0	0	0	0	87.8	117	117	117	87.8	58.5	0	0	702
Fan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	78	78	78	78	78	78	78	39	585
AC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heater	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Refrigerator	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Computer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mobile Phone	0	0	0	0	0	0	20.8	20.8	0	0	0	0	0	0	0	0	20.8	20.8	20.8	20.8	20.8	20.8	0	0	166
Iron	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water Pump																									
Total (kW)	0	0	0	0	43.7	43.7	81.9	81.9	0	0	0	0	0	0	0	0	191	220	307	307	278	226	78	39	

(b-O)

JULY LOAD PROFILE

Institutional	Total Load (kW)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum
Light Bulbs	87.40	0	0	0	0.75	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0.5	0	4.75
Audio	5.20	0	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.5	0	0	5.25
TV / Video	117.06	0	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0.75	1	1	1	0.75	0.5	0.5	0	6.5
Fan	156.08	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0.75	0.75	13.5
AC	156.08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heater	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Refrigerator	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Computer	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mobile Phone	41.62	0	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0.25	0.5	0.5	0.5	0.5	0.5	0	0	3.75
Iron	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water Pump	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**563.43**	0.75	0.75	0.75	1.5	1.25	0.75	2.25	2.25	0	0	0	0	0	0	0	0	2.75	3.25	3.25	4.25	4	3.5	1.75	0.75	

(c-I)

JULY LOAD PROFILE

Institutional	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum in kWh
Light Bulbs	0	0	0	65.6	43.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	87.4	87.4	87.4	43.7	0	415
Audio	0	0	0	0	0	0	2.6	2.6	0	0	0	0	0	0	0	0	3.9	3.9	3.9	3.9	3.9	2.6	0	0	27.3
TV / Video	0	0	0	0	0	0	58.5	58.5	0	0	0	0	0	0	0	0	87.8	117	117	117	87.8	58.5	58.5	0	761
Fan	117	117	117	117	117	117	117	117	0	0	0	0	0	0	0	0	156	156	156	156	156	156	117	117	2107
AC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heater	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Refrigerator	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Computer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mobile Phone	0	0	0	0	0	0	20.8	20.8	0	0	0	0	0	0	0	0	10.4	20.8	20.8	20.8	20.8	20.8	0	0	156
Iron	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water Pump																									
Total (kW)	117	117	117	183	161	117	199	199	0	0	0	0	0	0	0	0	258	298	298	385	356	325	219	117	

(c-O)

Table 3: Diversification of Residential Loads (inputs and Outputs), (a-I) Input for January (representing winter months), (a-O) Output for January (representing winter months), (b-I) Input for April (representing spring months), (b-O) Output for April (representing spring months), (c-I) Input for July (representing summer months), (c-O) Output for July (representing summer months)

The load requirements for the 2,081 households create a peak load of 385 kW during the summer months and a peak of nearly 229 kW during the winter months. Figure 1 shows the average load peaks for the residential customers for one year.

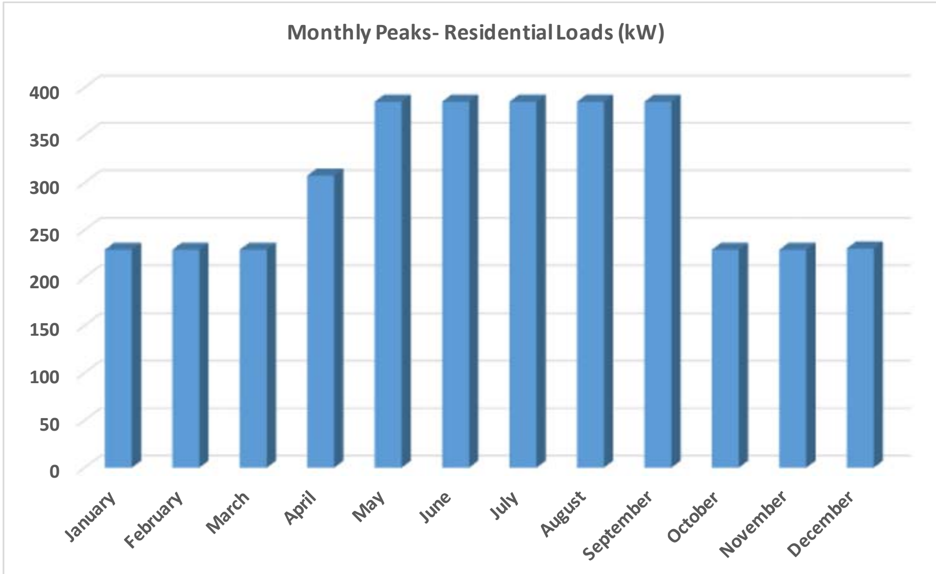
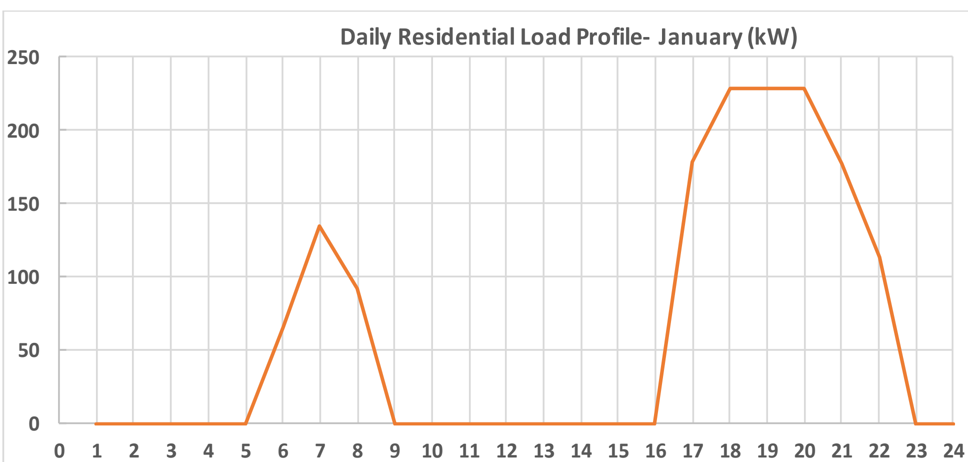
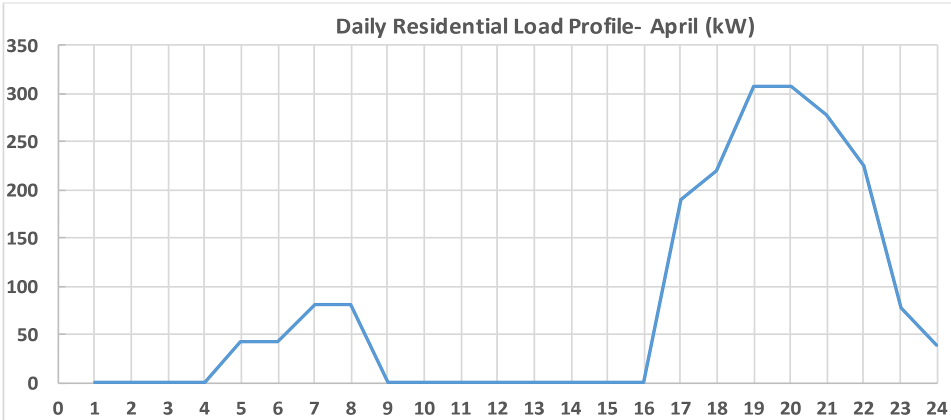


Figure 1: Monthly Load profile for Residential Loads

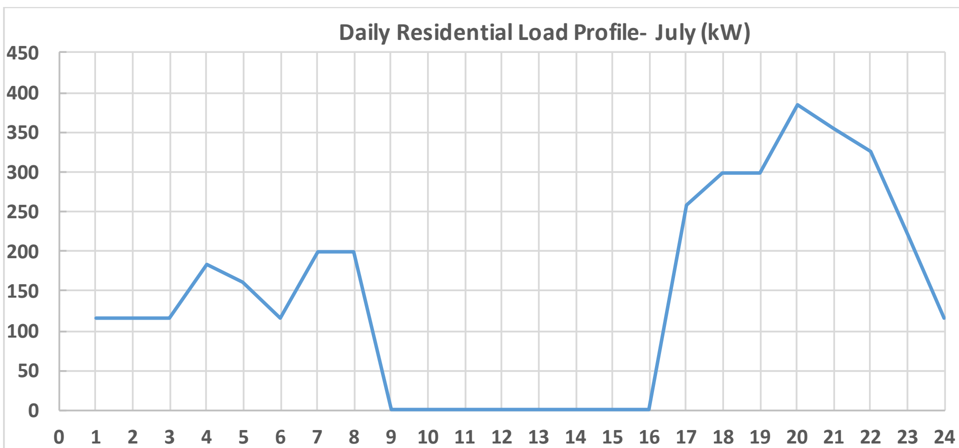
Figure 2 shows the load profile for the residential customers during one month in each season. This load curve represents the average of load for a particular hour over the whole month. For example, the average of load at 7 am in the month of April, for the 30 days of April is around 82kW and the same number at 5 am is about 44kW. The load profiles are thus essential in order to understand the requirements for the mini-grid. The load profile shows that the load consumption for the residential customers peak in early morning and in late evening.



(a) January daily-load profile



(b) April daily-load profile



(c) July daily-load profile

Figure 2: Monthly Load profile for Residential Loads in kW: (a) January (representing winter months), (b) April (representing spring months), and (c) July (representing summer months)

One of the main goals of the mini-grid is to provide the residential customers with reliable and affordable electricity. The mini-grid also needs to support the commercial and institutional customers. Next, the load profiles for the commercial and institutional customers were generated and the energy and power needed were calculated for these load profiles.

5.2 Commercial Load Assessment

The total commercial power demand for the complete target area is estimated at around 989.32 kW (Table 4). Some large-scale users such as big machining shop (23 kW), flour mills (18 kW), small machining shops (11 kW), metal works (8.5 kW), ice cream Shops (7.5 kW), irrigation pumps (7.5 kW), and big mechanical shops (7.5 kW) account for a significant portion of the total power demand for the commercial customers.

The irrigation pumps are typically located in remote areas, mostly away from residential as well as commercial areas. Hence supporting them involves significant additional reticulation and connection costs. We recommend that irrigation pumps be remotely powered and as such removed from the business load profile. Because of the limitations of the system size, based on client considerations, eliminating other large loads (greater than 7.5 kW) is necessary, in order to make the project feasible. These loads (with the exception of the ice cream shop) will change the load configuration so that the total load for the target area is estimated at around 173.32 kW with total daily energy consumption expected to be around 1,464.76 kWh (Table 4).

#	Commercial Loads	#	kW	Total Load (kW)	Duty cycle (hrs)	kWh / Day
1	Irrigiation Pump	0	0.00	0	5	0.00
2	Flour Machine/Mill	0	0.00	0	5	0.00
3	Telephone Tower	4	1.60	6.4	24	153.60
4	Bakery	8	0.15	1.2	8	9.60
5	Metal Works	0	8.50	0	5	0.00
6	Fruit/other processing units	1	0.40	0.4	8	3.20
7	Tailoring shops	45	0.60	27	8	216.00
8	Grocery shops	62	0.05	3.1	10	31.00
9	Oil Pump Station	1	1.00	1	12	12.00
10	Hotels/Restaurants	1	0.15	0.15	12	1.80
11	Cake and cookies shop	15	0.04	0.6	12	7.20
12	Cosmetic Shops	23	0.06	1.38	10	13.80
13	Fuel selling	24	0.05	1.2	10	12.00
14	TV/Radio Repair Shop	13	0.15	1.95	10	19.50
15	Butcher Shop	7	0.05	0.35	10	3.50
16	PCO/Mobile Shop	13	0.25	3.25	8	26.00
17	Pharmacy	11	0.10	1.1	12	13.20
18	Icecream Shop	3	7.50	22.5	12	270.00
19	Hamam /Public Bath	7	1.00	7	12	84.00
20	Mechanical shop (big)	0	7.50	0	6	0.00
21	Mechanical shop (medium)	2	3.00	6	6	36.00
22	Mechanical shop (small)	12	2.20	26.4	6	158.40
23	Clothes shop	84	0.08	6.72	8	53.76
24	Bicycle shop	5	0.10	0.5	10	5.00
25	Big machining shop (lathe)	0	23.00	0	4	0.00
26	Small machining shop (lathe)	0	11.00	0	4	0.00
27	Motor bike repairing shop	39	1.00	39	6	234.00
28	Fruit and vegetable shops	26	0.02	0.52	10	5.20
29	electronic repairing shops	4	0.15	0.6	10	6.00
30	Car wash units	6	2.50	15	6	90.00
	Total	**416**	**72.20**	**173.32**		**1464.76**

Table 4: Business Loads after Elimination of Irrigation Pumps

Accordingly, the amount of energy required to fulfill the demand generated by the commercial customers will be in the range of 414,785 kWh per year with a peak load of about 140kW and an average load of about 47kW. This would mean that a Solar PV plant of approximately 222kW will generate enough energy to support the demands of the commercial facilities.

The load profiles are prepared based on seasonal requirements using the following input and output tables for representative two of the four seasons. In detail, the same profile has been created for every month of the year, depending on circumstances of the respective month.

In all of these cases (see Table 5), we have used variable load and diversification factors of 0-1, that represents an approximate profile for operation of loads at different times in a day (details described in Section 6 of Appendix III – Design Methodology) to cater to worst case scenario, because we lack credible historic data or reliable customer input to enable sound engineering calculations.

JANUARY LOAD PROFILE																										
Institutional	Total Load (kW)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum
Irrigiation Pump	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Flour Machine/Mill	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Telephone Tower	6.4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	24
Bakery	1.2	0	0	0	0	0	0	0	0	0.5	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	5.75
Metal Works	0	0	0	0	0	0	0	0	0	0.5	0.75	0.75	0.5	0.5	0.75	0.5	0.5	0	0	0	0	0	0	0	0	4.75
Fruit/other processing units	0.4	0	0	0	0	0	0	0	0	0.75	0.75	1	1	1	1	1	0.75	0	0	0	0	0	0	0	0	7.25
Tailoring shops	27	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	6
Grocery shops	3.1	0	0	0	0	0	0	0	0	0.5	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	5.75
Oil Pump Station	1	0	0	0	0	0	0	0	0	0.75	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	7.75
Hotels/Restaurants	0.15	0	0	0	0	0	0	0	0	0.75	0.75	1	1	1	1	1	1	0	0	0	0	0	0	0	0	7.5
Cake and cookies shop	0.6	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	6
Cosmetic Shops	1.38	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	6
Fuel selling	1.2	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	6
TV/Radio Repair Shop	1.95	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	6
Butcher Shop	0.35	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	6
PCO/Mobile Shop	3.25	0	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	5.25
Pharmacy	1.1	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	6
Icecream Shop	22.5	0	0	0	0	0	0	0	0	0	0	0.5	0.5	0.5	0.5	0.5	0.5	0	0	0	0	0	0	0	0	3
Hamam /Public Bath	7	0	0	0	0	0	0	0	0	0.75	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	7.75
Mechanical shop (big)	0	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	6
Mechanical shop (medium)	6	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	6
Mechanical shop (small)	26.4	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	6
Clothes shop	6.72	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	6
Bicycle shop	0.5	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	6
Big machining shop (lathe)	0	0	0	0	0	0	0	0	0	0.75	0.75	0	1	1	1	1	0	0	0	0	0	0	0	0	0	5.5
Small machining shop (lathe)	0	0	0	0	0	0	0	0	0	0.75	0.75	0.75	1	1	1	1	0	0	0	0	0	0	0	0	0	6.25
Motor bike repairing shop	39	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	6
Fruit and vegetable shops	0.52	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	6
Electronic repairing shops	0.6	0	0	0	0	0	0	0	0	0.75	0.75	1	1	1	1	1	1	0	0	0	0	0	0	0	0	7.5
Car wash units	15	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	6
Total	**173.32**	1	1	1	1	1	1	1	1	19	21	21.5	22.5	22.5	22.8	22.5	20.3	1	1	1	1	1	1	1	1	

(a-I)

JANUARY LOAD PROFILE																									
Institutional	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum in kWh
Irrigiation Pump	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Flour Machine/Mill	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Telephone Tower	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	154
Bakery	0	0	0	0	0	0	0	0	0.6	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0	0	0	0	0	0	0	0	6.9
Metal Works	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fruit/other processing units	0	0	0	0	0	0	0	0	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.3	0	0	0	0	0	0	0	0	2.9
Tailoring shops	0	0	0	0	0	0	0	0	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	0	0	0	0	0	0	0	0	162
Grocery shops	0	0	0	0	0	0	0	0	1.55	2.33	2.33	2.33	2.33	2.33	2.33	2.33	0	0	0	0	0	0	0	0	17.8
Oil Pump Station	0	0	0	0	0	0	0	0	0.75	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	7.75
Hotels/Restaurants	0	0	0	0	0	0	0	0	0.11	0.11	0.15	0.15	0.15	0.15	0.15	0.15	0	0	0	0	0	0	0	0	1.13
Cake and cookies shop	0	0	0	0	0	0	0	0	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0	0	0	0	0	0	0	0	3.6
Cosmetic Shops	0	0	0	0	0	0	0	0	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	0	0	0	0	0	0	0	0	8.28
Fuel selling	0	0	0	0	0	0	0	0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0	0	0	0	0	0	0	0	7.2
TV/Radio Repair Shop	0	0	0	0	0	0	0	0	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	0	0	0	0	0	0	0	0	11.7
Butcher Shop	0	0	0	0	0	0	0	0	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0	0	0	0	0	0	0	0	2.1
PCO/Mobile Shop	0	0	0	0	0	0	0	0	0	2.44	2.44	2.44	2.44	2.44	2.44	2.44	0	0	0	0	0	0	0	0	17.1
Pharmacy	0	0	0	0	0	0	0	0	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0	0	0	0	0	0	0	0	6.6
Icecream Shop	0	0	0	0	0	0	0	0	0	0	11.3	11.3	11.3	11.3	11.3	11.3	0	0	0	0	0	0	0	0	67.5
Hamam /Public Bath	0	0	0	0	0	0	0	0	5.25	7	7	7	7	7	7	7	0	0	0	0	0	0	0	0	54.3
Mechanical shop (big)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mechanical shop (medium)	0	0	0	0	0	0	0	0	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	0	0	0	0	0	0	0	0	36
Mechanical shop (small)	0	0	0	0	0	0	0	0	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8	0	0	0	0	0	0	0	0	158
Clothes shop	0	0	0	0	0	0	0	0	5.04	5.04	5.04	5.04	5.04	5.04	5.04	5.04	0	0	0	0	0	0	0	0	40.3
Bicycle shop	0	0	0	0	0	0	0	0	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0	0	0	0	0	0	0	0	3
Big machining shop (lathe)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Small machining shop (lathe)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Motor bike repairing shop	0	0	0	0	0	0	0	0	29.3	29.3	29.3	29.3	29.3	29.3	29.3	29.3	0	0	0	0	0	0	0	0	234
Fruit and vegetable shops	0	0	0	0	0	0	0	0	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0	0	0	0	0	0	0	0	3.12
electronic repairing shops	0	0	0	0	0	0	0	0	0.45	0.45	0.6	0.6	0.6	0.6	0.6	0.6	0	0	0	0	0	0	0	0	4.5
Car wash units	0	0	0	0	0	0	0	0	11.3	11.3	11.3	11.3	11.3	11.3	11.3	11.3	0	0	0	0	0	0	0	0	90
Total (kW)	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	111	117	128	128	128	128	128	128	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	

(a-O)

JULY LOAD PROFILE

Institutional	Total Load (kW)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum
Irrigiation Pump	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Flour Machine/Mill	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Telephone Tower	6.4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	24
Bakery	1.2	0	0	0	0	0	0	0	0	0.5	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	5.75
Metal Works	0	0	0	0	0	0	0	0	0	0.5	0.75	0.75	0.5	0.5	0.75	0.5	0.5	0	0	0	0	0	0	0	0	4.75
Fruit/other processing units	0.4	0	0	0	0	0	0	0	0	0.75	0.75	1	1	1	1	1	0.75	0	0	0	0	0	0	0	0	7.25
Tailoring shops	27	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	6
Grocery shops	3.1	0	0	0	0	0	0	0	0	0.5	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	5.75
Oil Pump Station	1	0	0	0	0	0	0	0	0	0.75	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	7.75
Hotels/Restaurants	0.15	0	0	0	0	0	0	0	0	0.75	0.75	1	1	1	1	1	1	0	0	0	0	0	0	0	0	7.5
Cake and cookies shop	0.6	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	6
Cosmetic Shops	1.38	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	6
Fuel selling	1.2	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	6
TV/Radio Repair Shop	1.95	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	6
Butcher Shop	0.35	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	6
PCO/Mobile Shop	3.25	0	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	5.25
Pharmacy	1.1	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	6
Icecream Shop	22.5	0	0	0	0	0	0	0	0	0.5	0.5	0.75	1	1	1	0.75	0.75	0	0	0	0	0	0	0	0	6.25
Hamam /Public Bath	7	0	0	0	0	0	0	0	0	0.75	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	7.75
Mechanical shop (big)	0	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	6
Mechanical shop (medium)	6	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	6
Mechanical shop (small)	26.4	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	6
Clothes shop	6.72	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	6
Bicycle shop	0.5	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	6
Big machining shop (lathe)	0	0	0	0	0	0	0	0	0	0.75	0.75	0	1	1	1	1	0	0	0	0	0	0	0	0	0	5.5
Small machining shop (lathe)	0	0	0	0	0	0	0	0	0	0.75	0.75	0.75	1	1	1	1	0	0	0	0	0	0	0	0	0	6.25
Motor bike repairing shop	39	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	6
Fruit and vegetable shops	0.52	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	6
electronic repairing shops	0.6	0	0	0	0	0	0	0	0	0.75	0.75	1	1	1	1	1	1	0	0	0	0	0	0	0	0	7.5
Car wash units	15	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0	0	0	0	0	0	0	0	6
Total	**173.32**	1	1	1	1	1	1	1	1	19.5	21.5	21.8	23	23	23.3	22.8	20.5	1	1	1	1	1	1	1	1	

(b-I)

JULY LOAD PROFILE

Institutional	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum in kWh
Irrigiation Pump	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Flour Machine/Mill	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Telephone Tower	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	154
Bakery	0	0	0	0	0	0	0	0	0.6	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0	0	0	0	0	0	0	0	6.9
Metal Works	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fruit/other processing units	0	0	0	0	0	0	0	0	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.3	0	0	0	0	0	0	0	0	2.9
Tailoring shops	0	0	0	0	0	0	0	0	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	0	0	0	0	0	0	0	0	162
Grocery shops	0	0	0	0	0	0	0	0	1.55	2.33	2.33	2.33	2.33	2.33	2.33	2.33	0	0	0	0	0	0	0	0	17.8
Oil Pump Station	0	0	0	0	0	0	0	0	0.75	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	7.75
Hotels/Restaurants	0	0	0	0	0	0	0	0	0.11	0.11	0.15	0.15	0.15	0.15	0.15	0.15	0	0	0	0	0	0	0	0	1.13
Cake and cookies shop	0	0	0	0	0	0	0	0	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0	0	0	0	0	0	0	0	3.6
Cosmetic Shops	0	0	0	0	0	0	0	0	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	0	0	0	0	0	0	0	0	8.28
Fuel selling	0	0	0	0	0	0	0	0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0	0	0	0	0	0	0	0	7.2
TV/Radio Repair Shop	0	0	0	0	0	0	0	0	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	0	0	0	0	0	0	0	0	11.7
Butcher Shop	0	0	0	0	0	0	0	0	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0	0	0	0	0	0	0	0	2.1
PCO/Mobile Shop	0	0	0	0	0	0	0	0	0	2.44	2.44	2.44	2.44	2.44	2.44	2.44	0	0	0	0	0	0	0	0	17.1
Pharmacy	0	0	0	0	0	0	0	0	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0	0	0	0	0	0	0	0	6.6
Icecream Shop	0	0	0	0	0	0	0	0	11.3	11.3	16.9	22.5	22.5	22.5	16.9	16.9	0	0	0	0	0	0	0	0	141
Hamam /Public Bath	0	0	0	0	0	0	0	0	5.25	7	7	7	7	7	7	7	0	0	0	0	0	0	0	0	54.3
Mechanical shop (big)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mechanical shop (medium)	0	0	0	0	0	0	0	0	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	0	0	0	0	0	0	0	0	36
Mechanical shop (small)	0	0	0	0	0	0	0	0	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8	0	0	0	0	0	0	0	0	158
Clothes shop	0	0	0	0	0	0	0	0	5.04	5.04	5.04	5.04	5.04	5.04	5.04	5.04	0	0	0	0	0	0	0	0	40.3
Bicycle shop	0	0	0	0	0	0	0	0	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0	0	0	0	0	0	0	0	3
Big machining shop (lathe)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Small machining shop (lathe)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Motor bike repairing shop	0	0	0	0	0	0	0	0	29.3	29.3	29.3	29.3	29.3	29.3	29.3	29.3	0	0	0	0	0	0	0	0	234
Fruit and vegetable shops	0	0	0	0	0	0	0	0	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0	0	0	0	0	0	0	0	3.12
electronic repairing shops	0	0	0	0	0	0	0	0	0.45	0.45	0.6	0.6	0.6	0.6	0.6	0.6	0	0	0	0	0	0	0	0	4.5
Car wash units	0	0	0	0	0	0	0	0	11.3	11.3	11.3	11.3	11.3	11.3	11.3	11.3	0	0	0	0	0	0	0	0	90
Total (kW)	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	122	128	134	140	140	140	134	134	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	

(b-O)

Table 5: Diversification of Commercial Loads (inputs and Outputs) in kWh, (a-I) Input for January (typical for winter months), (a-O) Output for January (typical for winter months), (b-I) Input for July (typical for summer months), (b-O) Output for July (typical)

Based on the load demands of the commercial/industrial customers, there is an expected peak power requirement of around 140 kW during the summer months and a peak demand of about 128kW throughout the winter months. This can be seen in Figure 3 below. Once the system has been in operation for about 6-months to a year, we will be able to better understand behavior of commercial customers and can make adjustments to meet the realities on the ground.

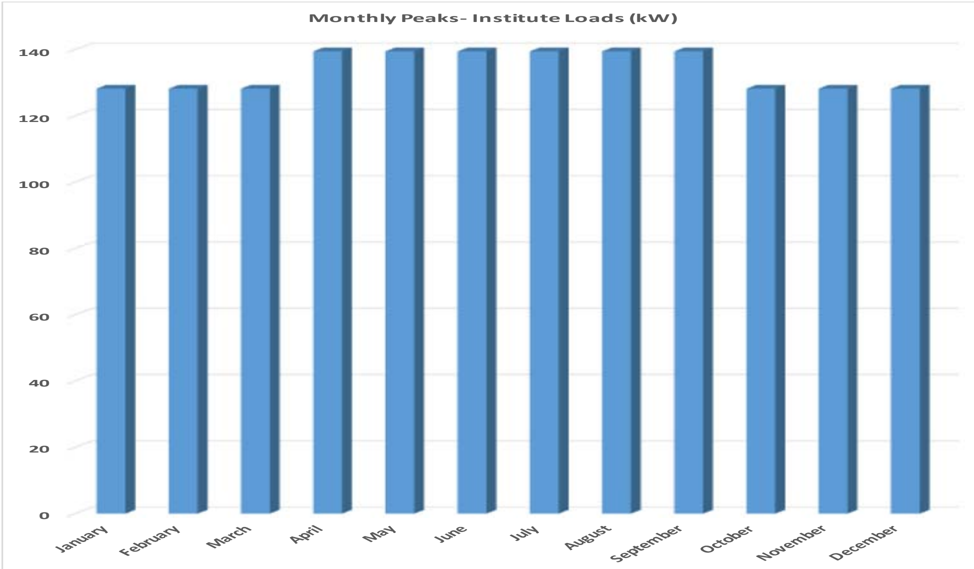
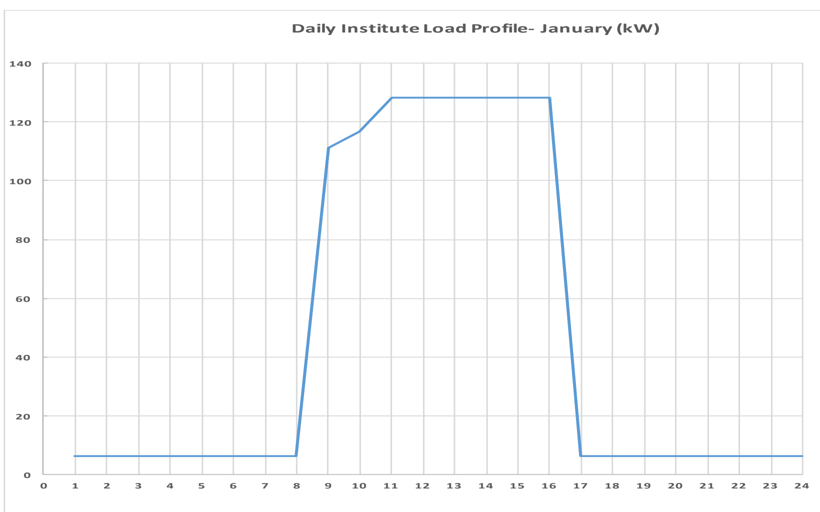
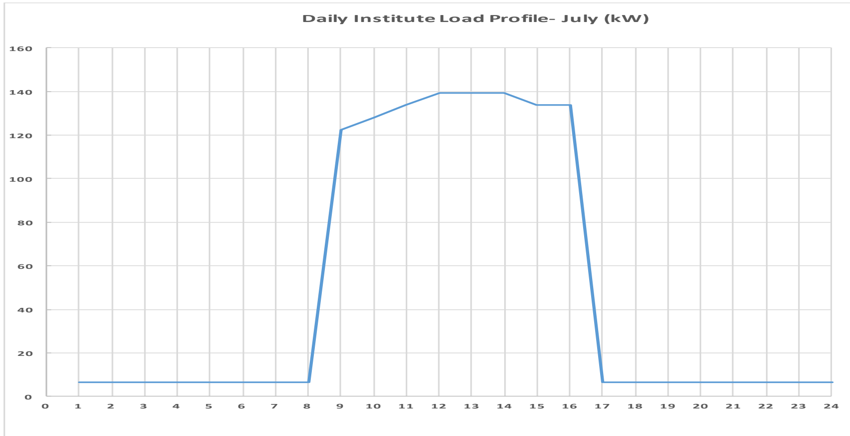


Figure 3: Monthly Peaks for Commercial and Industrial Loads

Figure 4 shows the load profile for the Commercial and Industrial (C&I) customers during the month of January and July. The load curve represents the average of load for a particular hour over the whole month. The load profile shows that during 24-hour period of a day, the C&I customers use the electricity during the day time (between 9 am and 5 pm). Also, most of the C&I businesses close down in the evening, hence, bringing the load close to zero (except about 6.4kW for Telephone tower).



(a)



(b)

Figure 4: Commercial and Industrial Load profile for the month of (a) January (winter) and (b) July (summer).

5.3 Institutional Load Assessment

The township and surrounding communities are home to total of 86 public buildings, consisting of two clinics, two schools, One Main and eleven small police posts, 69 mosques (main and local), a Municipality Office and one District Office are located in the cluster of villages. The exact numbers are shown in Table 6.

The power consumption of these institutions is around 76.25 kW. Except for the school, the district and the municipal offices, the other institutions require power both during the day time and at night time.

Institutional Loads	#	kW	Total Load (kW)	Duty cycle (hrs)	kWh / Day
Panwayee Clinic (Government)	1	3	3	12	36.00
Hashiimi Clinic (Private)	1	6.9	6.9	10	69.00
High School	1	7.6	7.6	8	60.80
Secondary school	1	0.6	0.6	8	4.80
Main Police Stations	1	13	13	12	156.00
Small police posts	10	0.7	7	8	56.00
Main mosques	2	1.2	2.4	5	12.00
Small mosques	67	0.25	16.75	5	83.75
Municpality	1	8	8	6	48.00
District Office	1	11	11	6	66.00
Total	**86**	**52.25**	**76.25**	**80**	**592.35**

Table 6: Institutional Load Requirement in kW

Accordingly, the amount of energy required to fulfill the demand generated by the institute customers will be in the range of 228,920 kWh per year with a peak load of about 64kW and an average load of about 26kW. This would mean that a Solar PV plant of approximately 123kW will generate enough energy to support the demands of the commercial facilities.

The load profiles are prepared based on the seasonal requirements using the following input and output tables for each of the twelve months.

In all of these cases (see Table 7), we have used variable load and diversification factors of 0-1, that represents an approximate profile for operation of loads at different times in a day (details described in Section 6 of Appendix III – Design Methodology) to cater to worst case scenario, because we lack credible historic data customer input to enable sound engineering calculations.

JANUARY LOAD PROFILE																										
Institutional	Total Load (kW)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum
Panwayee Clinic (Government)	3	0.25	0.25	0.25	0.25	0.25	0.5	0.5	0.75	1	1	1	0.5	0.5	0.75	1	1	1	1	1	1	0.5	0.5	0.25	0.25	15.25
Hashiimi Clinic (Private)	6.9	0.25	0.25	0.25	0.25	0.25	0.5	0.5	0.75	1	1	1	0.5	0.5	0.75	1	1	1	1	1	1	0.5	0.5	0.25	0.25	15.25
High School	7.6	0	0	0	0	0	0	0	0.25	0.75	0.75	0.75	0.25	0.25	0.75	0.75	0.75	0	0	0	0	0	0	0	0	5.25
Secondary school	0.6	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.25	0.25	0.75	0.75	0.75	0	0	0	0	0	0	0	0	5
Main Police Stations	13	0.25	0.25	0.25	0.25	0.25	0.25	0.5	0.5	0.75	1	1	0.5	0.5	0.75	1	1	1	0.75	0.5	0.25	0.25	0.25	0.25	0.25	12.5
Small police posts	7	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.5	0.75	0.75	0.75	0.5	0.5	0.75	0.75	0.75	0.75	0.75	0.5	0.25	0.25	0.1	0.1	0.1	9.5
Main mosques	2.4	0	0	0	0	0.5	0.75	0.5	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0	0	0	0	0	0	4
Small mosques	16.75	0	0	0	0	0.5	0.75	0.5	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0	0	0	0	0	0	4
Municpality	8	0	0	0	0	0	0	0	0.5	0.75	1	1	0.5	0.5	1	0.75	0.5	0.25	0	0	0	0	0	0	0	6.75
District Office	11	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	6
Total	**76.25**	0.85	0.85	0.85	0.85	1.85	2.85	2.6	3.25	5.75	6.25	7.25	4	4	6.5	7	8.25	5.5	5	3	2.5	1.5	1.35	0.85	0.85	

(a-I)

JANUARY LOAD PROFILE																									
Institutional	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum in kWh
Panwayee Clinic (Government)	0.75	0.75	0.75	0.75	0.75	1.5	1.5	2.25	3	3	3	1.5	1.5	2.25	3	3	3	3	3	3	1.5	1.5	0.75	0.75	45.8
Hashiimi Clinic (Private)	1.73	1.73	1.73	1.73	1.73	3.45	3.45	5.18	6.9	6.9	6.9	3.45	3.45	5.18	6.9	6.9	6.9	6.9	6.9	6.9	3.45	3.45	1.73	1.73	105
High School	0	0	0	0	0	0	0	1.9	5.7	5.7	5.7	1.9	1.9	5.7	5.7	5.7	0	0	0	0	0	0	0	0	39.9
Secondary school	0	0	0	0	0	0	0	0	0.45	0.45	0.45	0.15	0.15	0.45	0.45	0.45	0	0	0	0	0	0	0	0	3
Main Police Stations	3.25	3.25	3.25	3.25	3.25	3.25	6.5	6.5	9.75	13	13	6.5	6.5	9.75	13	13	13	9.75	6.5	3.25	3.25	3.25	3.25	3.25	163
Small police posts	0.7	0.7	0.7	0.7	0.7	0.7	0.7	3.5	5.25	5.25	5.25	3.5	3.5	5.25	5.25	5.25	5.25	5.25	3.5	1.75	1.75	0.7	0.7	0.7	66.5
Main mosques	0	0	0	0	1.2	1.8	1.2	0	0	0	0	0	0	0	0	1.8	1.8	1.8	0	0	0	0	0	0	9.6
Small mosques	0	0	0	0	8.38	12.6	8.38	0	0	0	0	0	0	0	0	12.6	12.6	12.6	0	0	0	0	0	0	67
Municpality	0	0	0	0	0	0	0	4	6	8	8	4	4	8	6	4	2	0	0	0	0	0	0	0	54
District Office	0	0	0	0	0	0	0	0	0	0	11	11	11	11	11	11	0	0	0	0	0	0	0	0	66
Total (kW)	6.43	6.43	6.43	6.43	16	23.3	21.7	23.3	37.1	42.3	53.3	32	32	47.6	51.3	63.7	44.5	39.3	19.9	14.9	9.95	8.9	6.43	6.43	

(a-O)

MARCH LOAD PROFILE																										
Institutional	Total Load (kW)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum
Panwayee Clinic (Government)	3	0.25	0.25	0.25	0.25	0.25	0.5	0.5	0.75	1	1	1	0.5	0.5	0.75	1	1	1	1	1	1	0.5	0.5	0.25	0.25	15.25
Hashiimi Clinic (Private)	6.9	0.25	0.25	0.25	0.25	0.25	0.5	0.5	0.75	1	1	1	0.5	0.5	0.75	1	1	1	1	1	1	0.5	0.5	0.25	0.25	15.25
High School	7.6	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.25	0.25	0.75	0.75	0.75	0	0	0	0	0	0	0	0	5
Secondary school	0.6	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.25	0.25	0.75	0.75	0.75	0	0	0	0	0	0	0	0	5
Main Police Stations	13	0.25	0.25	0.25	0.25	0.25	0.25	0.5	0.5	0.75	1	1	0.5	0.5	0.75	1	1	1	0.75	0.5	0.25	0.25	0.25	0.25	0.25	12.5
Small police posts	7	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.5	0.75	0.75	0.75	0.5	0.5	0.75	0.75	0.75	0.75	0.75	0.5	0.25	0.25	0.1	0.1	0.1	9.5
Main mosques	2.4	0	0	0	0	0.5	0.75	0.5	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0	0	0	0	0	0	4
Small mosques	16.75	0	0	0	0	0.5	0.75	0.5	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0	0	0	0	0	0	4
Municpality	8	0	0	0	0	0	0	0	0.5	0.75	1	1	0.5	0.5	1	0.75	0.5	0.25	0	0	0	0	0	0	0	6.75
District Office	11	0	0	0	0	0	0	0	0.75	1	1	1	0.25	0.25	0.25	0.5	0.5	0	0	0	0	0	0	0	0	5.5
Total	**76.25**	0.85	0.85	0.85	0.85	1.85	2.85	2.6	3.75	6.75	7.25	7.25	3.25	3.25	5.75	6.5	7.75	5.5	5	3	2.5	1.5	1.35	0.85	0.85	

(b-I)

MARCH LOAD PROFILE																									
Institutional	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum in kWh
Panwayee Clinic (Government)	0.75	0.75	0.75	0.75	0.75	1.5	1.5	2.25	3	3	3	1.5	1.5	2.25	3	3	3	3	3	3	1.5	1.5	0.75	0.75	45.8
Hashiimi Clinic (Private)	1.73	1.73	1.73	1.73	1.73	3.45	3.45	5.18	6.9	6.9	6.9	3.45	3.45	5.18	6.9	6.9	6.9	6.9	6.9	6.9	3.45	3.45	1.73	1.73	105
High School	0	0	0	0	0	0	0	0	5.7	5.7	5.7	1.9	1.9	5.7	5.7	5.7	0	0	0	0	0	0	0	0	38
Secondary school	0	0	0	0	0	0	0	0	0.45	0.45	0.45	0.15	0.15	0.45	0.45	0.45	0	0	0	0	0	0	0	0	3
Main Police Stations	3.25	3.25	3.25	3.25	3.25	3.25	6.5	6.5	9.75	13	13	6.5	6.5	9.75	13	13	13	9.75	6.5	3.25	3.25	3.25	3.25	3.25	163
Small police posts	0.7	0.7	0.7	0.7	0.7	0.7	0.7	3.5	5.25	5.25	5.25	3.5	3.5	5.25	5.25	5.25	5.25	5.25	3.5	1.75	1.75	0.7	0.7	0.7	66.5
Main mosques	0	0	0	0	1.2	1.8	1.2	0	0	0	0	0	0	0	0	1.8	1.8	1.8	0	0	0	0	0	0	9.6
Small mosques	0	0	0	0	8.38	12.6	8.38	0	0	0	0	0	0	0	0	12.6	12.6	12.6	0	0	0	0	0	0	67
Municpality	0	0	0	0	0	0	0	4	6	8	8	4	4	8	6	4	2	0	0	0	0	0	0	0	54
District Office	0	0	0	0	0	0	0	8.25	11	11	11	2.75	2.75	2.75	5.5	5.5	0	0	0	0	0	0	0	0	60.5
Total (kW)	6.43	6.43	6.43	6.43	16	23.3	21.7	29.7	48.1	53.3	53.3	23.8	23.8	39.3	45.8	58.2	44.5	39.3	19.9	14.9	9.95	8.9	6.43	6.43	

(b-O)

MAY LOAD PROFILE																										
Institutional	**Total Load (kW)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**Sum**
Panwayee Clinic (Government)	3	0.5	0.5	0.5	0.5	0.5	0.5	0.75	0.75	1	1	1	0.75	0.75	0.75	1	1	1	1	1	1	0.5	0.5	0.5	0.5	17.75
Hashiimi Clinic (Private)	6.9	0.5	0.5	0.5	0.5	0.5	0.5	0.75	0.75	1	1	1	0.75	0.75	0.75	1	1	1	1	1	1	0.5	0.5	0.5	0.5	17.75
High School	7.6	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.25	0.25	0.75	0.75	0.75	0	0	0	0	0	0	0	0	5
Secondary school	0.6	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.25	0.25	0.75	0.75	0.75	0	0	0	0	0	0	0	0	5
Main Police Stations	13	0.25	0.25	0.25	0.25	0.25	0.25	0.5	0.5	0.75	1	1	0.5	0.5	0.75	1	1	1	0.75	0.5	0.25	0.25	0.25	0.25	0.25	12.5
Small police posts	7	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.5	0.75	0.75	0.75	0.75	0.5	0.75	0.75	0.75	0.75	0.75	0.5	0.2	0.2	0.2	0.2	0.2	10.65
Main mosques	2.4	0	0	0	0	0.5	0.75	0.5	0	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0	0	0	0	4.75
Small mosques	16.75	0	0	0	0	0.5	0.75	0.5	0	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0	0	0	0	4.75
Municpality	8	0	0	0	0	0	0	0	0.5	0.75	1	1	0.5	0.5	1	0.75	0.5	0.25	0	0	0	0	0	0	0	6.75
District Office	11	0	0	0	0	0	0	0	0.75	1	1	1	0.25	0.25	0.25	0.5	0.5	0	0	0	0	0	0	0	0	5.5
Total	**76.25**	1.45	1.45	1.45	1.45	2.45	2.95	3.2	3.75	6.75	7.25	7.25	4	3.75	5.75	6.5	6.25	5.5	5	4.5	3.95	1.45	1.45	1.45	1.45	

(c-I)

MAY LOAD PROFILE																									
Institutional	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**Sum in kWh**
Panwayee Clinic (Government)	1.5	1.5	1.5	1.5	1.5	1.5	2.25	2.25	3	3	3	2.25	2.25	2.25	3	3	3	3	3	3	1.5	1.5	1.5	1.5	53.3
Hashiimi Clinic (Private)	3.45	3.45	3.45	3.45	3.45	3.45	5.18	5.18	6.9	6.9	6.9	5.18	5.18	5.18	6.9	6.9	6.9	6.9	6.9	6.9	3.45	3.45	3.45	3.45	122
High School	0	0	0	0	0	0	0	0	5.7	5.7	5.7	1.9	1.9	5.7	5.7	5.7	0	0	0	0	0	0	0	0	38
Secondary school	0	0	0	0	0	0	0	0	0.45	0.45	0.45	0.15	0.15	0.45	0.45	0.45	0	0	0	0	0	0	0	0	3
Main Police Stations	3.25	3.25	3.25	3.25	3.25	3.25	6.5	6.5	9.75	13	13	6.5	6.5	9.75	13	13	13	9.75	6.5	3.25	3.25	3.25	3.25	3.25	163
Small police posts	1.4	1.4	1.4	1.4	1.4	1.4	1.4	3.5	5.25	5.25	5.25	5.25	3.5	5.25	5.25	5.25	5.25	5.25	3.5	1.4	1.4	1.4	1.4	1.4	74.6
Main mosques	0	0	0	0	1.2	1.8	1.2	0	0	0	0	0	0	0	0	0	1.8	1.8	1.8	1.8	0	0	0	0	11.4
Small mosques	0	0	0	0	8.38	12.6	8.38	0	0	0	0	0	0	0	0	0	12.6	12.6	12.6	12.6	0	0	0	0	79.6
Municpality	0	0	0	0	0	0	0	4	6	8	8	4	4	8	6	4	2	0	0	0	0	0	0	0	54
District Office	0	0	0	0	0	0	0	8.25	11	11	11	2.75	2.75	2.75	5.5	5.5	0	0	0	0	0	0	0	0	60.5
Total (kW)	9.6	9.6	9.6	9.6	19.2	24	24.9	29.7	48.1	53.3	53.3	28	26.2	39.3	45.8	43.8	44.5	39.3	34.3	28.9	9.6	9.6	9.6	9.6	

(c-O)

JULY LOAD PROFILE																										
Institutional	**Total Load (kW)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**Sum**
Panwayee Clinic (Government)	3	0.5	0.5	0.5	0.5	0.5	0.5	0.75	0.75	1	1	1	0.75	0.75	0.75	1	1	1	1	1	1	0.5	0.5	0.5	0.5	17.75
Hashiimi Clinic (Private)	6.9	0.5	0.5	0.5	0.5	0.5	0.5	0.75	0.75	1	1	1	0.75	0.75	0.75	1	1	1	1	1	1	0.5	0.5	0.5	0.5	17.75
High School	7.6	0	0	0	0	0	0	0	0	0.25	0.25	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0.75
Secondary school	0.6	0	0	0	0	0	0	0	0	0.25	0.25	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0.75
Main Police Stations	13	0.25	0.25	0.25	0.25	0.25	0.25	0.5	0.5	0.75	1	1	0.5	0.5	0.75	1	1	1	0.75	0.5	0.25	0.25	0.25	0.25	0.25	12.5
Small police posts	7	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.5	0.75	0.75	0.75	0.75	0.5	0.75	0.75	0.75	0.75	0.75	0.5	0.2	0.2	0.2	0.2	0.2	10.65
Main mosques	2.4	0	0	0	0	0.5	0.75	0.5	0	0	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0	0	0	4.75
Small mosques	16.75	0	0	0	0	0.5	0.75	0.5	0	0	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0	0	0	4.75
Municpality	8	0	0	0	0	0	0	0	0.5	0.75	1	1	0.5	0.5	1	0.75	0.5	0.25	0	0	0	0	0	0	0	6.75
District Office	11	0	0	0	0	0	0	0	0.75	1	1	1	0.25	0.25	0.25	0.5	0.5	0	0	0	0	0	0	0	0	5.5
Total	**76.25**	1.45	1.45	1.45	1.45	2.45	2.95	3.2	3.75	5.75	6.25	6.25	3.5	3.25	4.25	5	4.75	4	5	4.5	3.95	2.95	1.45	1.45	1.45	

(d-I)

JULY LOAD PROFILE																									
Institutional	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**Sum in kWh**
Panwayee Clinic (Government)	1.5	1.5	1.5	1.5	1.5	1.5	2.25	2.25	3	3	3	2.25	2.25	2.25	3	3	3	3	3	3	1.5	1.5	1.5	1.5	53.3
Hashiimi Clinic (Private)	3.45	3.45	3.45	3.45	3.45	3.45	5.18	5.18	6.9	6.9	6.9	5.18	5.18	5.18	6.9	6.9	6.9	6.9	6.9	6.9	3.45	3.45	3.45	3.45	122
High School	0	0	0	0	0	0	0	0	1.9	1.9	1.9	0	0	0	0	0	0	0	0	0	0	0	0	0	5.7
Secondary school	0	0	0	0	0	0	0	0	0.15	0.15	0.15	0	0	0	0	0	0	0	0	0	0	0	0	0	0.45
Main Police Stations	3.25	3.25	3.25	3.25	3.25	3.25	6.5	6.5	9.75	13	13	6.5	6.5	9.75	13	13	13	9.75	6.5	3.25	3.25	3.25	3.25	3.25	163
Small police posts	1.4	1.4	1.4	1.4	1.4	1.4	1.4	3.5	5.25	5.25	5.25	5.25	3.5	5.25	5.25	5.25	5.25	5.25	3.5	1.4	1.4	1.4	1.4	1.4	74.6
Main mosques	0	0	0	0	1.2	1.8	1.2	0	0	0	0	0	0	0	0	0	0	1.8	1.8	1.8	1.8	0	0	0	11.4
Small mosques	0	0	0	0	8.38	12.6	8.38	0	0	0	0	0	0	0	0	0	0	12.6	12.6	12.6	12.6	0	0	0	79.6
Municpality	0	0	0	0	0	0	0	4	6	8	8	4	4	8	6	4	2	0	0	0	0	0	0	0	54
District Office	0	0	0	0	0	0	0	8.25	11	11	11	2.75	2.75	2.75	5.5	5.5	0	0	0	0	0	0	0	0	60.5
Total (kW)	9.6	9.6	9.6	9.6	19.2	24	24.9	29.7	44	49.2	49.2	25.9	24.2	33.2	39.7	37.7	30.2	39.3	34.3	28.9	24	9.6	9.6	9.6	

(d-O)

SEPTEMBER LOAD PROFILE																										
Institutional	**Total Load (kW)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**Sum**
Panwayee Clinic (Government)	3	0.5	0.5	0.5	0.5	0.5	0.5	0.75	0.75	1	1	1	0.75	0.75	0.75	1	1	1	1	1	1	0.5	0.5	0.5	0.5	17.75
Hashiimi Clinic (Private)	6.9	0.5	0.5	0.5	0.5	0.5	0.5	0.75	0.75	1	1	1	0.75	0.75	0.75	1	1	1	1	1	1	0.5	0.5	0.5	0.5	17.75
High School	7.6	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.25	0.25	0.75	0.75	0.75	0	0	0	0	0	0	0	0	5
Secondary school	0.6	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.25	0.25	0.75	0.75	0.75	0	0	0	0	0	0	0	0	5
Main Police Stations	13	0.25	0.25	0.25	0.25	0.25	0.25	0.5	0.5	0.75	1	1	0.5	0.5	0.75	1	1	1	0.75	0.5	0.25	0.25	0.25	0.25	0.25	12.5
Small police posts	7	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.5	0.75	0.75	0.75	0.75	0.5	0.75	0.75	0.75	0.75	0.75	0.5	0.2	0.2	0.2	0.2	0.2	10.65
Main mosques	2.4	0	0	0	0	0.5	0.75	0.5	0	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0	0	0	0	4.75
Small mosques	16.75	0	0	0	0	0.5	0.75	0.5	0	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.75	0	0	0	0	4.75
Municpality	8	0	0	0	0	0	0	0	0.5	0.75	1	1	0.5	0.5	1	0.75	0.5	0.25	0	0	0	0	0	0	0	6.75
District Office	11	0	0	0	0	0	0	0	0.75	1	1	1	0.25	0.25	0.25	0.5	0.5	0	0	0	0	0	0	0	0	5.5
Total	**76.25**	1.45	1.45	1.45	1.45	2.45	2.95	3.2	3.75	6.75	7.25	7.25	4	3.75	5.75	6.5	6.25	5.5	5	4.5	3.95	1.45	1.45	1.45	1.45	

(e-I)

SEPTEMBER LOAD PROFILE																									
Institutional	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum in kWh
Panwayee Clinic (Government)	1.5	1.5	1.5	1.5	1.5	1.5	2.25	2.25	3	3	3	2.25	2.25	2.25	3	3	3	3	3	3	1.5	1.5	1.5	1.5	53.3
Hashiimi Clinic (Private)	3.45	3.45	3.45	3.45	3.45	3.45	5.18	5.18	6.9	6.9	6.9	5.18	5.18	5.18	6.9	6.9	6.9	6.9	6.9	6.9	3.45	3.45	3.45	3.45	122
High School	0	0	0	0	0	0	0	0	5.7	5.7	5.7	1.9	1.9	5.7	5.7	5.7	0	0	0	0	0	0	0	0	38
Secondary school	0	0	0	0	0	0	0	0	0.45	0.45	0.45	0.15	0.15	0.45	0.45	0.45	0	0	0	0	0	0	0	0	3
Main Police Stations	3.25	3.25	3.25	3.25	3.25	3.25	6.5	6.5	9.75	13	13	6.5	6.5	9.75	13	13	13	9.75	6.5	3.25	3.25	3.25	3.25	3.25	163
Small police posts	1.4	1.4	1.4	1.4	1.4	1.4	1.4	3.5	5.25	5.25	5.25	5.25	3.5	5.25	5.25	5.25	5.25	5.25	3.5	1.4	1.4	1.4	1.4	1.4	74.6
Main mosques	0	0	0	0	1.2	1.8	1.2	0	0	0	0	0	0	0	0	0	1.8	1.8	1.8	1.8	0	0	0	0	11.4
Small mosques	0	0	0	0	8.38	12.6	8.38	0	0	0	0	0	0	0	0	0	12.6	12.6	12.6	12.6	0	0	0	0	79.6
Municpality	0	0	0	0	0	0	0	4	6	8	8	4	4	8	6	4	2	0	0	0	0	0	0	0	54
District Office	0	0	0	0	0	0	0	8.25	11	11	11	2.75	2.75	2.75	5.5	5.5	0	0	0	0	0	0	0	0	60.5
Total (kW)	9.6	9.6	9.6	9.6	19.2	24	24.9	29.7	48.1	53.3	53.3	28	26.2	39.3	45.8	43.8	44.5	39.3	34.3	28.9	9.6	9.6	9.6	9.6	

(e-O)

DECEMBER LOAD PROFILE																										
Institutional	Total Load (kW)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum
Panwayee Clinic (Government)	3	0.25	0.25	0.25	0.25	0.25	0.5	0.5	0.75	1	1	1	0.5	0.5	0.75	1	1	1	1	1	1	0.5	0.5	0.25	0.25	15.25
Hashiimi Clinic (Private)	6.9	0.25	0.25	0.25	0.25	0.25	0.5	0.5	0.75	1	1	1	0.5	0.5	0.75	1	1	1	1	1	1	0.5	0.5	0.25	0.25	15.25
High School	7.6	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.25	0.25	0.75	0.75	0.75	0	0	0	0	0	0	0	0	5
Secondary school	0.6	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0.25	0.25	0.75	0.75	0.75	0	0	0	0	0	0	0	0	5
Main Police Stations	13	0.25	0.25	0.25	0.25	0.25	0.25	0.5	0.5	0.75	1	1	0.5	0.5	0.75	1	1	1	0.75	0.5	0.25	0.25	0.25	0.25	0.25	12.5
Small police posts	7	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.5	0.75	0.75	0.75	0.5	0.5	0.75	0.75	0.75	0.75	0.75	0.5	0.25	0.25	0.1	0.1	0.1	9.5
Main mosques	2.4	0	0	0	0	0.5	0.75	0.5	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0	0	0	0	0	0	4
Small mosques	16.75	0	0	0	0	0.5	0.75	0.5	0	0	0	0	0	0	0	0	0.75	0.75	0.75	0	0	0	0	0	0	4
Municpality	8	0	0	0	0	0	0	0	0.5	0.75	1	1	0.5	0.5	1	0.75	0.5	0.25	0	0	0	0	0	0	0	6.75
District Office	11	0	0	0	0	0	0	0	0.75	1	1	1	0.25	0.25	0.25	0.5	0.5	0	0	0	0	0	0	0	0	5.5
Total	**76.25**	0.85	0.85	0.85	0.85	1.85	2.85	2.6	3.75	6.75	7.25	7.25	3.25	3.25	5.75	6.5	7.75	5.5	5	3	2.5	1.5	1.35	0.85	0.85	

(f-I)

DECEMBER LOAD PROFILE																									
Institutional	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Sum in kWh
Panwayee Clinic (Government)	0.75	0.75	0.75	0.75	0.75	1.5	1.5	2.25	3	3	3	1.5	1.5	2.25	3	3	3	3	3	3	1.5	1.5	0.75	0.75	45.8
Hashiimi Clinic (Private)	1.73	1.73	1.73	1.73	1.73	3.45	3.45	5.18	6.9	6.9	6.9	3.45	3.45	5.18	6.9	6.9	6.9	6.9	6.9	6.9	3.45	3.45	1.73	1.73	105
High School	0	0	0	0	0	0	0	0	5.7	5.7	5.7	1.9	1.9	5.7	5.7	5.7	0	0	0	0	0	0	0	0	38
Secondary school	0	0	0	0	0	0	0	0	0.45	0.45	0.45	0.15	0.15	0.45	0.45	0.45	0	0	0	0	0	0	0	0	3
Main Police Stations	3.25	3.25	3.25	3.25	3.25	3.25	6.5	6.5	9.75	13	13	6.5	6.5	9.75	13	13	13	9.75	6.5	3.25	3.25	3.25	3.25	3.25	163
Small police posts	0.7	0.7	0.7	0.7	0.7	0.7	0.7	3.5	5.25	5.25	5.25	3.5	3.5	5.25	5.25	5.25	5.25	5.25	3.5	1.75	1.75	0.7	0.7	0.7	66.5
Main mosques	0	0	0	0	1.2	1.8	1.2	0	0	0	0	0	0	0	0	1.8	1.8	1.8	0	0	0	0	0	0	9.6
Small mosques	0	0	0	0	8.38	12.6	8.38	0	0	0	0	0	0	0	0	12.6	12.6	12.6	0	0	0	0	0	0	67
Municpality	0	0	0	0	0	0	0	4	6	8	8	4	4	8	6	4	2	0	0	0	0	0	0	0	54
District Office	0	0	0	0	0	0	0	8.25	11	11	11	2.75	2.75	2.75	5.5	5.5	0	0	0	0	0	0	0	0	60.5
Total (kW)	6.43	6.43	6.43	6.43	16	23.3	21.7	29.7	48.1	53.3	53.3	23.8	23.8	39.3	45.8	58.2	44.5	39.3	19.9	14.9	9.95	8.9	6.43	6.43	

(f-O)

Table 7: Diversification of Institutional Loads (inputs and Outputs) in kWh, (a-I) Input for January, (a-O) Output for January, (b-I) Input for March, (b-O) Output for March, (c-I) Input for May, (c-O) Output for May (d-I) Input for July, (d-O) Output for July, (e-I) Input for September, (e-O) Output for September (f-I) Input for December, (f-O) Output for December

The load profile for the institutional loads varies in the range of 50 to 60 kW with the monthly peaks varying from 49 in July and August to about 64 in January. The variation in the peak loads is mainly due to the seasonal changes (Figure 5).

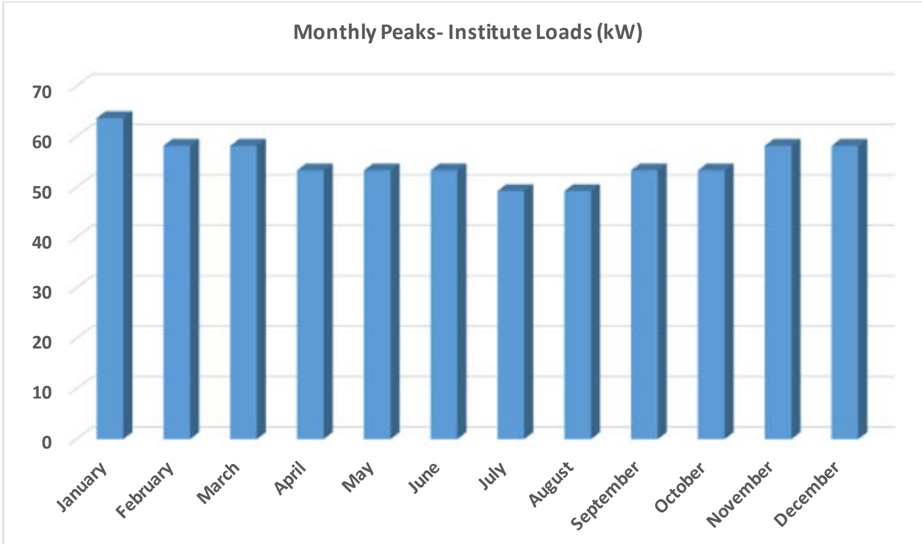
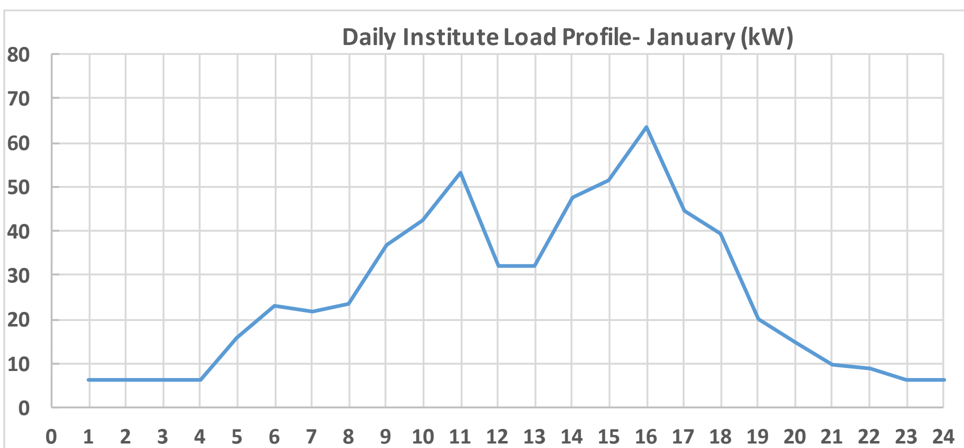
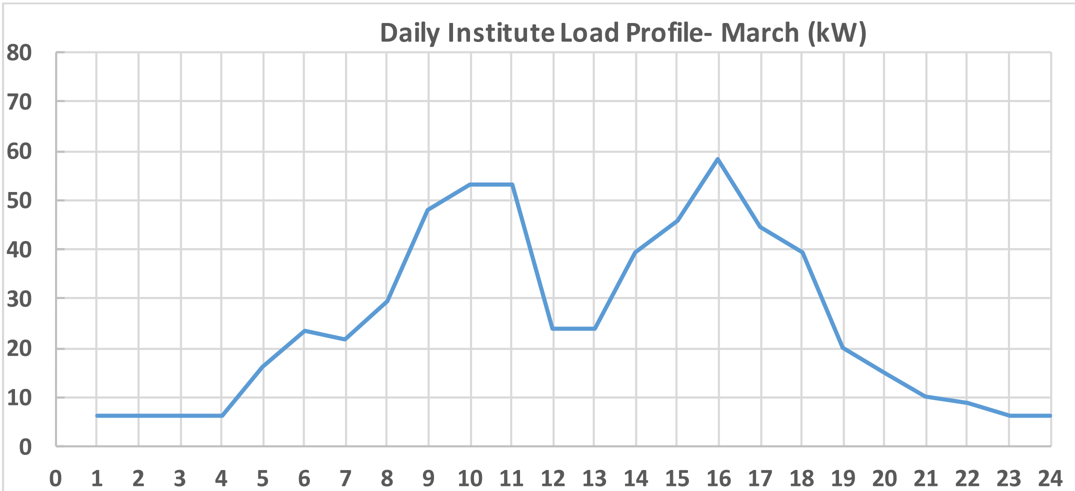


Figure 5: Monthly Peaks for Institutional Loads

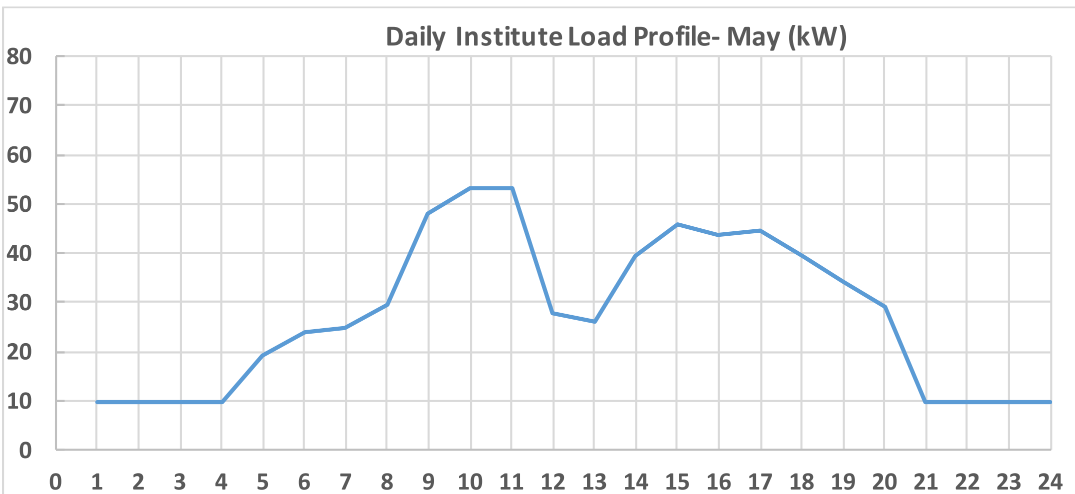
Figure 6 shows the load distribution during one day in the month of January, March, May, July, September and December. As it can be seen that there is a minimum load that is constantly required throughout the day and then there are other loads that turn on and off during the course of the day creating different size peaks at different times. There are load spikes in the morning and evening due to the operation of Mosques and there is an increase in the load during the middle of day due to operation of schools.



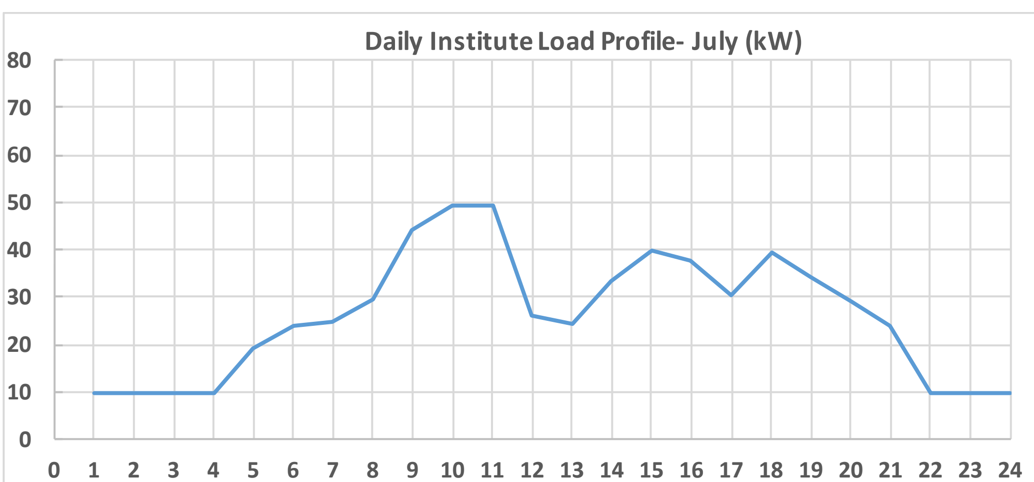
(a) for January in kW



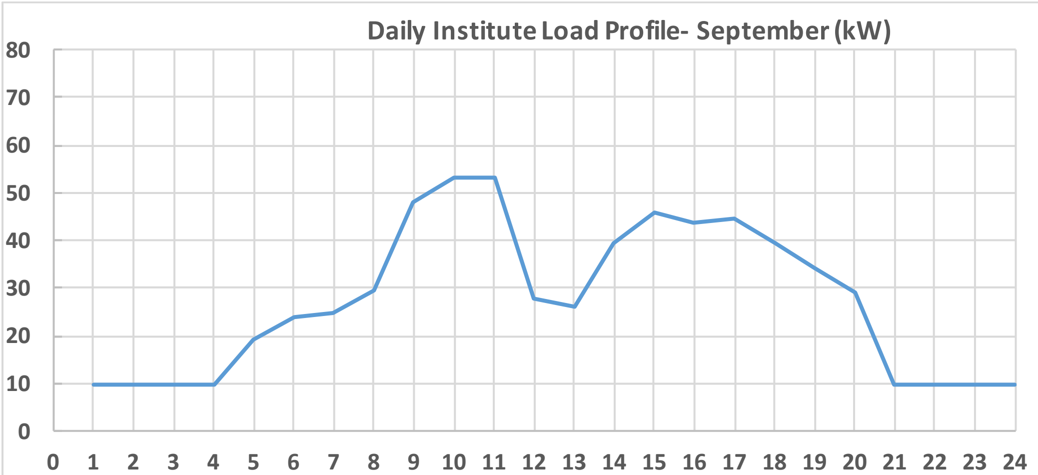
(b) For March in kW



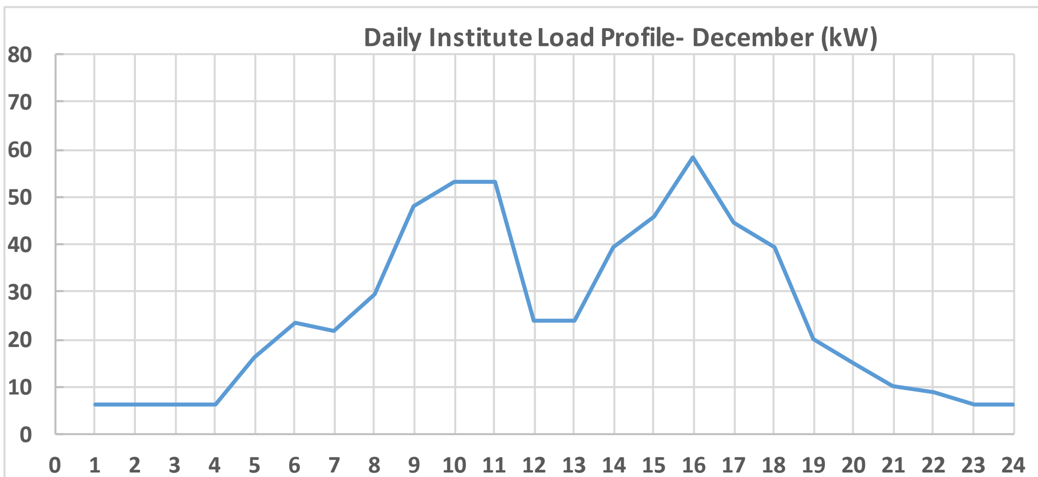
(c) For May in kW



(d) For July in kW



(e) For September in kW



(f) For December in kW

Figure 6: Institutional Load profile for the month of (a) January, (b) March, (c) May, (d) July, (e) Sept & (f) Dec

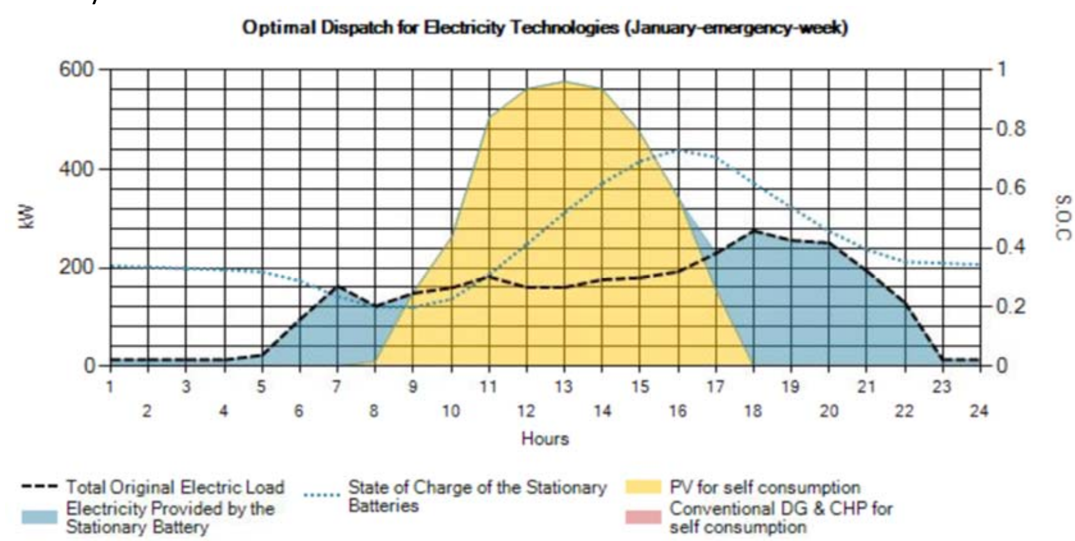
As seen in the previous chapters, the load profile and the peak load of the different kinds of loads, namely, residential, commercial and institutional, are completely different. As the centralized mini-grid will support all types of loads, it is necessary to create a cumulative load profile. The cumulative load profile will represent the size and nature of the load that the mini-grid will be required to serve. The next chapter calculates and discusses the overall power demand for the target community consisting of 25 neighborhoods and suburbs.

6. SYSTEM SIZING

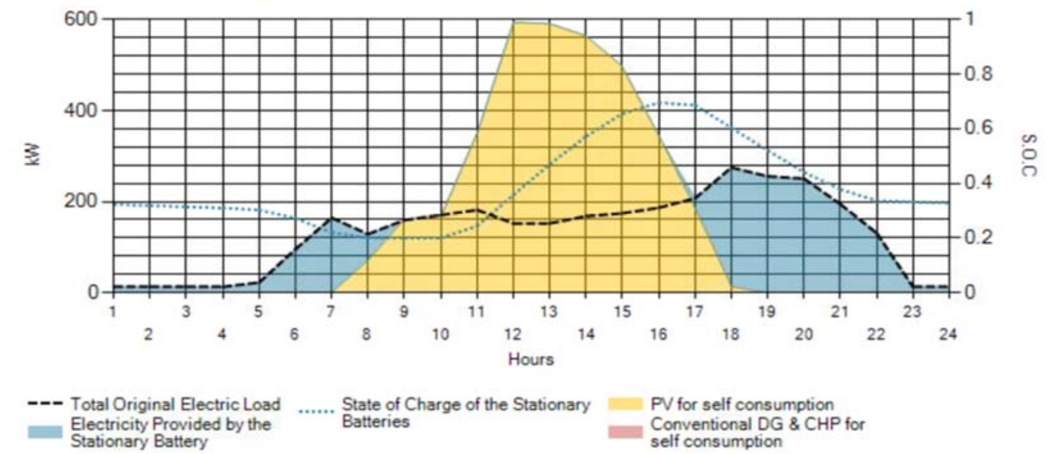
The mini-grid can be designed for different modes of operation; if the goal is to achieve a mini-grid that will operate without any fossil fuel based electricity generation and be a 100% renewable energy based mini-grid then an approximately 1,221kW-dc Solar PV and a 4400kWh BESS can support the current load profile. This mini-grid will need an approximately 425kW diesel generator for providing back up power on the days that there won't be enough solar irradiation to generate the required energy. However, this size will produce excess energy that, at this time, is not supported by the client.

Alternatively, a proposed 1000kW Solar PV with a 3500kWh BESS and a 75kW diesel generator can ascertain a stable operation of the mini-grid. The mini-grid can completely support the loads for about 8 months of the year with 100% solar based generation but will need some amount of diesel in order to support all the loads for the remaining 4 months of the year. Figure 14, shows the charging and discharging curve for the mini-grid; it can be seen that in the months of May, June, July and August there is a need for diesel generator to operate in order to support the loads for a few hours. This can be achieved with a 75kW diesel generator. Also, the mini-grid will need diesel generator for providing back up power on the days that there won't be enough solar irradiation to generate the required energy. The total amount of diesel required to support a peak load of approximately 425kW will be around 425kW. If we are assuming that a 75kW diesel generator will be required for the regular operation of the mini-grid then it is proposed that another 425kW generator be present for back up operational support.

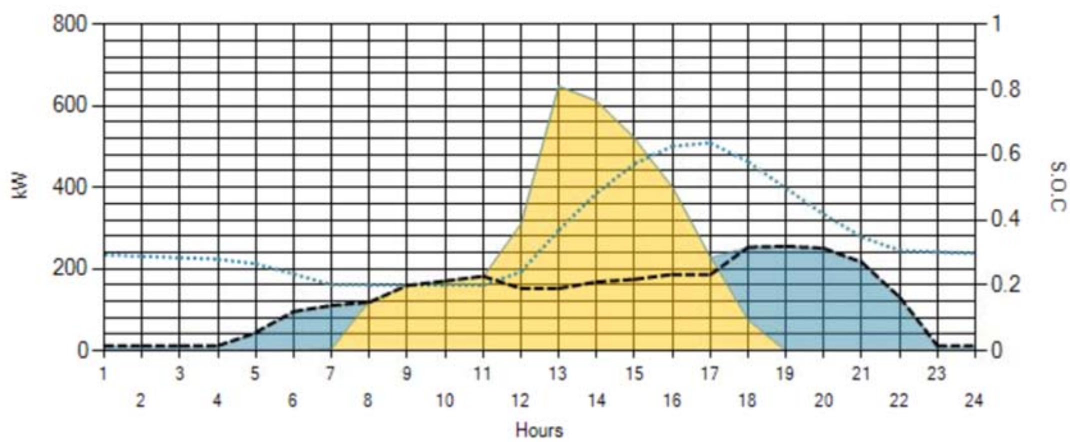
Figures 7 provide overview of the operation of the system, including the load profile, the PV power generated by the system, the energy supplied by the BESS and diesel generators on a month-by-month basis.



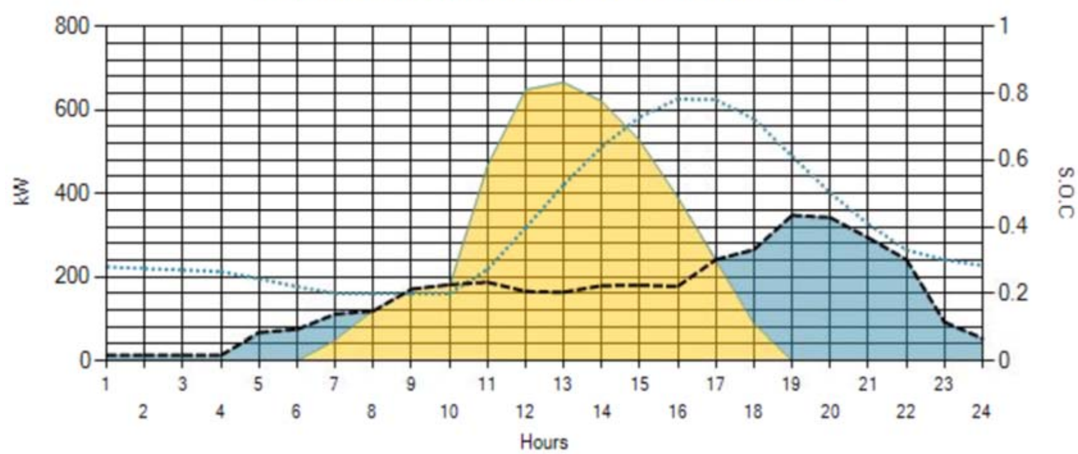
Optimal Dispatch for Electricity Technologies (February-emergency-week)



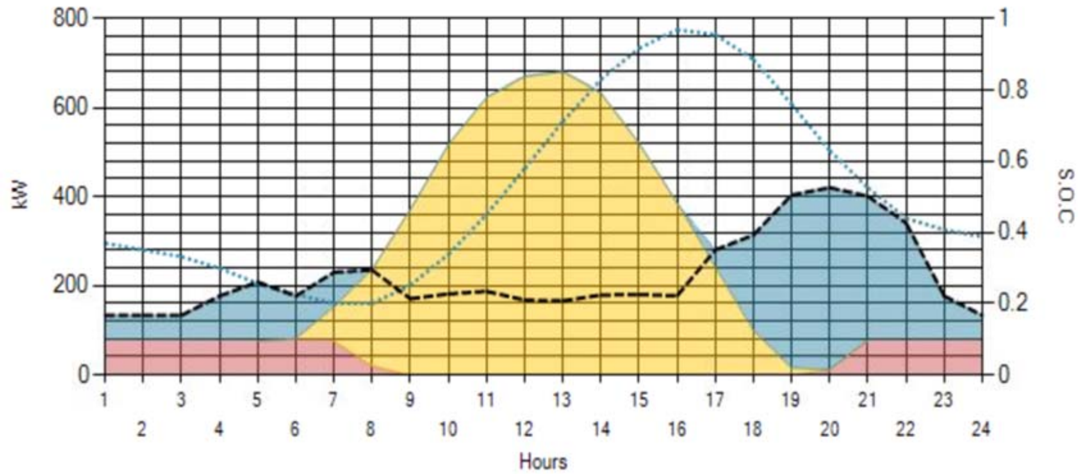
Optimal Dispatch for Electricity Technologies (March-emergency-week)



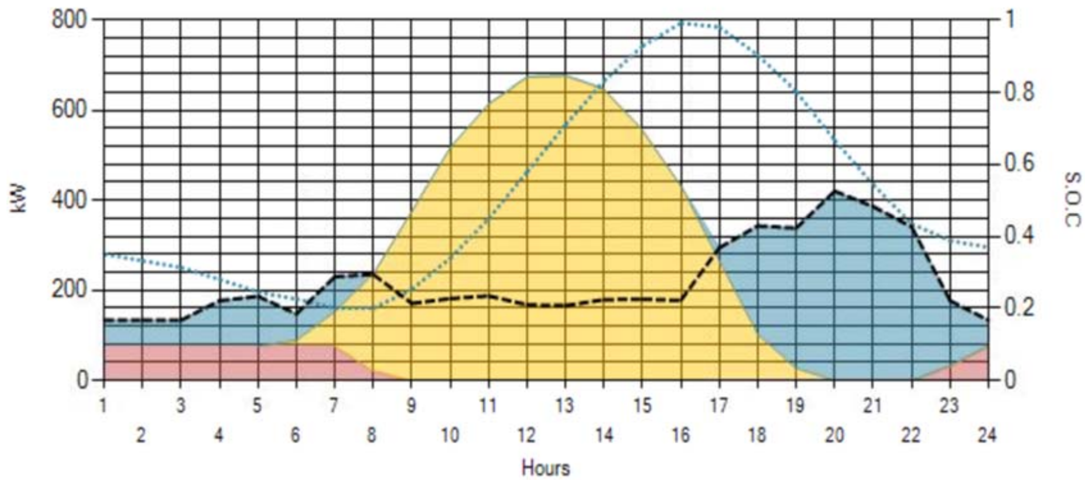
Optimal Dispatch for Electricity Technologies (April-emergency-week)



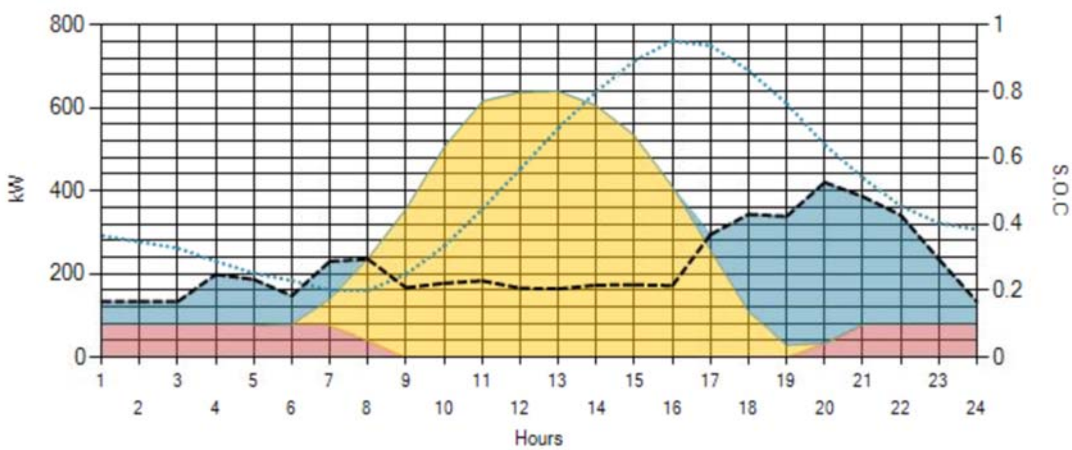
Optimal Dispatch for Electricity Technologies (May-emergency-week)



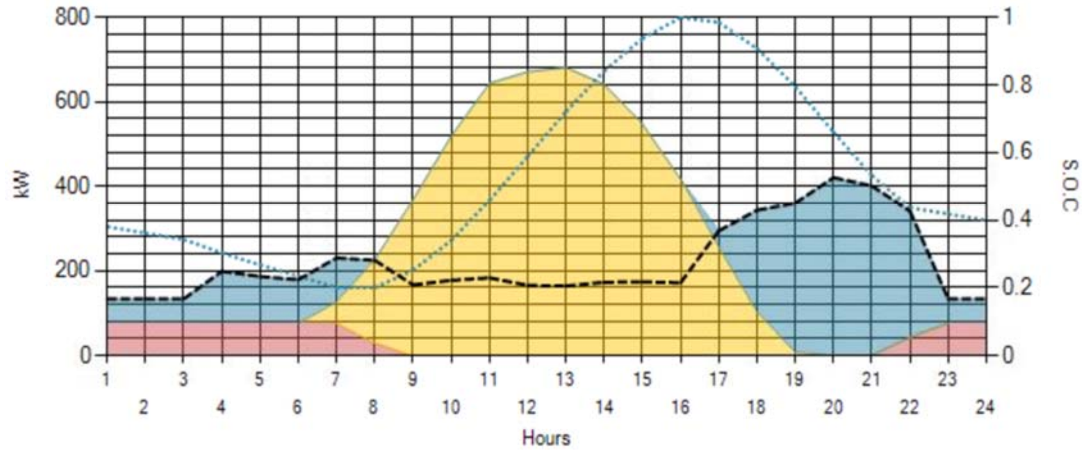
Optimal Dispatch for Electricity Technologies (June-emergency-week)



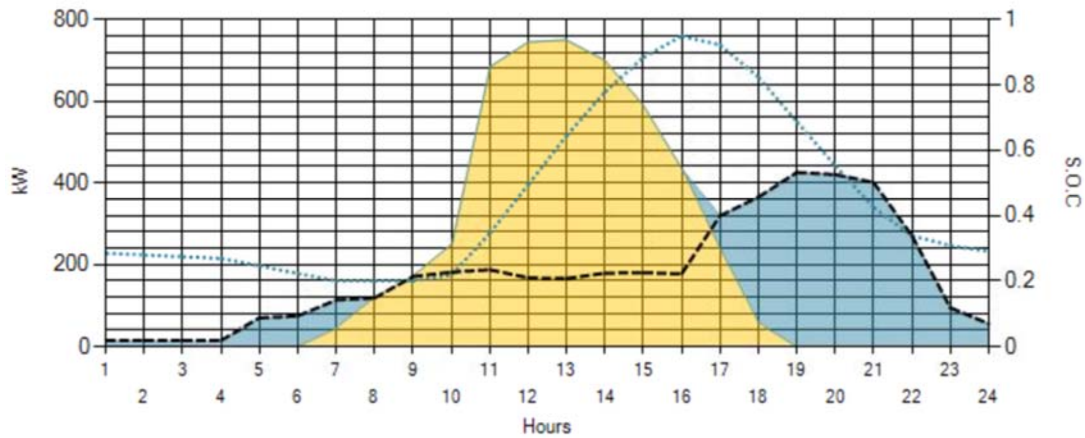
Optimal Dispatch for Electricity Technologies (July-emergency-week)



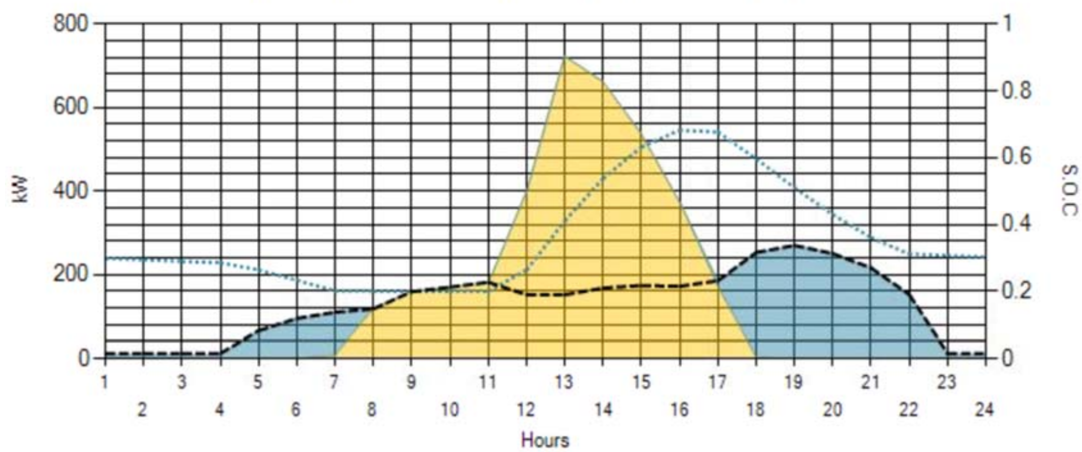
Optimal Dispatch for Electricity Technologies (August-emergency-week)

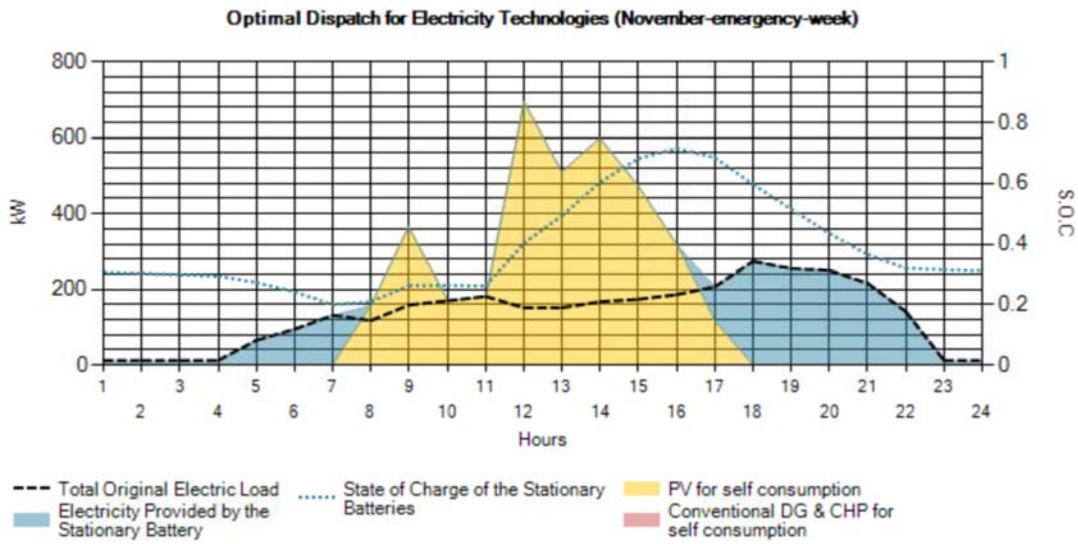


Optimal Dispatch for Electricity Technologies (September-emergency-week)



Optimal Dispatch for Electricity Technologies (October-emergency-week)





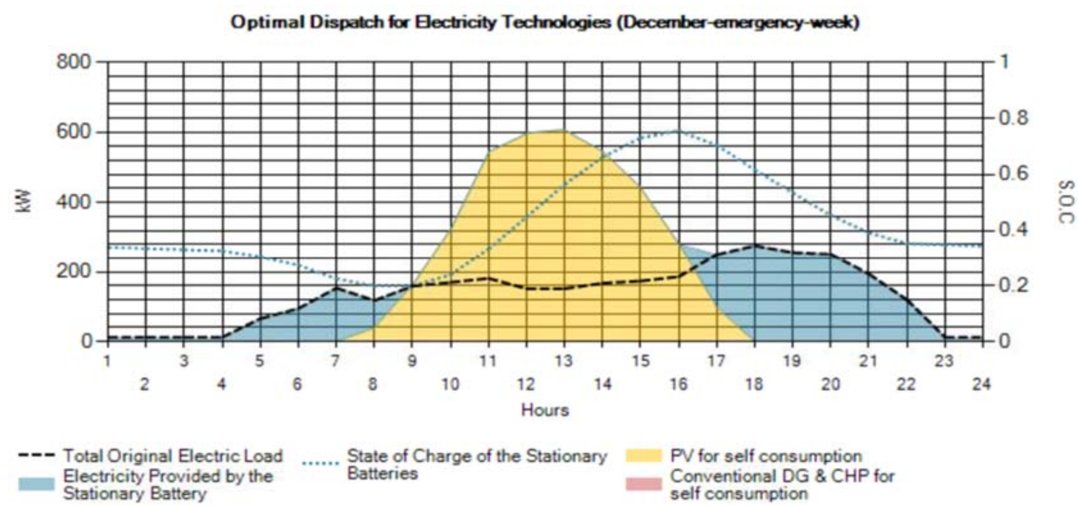


Figure 7: Optimal Charging and dispatch schedule for 600kW-dc Solar PV and 3500kWh BESS mini-grid.

In calculating the system size and the associated BESS, the design assumes a round-trip efficiency of 81% for the BESS (Lux Research – Press release on Li-Ion Cost edge for Stationary Energy Storage)[1], which translates to slightly smaller system size than other types of batteries.

For the estimated load profile based on reduced commercial loads, a mini-grid with a solar PV generator of about **1,000kW-dc** with a **3,500kWh** of battery storage is expected to operate with an estimated diesel cost of about **$19,500 per year** for a **75kW** diesel generator. Since the peak load is expected to be about 425kW, the system is proposed to have multiple diesel generators with a combined generation capacity of about 425kW. Having multiple generators will add redundancy to the backup system and reduce the need

[1] http://www.luxresearchinc.com/news-and-events/press-releases/read/li-ion-retains-cost-edge-stationary-energy-storage

for operating one large generator, hence having a more efficient operation. Table 8 shows some basic calculations associated with the discussed system. The second column gives an estimate of the average monthly loads. Column 3 gives the estimate of the energy that will be generated by the 1000kW-dc solar system. Column 4 shows the energy generated from PV that will be used to support the loads. Column 5 gives an estimate of the surplus energy available from the PV system. Column 6 gives an estimate of the amount of energy supplied by the diesel generator. It should be noted that the amount of "Energy Supplied by Diesel" is not a simple difference between the "Average monthly Loads" and "Energy Supplied by Solar PV", rather a much higher number. The reason being that out of the estimated "Average Monthly Loads" not all of it is daytime load. DER-CAM does a detailed hour-by-hour calculation to estimate the amount of load that would directly be served by the solar production during the daytime and also the amount of energy that will be needed to charge the batteries, which will support the loads at night. Because of the charging and discharging efficiencies of the battery (roundtrip efficiency of about 90% x 90% = 81%), the amount of energy used to charge the batteries and then support the loads causes a higher amount of energy supplied by diesel. Column 7 gives an estimate of the Loss of Load Probability in absence of an operating 75kW diesel generator.

	Average Monthly Loads (MWh)	**Energy Supplied by Solar PV (MWh)**	**Energy Used (MWh)**	**Surplus Energy (MWh)**	**Energy Supplied by Diesel (MWh)**	**Loss of Load Probability (LoLP)**
January	98.21	117.46	111.39	6.07	0.00	0%
February	88.00	112.97	99.08	13.89	0.00	0%
March	95.43	140.71	106.27	34.44	0.00	0%
April	111.12	148.39	124.98	23.41	0.00	0%
May	164.49	156.73	156.73	0.00	26.61	16%
June	156.55	155.64	155.64	0.00	19.66	13%
July	163.18	153.75	153.75	0.00	27.88	17%
August	161.79	158.15	158.15	0.00	23.24	14%
September	125.96	163.85	143.63	20.22	0.00	0%
October	96.78	156.70	108.70	48.00	0.00	0%
November	95.31	136.97	107.67	29.30	0.00	0%
December	99.29	118.51	113.03	5.48	0.00	0%
	1456.10	**1719.83**	**1539.00**	**180.82**	**97.40**	**6.69%**

Table 8: Calculations for a 1000kW-dc PV System with a 3,491kWh BESS

Table 9 provides a detailed calculation on the amount and cost of diesel needed to produce the energy needed to support the 1000kW-dc mini-grid.

Size of Diesel Generator (kW)	Hours of Operation per month	Fuel Consumption per hour (Gallon)	Total Fuel Consumed (liters)	Diesel Cost per liter	Total Diesel Cost	Cost of Energy by diesel ($/kWh)
75.00	0.00	6.10	0.00	$0.65	$0.00	$0.00
75.00	0.00	6.10	0.00	$0.65	$0.00	$0.00
75.00	0.00	6.10	0.00	$0.65	$0.00	$0.00
75.00	0.00	6.10	0.00	$0.65	$0.00	$0.00
75.00	354.84	6.10	8193.57	$0.65	$5,325.82	$0.20
75.00	262.11	6.10	6052.34	$0.65	$3,934.02	$0.20
75.00	371.79	6.10	8585.08	$0.65	$5,580.30	$0.20
75.00	309.88	6.10	7155.44	$0.65	$4,651.04	$0.20
75.00	0.00	6.10	0.00	$0.65	$0.00	$0.00
75.00	0.00	6.10	0.00	$0.65	$0.00	$0.00
75.00	0.00	6.10	0.00	$0.65	$0.00	$0.00
75.00	0.00	6.10	0.00	$0.65	$0.00	$0.00
	1,298.62		**29,986.43**		**$19,491.18**	

Table 9: Amount and Cost of Diesel needed for a 1000kW-dc solar based mini-grid using a 75kW diesel generator

The design of electrical distribution system of the mini-grid emphasizes reliability. The building blocks of reliability are redundant electrical supplies, reliable feeders, multiple feeder paths, control system simplicity and reduction of possible human error. One of the design criteria is that the system should be able to operate without connection to the utility supply, in island mode.

7. SYSTEM DESIGN

The Kandahar mini-grid is based on the electricity being supplied by Solar PV + Battery Energy Storage System (BESS) and use of Diesel Generator as back up source of energy when PV/Battery output is not adequate.

7.1 System Sizing

Load: 425kW Peak Load
PV: 1000kW-dc/800kW-ac
BESS: 3500kWh
Diesel: 425kW + 75kW
Grid-Tied Transformer: 750kVA

7.2 Configuration

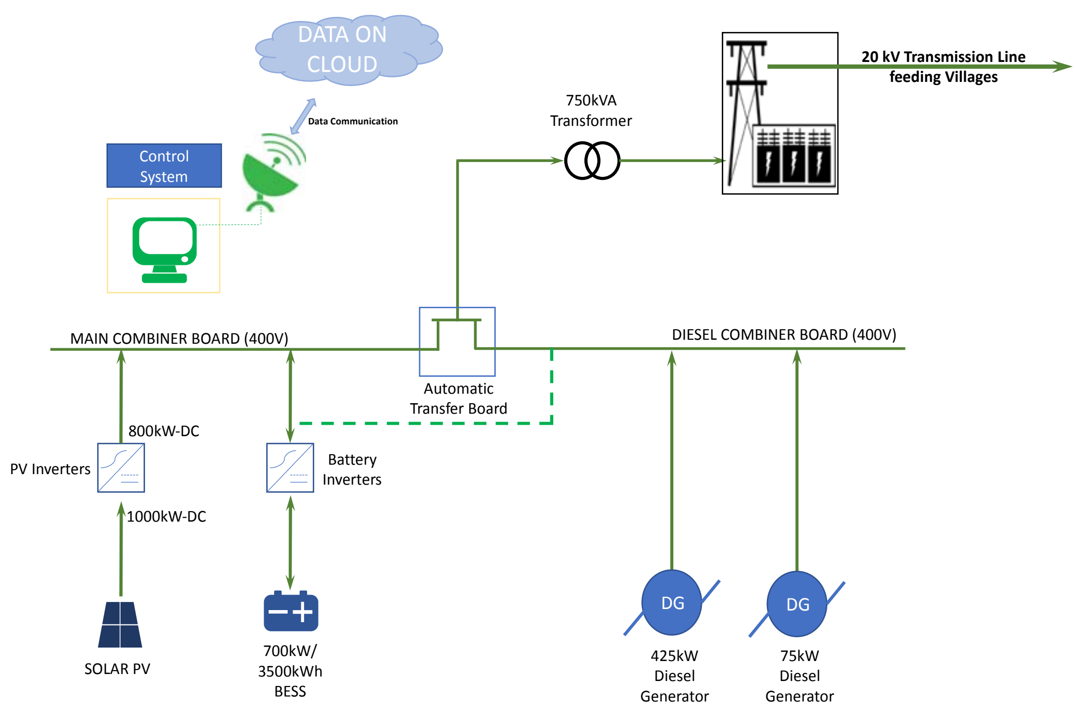


Figure 8: Block Diagram

7.3 Simplified One-Line

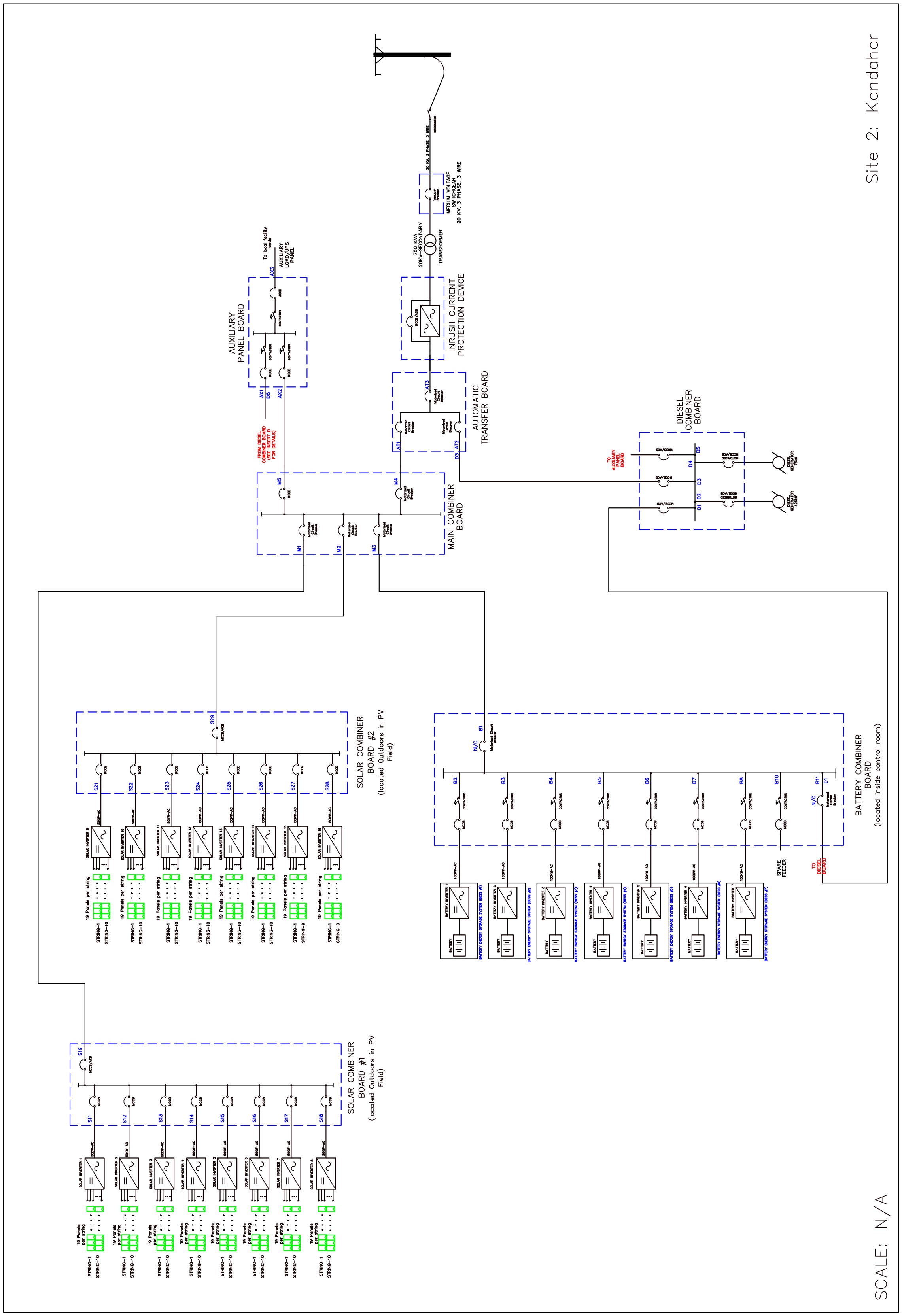


Figure 9: One-Line Diagram

7.4 Operation Logic

The high-level operating logic is the following:

1. As there is no utility, BESS will provide the master voltage and frequency. Solar inverters will follow this reference. System is started with BESS setting up the master voltage and frequency.
2. During day time when solar PV output is high enough, solar PV will be used to support the loads and simultaneously charge the BESS. BESS when sufficiently charged will also act as a buffer to manage short term solar variability.
3. In the evening, as the production from Solar PV starts declining, BESS starts discharging and the PV/BESS combination supports the load. Upon sunset PV inverters get switched OFF while BESS continues to support the load. This operation is carried out by the Automatic Transfer Panel, which is able to manage complex interactions between the various sources, including the PV, the BESS and the Diesel Generators. This operation is carried out by the SCADA and the PV/BESS inverters are able to follow the logic.
4. During the course of evening and night, BESS will support the loads without any PV. When the State of Charge (SOC) of the BESS drops to a predefined set point, the BESS inverters get switched OFF and the system transitions automatically to diesel operation. For a very short period of time (< 5 minutes) the diesel and BESS will operate in parallel in order to make sure that there is no interruption during the switch over from BESS to diesel. PV inverters will continue to remain OFF.
5. 75kW diesel generator unit will start first in case the load is below 50KW and will continue to power the load until load exceeds 75KW. At this point the 425KW generator starts automatically and the load gets transferred from the 75KW unit to the 425KW unit. There will be a very short period of parallel operation between both the diesel generators to avoid any interruption in the supply during this process. However, in case load at the end of step 4 above is higher than 75KW, the 425KW unit starts straight away skipping the 75KW generator operation.
6. In the morning, as the sun comes up, PV starts charging the BESS while diesel generator supports the load. This continues until output from solar PV is high enough to support the load (see step 7).
7. When the output from PV is high enough to support the load, diesel units get switched OFF and Solar PV takes over supporting the load while charging the BESS. The transition from diesel to PV+BESS is done with momentary paralleling in order to make sure that the transition from Diesel from PV is smooth and without interruption.
8. Load management to limit the load to the generation (to be done by reticulation system supplier). The SCADA system can be accessed via internet to check the actual PV production. They should also check the meteorological department forecast (cloudy/sunny) to make a day ahead planning. Battery will handle any short-term

variability. The operation is carried out by SCAD and the PV/BESS inverters are able to follow the logic

9. During days with extended cloud overcast, diesel will continue to support the grid till PV output is high enough to support the load. Solar production during this time will be used to charge the BESS.
10. Emergency operation: During normal operation batteries are charged solely by solar PV. However, in the event of an emergency when batteries SOC level drops to a very low value, it is possible to use the diesel generators to provide emergency charging power to the batteries. PV inverters will be OFF during this operation. Diesel generator will act as the master during this operation and battery inverters will follow this reference signal.
11. Control system provided by the BESS supplier together with SCADA system should manage this operation logic and provide charge/discharge set points to BESS inverters and on/off commands for PV and diesel for optimum performance.

8. SOLAR PV SYSTEM

8.1 Codes and Standards

8.1.1 Qualification Standards for PV Modules

- **IEC 61215:** International test standard for crystalline silicon terrestrial photovoltaic (PV) modules. Design qualification and type approval. Not a certification program.
- **IEC 61646:** International test standard for thin-film terrestrial photovoltaic (PV) modules. Design qualification and type approval. Not a certification program.
- **IEC 62108:** International test standard for concentrator modules/assemblies. Design qualification and type approval. Not a certification program.
- **IEEE 1262-1995:** Recommended practice for qualification of crystalline and thin -film PV modules. A test standard; Discontinued after the introduction of IEC 61646.
- **ANSI/UL 1703-2004**, Standard for Safety for Flat-Plate PV Modules and Panels
- **ASTM WK25362**, Practice for Photovoltaic Module Reliability Assessment
- **IEC-TC82** IEC Technical Committee (IEC-TC82) Solar photovoltaic energy systems
- **UL1703** for Flat-Plate PV Modules and Panels. Comply with NEC, OSHA and NFPA.
- **UL1741** for Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources
- **UL 2703** – Rack Mounting System & Clamping Device for Flat-Plate PV Modules & Panels
- **UL 1699,** for Arc-Fault Circuit-Interrupters
- **UL 1699B,** AC AFCIs
- ASTM PV standards **E44.09** for PV Electric Power Conversion
- **IEC61215, IEC61730, IEC 62804 (PID FREE)**
- **IEC 62716** (Ammonia Test)
- **IEC 61730** Electrical and Mechanical Safety
- **IEC 61701** (Salt Spray Test)
- **IEC 60364-4-41** Protection Against Electric Shock
- **TS EN 13501-5** (Ignitability Test)
- Quality Certificates: **ISO 9001:2015, ISO 14001:2015, OHSAS 18001:2007**
- **PID Test 1000V**
- **Other applicable standards**

8.1.2 Qualification Standards for Inverters:

- **UL 1741**
- **Surge Testing ANSI 62.41 and IEEE 1547-2003**
- **Protection IEC 62109-1/2**
- **IEC 61727**

- **IEC 62116**
- **Other applicable standards**

8.2 Design and Sizing

Based on the load profile created for the villages, the Kandahar mini-grid (Latitude: 31°32’28.58”N and Longitude: 65°28’39”E) will have to support an average load of approximately 166.22kW with a peak load of 425.91kW. The amount of energy to be generated over a period of 1-year is estimated to be around 1456MWh. The solar energy produced during the day time will be used to support the loads and also to charge the batteries. Diesel generator(s) will be used to provide supplemental energy in case the solar PV is not able to provide enough energy required to support the loads.

The proposed Kandahar mini-grid will rely mainly on solar PV based renewable energy generation to support the loads. The panels are proposed to be installed at a 30° tilt at an Azimuth of 0° (South-facing). The micro-grid modeling software DER-CAM is utilized to conduct the sizing of the mini-grid at Kandahar based on the load profile. The load profile provides an estimate of the energy required by the loads on an hour-by-hour basis for one full year, thus, providing 8760 data points for a period of one-year. DER-CAM takes the Solar Insolation data and the load data for one year and provides the best sizing option for solar, battery and diesel resources optimized for the least operating cost.

Based on the load profile, the Kandahar mini-grid is proposed to have a PV array providing 1000kW-dc of solar generation that would provide approximately 800kW-ac power. The system is proposed to have 16 string inverters of 50kW-ac output each in order to achieve the 800kW-ac output. The mini-grid will also have 3500kWh of Battery Energy Storage System (BESS) and diesel generators that can support a peak load of 425kW. The total land area required for the Kandahar mini-grid generation site is approximately 21,500m^2.

8.3 PV Layout

The PV field at the Kandahar location has a total of 3002 panels mounted on an adjustable tilt racking system. The maximum tilt for the panels will be at 30° at an Azimuth of 0° (south facing). There are a total of 12 rows of ground mount structures with each row consisting of two sets of panels mounted in portrait mode. One of the most important things to calculate is the appropriate inter-row spacing in order to avoid shading of panels. First, let us calculate the approximate height of the mounted panels. As it can be seen in Figure 10, the length of each panel is approximately 1960 mm and if two panels are mounted in portrait mode then the total length is 3945mm. For Kandahar site, if the maximum tilt we are considering is 30°, then the height of the mounting structure at the highest point will be: 3945*Sin 30°=1972.5mm

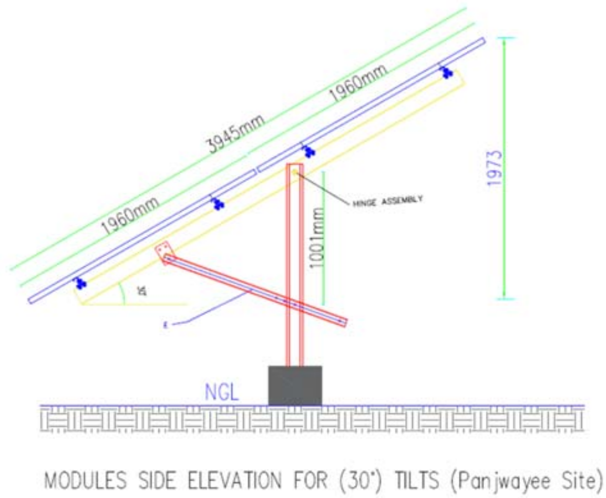


Figure 10: Solar Panel mounting in portrait mode

8.3.1 Tilt Angle Analysis

Following numbers from NREL's PV-Watts shows the annual energy production for different tilts angles: (see attached PV Watts reports for the different scenarios).

Panel Tilt Angle	Annual Average Solar Radiation (kWh/m^2/day)	Annual AC Energy produced (kWh)
7 Degree	6.27	1,682,095
15 Degree	6.52	1,751,986
20 Degree	6.63	1,781,089
25 Degree	6.70	1,798,996
30 Degree	**6.72**	**1,805,793**
31.5 Degree	6.71	1,805,668
35 Degree	6.69	1,801,623

If fixed tilt angle is used, we recommend 30 Degrees because it has the maximum amount of energy produced over the whole year, namely 1,020,357 kWh.

Using variable tilt angles with three tilts at three seasons, we record an increased output of 3.28% for total of 59,168 kWh, which translates to additional revenue of $7,691.84 per annum at tariff rate of $0.13 per kWh and total of $192,296 over the 25 year life span of the system (see table below).

Tilt Angle	Month	Output in kWh
7 deg	May	180,731
	June	174,497
	July	169,789
	August	162,962
30 deg	March	161,488
	April	161,403
	September	165,096
	October	165,948
35 Deg	November	146,589
	December	140,373
	January	119,422
	February	116,663
Total Output		**1,864,961**
Output at 30 Deg. Only		1,805,793
Increased Output		**59,168**
Anticipated tariff		$0.13
Annual Additional Revenue		**$ 7,691.84**
System's Lifespan		25
Saving over Lifespan		**$ 192,296.00**

8.3.2 Inter Row Spacing

The inter row spacing is calculated based on the 30° panel tilt and the Solar Azimuth Angle and the Solar Altitude Angle for winter Solstice day (Dec 21st). Since the sunrises and sunset times on winter solstice day are approximately 7 am and 5 pm respectively, for maximum production during a day the inter-row spacing can be calculated for 8 am and/or 4 pm. When the solar system is in the grid connected mode it is a common practice to calculate the inter-row spacing based on the sun position for 9 am and 3 pm but in case of a micro grid it is essential to get the maximum energy generation from the system. The maximum row separation distance is calculated based on the height of the row and the sun location.

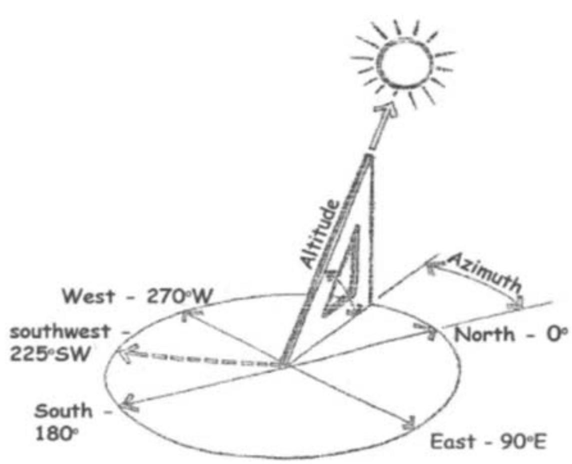


Figure 11: Calculation of Inter-Row Spacing

The minimum row spacing has to be more than the length of the shadow, L, as seen in Figure 11.

$$L = H \times Cos\ \psi / Tan\ \alpha$$

Where, H is the height of the row, ψ is the azimuth angle between solar azimuth and array azimuth (in degrees) and α is the solar altitude angle (in degrees). The value of Solar Azimuth and Solar Altitude angles can be estimated from Figure 12 showing the Sun Path Chart for a location at 30°N.

Case #1: Inter-row spacing for 9 am and 3 pm

If the height of the row is considered to be 1973mm, the value of solar azimuth angle to be 44° (at 9am/3pm on Dec 21st) and solar altitude angle to be 21° (at 9am/3pm on Dec 21st), then the maximum row separation is calculated to be 3695mm (12.1 feet).

Case #2: Inter-row spacing for 8 am and 4 pm

If the height of the row is considered to be 1973mm, the value of solar azimuth angle to be 54° (at 8am/4pm on Dec 21st) and solar altitude angle to be 12° (at 8am/4pm on Dec 21st), then the maximum row separation is calculated to be 5455mm (17.9 feet)

Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
December	0	0	0	0	0.0	0.0	0.0	48.8	313.5	514.5	683	747.2	758.8	685.6	556.8	349.9	120.8	0.0	0.0	0	0	0	0	0

Table 10: Global Effective Horizontal Irradiance Data (GH-Effective) for a South Facing - 30 degree Tilt

Based on the above table we can see that for the Kandahar location there is good irradiation available between 9 am and 4 pm. So, for the islanded mode of operation for the micro grid, we recommend the inter-row spacing to be about 18 feet (5486mm).

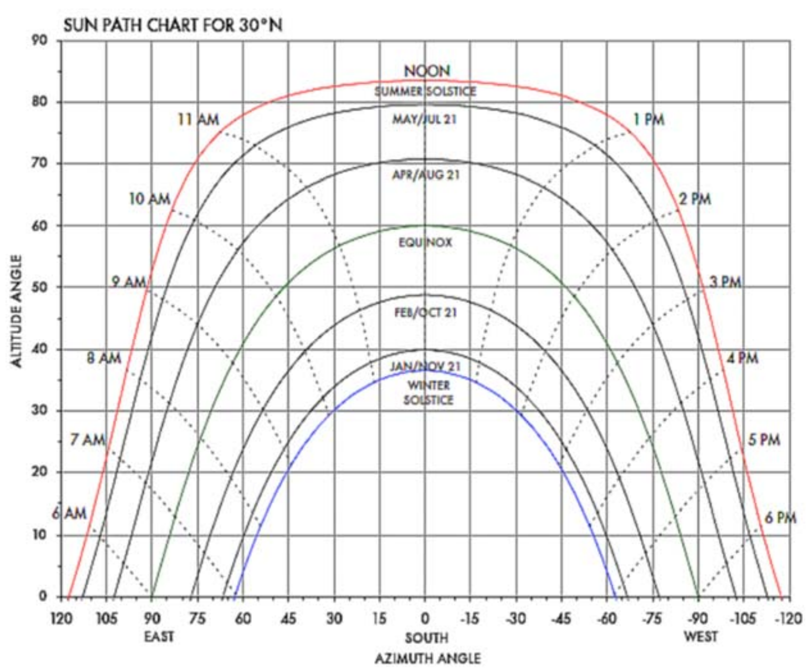


Figure 12: Sun Path Chart for Kandahar Location

8.3.3 Inter Row Space Analysis

As the inter-row spacing is reduced, the total annual energy production is reduced due to shading of panels, especially during the early morning and late afternoon hours. The inter-row spacing can be reduced and the ground coverage ratio (GCR) be lowered but the effect is a net loss in total energy produced.

The following table gives the annual energy generation data for different inter-row spacing models for the Kandahar solar plant. The data had been generated by Helioscope Simulation using 30 Degrees tilt angle as the baseline.

Inter-row Spacing	Annual AC Energy produced (GWh)	kWh/kW
10 feet (~3 meters)	1.745 GWh	1,735.2
12 feet (~3.7 meters)	1.764 GWh	1,753.9
15 feet (~4.6 meters)	1.778 GWh	1,768.2
18 feet (~5.5 meters)	**1.785 GWh**	**1,774.5**
20 feet (~6 meters)	1.786 GWh	1,776.0

The land size and annual energy production is optimized by selecting the inter-row spacing after which further increase does not provide any significant increase in production. The table shows that 12 foot (3.66 meters) inter-row spacing will enable the generation of 1,764 GWh of energy, while at inter row spacing of 18 feet (5.49 meters) 1.785 GWh of energy is produced. This translates to an increase of 21,000 kWh per year or a total of 525,000 kWh for the lifespan of the system. At a tariff rate of $0.13 per kWh, the additional production at 18 feet will translate to additional income of $2,730 per year for total of $68,250 for the life span of the system. This is shown in the table below:

Inter-Row Spacing	Output in GWh
12 foot	1.764
18 Foot	1.785
Difference in GWh per year	0.021
Difference in kWh per year	21,000
Difference in kWh per Life span of 25 years	525,000.00
Tariff	$0.13
Total add'l Income/Year	$ 2,730
Total Income over Life span of 25 years	$ 68,250.00

By using inter-row spacing of 12 foot (3.66 meters) compared to 18 foot (5.49 meters), the total area saved will amount 3,052 square meters or about 1.5 Jerib. At a typical cost of less than US$ 10,000 per jerib, the increased row spacing cost will be offset in less than 4 years.

Row space for 12 Ft	3.66	meters
Row space for 18 Ft	5.49	meters
Difference	1.83	meters
Length of row	139	meters
Number of rows	12	
Total Land area saved	3052.44	m2
Total Land Area Saved	1.53	Jerib
Cost per Jerib	$10,000.00	

8.3.4 Solar Panels

The primary component common to all Solar PV systems is the PV array. An array consists of individual PV modules that are electrically connected to produce a desired voltage, current and power output. Modules and arrays produce DC power, which can be used to charge batteries or can be converted to AC power by inverters to power AC loads.
The voltage of PV modules varies with temperature, and the current varies proportionately to the solar irradiance, so the power output is always varying.

8.3.5 I-V Curve

The current-voltage (I-V) characteristic is the basic electrical output profile of a PV module. The I-V characteristic represents all possible current-voltage operating points and power output for a given PV module at a specified condition of incident solar radiation and cell temperature. Certain points on I-V curves are used to rate module performance and are the basis for the electrical design of the PV array. The parameters include Open-circuit voltage (V_{OC}), short-circuit current (I_{SC}), maximum power voltage (V_{MP}), maximum power current (I_{MP}) and maximum power (P_{MP}). It is important to note that the I-V curve changes with cell temperature and irradiance, and that I-V parameters have meaning only when these conditions are specified.

The V_{OC} is the maximum voltage on an I-V curve and is the operating point for the PV array under infinite load or open-circuit condition and no current output. The V_{OC} is used to determine the maximum circuit voltage for modules and arrays. Increasing temperature reduces the V_{OC} for crystalline silicon solar cells.

The I_{SC} is the maximum current on an I-V curve and is the operating point for a PV device under no load condition and no voltage output. The I_{SC} is used to determine maximum circuit design currents for modules and arrays and is significantly affected by varying solar irradiance.

8.3.6 Temperature Coefficient

A temperature coefficient is the rate of change in voltage, current and power output from a PV module due to changing cell temperature. Temperature coefficient can be expressed as a unit (absolute) change or percentage (relative) change per degree of temperature change. Typically, the temperature coefficient for Silicon is negative, meaning that the voltage reduces with increase in the cell temperature.

Refer to technical specifications for detailed specs for solar PV system.

8.4 PV Inverters

Power conditioning equipment converts, controls and processes the DC power, produced by the PV array, to make the power compatible with other equipment or loads. Power conditioning equipment includes inverters, charge controllers, rectifiers, DC-DC converters, maximum power point trackers and power quality equipment. A power conditioning unit is a device that includes more than one power conditioning function. An inverter is a device that converts DC power to AC power. In PV system, the inverter converts the DC power from the PV array to AC power that can be used to charge the batteries and support AC loads. Inverters are characterized by power source, power ratings, input and output voltages, power quality, waveform, and power conversion efficiency.

Battery based inverters are used in stand-alone PV systems and operate directly from battery banks as their input source. Most battery-based inverters are bi-directional and include in-built battery chargers.

8.4.1 Maximum Power Point Tracking (MPPT)

A maximum power point tracker is a device or circuit that uses electronics to continually adjust the load on a PV device under changing temperature and irradiance conditions to keep it operating at it maximum power point.

The operating point at which the PV array produces its maximum power output lies between its open-circuit and short-circuit condition, when the device is electrically loaded with some finite resistance. The maximum power point (P_{MP}) is the operating point on the I-V curve where the product of current and voltage is at its maximum.

The voltage and current output from an array can vary with temperature, irradiance, and load. Various combinations of these factors produce power output anywhere between the maximum rated power level and zero. For any combination of temperature and irradiance, there is a maximum possible power output that corresponds to a certain voltage and current.

Refer to technical specifications for detailed specs for PV inverters.

8.5 PV Strings

The PV string sizing discussed here is based on the use of 335W, 72-cell, 18% efficient polycrystalline PV module and a 50kW String PV-inverter. Each inverter has the ability to have 10 PV strings as input. Based on the allowed input for the inverters and the voltage and current ratings for the solar panels, each solar string will have 19 solar panels connected in series. This will allow approximately 6kW-dc output from each PV string. 10 such strings (of 19 panels in each string) will be connected to one PV inverter.

Each inverter will have an output of 50kW-ac and outputs from 8 inverters will be connected to a combiner panel. Total of 2 combiner panels will combine the output from all the 16 inverters. The details of the solar panels, inverters and combiner panel are provided in the drawing set.

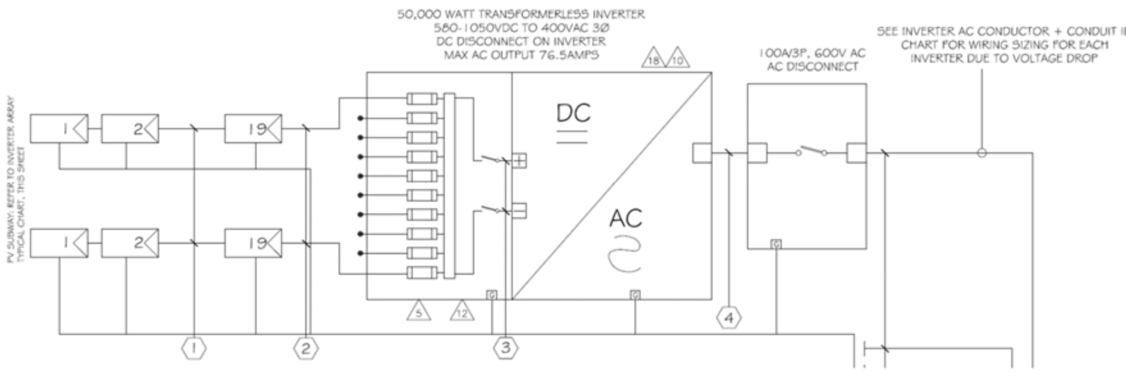


Figure 13: String of 19 PV panels and 10 such strings connected to one PV inverter.

TYPICAL FOR INVERTERS A-N

14-PHOTOVOLTAIC ARRAYS
190 PANELS AT 335 WATTS EACH
19 IN SERIES BY 10 IN PARRALLEL
TOTALS = 63,650 WATTS
VOC = 46.1 VAC ISC = 93.1 AMPS
VMP = 38.0 VDC IMP = 8.82 AMPS
SEE SHEET E-3 FOR WIRING DETAIL

TYPICAL FOR INVERTERS O-P

2-PHOTOVOLTAIC ARRAYS
171 PANELS AT 335 WATTS EACH
19 IN SERIES BY 9 IN PARRALLEL
TOTALS = 57,285 WATTS
VOC = 46.1 VAC ISC = 93.1 AMPS
VMP = 38.0 VDC IMP = 8.82 AMPS
SEE SHEET E-92 FOR WIRING DETAIL

NOTE: SYSTEM IS DESIGNED IN
ACCORDANCE TO THE NEC 2011

Figure 14: Specification of strings and PV inverter

8.5.1 Breaker Sizing

The Breaker size is calculated based on the capacity of each feeder, its continuous maximums current, and the design fault level. Once the breaker size is identified, the wiring size can be calculated/derived.

For each feeder, the continuous maximum current is taken from the PV inverter data sheet, the battery inverter or the diesel generator, depending on which equipment's data is needed.

The design fault calculation is provided in section 12.2.1 for each type of equipment. This section also includes the formulae used to calculate the faults. As per the National Electrical Code (NEC) article 240, the breakers are sized at least 20% more than the maximum inerter current and the breaker interruption capacity has to be more than the fault current.

The following tables provide the breaker sizing for each of the source and feeder type:

Feeder Name	Max. Current (A)	Max. Current x 125% (NEC 690.8) (A)	Rated Voltage (V)	Max. LV Fault Level (A)	Breaker Rating Continious * (A)	Breaker Interrupting Capacity* (A)	Max. Voltage drop for cable selection	Cable Size- Cu (mm2)
Feeder from Inverter A	76.5	95.63	400	21189	100	40000	3%	4x 1-core 55mm2 cable and 1x 1-core 25mm2 cable
Feeder from Inverter B	76.5	95.63	400	21189	100	40000	3%	4x 1-core 55mm2 cable and 1x 1-core 25mm2 cable
Feeder from Inverter C	76.5	95.63	400	21189	100	40000	3%	4x 1-core 55mm2 cable and 1x 1-core 25mm2 cable
Feeder from Inverter D	76.5	95.63	400	21189	100	40000	3%	4x 1-core 55mm2 cable and 1x 1-core 25mm2 cable
Feeder from Inverter E	76.5	95.63	400	21189	100	40000	3%	4x 1-core 55mm2 cable and 1x 1-core 25mm2 cable
Feeder from Inverter F	76.5	95.63	400	21189	100	40000	3%	4x 1-core 55mm2 cable and 1x 1-core 25mm2 cable
Feeder from Inverter G	76.5	95.63	400	21189	100	40000	3%	4x 1-core 55mm2 cable and 1x 1-core 25mm2 cable
Feeder from Inverter H	76.5	95.63	400	21189	100	40000	3%	4x 1-core 55mm2 cable and 1x 1-core 25mm2 cable
Ouput from Combiner Board to Main Combiner Board	612	765.00	400	21189	No Breaker	N/A	3%	12 x 1-Core 150mm2 cable and 3x 1-Core 55mm2

Table 11: Wire and Breaker Sizing for AC combiner Board # 1

Feeder Name	Max. Current (A)	Max. Current x 125% (NEC 690.8)(A)	Rated Voltage (V)	Max. LV Fault Level (A)	Breaker Rating Continious * (A)	Breaker Interrupting Capacity* (A)	Max. Voltage drop for cable selection	Cable Size- Cu (mm2)
Feeder from Inverter I	76.5	95.63	400	21189	100	40000	3%	4x 1-core 55mm2 cable and 1x 1-core 25mm2 cable
Feeder from Inverter J	76.5	95.63	400	21189	100	40000	3%	4x 1-core 55mm2 cable and 1x 1-core 25mm2 cable
Feeder from Inverter K	76.5	95.63	400	21189	100	40000	3%	4x 1-core 55mm2 cable and 1x 1-core 25mm2 cable
Feeder from Inverter L	76.5	95.63	400	21189	100	40000	3%	4x 1-core 55mm2 cable and 1x 1-core 25mm2 cable
Feeder from Inverter M	76.5	95.63	400	21189	100	40000	3%	4x 1-core 55mm2 cable and 1x 1-core 25mm2 cable
Feeder from Inverter N	76.5	95.63	400	21189	100	40000	3%	4x 1-core 55mm2 cable and 1x 1-core 25mm2 cable
Feeder from Inverter O	76.5	95.63	400	21189	100	40000	3%	4x 1-core 55mm2 cable and 1x 1-core 25mm2 cable
Feeder from Inverter P	76.5	95.63	400	21189	100	40000	3%	4x 1-core 55mm2 cable and 1x 1-core 25mm2 cable
Ouput from Combiner Board to Main Combiner Board	612	765.00	400	21189	No Breaker	N/A	3%	12 x 1-Core 150mm2 cable and 3x 1-Core 55mm2

Table 12: Wire and Breaker Sizing for AC combiner Board # 2

Feeder Name	Max. Current (A)	Max. Current x 125% (NEC 690.8)(A)	Rated Voltage (V)	Max. LV Fault Level (A)	Breaker Rating Continious (A)	Breaker Interrupting Capacity (A)	Max. Voltage drop for cable selection	Cable Size- Cu (mm2)
Feeder from Inverter 1	144	180.00	400	21189	200	40000	3%	4 x 1-Core 120mm2 cable and 1X 1-Core 25mm2
Feeder from Inverter 2	144	180.00	400	21189	200	40000	3%	4 x 1-Core 120mm2 cable and 1X 1-Core 25mm2
Feeder from Inverter 3	144	180.00	400	21189	200	40000	3%	4 x 1-Core 120mm2 cable and 1X 1-Core 25mm2
Feeder from Inverter 4	144	180.00	400	21189	200	40000	3%	4 x 1-Core 120mm2 cable and 1X 1-Core 25mm2
Feeder from Inverter 5	144	180.00	400	21189	200	40000	3%	4 x 1-Core 120mm2 cable and 1X 1-Core 25mm2
Feeder from Inverter 6	144	180.00	400	21189	200	40000	3%	4 x 1-Core 120mm2 cable and 1X 1-Core 25mm2
Feeder from Inverter 7	144	180.00	400	21189	200	40000	3%	4 x 1-Core 120mm2 cable and 1X 1-Core 25mm2
Spare Feeder	144	180.00	400	21189	200	40000	3%	4 x 1-Core 120mm2 cable and 1X 1-Core 25mm2
Ouput from BESS Combiner Board to Main Combiner Board	1152	1440.00	400	21189	1500	50000	3%	16 x 1-Core 240mm2 cable and 4x 1-Core 120mm2
Ouput from Diesel Combiner Board to BESS Combiner Board	614	767.50	400	21189	800	50000	3%	12 x 1-Core 150mm2 cable and 3x 1-Core 55mm2

Table 13: Wire and Breaker Sizing for Battery Combiner Board

Feeder Name	Max. Current (A)	Max. Current x 125% (NEC 690.8)(A)	Rated Voltage (V)	Max. LV Fault Level (A)	Breaker Rating Continious (A)	Breaker Interrupting Capacity (A)	Max. Voltage drop for cable selection	Cable Size- Cu (mm2)
Ouput from PV Combiner Board #1 to Main Combiner Board	612	765.00	400	21189	800	50000	3%	12 x 1-Core 150mm2 cable and 3x 1-Core 55mm2
Ouput from PV Combiner Board #1 to Main Combiner Board	612	765.00	400	21189	800	50000	3%	12 x 1-Core 150mm2 cable and 3x 1-Core 55mm2
Ouput from BESS Combiner Board to Main Combiner Board	1152	1440.00	400	21189	1500	50000	3%	16 x 1-Core 240mm2 cable and 4x 1-Core 120mm2
Ouput from Main Combiner Board to Auto Transfer Panel	1082.6	1353.25	400	21189	1400	50000	3%	12 x 1-Core 354.7mm2 cable and 3x 1-Core 120mm2
Ouput from Main Combiner Board to Auxiliary Panel Board	165	206.25	400	21189	200	40000	3%	12 x 1-Core 120mm2 cable and 3x 1-Core 25mm2

Table 14: Wire and Breaker Sizing for Main Combiner Board

Feeder Name	Max. Current (A)	Max. Current x 125% (NEC 690.8)(A)	Rated Voltage (V)	Max. LV Fault Level (A)	Breaker Rating Continious (A)	Breaker Interrupting Capacity (A)	Max. Voltage drop for cable selection	Cable Size- Cu (mm2)
Incoming from Main Combiner Board to Auto Transfer Panel	1082.6	1353.25	400	21189	1400	50000	3%	12 x 1-Core 354.7mm2 cable and 3x 1-Core 120mm2
Incoming from Diesel Combiner Board to Auto Transfer Panel	614	767.50	400	21189	800	50000	3%	12 x 1-Core 150mm2 cable and 3x 1-Core 55mm2
Ouput from Auto Transfer Panel to Inrush Current Device	1082.6	1353.25	400	21189	1400	50000	3%	12 x 1-Core 354.7mm2 cable and 3x 1-Core 120mm2

Table 15: Wire and Breaker Sizing for Auto Transfer Panel

Feeder Name	Max. Current (A)	Max. Current x 125% (NEC 690.8)(A)	Rated Voltage (V)	Max. LV Fault Level (A)	Breaker Rating Continious (A)	Breaker Interrupting Capacity (A)	Max. Voltage drop for cable selection	Cable Size- Cu (mm2)
Ouput from 425kW Diesel Generator to Diesel Combiner Board	614.00	767.50	400	21189	800	50000	3%	12 x 1-Core 150mm2 cable and 3x 1-Core 55mm2
Ouput from 75kW Diesel Generator to Diesel Combiner Board	108.25	135.31	400	21189	150	40000	3%	4 x 1-Core 55mm2 cable and 1x 1-Core 25mm2
Ouput from Diesel Combiner Board to BESS combiner Board	614	767.50	400	21189	800	50000	3%	12 x 1-Core 150mm2 cable and 3x 1-Core 55mm2
Ouput from Diesel Combiner Board to Auto Transfer Panel	614	767.50	400	21189	800	50000	3%	12 x 1-Core 150mm2 cable and 3x 1-Core 55mm2
Ouput from Diesel Combiner Board to Auxiliary Panel Board	165.00	206.25	400	21189	200	40000	3%	12 x 1-Core 120mm2 cable and 3x 1-Core 25mm2

Table 16: Wire and Breaker Sizing for Diesel Combiner Board

8.5.2 Sample Wire Sizing Calculations

The wire sizing calculation varies from equipment to equipment due to the type; here we are showing one example for reference. The AC wire run from the Solar Inverter to the AC combiner panel would be calculated as follows:

Number for further calculations of Max circuit current:
76.5 Amps x 125% (NEC 690.8) = **95.625 Amps.**

We also take into account any de-rating combiner panel would be calculated as follows:

The Maximum Amperage output rating (on equipment cut sheet is **76.5 Amps.**)
If we calculate the same number, then it is:
50,000 watts/400V=125amps/1.732=**72.2 Amps**

Since, according to the equipment specification sheet, the equipment supports a max current output of 76.5 amps, we will take that factors for ambient temp NEC 2014 Table 310.15(B)(2)(a), which in this case is 1.00, so no changes. The other factor would be for more than 3 current carrying conductors in a single conduit NEC 2014 table 310.15(B)(3)(a).

Which again for this is 100% as we don't have any more than 3 current carrying conductors per conduit run.

Using NEC 2014 Table 310.15 (B) (16) wire size would be **#3** (25mm^2) that has a amperage rating of **100amp** in the 75deg table and 115amp in 90 deg table.

Then, we apply voltage drop:

$$VD = 0.5 \times I \times R$$

$$VD = 0.5 \times I \times 2 \times L \times R / 1000.$$

Where;

VD = Voltage Drop in Volts

I = Wire Current in Amperes

R = Wire Resistance in Ohms (Ω) [Ω/km or] or (Ω/kft)

L = wire distance in meters or feet.

That gets us to the 1/0 (50mm^2**)** conductor size. There is a chart that is involved with the wire resistance in ohms or a calculation for that, but we use a program that holds all of that data for the voltage drop. Due to system being an off-grid setup we designed for a 1% VD. So, here we propose a conductor size of **50mm^2.**

SYMBOL	CIRCUIT	IMAX (AMPS)	SETS	MATERIAL	INSULATION	RACEWAY	SIZE (mm2)	QTY	CONDUCTOR	MAX. 1 WAY LENGTH (m)	VOLTAGE DROP (1%)	OPERATING VOLTAGE (V)
1	PV MODULE WIRING (INTEGRATED BY MANUFACTURER)	11.64	1	cu	2K PV	FREE AIR	4	1	DC+	1	0.02%	620
							4	1	DC-			
							4	1	G			
2	PV HOME RUN WIRING	11.64	1	cu	2K PV	FREE AIR	4	1	DC+	45.72	1.12%	620
							4	1	DC-			
							4	1	G			
3	PV DC OUTPUT CURCUIT	90 (MAX)	1	cu	MANUF.	INTG.	MANUF.	1	DC+	0.5	NA	620
							MANUF.	1	DC-			
							MANUF.	1	G			
4	INVERTER OUTPUT CIRCUIT (SHORT RUN)	76.5	1	cu	THWN-2	50mm PVC-Sch-40	50	3	L	1	0.012%	400
							50	1	N			
							25	1	G			
5	INVERTER OUTPUT CIRCUIT (LONG RUN)	76.5	1	cu	THWN-2	50mm PVC-Sch-40	50	3	L	81.38	1.09%	400
							50	1	N			
							25	1	G			
6	AC FEEDER FROM AC COMBINER 1	612	3	cu	THWN-2	Trench	150	3	L	86.56	1.08%	400
							150	1	N			
							50	1	G			
7	AC FEEDER FROM AC COMBINER 2	612	3	cu	THWN-2	Trench	150	3	L	71.32	0.89%	400
							150	1	N			
							50	1	G			

8	BATTERY AC OUTPUT CIRCUIT	144	1	CU	THWN-2	Trench	120	3	L	22.86	0.29%	400
							120	1	N			
							25	1	G			
9	BATTERY COMBINER PANEL OUTPUT	1440	4	CU	THWN-2	Trench	240	3	L	10	0.10%	400
							240	1	N			
							120	1	G			
10	GENERATOR COMBINER TO BATTERY COMBINER	614	3	CU	THWN-2	Trench	150	3	L	10	0.11%	400
							150	1	N			
							50	1	G			
11	GENERATOR COMBINER TO TRANSFER SWITCH	614	3	CU	THWN-2	Trench	150	3	L	10	0.11%	400
							150	1	N			
							50	1	G			
12	TRANSFER SWITCH FROM MAIN COMBINER PANEL	1354	3	CU	THWN-2	Trench	300	3	L	10	0.13%	400
							300	1	N			
							120	1	G			
13	AUX PANEL FROM MAIN COMBINER PANEL	165	1	CU	THWN-2	Trench	120	3	L	10	0.13%	400
							120	1	N			
							25	1	G			
14	AUX PANEL FROM GENERATOR COMBINER	165	1	CU	THWN-2	Trench	120	3	L	10	0.13%	400
							120	1	N			
							25	1	G			
15	425KW GENERATOR TO GENERATOR COMBINER	614	3	CU	THWN-2	Trench	150	3	L	31.61	0.41%	400
							150	1	N			
							50	1	G			
16	75KW GENERATOR TO GENERATOR COMBINER	108.25	3	CU	THWN-2	Trench	50	3	L	31.61	0.14%	400
							50	1	N			
							25	1	G			

Table 17: Conductor and Raceway Schedule

Conductor and Raceway Schedule												
SYMBOL	CIRCUIT	IMAX (AMPS)	SETS	MATERIAL	INSULATION	RACEWAY	SIZE (mm2)	QTY	CONDUCTOR	MAX. 1 WAY LENGTH (m)	VOLTAGE DROP (1%)	OPERATING VOLTAGE (V)
1	AUTOMATIC TRANSFER PANEL TO INRUSH CURRENT DEVICE	1354	3	CU	THWN-2	Trench	300	3	L	10	<1%	400
							300	1	N			
							120	1	G			
2	INRUSH CURRENT DEVICE TO TRANSFORMER	1354	3	CU	THWN-2	Trench	300	3	L	10	<2%	400
							300	1	N			
							120	1	G			
3	TRANSFORMER TO MV SWITCHGEAR	60	1	CU	THWN-2	Trench	120	3	L	20	<1%	20000
							120	1	N			
4	MV SWITCHGEAR TO TRANSMISSION	60	1	CU	THWN-2	100mm PVC-Sch-40	120	3	L	30	<1%	20000
							120	1	N			
							95	1	G			

Table 18: Conductor and Raceway Schedule for Automatic Transfer Switch

CONDUCTOR AND RACEWAY SCHEDULE - AC COMBINER 1												
SYMBOL	CIRCUIT	IMAX (AMPS)	SETS	MATERIAL	INSULATION	RACEWAY	SIZE (mm2)	QTY	CONDUCTOR	MAX. 1 WAY LENGTH (m)	VOLTAGE DROP (1%)	OPERATING VOLTAGE (V)
A	INVERTER OUTPUT CIRCUIT (LONG RUN)	76.5	1	CU	THWN-2	38mm PVC-Sch-40	35	3	L	18.74	0.50%	400
							35	1	N			
							25	1	G			
B	INVERTER OUTPUT CIRCUIT (LONG RUN)	76.5	1	CU	THWN-2	38mm PVC-Sch-40	35	3	L	9.9	0.27%	400
							35	1	N			
							25	1	G			
C	INVERTER OUTPUT CIRCUIT (LONG RUN)	76.5	1	CU	THWN-2	38mm PVC-Sch-40	35	3	L	2.46	0.07%	400
							35	1	N			
							25	1	G			
D	INVERTER OUTPUT CIRCUIT (LONG RUN)	76.5	1	CU	THWN-2	38mm PVC-Sch-40	35	3	L	15.11	0.41%	400
							35	1	N			
							25	1	G			
E	INVERTER OUTPUT CIRCUIT (LONG RUN)	76.5	1	CU	THWN-2	38mm PVC-Sch-40	35	3	L	26.44	0.71%	400
							35	1	N			
							25	1	G			

CONDUCTOR AND RACEWAY SCHEDULE - AC COMBINER 2												
SYMBOL	CIRCUIT	IMAX (AMPS)	SETS	MATERIAL	INSULATION	RACEWAY	SIZE (mm2)	QTY	CONDUCTOR	MAX. 1 WAY LENGTH (m)	VOLTAGE DROP (1%)	OPERATING VOLTAGE (V)
F	INVERTER OUTPUT CIRCUIT (LONG RUN)	76.5	1	CU	THWN-2	38mm PVC-Sch-40	35	3	L	3.25	0.09%	400
							35	1	N			
							25	1	G			
G	INVERTER OUTPUT CIRCUIT (LONG RUN)	76.5	1	CU	THWN-2	38mm PVC-Sch-40	35	3	L	14.3	0.38%	400
							35	1	N			
							25	1	G			
H	INVERTER OUTPUT CIRCUIT (LONG RUN)	76.5	1	CU	THWN-2	38mm PVC-Sch-40	35	3	L	41.55	89.00%	400
							35	1	N			
							25	1	G			
I	INVERTER OUTPUT CIRCUIT (LONG RUN)	76.5	1	CU	THWN-2	38mm PVC-Sch-40	35	3	L	54	0.91%	400
							35	1	N			
							25	1	G			
J	INVERTER OUTPUT CIRCUIT (LONG RUN)	76.5	1	CU	THWN-2	38mm PVC-Sch-40	35	3	L	48.28	1.08%	400
							35	1	N			
							25	1	G			

Table 19: Conductor and Raceway Schedule for - AC Combiner 1 & 2

Wire/cable sizes are calculated using applicable software. Cable software does not print out any calculations. It simply suggests the wire/cable size based on current, voltage drop allowed and distance. This is pretty standard. We cannot get the calculation logic used by the software company. Breaker size has to be at least 20% more than the max inverter current. Breaker interruption capacity has to be more than the fault current.

8.5.3 Grounding

Grounding provides a path for fault current or lightning surges to flow through to protect people and equipment from electric shock hazards. Number of Earthing Electrode and Earthing Resistance depends on the resistivity of soil and time for fault current to pass through (1 sec). If we divide the area for earthing required by the area of one earth plate gives the number of earth pits required. There is no general rule to calculate the exact number of earth pits and size of earthing strip, but discharging of leakage current is certainly dependent on the cross-section area of the material so for any equipment the earth strip size is calculated on the current to be carried by that strip. For most of the electrical equipment like transformer, diesel generator set etc., the general concept is to have 4 number of earth pits. 2 no's for body earthing with 2 separate strips with the pits shorted and 2 no's for Neutral with 2 separate strips with the pits shorted. The strip connected should be capable to carry at least the neutral current, which means a strip of GI 25x3mm should be enough to carry the current and for body a strip of 25×3 will do the needful. Normally we can consider the strip size that is generally used as standards.

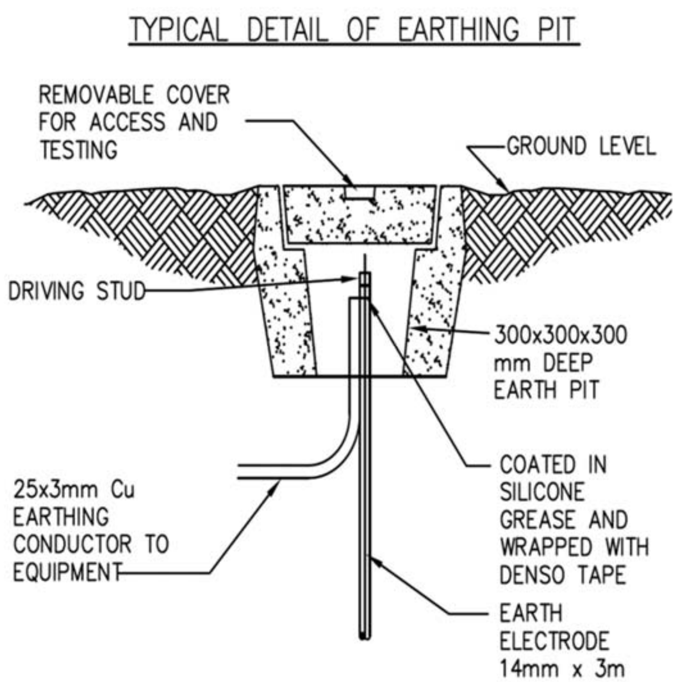


Figure 15: Typical Design for Earthing Pit and earthing conductor

The grounding shall be prepared as per the required test. It may need additional grounding rods, underground cable loops or ground well. The Contractor shall apply all requirements to achieve the final test for all grounding systems for this mini-grid solar power plant.

8.5.4 Equipment Grounding Conductor (EGC)

PV modules mounted to metal racks are effectively grounded when the module frames are secured to and in electrical contact with the rack, and the rack is grounded. However, since the integrity of the electrical contact between the module frames and mounting structure cannot always be assured, individual module frames are connected together with equipment grounding conductors (EGC). This can be accomplished with a few continuous runs of bare conductor that are secured to each module with a special connector, or with many short bonding jumpers between adjacent modules. When ground-fault protection is used, PV circuit equipment grounding conductors are sized in accordance with Article 250, which establishes the minimum size for equipment grounding conductors based on the overcurrent protection rating in the circuit. NEC table 250.122 is used for sizing. For example, if the PV output circuit overcurrent protection device is 60 A, then a 10 AWG equipment grounding conductor is required. The size of equipment grounding conductors are shown with the associated wire runs in Table 17, 18 and 19.

8.5.5 Grounding Electrode Conductor (GEC)

A grounding electrode is a conductor rod, plate, or wire buried in the ground to provide a low-resistance connection to the earth. NEC 690.47 establishes requirements for grounding electrodes used for PV systems. Most PV systems involve both AC and DC systems, and they are considered two separate systems according to NEC article 690 since the DC grounded conductor is not directly connected to the AC grounded conductor. The size of equipment grounding conductors are shown with the associated wire runs in Table 17, 18 and 19.

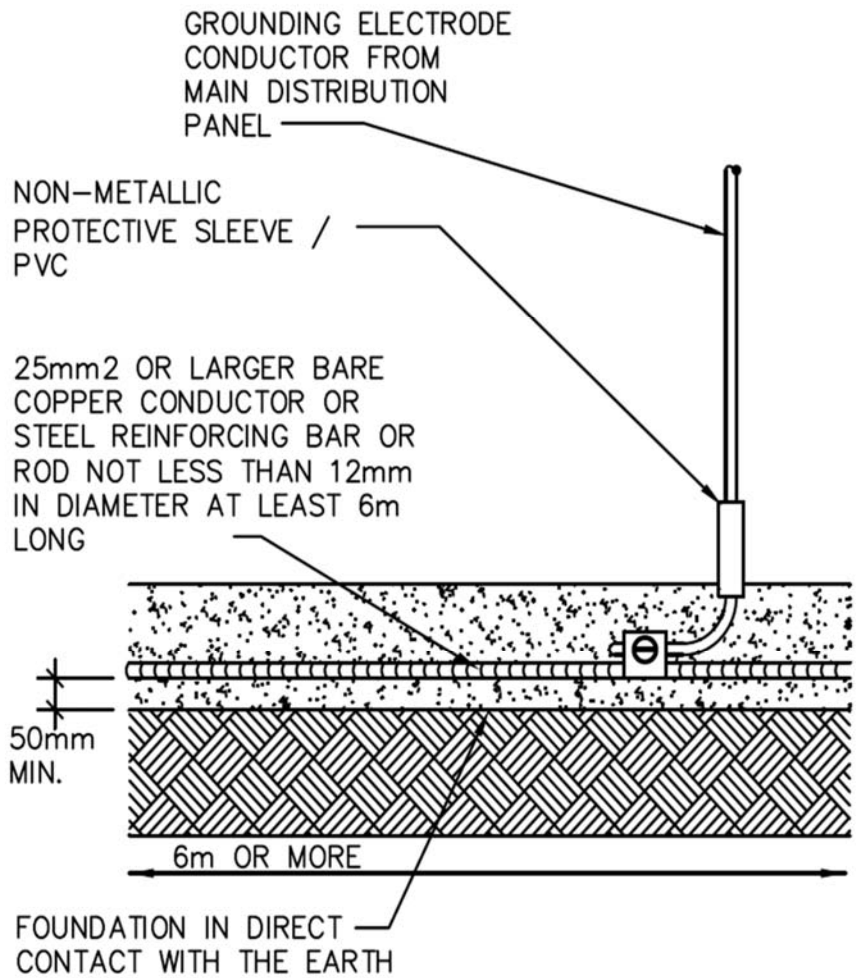


Figure 16: Grounding Electrode Conductor sizing details.

8.5.6 Ground Fault Protection

Ground Fault is the undesirable situation where the current flows through grounding conductors. Ground Fault Protection is mentioned in NEC 690.5 and is not required for ground mounted arrays.

8.5.7 Lightning Protection

Because PV arrays are not mounted on elevated structures, many PV systems are protected from potential lightning that can cause severe damage. Lightning protection system requirements are covered briefly in Article 250 and more extensively in NFPA 780 (Standard for the Installation of Lightning Protection Systems). Lightning protection systems consist of a low-impedance network of air terminals (lightning rods) connected to a special grounding electrode system and not connected to the DC or array electrode conductors. The lightning protections is covered in detail in the section covering poles and reticulation systems.

8.5.8 Monitoring

PV systems consist of different components to transfer energy. Measuring the electrical parameters at certain intervals can help gather more information about system operating status and alert users to possible problems. Measuring the output of the system is essential for production-based financial incentives. The traditional monitoring method entails simply comparing actual energy generation to that predicted from the simulation software. The advantage of this approach is simplicity, affordability, and reliability. There are multiple levels at which a PV system can be monitored; they can be classified as:

8.5.9 Inverter Monitoring

Inverter-level AC and DC monitoring offers insights into an inverter's status, given the strategic location of the inverter to monitor the performance of the PV system. Most inverter manufacturers embed their devices with monitoring functionality.

8.6 Solar Combiner Board #1

The Solar Combiner Board #1 is proposed to be installed in the PV field that would combine the inputs from 8 inverters (Inverters A to H). A total of two combiner boards are proposed. The sizing and specifications of both the combiner boards is exactly similar. Each combiner board is a 3-phase, 400V, 800A panel. The details of the Solar Combiner Board #1 is discussed in Chapter 6: Low-Voltage Combiner Boards.

8.7 Solar Combiner Board #2

The solar combiner board #2 is proposed to be installed in the PV field that would combine the inputs from 8 inverters (Inverters I to P). This combiner board is a 3-phase, 400V, 800A panel. The details of the Solar Combiner Board #2 is discussed in Chapter 6: Low-Voltage Combiner Boards.

8.8 Weather Station

Two (2) weather stations shall be installed to provide adequate meteorological data to evaluate system performance.
One weather station shall be located at Control room building and the other will be located in the field.
The station shall essentially include sensors for the following parameters:

Standard Pyranometer

- Irradiations at Tilt Plane in W/m^2.
- Insolation at Plane of Array in Wh/m^2

- Global irradiation in W/m^2.
- Global Insolation in Wh/m^2
- Cell temperature in °C.
- Environment temperature in °C.
- Humidity sensor

Dedicated pyranometers shall be used for measurement of global irradiation on tilted plane of array and global horizontal irradiation.

Refer to technical specifications for detailed specs for Weather Station

Air temperature sensor specifications:

- Range -40°C to +70°C
- Resolution 0.1
- Accuracy ± 0.3°C at 20°C
- Sampling Rate 1 Hz
- Units °C, °F, °K

PV module temperature sensor specifications:

- Measurement range: -20 TO 100°C
- Sensor type: platinum resistance wire
- Electrical output: PT100
- Cable 3 mt, connection with 3 conductors
- Mounting: tape (included)

All weather station will be integrated in the SCADA system.
Weather stations located on the field will be provided with data logger capable of collecting the data points with capability of recording and storing environmental data without AC power for two (2) days. Both the weather station and the data logger will be tamper proof.

8.9 Additional Requirements

All the material and works must be in accordance with the most advance practice for this type of equipment. Other than specified hereafter all the materials and realized works will be in accordance with latest edition of the IEC recommendations.

The delivery and the equipment in it shall be designed to meet the requirements of the following codes and standards: International Electrotechnical Commission (IEC) / National Electrical Code (NEC).

The design, materials, manufacturing, transportation, inspection, tests and packaging of the equipment and systems supplied shall be carried out as per International practices.

8.10 Exceptions to this Specification

Any proposal for deviation from this Specification and all other documents and drawings referenced in this Specification, shall be clearly written, in a complete and explicit way. The form shall be signed and submitted for approval to Employer. Contractor shall not proceed with implementation of any deviation that has not been previously indicated and has not been approved in writing by Employer.

8.11 Guarantees

The Contractor shall guarantee all characteristic required. The Contractor shall present and supervise all the guarantee tests.

The Contractor shall guarantee that the supplied equipment, material, or part thereof shall follow the specifications hereto and shall be unused products, free from any defects in design, material or workmanship. Spare parts furnished shall be identical or equivalent to original parts (spare parts are quoted as optional).
The warranty period must be twelve months from the date of commissioning (provisional plant acceptance) or 24 months from the date pf delivery whichever is earlier.
This warranty implies that the Contractor shall repair, or replace if necessary, all the elements damaged during this period.

8.12 Document Discrepancy

In case of discrepancy between the documents included in this Specification, the following order of priority shall prevail:

- Applicable legislation only if more restrictive criteria are not established in the Data Sheets Requisition or Specification.
- Data Sheets.
- Technical Specification.
- Other specifications and standards of the project.
- International Codes and Standards.

8.13 Spare Parts

Two detailed spare parts lists shall be included. One list will include all recommended spare parts for commissioning and the other list with recommended spare part for ten (10) year operation. Both lists will include:

- Spare part description

- Quantity
- Unit Price

Furthermore, two-year operation spare parts list will include a recommended planning for equipment replacement (operation hours).

8.14 Bill of Quantities

Refer to the Bill of Quantity which will be separately attached in the design package.

9. BESS DESIGN

9.1 Justification for Containerized BESS

Battery energy storage systems based on Li ion batteries are supplied by companies like SAFT, Samsung, LG Chem, TESLA etc. These are normally supplied by the manufacturers as factory assembled and tested units complete with sub systems for thermal management, cooling, battery management, fire protection etc. Hence many of the manufacturers supply these preassembled units as building blocks (e.g. units of 500kWh) fully assembled, wired and tested in e-houses or containers. A big advantage with this arrangement is the ability to procure fully assembled and tested units with manufacturer's warranty for the assembled unit.

An alternative approach is to assemble the entire battery system on racks within building. This is typically done for large installations where multi-level arrangements may be necessary due to space constraint. In this case either the manufacturer designs and assembles the battery unit at site or a specialized assembler/system integrator will come on board once the actual products have been ordered and shipped to the site to integrate them into one fully functional system. This will include rack work, wiring, and provision of battery management system, thermal management, cooling systems, fire protection and testing. As this involves a significant amount of onsite work, manufacturers do not prefer that and do it only for very large installations.

Another option is to procure the battery cells from manufacturers and recruit the services of a certified battery assemblers to assemble the batteries and associated components onsite. In this case battery assemblers provide the design and do the assembly work. One must then negotiate with manufacturers about how the warranty for the assembled unit is handled. Manufacturer may guarantee cells/battery packs but may not guarantee the system. This may come from the assemblers. The main question will then be about the financial risks if the assembler does not have the financial credibility to provide these guarantees.

Between the above, we would suggest a manufacturer assembled, fully tested and guaranteed containerized/e-house version for an installation like this case. This would make sure that a fully assembled, tested and guaranteed system at competitive prices is provided. For small and medium size systems, this will be more cost effective than onsite assembly work due to standardization of design, volume manufacturing, less engineering and onsite work. We do not have accurate figures for comparison but for small and medium size systems getting a preassembled and tested unit may be 10% to 20% more cost effective than onsite assembly. For a 3500kWh system this would mean a saving of about $150K in capital costs plus the comfort of a fully guaranteed system.

In addition to the fully assembled battery unit, BESS system also includes inverters, Power conditioning unit, and a site controller. These are normally manufactured by inverter manufacturers. However, as they must work as an integrated system it is normal to buy the entire BESS (assembled battery system, inverters and site controllers) from one vendor – the BESS supplier. For small installations like this, the site controller functionality is enhanced to cover the mini-grid/mini grid functionalities. In this case BESS supplier also performs and takes over the role of system integrator.

In terms of cost, the containerized BESS system costs about US$xxx per kWh, which translates to around $x,xxx,xxx for a 3,500 kWh BESS as is required in Kandahar.

For a similar sized BESS assembled on site, using US and European products, the following costs may incur:

- Li-Ion Battery: $xxx/kWh x 3500 kWh = $x,xxx,xxx
- Racking and other accessories, including AC systems, etc.: $xx,xxx
- Construction of additional space for the BESS: $xx,xxx
- Costs for isolating each 500kWh from the next since any thermal mishaps will destroy the whole system: $xx,xxx
- Cost of testing and commissioning the assembly: $xx,xxx
- Battery Inverters: 7 x 100 kW @ $xx,xxx x 7 = $xxx,xxx
- Provision of site controller & integration with other components: $xx,xxx

TOTAL Cost: $x,xxx,xxx

So, the containerized BESS system offers a gross financial benefit of US$ 290,000. However, taking into consideration unreliable warranty, possible system defects, possible inadequate system controls and integration, possible reduced round-trip efficiency, possibly shorter life cycle and reliability of service, the net cost effect of an onsite assembled Li-Ion BESS system may be in the range of excess of $250,000-350,000 more than a containerized system. In other words, the onsite assembled BESS system may be around 20% more expensive than a containerized BESS system.

In addition to that, the onsite assembled system has the disadvantage of not having a single point of responsibility that will assume full responsibility for the sound operation of the system and offer credible guarantee over the life span of the BESS system. The Battery manufacturer may offer its own warranty, while the inverter manufacturer and other component manufacturers may offer their respective warranties. However, this complex system does not have a single source that offers warranties to the user.
Furthermore, assembly design and work by certified assemblers in a country such as Afghanistan, where highly skilled workforce in the area of solar power systems and electric

installations is a rarity, the situation of maintaining or honoring any type of warranties may prove to be a difficult task altogether.

Other disadvantages of an onsite assembled system are the round-trip-efficiency of the battery that may be affected by less than ideal BESS design.

On the other hand, a containerized BESS system will have all components already integrated into it, so that the efficiency, reliability and life span of the system will be maximized. Furthermore, the integrated components will be the responsibility of a single integrator that in this case will be the BESS supplier, who will assume responsibility for all components and will provide all controls so that we can be assured of a fully functional system. As a matter of fact, the complete package from BESS supplier will include battery containers, battery management system, inverters, controls system and system integration.

Today, many manufacturers are available in Europe, Korea, Japan, China and other parts of the world, that are making the containerized BESS into a competitive product with choices of suppliers. Being scalable also allows for expansion of the BESS at any time. As a matter of fact, today's technology for Li-Ion batteries relies almost exclusively on containerized BESS for utility scale system of this size.

Such containerized systems are built in compliance with international standards for outdoor applications, so that they are weather proof, humidity tolerant, suitable for summer heat and winter cold, fitted with adequate grounding, lightning protection and other related safety and operational standards. Only thus are the manufacturers able to offer up to ten years warranty on their products.

Furthermore, containers can be relocated to a different site and used in case of arrival of grid connection to the site. Users can be fully trained in operation, maintenance and repair of containerized BESS. Energy smoothing through standard system design can ensure that charging and discharging sequence is optimized. As an additional caveat, in such systems, shipping and installation is also less problematic and ensures system reliability.

A system designer has a choice of designing a utility scale PV with an AC coupling or a DC coupling system.

We have chosen to design the system as AC-coupled. This means that the PV outputs are converted on site from DC to AC power and then transmitted to the control room, where it is reconverted to DC power to charge the BESS system. For this purpose, one-directional inverters are used in the PV array field and bi-directional inverters are used in the control room to charge the BESS.

We suggested an AC coupled design for the solar and BESS system for following reasons:

- Enables use of standard solar PV and BESS inverters
- Modular design - Easy to add more solar or BESS in future
- Provides ability to charge BESS from other sources – e.g. diesel
- Allows flexibility in locating BESS. No need to locate it close to solar PV
- Enables use of staring inverters for PV and central inverters for BESS

A DC-coupled system would transmit DC power from the inverter over long distances and then connect everything on the DC side, which is then converted to AC power at a one-directional inverters. The components needed for DC coupling of utility scale systems are manufactured by only a handful of manufacturers and are fairly expensive, rendering DC coupled systems very rare, if at all found. This is why in this design; an AC coupled system is used.

Recommendation:
We strongly recommend the use of a containerized pre-assembled, pre-certified, pre-integrated and pre-optimized system that costs less than an onsite assembled system by more than $95,000 to acquire. However, the effective net economic disadvantage, taking into consideration factors such as unreliable warranty, possible system defects, possible inadequate system controls and integration, possible reduced round-trip efficiency, possibly shorter life cycle and reliability of service, will be in the range of $250,000 to $350,000 or around 20%.

9.2 Codes and Standards

IEEE 1547 Interconnection of Distributed generation
UL 1741 requirements cover inverters, converters, charge controllers, and interconnection system equipment.
IEC 62477-1 Power Electronics Converter System
IEC 61000-6-2, 4 Electromagnetic Compatibility
IEC 61850 Remote Communication
UL 1642, IEC 62619 Cell Safety
IEC 60950 Module Safety
IEC 61508 Container Safety
IEC 62040-2 EMC (Cat C1 and C3)
IP33, ISO668, ISO12944 Level C51 – Container Specifications
IEC 60721 Environment (dust, chemical, wind, fire exposure, etc)
ISO9001, ISO14000 Quality Management and Environmental Management

9.3 Design and Sizing

Based on the estimated load profile created for Kandahar, a mini-grid with a solar PV generator of about 1000kW-dc with a 3,500kWh of battery storage and a 75+425kW diesel generator for backup power is proposed. Please refer to Section 6 above for details on system sizing.

9.4 Configuration

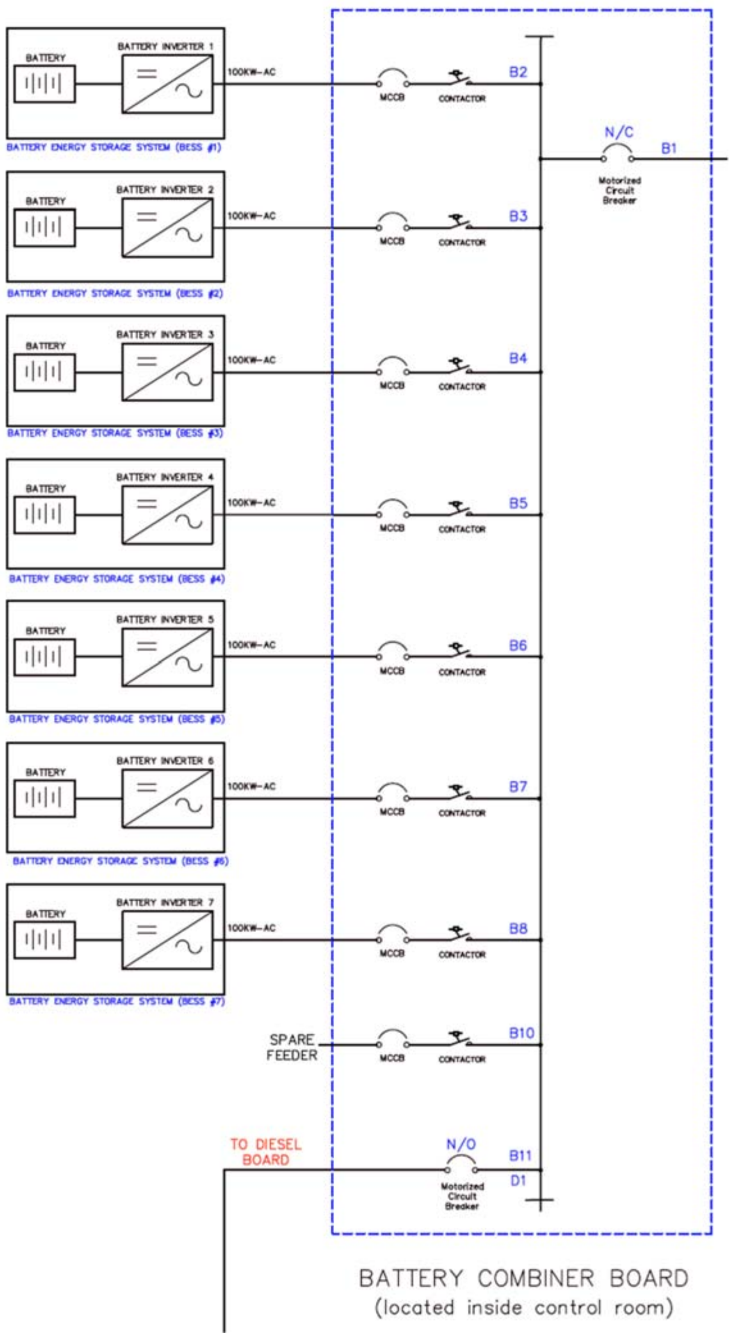


Figure 17: BESS Configuration

9.5 General Conditions

We recommend a manufacturer assembled, fully tested and guaranteed containerized/e-house version for an installation like the Kandahar mini-grid. This would make sure that a fully assembled, tested and guaranteed system at competitive price is provided. BESS is provided as a complete solution from the manufacturer in ready to install containers integrating Battery Management System (BMS), thermal management and safety management. In the containerized system, safety is priority with a consistent approach embracing cell, module, string and container designs. The BMS and thermal management system should be provided to ensure highest energy efficiency, availability, maintainability and life time.

In addition to the fully assembled battery unit, BESS system will also include inverters (Power conditioning unit) and a site controller (BESS control system). For small installations like this, the site controller functionality is enhanced to cover the microgrid/mini grid functionalities. In this case BESS supplier can also perform and take over the role of system integrator.

The complete package from BESS supplier will include battery containers, battery management system, inverters, controls system and system integration.
The BESS configuration includes battery, inverters, control system and combiner board. The exact configuration of the BESS will eventually depend on the supplier of the BESS. The general layout will have batteries installed in a container and the number of containers will be determined by the supplier. For the Kandahar mini-grid the requirement is to have battery with a storage capacity of 3500kWh. It is common to have about 500kWh installed in a single 20’x8’ shipping container. With that assumption, the Kandahar mini-grid will require about 7 battery containers. Again, depending upon the BESS supplier, the inverters, control equipment and/or combiner boards might either be available in separate containers or may have to be installed in the equipment room.

Key Features are:

- Latest generation of Li-Ion technology
- Advanced industrial design offering highest safety and robustness
- 20 years of design life
- Sophisticated battery management for enhanced operability
- Monitoring and Control of voltage and temperature at cell level
- Real time supervision of charge and discharge current limits
- Real time indication of State of Charge (SOC)
- Balancing of SOC between cells and strings
- Alarms and fault management
- Advanced thermal system based on air conditioning unit and controllable fans

- High cooling efficiency
- Safety system with smoke detection, fire suppression system and alarms
- Quick and cost-effective installation with containers delivered – plug and play- ex factory due to ready to deploy solution
- Easy system integration
- Scalable configuration
- Safety driven design guarantees safe behavior in case of abuse usage
- Auxiliary power supply 400AC for HVAC, FSS and lighting and 24V DC for electronics and fans.

Refer to technical specifications for detailed specs for BESS design.

9.6 Battery Inverters

Application: the inverter has to be suitable for grid forming and grid following modes of operation. During Mini-grid operation the inverters will set the voltage and frequency for PV inverters to follow.

- It should be possible to parallel all the battery inverters in both grid-forming and grid-following modes.
- It should be possible to charge and discharge batteries while it is in grid-forming mode.
- Black start functionality required
- Short-term (<5min) paralleling between battery and diesel is required

Refer to technical specifications for detailed specs for Battery Inverters.

9.7 BESS Control System

- BESS control system will provide On/Off commands and set-points (voltage, frequency, active power, and reactive power) for the solar and battery inverters based on load, weather forecast and operating status of PV, batteries and diesel.
- BESS control system will implement the mini-grid operations logic jointly with the SCADA system. Communication btw test control system & SCADA shall be through MODBUS TCP/IP

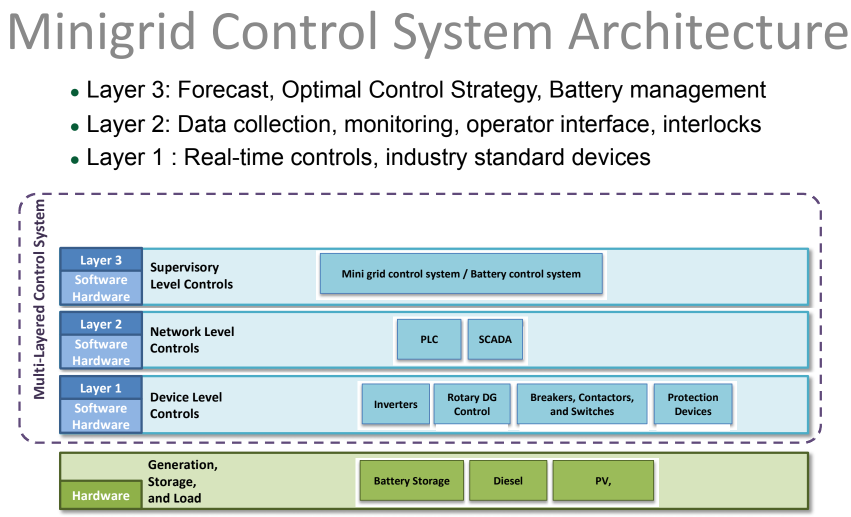


Figure 18: Mini-Grid Control System Architecture

The Purpose of a PV-inverter is to convert DC power to Ac power and feed the power system. In a typical solar application with battery backup, the battery system is equipment with a charge regulator that ensures that the state of charge of the Battery is within the desired and required parameters. In a large-scale utility application, the BESS has its own bi-directional inverters that supply the AC power from the PV system's Main Combiner Board to the Battery system as a converted DC power and then transfers the charge from the BESS to the Main Control Board after converting it to AC Power.

Battery based inverter/chargers are bi-directional in nature, including both a battery charger and an inverter. They require a battery to operate. Battery-based inverter/chargers may be grid-interactive, standalone grid-tied or off-grid, depending on their UL rating and design. The primary benefit of inverter/chargers is that they provide for continuous operation of critical loads irrespective of the presence or condition of the grid. UL1741 requires the grid-tied generation source to stop generating power in the event of a grid outage. This de-powering is known as anti-islanding, as opposed to 'islanding' which is defined as generating power to power a location in the event of a grid outage. Therefore, UL1741 grid-tie inverters will not generate power in the event of a grid outage, so a user will experience an outage irrespective of the availability solar harvest. Battery-based inverter/chargers will power the critical loads in the event of a grid outage, but will do so in a manner to not create the islanding condition. Further, UL1741 inverter/chargers may be rated as either interactive or standalone. The former export excess power to the grid, while the latter do not–by rating and by definition. In all instances, the battery based inverter/charger manages energy between the array and the grid while keeping the batteries charged. They monitor battery status and regulate how the batteries are charged.

Battery control system doubling up as Mini-grid control system shall perform the following:

- Monitor BESS internal systems, inverters, battery state of charge, loads and generation (PV, battery, diesel) etc.

- Prepare day ahead forecast of load and PV generation and schedule operation of BESS and diesel generation
- Provide control strategy for optimized Mini-grid operation
    - Automatic starting of diesel generation
    - On/Off commands and operation set points for diesel generation
    - Commands and control for synchronous operation of diesel units
    - Diesel generation ramp and ramp down commands and set points
    - BESS inverter on/off commands
    - Battery rate of charge/discharge set points
    - Battery ramp up and ramp down commands and set points
    - Commands and control for synchronous operation of battery and diesel
    - Managing the load transition from battery to diesel and from diesel to PV+BESS combination. The idea it to ramp down output from one unit while ramping up the other unit for a smooth bump-less transition
    - PV curtailment if needed
    - On/off commands for PV inverters
    - Black start
- Battery control system will communicate with field devices through the Plant controller unit of the SCADA system

9.8 Systems Integration

- BESS supplier shall also play the role of a system integrator and provide system integration services.
- The system integrator must integrate the PV, BESS, Diesel and the controlling devices with the battery control system and SCADA as part of commissioning work to form a functioning Mini Grid that can work both in grid connected and islanded modes.

9.9 BESS Combiner Board

The current designed configuration has 7 containers of 500kWh each with a bi-directional battery inverter of 100kW. Each inverter is 100kW, 400V, 50Hz, 3-phase, 4. The output from the 7 inverters is connected to a battery combiner panel. The BESS combiner panel is a 2000A, 400V, 3-phase 4-wire panel with a total of 10 feeders. The Details for the Battery Combiner board is discussed in Chapter 6: Low-Voltage Combiner Boards.

9.10 Additional Requirements

All the material and works must be in accordance with the most advance practice for this type of equipment. Other than specified hereafter all the materials and realized works will be in accordance with latest edition of the IEC recommendations.

The delivery and the equipment in it shall be designed to meet the requirements of the following codes and standards: International Electrotechnical Commission (IEC) / National Electrical Code (NEC).

The design, materials, manufacturing, transportation, inspection, tests and packaging of the equipment and systems supplied shall be carried out as per International practices.

9.11 Exceptions to this Specification

Any proposal for deviation from this Specification and all other documents and drawings referenced in this Specification, shall be clearly written, in a complete and explicit way. The form shall be signed and submitted for approval to Employer. Contractor shall not proceed with implementation of any deviation that has not been previously indicated and has not been approved in writing by Employer.

9.12 Guarantees

The Contractor shall guarantee all characteristic required. The Contractor shall present and supervise all the guarantee tests.

The Contractor shall guarantee that the supplied equipment, material, or part thereof shall follow the specifications hereto and shall be unused products, free from any defects in design, material or workmanship. Spare parts furnished shall be identical or equivalent to original parts (spare parts are quoted as optional).

The warranty period must be twelve months from the date of commissioning (provisional plant acceptance) or 24 months from the date pf delivery whichever is earlier.
This warranty implies that the Contractor shall repair, or replace if necessary, all the elements damaged during this period.

9.13 Document Discrepancy

In case of discrepancy between the documents included in this Specification, the following order of priority shall prevail:

- Applicable legislation only if more restrictive criteria are not established in the Data Sheets Requisition or Specification.
- Data Sheets.
- Technical Specification.
- Other specifications and standards of the project.
- International Codes and Standards.

9.14 Documentation and Drawings

The system supplier has to provide the following drawings and documents:

1. Detailed Single-Line Diagram
2. Detailed Three-Line Diagrams
3. Wiring diagrams
4. Assembly/shop floor drawings
5. General arrangement drawings
6. Foundation plan
7. Installation manual
8. Operating and troubleshooting manual
9. Software details for the control system
10. Test Certificates (Factory tests and Type test)

9.15 Factory Acceptance Tests

- All factory tests as per IEC or NEC
- Standard Visual, Mechanical and Electrical Factory Acceptance tests and inspections to be performed
- Details on standard Factory Acceptance Test to be provided by the manufacturer/assembler of the Battery Energy Storage System
- Option for factory inspection and witness test

9.16 Spare Parts

Two detailed spare parts lists shall be included. One list will include all recommended spare parts for commissioning and the other list with recommended spare part for ten (10) year operation. Both lists will include:

- Spare part description
- Quantity
- Unit Price

Furthermore, two-year operation spare parts list will include a recommended planning for equipment replacement (operation hours).

9.17 Bill of Quantities

Refer to the Bill of Quantity which will be separately attached in the design package.

10. LOW VOLTAGE SWITCH BOARDS

10.1 Codes and Standards

The delivery and the equipment in Low-Voltage Switchgear shall be designed to meet the requirements of the following codes and standards:

- **IEC 61439-1 and IEC 61439-2** testing is to be accomplished successfully in compliance with
- **IEC 61439-3** Distribution Boards
- **IEC / TR 61641** Test verification under arc fault conditions in accordance with
- **IEC 60529** Degree of protection
- **IEC 60364-4-41** Protection against electric shock (safety class) in acc. with
- **IEC 62271-202** factory-assembled stations described in
- **IEC 61439-2** mounting designs for switchgear
- **IEC 60364-7-729** The minimum dimensions for operating and Maintenance gangways according to
- The minimum clearances between switchboards and obstacle as specified by the manufacturer must be observed.
- **IEC 61439-1** Environmental conditions
- **IEC 61439-1 and -3** Rated Diversity Factor for switchgear in accordance with
- **IEC 61439-1 and IEC 61439-6** Busbar Trunking System
- **IEC 60364-1** Personal Safety
- **IEC 60947-2** Circuit Breakers
- **IEC 60364-4-41** Residual Current Devices
- **IEC 60947-2** circuit-breakers with fault current protection in accordance with
- **IEC 62606** Arc-fault detection devices (AFDD) are specified in IEC 62606
- **IEC 60947-2** Low-voltage circuit breakers
- **IEC 60898-1** Miniature circuit-breaker in accordance with
- **IEC 60947-1** The standard basis for low-voltage switching devices in general
- **Other applicable standards**

10.2 Solar Combiner Board #1

The solar combiner boards are proposed to be installed in the PV field that would combine the inputs from 8 inverters each. A total of two combiner boards are proposed. The sizing and specifications of both the combiner boards is exactly similar.
Each combiner board is a 3-phase, 400V, 800A panel. Maximum Short Circuit current happens when it is grid connected and fed by the utility, nevertheless, the impedance (5%) of the 750kVA transformer limit this to maximum 10000kVA (which is less than 15kA at 400V). The low voltage combiner boards are designed for a minimum of 36kA which is more than adequate.

Since each inverter has a maximum AC output of 76.5A, the incoming feeders from the inverters have a Molded Case Circuit Breaker (MCCB) with a 100A rating. Each MCCB must have inbuilt overcurrent and short-circuit protection. Each MCCB must have the capability to be capability to interact with the SCADA system and communicate its operating status (communicate whether it is on or off via SCADA). The outgoing feeder from the solar combiner board must have a motorized circuit breaker rated for 800A.

By combining the AC outputs from 8 inverters, a higher gauge cable can be used thus reducing the losses. The Solar combiner board #1 has the following key specifications.

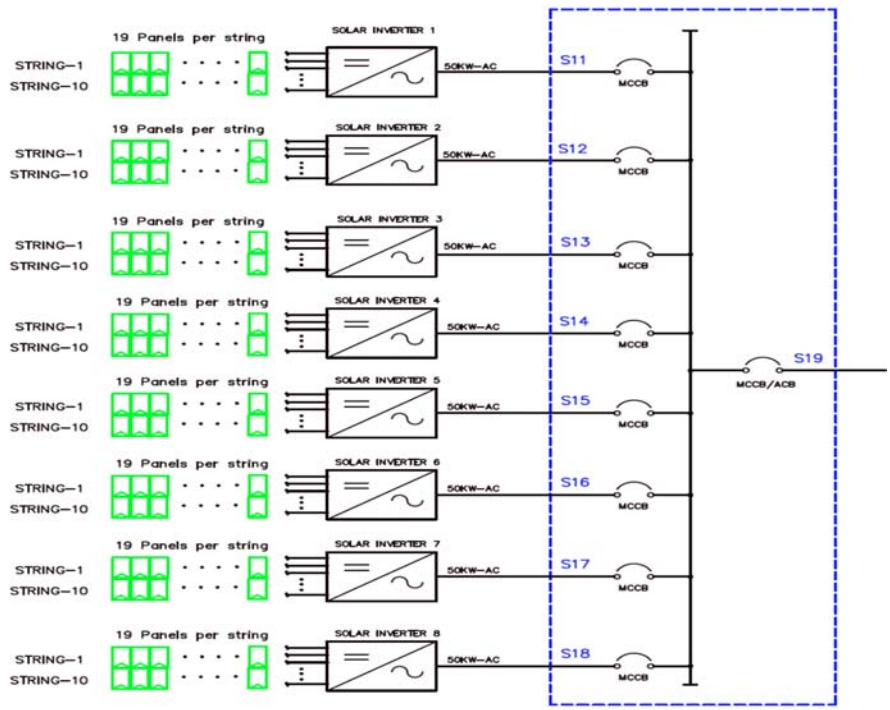


Figure 19: Simplified drawing showing the connection for Solar Panels, Inverters and Combiner Panel#1

Refer to technical specifications for detailed specs for combiner board#1.

10.3 Solar Combiner Board #2

The Solar Combiner board #2 is a 3-phase, 400V, 800A panel. Since each inverter has a maximum AC output of 76.5A, the incoming feeders from the inverters have a Molded Case Circuit Breaker (MCCB) of a 100A rating.

Maximum Short Circuit current happens when it is grid connected and fed by the utility, nevertheless, the impedance (5%) of the 750kVA transformer limit this to maximum 10000kVA (which is less than 15kA at 400V). The low voltage boards are designed for a minimum of 36kA which is more than adequate. Each MCCB must have inbuilt overcurrent and short-circuit protection. Each MCCB must have the capability to be capability to interact with the SCADA system and communicate its operating status (communicate whether it is on or off via SCADA). The outgoing feeder from the solar combiner board must have a motorized circuit breaker rated for 800A. By combining the AC outputs from 8 inverters, a higher gauge cable can be used thus reducing the losses. The Solar combiner board #2 has the following key specifications.

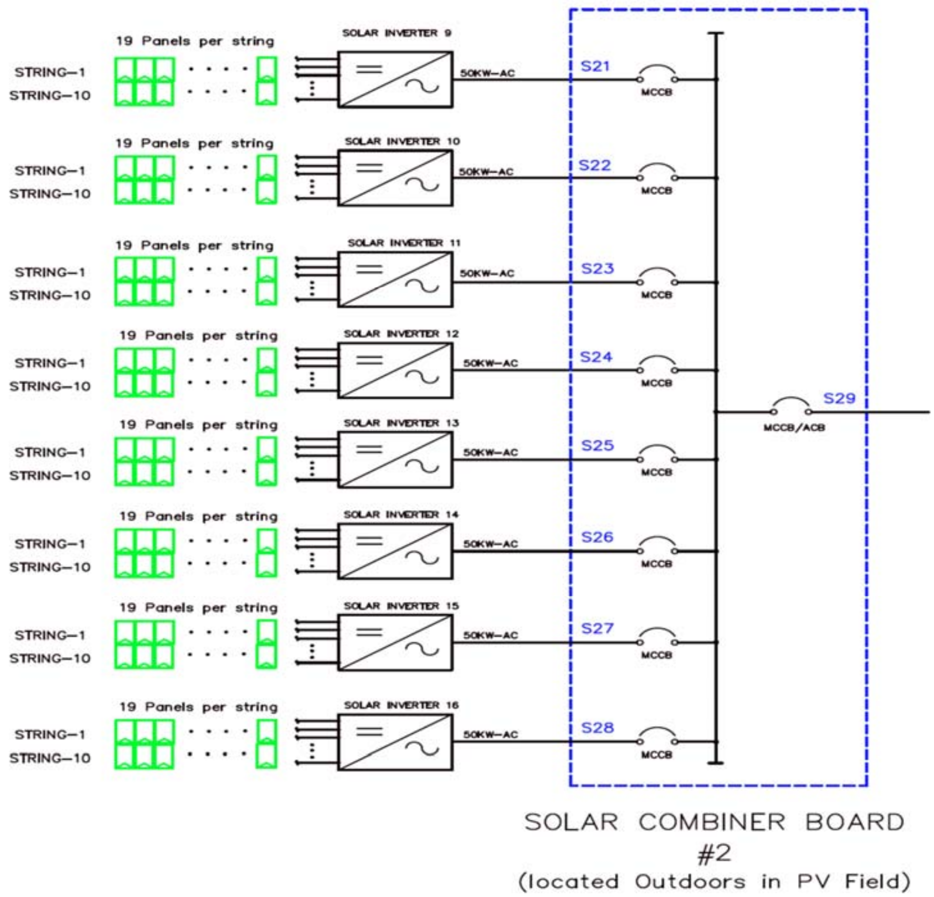


Figure 20: Simplified drawing showing the connection for Solar Panels, Inverters and Combiner Panel#2

Refer to technical specifications for detailed specs for combiner board#2.

10.4 Battery Energy Storage System (BESS) Combiner Board

The current designed configuration has 7 containers of 500kWh each with a bi-directional battery inverter of 100kW. Each inverter is 100kW, 400V, 50Hz, 3-phase, 4 wire. The output from the 7 inverters is connected to a battery combiner panel. BESS combiner board is a 3-

phase, 400V, 2000A panel. Maximum Short Circuit current happens when it is grid connected and fed by the utility, nevertheless, the impedance (5%) of the 750kVA transformer limit this to maximum 10000kVA (which is less than 15kA at 400V). The low voltage boards are designed for a minimum of 36kA which is more than adequate.

The BESS combiner panel is a 2000A, 400V, 3-phase 4-wire panel with a total of 10 feeders. 7 feeders are connected to the 7 battery inverters (Max current rating of 173 A) and have a Molded Case Circuit Breaker (MCCB) of a 200A rating and a contractor for protection. Each MCCB must have inbuilt overcurrent and short-circuit protection. Each MCCB must have the capability to interact with the SCADA system and communicate its operating status (communicate whether it is on or off via SCADA). The opening and closing of each contactor will be controlled via commands sent by SCADA.

Maximum Short Circuit current happens when it is grid connected and fed by the utility, nevertheless, the impedance (5%) of the 750kVA transformer limit this to maximum 10000kVA (which is less than 15kA at 400V). The low voltage boards are designed for a minimum of 65kA which is more than adequate.

The outgoing feeder from the *BESS Combiner Board* to the *Main Combiner Board* is normally-closed and the charging of the batteries takes place through the power flow from the *Solar Combiner Boards* (both 1 and 2) to the *Main Combiner Board* and from there to the *BESS combiner Board.* This main feeder is rated for 1500A and has a motorized breaker for controlling the operations that receives the operation command from SCADA.

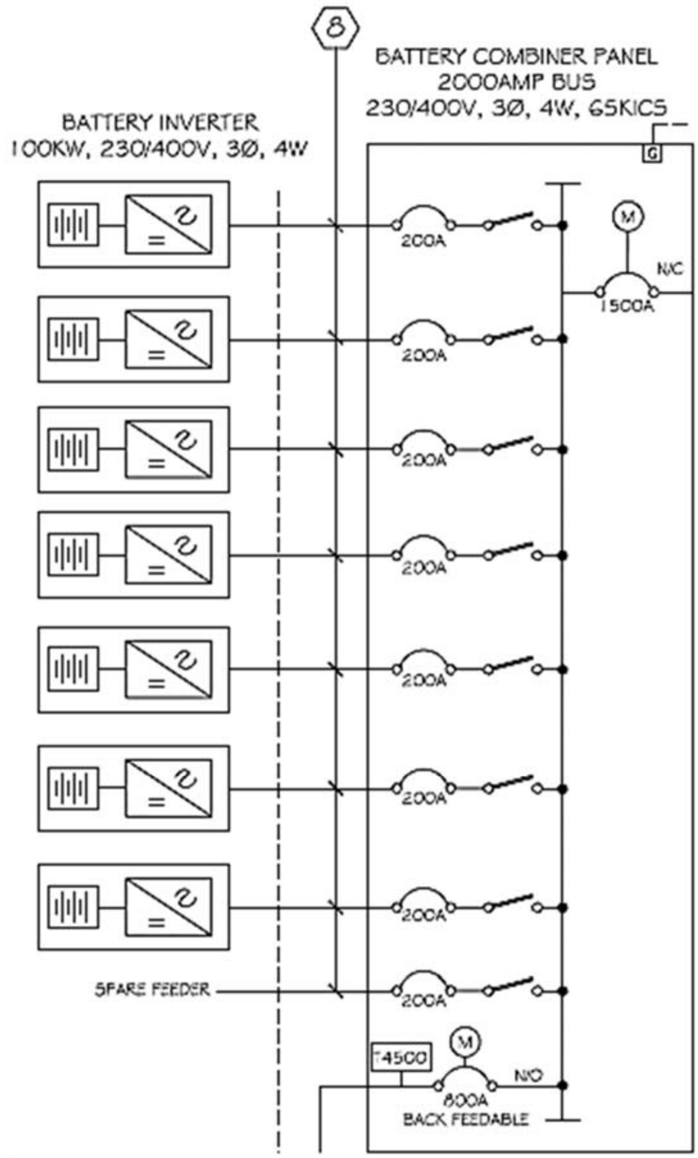


Figure 21: Battery Combiner Panel/Board details

One feeder on the BESS combiner board is connected to the diesel board and is normally-open. This feeder is only used in case of emergency when the charge level of batteries is lower than the acceptable level. In this scenario, the main output feeder from the *BESS Combiner Board* to the *Main Combiner Board* will be opened, the feeder from the *Diesel Combiner Board* will be closed and the batteries will be charged from the diesel generator. The feeder to the *Diesel Combiner Board* is rated for 800A and has a motorized breaker for controlling the operations that receives the operation command from SCADA.

The BESS combiner board is provided with spare feeders that may be used in case the number of battery containers are more than 5.

Refer to technical specifications for detailed specs for BESS combiner board.

10.5 Diesel Combiner Board

The *Diesel Generator Combiner Board* is a 400V, 1000A, 3-phase, 4-wire panel board. The diesel combiner board has two incoming feeders from two different diesel generators, namely, a 425kW generator and a 75kW generator. The 425kW and 75kW generators are connected to the combiner board through an 800A and a 150A motorized circuit breaker, respectively. Generator protection with auto-synchronizer (similar to SEL700G) is used with the two diesel generators to make sure that their operation is synchronized. Both the breakers must have inbuilt overcurrent and short-circuit protection. Each combiner board is a 3-phase, 400V, 1000A panel. Maximum Short Circuit current happens when it is grid connected and fed by the utility, nevertheless, the impedance (5%) of the 750kVA transformer limit this to maximum 10000kVA (which is less than 15kA at 400V). The low voltage boards are designed for a minimum of 36kA which is more than adequate.

Each breaker must have the capability to interact with the SCADA system and should be able to execute On/OFF switching through SCADA commands. The operation logic is such that the 75kW diesel generator unit will start first, in case the load is below 75KW and will continue to power the load until load exceeds 75KW. At this point the 425KW generator starts automatically and the load gets transferred from the 75KW unit to the 425KW unit. There will be a small amount of time of parallel operation of the two diesel generators. However, in case the initial load is detected to be higher than 75KW, the 425KW unit starts straight away skipping the 75KW generator operation. Typically, one of the generators start first and supports the load. When the load approaches a threshold the second generator starts, synchronizes with the first one and takes over the load. After this the first generator is disconnected. The Mini-grid control system/SCADA will have the logic to monitor the load (based on power meter in the medium voltage switchgear) and start, synchronize and stop the generators.

There are three outgoing feeders from the diesel combiner board. The main output feeder from the *Diesel Combiner Board* connects to the *Automatic Transfer Board* and provides power to the mini-grid when the energy available from the PV+BESS is not enough to support the loads. This feeder has a motorized 800A circuit breaker and receives the ON/OFF operational command from SCADA. At the time when the grid loads are supported by the operation of diesel generator, the Auxiliary Panel serving the local building loads also receives power from the diesel combiner board. This takes place through the fourth feeder on the diesel combiner board through a 200A MCCB.

The fifth feeder from the *Diesel Combiner board* connects to the *BESS Combiner board* and has an 800A motorized circuit breaker. This feeder is used to synchronize the diesel generators to the BESS; this is achieved through an Auto-Synchronizer (similar to T4500). At the time of transfer from BESS to diesel generator the feeder between diesel and BESS is used to synchronize the sources and synchronize diesel to BESS. This allows a smooth transition from BESS to diesel and the same logic is used when the source needs to be switched from diesel to PV+BESS. The operation logic does not call for continuous parallel operation of the BESS and the generator. Typically, the BESS supports the load and the generator kicks in when the BESS state of charge drops to a pre-set value. At this point generator is paralleled with the BESS for a very short time (less than a few minutes) and load is transferred from BESS to the generator. The purpose is to minimize interruptions during this transition. BESS is disconnected from the bus after this transition. The Minigrid control system/SCADA will have the logic to monitor the BESS state of charge and start, synchronize and stop the generators.

10.5.1 Reverse Power Flow Issues

Reverse power flow typically happens during parallel operation of generators when one of the generators is faulty or prime mover is not in operation resulting in the generator operating as a motor. We think reverse power relays are not needed in this case for following reasons:

- The operation logic does not call for continuous parallel operation of generators. We will only have momentary paralleling (less than a few minutes) to minimize interruptions during transitions.
- The probability of one of the generators failing during the few minutes of parallel operation is extremely low justifying the investment in reverse power schemes.
- Reverse power schemes can be implemented in future if continuous parallel operation is required in future

Similarly, remedial measures for limiting circulating currents in the common neutral which bonds the wye connections of the generating sources are also not required as the generators will be in parallel operation only momentarily (less than few minutes)
Because of the above additional elaborations, we have decided to revise our statement on reverse power flow issue as follows:

“The operation logic does not call for continuous parallel operation of generators. We will only have momentary paralleling (less than a few minutes) to minimize interruptions during transitions. The synchronization mechanism will ensure that generators are working at the time of synchronization. As the parallel operation is limited to just during transitions we feel that the risk of reverse power flow is negligible.”

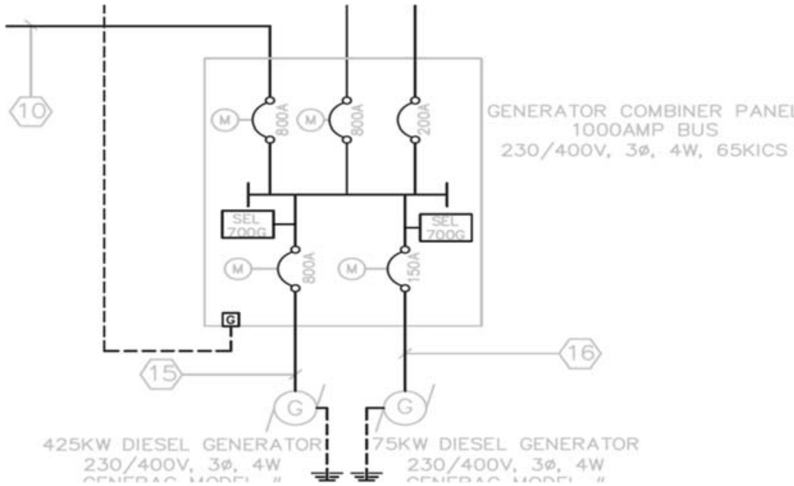


Figure 22: Simplified drawing showing the connection for the Diesel Combiner Board

Refer to technical specifications for detailed specs for Diesel combiner board.

10.6 Main Combiner Board

The main combiner board is a 4000A panel that combines the feed from the two solar combiner boards and the feed from the BESS combiner board. The output from this panel is connected to the Automatic Transfer switch and serves as main feeder providing the feed from the PV+BESS system. A 400A Auxiliary Panel also gets the feed from the Main combiner panel to serve the local loads including all the lighting, HVAC, etc. loads.

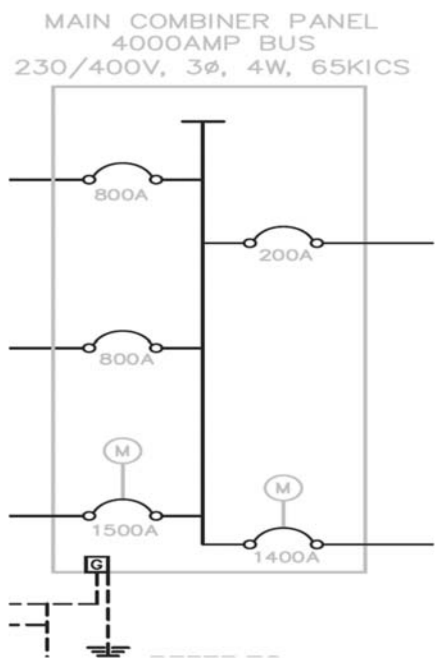


Figure 23: Main Combiner Panel

Refer to technical specifications for detailed specs for main combiner board.

10.7 Automatic Transfer Board

A transfer switch allows an electrical system to be quickly and safely switched from primary power source to an alternate power source in order to keep critical loads operating without interruption.

The transfer board is used with PV system in off-grid situation where an alternate power from diesel generator is relied upon when insolation is low, or the PV system cannot charge the batteries. Automatic transfer board continually monitors the primary power source (PV+Battery); when the voltage falls below a certain level, the switch automatically starts a power transfer, such as sending electronic signal to the diesel generator to initiate its start-up sequence. When SCADA detects proper voltage and frequency on the alternate source, it completes the transfer. The transfer board is programmed in such a way that the transfer happens without an interruption in the power supply. In order to achieve the smooth transition, each transfer takes place with a very short-term paralleling of the distributed generation resources (<5 min). The switching will also manage an automatic and controlled transfer back to the primary power when it becomes available again.

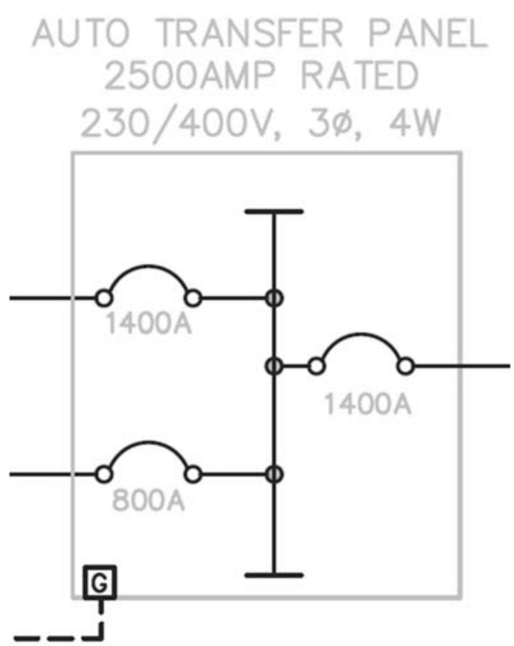


Figure 24: Auto Transfer Panel

Refer to technical specifications for detailed specs for automatic transformer board.

10.8 Inrush Current Limiting Device

The inrush current limiting device is the ideal soft-starting solution for medium and low voltage transformers. The sophisticated control ensures the elimination of the magnetizing inrush current, thus, eliminates nuisance tripping as well as dynamic shock to the transformer windings. The starter can be supplied with options such as Line and Bypass vacuum contactors or circuit breakers, connect switches, main and control protection fuses, transformer protection relay, etc.

Refer to technical specifications for detailed specs for Inrush Current.

10.9 Auxiliary Panel Board

The Auxiliary Panel board is the panel board that would supply power to all the local loads. These would include all the lighting, HVAC, control equipment, etc. loads at the facility and around the power plant. The auxiliary panel has two different input feeders that will be interlocked and only one feeder will feed the panel at any point in time. The Auxiliary panel will get the energy feed from the main combiner panel when the mini-grid is served by the PV+BESS system. During the mini-grid operation when the loads are served by the Diesel generators, the feeder from the main combiner panel will disconnect and the feeder from the Diesel combiner panel will connect to provide the power to the Auxiliary panel. The local panel will also have an Uninterruptable Power Supply (UPS) that would support all the critical local loads during the period of switching or during the period of emergency when there is not power supply.

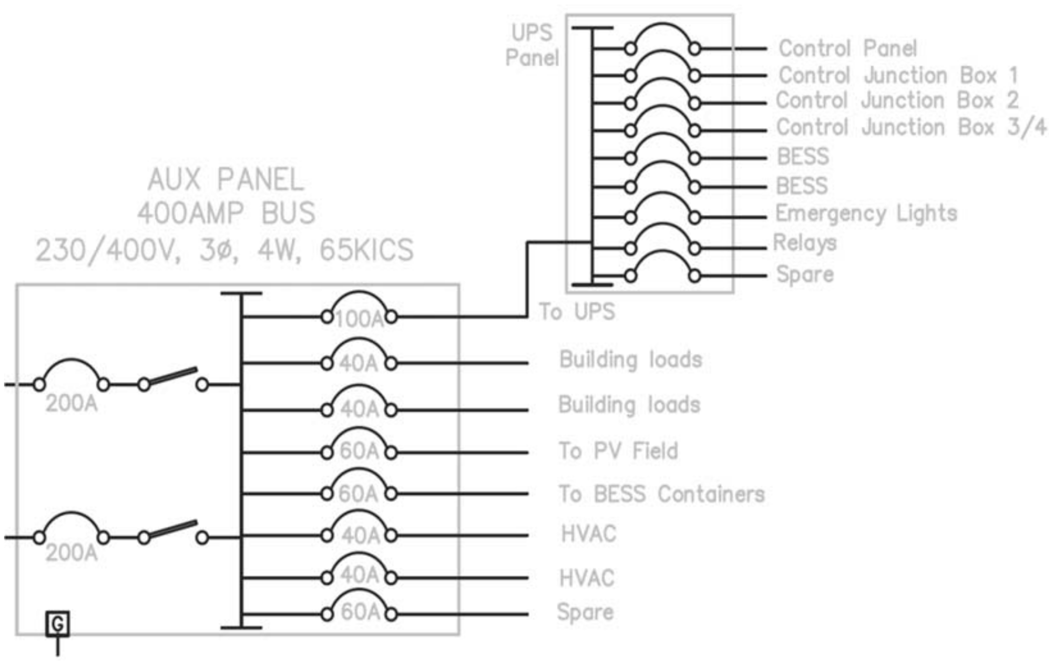


Figure 25: Aux Panel

Refer to technical specifications for detailed specs for auxiliary panel board

10.10 Uninterruptable Power Supply

An uninterruptable power supply (UPS) is a battery based system that includes all the additional power conditioning equipment, such as inverters, chargers, to make a complete self-sustained power source. In the standby mode, the UPS keeps its batteries at full state of charge from the available power. When there is a loss of power, an automatic transfer circuit isolates critical loads from the main supply and supplies AC power inverted from the DC power from the battery. The UPS power will be used to back up computers, security systems, lights, power required for the control systems and other critical loads in event of power loss. The UPS supports the critical operation of the control boxes, server, relays, RIO boxes, etc. requiring 6.6kVA supply. Details of the SCADA system are shared in Chapter 14 on SCADA Layout and specifications. The size of the UPS battery back determines the magnitude and duration of critical loads operation.

10.11 Additional Requirements

All the material and works must be in accordance with the most advance practice for this type of equipment. Other than specified hereafter all the materials and realized works will be in accordance with latest edition of the IEC recommendations.

The delivery and the equipment in it shall be designed to meet the requirements of the following codes and standards: International Electro-technical Commission (IEC)/National Electrical Code (NEC).The design, materials, manufacturing, transportation, inspection, tests and packaging of the equipment and systems supplied shall be carried out as per International practices.

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Any proposal for deviation from this Specification and all other documents and drawings referenced in this Specification, shall be clearly written, in a complete and explicit way. The form shall be signed and submitted for approval to Employer. Contractor shall not proceed with implementation of any deviation that has not been previously indicated and has not been approved in writing by Employer.

10.13 Guarantees

The Contractor shall guarantee all characteristic required. The Contractor shall present and supervise all the guarantee tests. The Contractor shall guarantee that the supplied equipment, material, or part thereof shall follow the specifications hereto and shall be unused products, free from any defects in design, material or workmanship. Spare parts

furnished shall be identical or equivalent to original parts (spare parts are quoted as optional).
The warranty period must be twelve months from the date of commissioning (provisional plant acceptance) or 24 months from the date pf delivery whichever is earlier.
This warranty implies that the Contractor shall repair, or replace if necessary, all the elements damaged during this period.

10.14 Document Discrepancy

In case of discrepancy between the documents included in this Specification, the following order of priority shall prevail:

- Applicable legislation only if more restrictive criteria are not established in the Data Sheets Requisition or Specification.
- Data Sheets.
- Technical Specification.
- Other specifications and standards of the project.
- International Codes and Standards.

10.15 Documentation and Drawings

The system supplier has to provide the following drawings and documents:

1. Detailed Single-Line Diagram
2. Detailed Three-Line Diagrams
3. Wiring diagrams
4. Assembly/shop floor drawings
5. General arrangement drawings
6. Foundation plan
7. Installation manual
8. Operating and troubleshooting manual
9. Software details for the control system
10. Interface details for communication
11. Test Certificates (Factory tests and Type test)

10.16 Factory Acceptance Tests

- All factory tests as per IEC or NEC
- Visual/Mechanical Inspections
    - General Visual and Mechanical Inspections
        - Check the layout of fitted components
        - Check the overall dimension of switchboard, size of busbars, cables and earthing conductors and location of feeder entry point.
        - Check and verify the brand, model, and circuit identification of components installed such as breakers, current transformers, fuses, ammeters, voltmeters, power meters and protection relays

        - Check overall paint work, door locking device, door gasket, door hinges, door cut-out holes
        - Check the busbar and cable tightening, the marking, busbar clearance, base angle bar and plinth
        - Check the labels, name plate and phase identification
    - Moisture and Corona Inspections
    - Wiring and Bolted Connection Checks
    - General Wiring Checks
    - Moving Parts and Interlocks
    - Insulators and Barrier Checks
- Electrical Tests
    - Bolted Connection Electrical Tests
    - Insulation Electrical Tests
    - Dielectric Withstand Tests
    - Control Wiring Electrical Tests
    - Instrument Transformers
    - Circuit Breakers and Switches
    - Control Power Transfer Scheme
    - Metering Electrical Tests
    - Current Injection Tests
    - System Function Test
    - Cubicle Heaters
    - Surge Arresters
    - Dual-Source Phasing Check
- Option for factory inspection and witness test

10.17 Spare Parts

Two detailed spare parts lists shall be included. One list will include all recommended spare parts for commissioning and the other list with recommended spare part for ten (10) year operation. Both lists will include:

- Spare part description
- Quantity
- Unit Price

Furthermore, two-year operation spare parts list will include a recommended planning for equipment replacement (operation hours).

10.18 Bill of Quantities

Refer to the Bill of Quantity which will be separately attached in the design package.

11. DIESEL GENERATOR

11.1 Codes and Standards

- **IEC 60034** Rotating Electrical Machines
- **IEC 60085** Thermal Evaluation and Classification of Electrical Insulation
- **IEC 60529** Degrees of Protection provided by Enclosures (IP Code)
- **ISO 10816** Specification for Mechanical Performance: Vibration
- **ISO 3046** Specification for Reciprocating Internal Combustion Engines
- **SI 426** European Commission (dangerous substances) (Classification, packing, labelling, and Notification of Regulations 1992.
- **CIMAC** Congress International des Machines a Combustion
- **ISO 9000** Recommendations for Diesel Engine Acceptance Tests Quality assurance
- **Other applicable standards**

11.2 Design and Sizing

Since the peak load is expected to be about 425kW, the system is proposed to have multiple diesel generators (425kW + 75kW). Having multiple generators will add redundancy to the backup system and reduce the need for operating one large generator all the time, hence having a more efficient operation.

11.2.1 Operation Mode for Diesel Generator

During the course of the day, PV + BESS will support the loads. During evenings and nights, BESS will support the loads without any PV. When the State of Charge (SOC) of the BESS drops to a predefined set point, the BESS inverters get switched OFF and the system transitions automatically to diesel operation. The 75kW diesel generator unit will start first in case the load is below 75 KW and will continue to power the load until load exceeds 75KW. At this point the 425 KW generator starts automatically and the load gets transferred from the 75 KW unit to the 425 KW unit.

11.2.2 Charging Battery by Diesel Generator

At times during the operation of the generator it might be operating at less than 100% of its operating capacity. The diesel combiner board has a feeder that is connected to the BESS combiner board. This allows for the diesel generator to charge the batteries in case

- The charge in the battery is too late for safe operation, and/or
- In the scenario when some load needs to be added to the diesel generator so that the diesel operates efficiently and in a stable manner.

11.3 Configuration

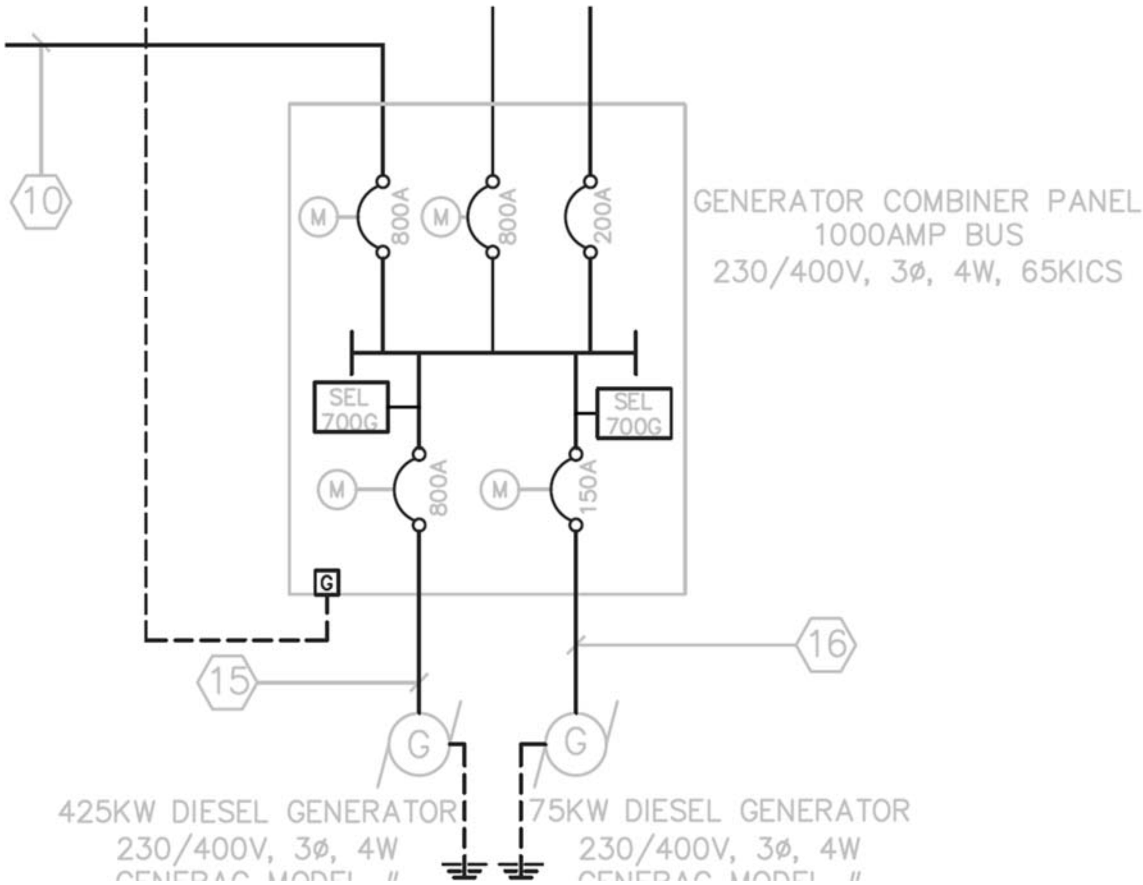

Figure 26: Diesel Combiner Board Configuration

The configuration of diesel generators proposed for the Kandahar mini-grid is to have two diesel generators of 425 and 75 kW capacity connected to the diesel combiner board. The operation of the diesel generators will mostly be individual and only in some situations there will be parallel operation of the two diesel generators needed for a very short period of time. This parallel operation will be to make sure that there is no interruption in the power supply.

Refer to technical specifications for detailed specs for diesel generator.

11.4 Diesel Combiner Board

The *Diesel Generator Combiner Board* is a 400V, 1000A, 3-phase, 4-wire panel board. The diesel combiner board has two incoming feeders from two different diesel generators, namely, a 425kW generator and a 75kW generator. The 425kW and 75kW generators are connected to the combiner board through an 800A and a 150A motorized circuit breaker, respectively. The details about the Diesel Combiner Board is presented in Chapter 6: Low-Voltage Combiner Boards.

11.5 Working, Design and Construction of a Diesel Engine

In diesel engines, exceedingly compressed air and ignition fuel are fused together to generate the mechanical energy, which is later converted to electrical energy. The air is taken in from the atmosphere and is subjected to high compression. This process heats up the engine, and when diesel fuel is injected, due to high temperatures and pressure the fuel ignites.

In case of a diesel engine, air is taken in separately and diesel is injected separately via injectors, this leads to a better air-fuel compression ratio because only the air is compressed in this scenario. Depending on the mode of operation the diesel engines can be classified into 2-cycle or 4-cycle engines.

11.5.1 Generator

- The governor of the generator regulates the speed of the engine in accordance with the ISO 8528 Part-1 Class3.
- The voltage regulation is to be maintained constant at 0.5% from no-load to full load settings.
- The random fluctuations in the voltage during operation should be within 0.5% during normal operation
- The random fluctuations in the frequency should be within 0.25% during normal operation of the generator
- The radio frequency emissions should comply with the military and IEC standards
- The Electromagnetic compatibility should be according to EN61000-6-4/EN61000-6-2
- The generator should be enclosed in a sound attenuated canopy

11.5.2 Engine

- The engine should be a 4 stroke, turbocharged diesel engine.
- The bore diameter of the cylinder should be about 5.5 inches and the piston should travel 6 inches
- The volume of the cylinders in the engine should be 855 cubic inches and the cylinder block should be made of cast iron
- A battery of approx. 100 amp/hr is to be used and the battery charging alternator should be able to provide 55 amps.
- 24 V negative earth supply is required for starting motor and engine operation
- A direct injection type fuel system is to be used with the fuel filter having spin on filter with water separator
- The engine should be able to operate at ambient temperatures of 50° C

11.5.3 Alternator

- A brushless, 4- pole, revolving field type machine is to be used
- The stator winding pitch parameter is to be maintained at 2/3rd pitch for all the 4-wire applications
- A single bearing, flexible disc arrangement is to be used while attaching the alternator to an engine
- Low voltage insulation i.e. the class H type is to be utilized. This insulation should be able to withstand the temperatures up to 150°C
- The phase connections follow the phase rotation of A, B, C where A leading B leading C by 120° in counter clockwise direction
- Direct drive centrifugal blower fan is to be used for cooling during operation
- The total harmonic distortion of the sine wave should be less than 1.5% during no-load and less than 5% for non-distorting balanced linear load
- The Telephone Influence Factor (TIF) which is a measure of interference of power-line harmonics with telephone lines should be less than 50 as per NEMA guidelines
- The total harmonic factor should be less than 2%

11.5.4 Available Voltages

- The available voltage range varies depending on the type of connection between the two conductors.
- For a line-to-line connection, at 50 Hz, the available voltages should be 190, 200, 220, 380, 400, 416, 440, 480
- For a line-neutral connection, at 50 Hz, the available voltage range should be 110, 115, 127, 220, 230, 240, 254, 277

11.5.5 Fuel Tank and Fuel consumption

- An 800-900 L (250L for the smaller generator) base fuel tank should be equipped with the diesel generator
- While operating in prime mode, the consumption should be in the range of 70-76 L/hr (20L/hr for the smaller generator)
- While operating in standby mode, the consumption should be in the range of 80-84 L/hr (22-25L/hr for the smaller generator)

11.5.6 Control System

- The engine should be equipped with a control panel, which should be able to regulate the voltage, control the governor action, engine protection, etc.

- The inbuilt control panel should be able to start the generator locally or via a remote signal
- The control panel should consist of LED indicators pertaining to various diesel generator parameters like running mode, oil level, engine temperatures, common warnings, failure conditions, etc.
- The generator should be equipped with an emergency stop switch
- The control system should be equipped with basic engine protection equipment

A control panel should have options to enable enhancements or better capabilities like paralleling option, security keys, additional input and output models, etc.

11.6 Additional Requirements

All the material and works must be in accordance with the most advance practice for this type of equipment. Other than specified hereafter all the materials and realized works will be in accordance with latest edition of the IEC recommendations.

The delivery and the equipment in it shall be designed to meet the requirements of the following codes and standards: International Electro-technical Commission (IEC)/National Electrical Code (NEC).The design, materials, manufacturing, transportation, inspection, tests and packaging of the equipment and systems supplied shall be carried out as per International practices.

11.7 Exceptions to this Specification

Any proposal for deviation from this Specification and all other documents and drawings referenced in this Specification, shall be clearly written, in a complete and explicit way. The form shall be signed and submitted for approval to Employer. Contractor shall not proceed with implementation of any deviation that has not been previously indicated and has not been approved in writing by Employer.

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11.9 Document Discrepancy

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- Technical Specification.
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- International Codes and Standards.

11.10 Documentations and Drawings

- Detailed Single-Line Diagram
- Detailed Three-Line Diagrams
- Wiring diagrams
- Assembly/shop floor drawings
- General arrangement drawings
- Foundation plan
- Installation manual
- Operating and troubleshooting manual
- Software details for the control system
- Interface details for communication
- Test Certificates (Factory tests and Type test)

11.11 Factory Acceptance Tests

- Factory tests as per IEC or NEC
- Testing of the impact load acceptance
    a. demonstrate that the response of the generator to load meets the specified limits of
        i. Rated voltage,
        ii. Frequency, and
        iii. Recovery time.
    b. Monitor the transient graphs for voltage and frequency in real time.
- Test the full functionality of the generator

a. Simulate the protection alarms and shutdowns to test the operation and safety of generator set,

- Perform load-proving test.
  a. Demonstrate the capability of generator to continuously carry rated load for a period of time, depending on the required continuous or standby ratings.
  b. Key parameter readings to be taken at regular intervals specific to the requirements.

11.12 Spare Parts

Two detailed spare parts lists shall be included. One list will include all recommended spare parts for commissioning and the other list with recommended spare part for ten (10) year operation. Both lists will include:

- Spare part description
- Quantity
- Unit Price

Furthermore, two-year operation spare parts list will include a recommended planning for equipment replacement (operation hours).

11.13 Bill of Quantity

Refer to the Bill of Quantity which will be separately attached in the design package.

12. TRANSFORMER

12.1 Codes and Standards

The transformers shall be designed, manufactured and tested according to the following Standards:

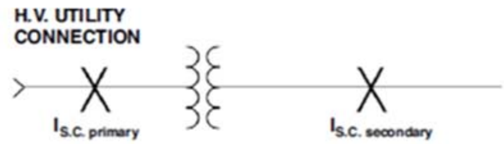
- **IEC 60044-1, -2, -3** Current Transformers for protection; Instrument transformers.
- **IEC 60060** High voltage test techniques.
- **IEC 60071** Insulation co-ordination.
- **IEC 60076, -11** Power transformers; Operating Temperatures
- **IEC 61936-1** Spatial requirements, Site Installation
- **IEC 60137** Bushings for alternating voltages above 1000 V.
- **IEC 60233** Test on hollow insulators for use in electrical equipment.
- **IEC 60551** Determination of transformer and reactor sound level.
- **IEC 60722** Guide to the lightning impulse and switching impulse testing.
- **IEC 62271-105** Switch-disconnectors
- **IEC 60909-0** Short circuit calculations
- **Other applicable standards**

12.2 Design and Sizing

A 750kVA step up transformer will be used to step up the system voltage from 400V three-phase to 20kV. The secondary voltage of 20kV is selected due the prospect of connecting the mini-grid to the main utility transmission line in the future. The Kandahar mini-grid has three sources of energy supply, namely, solar PV, BESS and diesel. All the supply systems are designed to supply power at 400V, 3-phase, 50Hz. Based on the estimated load profile, the mini-grid will have a peak load of about 425kW. It is expected that as the villages are exposed to the option of having reliable electricity, the consumption of electricity would increase over the coming years. Keeping that in mind a 750kVA transformer is proposed for the Kandahar site.

12.2.1 Fault Level Calculations

The following table contains faults in two steps – theoretical max with infinite fault level of the utility and the real max with 20KA fault level. Also fault level can be stated in MVA and kA. In the following table, the MVA fault is shown first and then the KA fault. Calculations are based on following formula:



Step A. **Calculate the "f" factor ($I_{S.C.\ primary}$ known)**

3Ø Transformer ($I_{S.C.\ primary}$ and $I_{S.C.\ secondary}$ are 3Ø fault values)

$$f = \frac{I_{S.C.\ primary} \times V_{primary} \times 1.73\ (\%Z)}{100{,}000 \times kVA_{transformer}}$$

1Ø Transformer ($I_{S.C.\ primary}$ and $I_{S.C.\ secondary}$ are 1Ø fault values: $I_{S.C.\ secondary}$ is L-L)

$$f = \frac{I_{S.C.\ primary} \times V_{primary} \times (\%Z)}{100{,}000 \times kVA_{transformer}}$$

Step B. **Calculate "M" (multiplier).**

$$M = \frac{1}{1+f}$$

Step C. **Calculate the short-circuit current at the secondary of the transformer. (See Note under Step 3 of "Basic Point-to-Point Calculation Procedure".)**

$$I_{S.C.\ secondary} = \frac{V_{primary}}{V_{secondary}} \times M \times I_{S.C.\ primary}$$

Fault from utility			
Utility Fault current	20000	A	
Utility voltage	20000	V	
Fault MVA	692.8	MVA	
Transformer Rating	750	KVA	
Transformer Impedance	5	%	
Transformer Fault Level	15	MVA	
System Fault	14.68	MVA	
System Fault Current at 400V	21192.43	Amps	
Fault generated by Battery			
Battery/Inverter capacity	700	KW	
Rated Current at 400V	1010.39	A	
Max Current	2020.79	A	
Fault level	1.4	MVA	
Fault generated by Diesel			
Diesel capacity	425	KW	

Power Factor	0.8		
Rated current at 400V	766.82	A	
Reactance	0.15		
Fault current	5112.11	A	
Fault level	3.54	MVA	
Total Fault level from Battery and Diesel	4.94	MVA	
Fault level from from Utility	14.68	MVA	
Design fault level at 400V	14.68	MVA	the higher of the two
Design fault level at 20KV	692.8	MVA	

Table 20: Fault Level Calculation

12.3 Configuration

The proposed configuration of the step-up transformer is recommended to be a Star-Star configuration. The alternate configuration can be a Delta on the utility side, as is a common practice in Afghanistan.

12.3.1 Star-Star configuration

Some of the advantages of having a Star configuration on the utility side are:

- Solid grounding can be achieved with a Star configuration,
- With the Star configuration, any fault in the MV line is easy to detect
- Insulation level can be phase to earth
- Low transient voltage stress

The disadvantages of a star-star configuration are

- Any ground fault will result on system tripping, and
- The system will have high fault currents and thermal stress.

12.3.2 Star-Delta configuration

The advantages of having a Star-Delta configuration (with delta on the utility side) are:

- The system will not trip during any transient faults
- Low fault current and low thermal stress

The disadvantages of a star-delta configuration are

- The system needs high insulation level – line to line
- High transient voltage stress
- The system needs additional equipment to detect faults

Note- In either of the system configuration, the step-down transformers for loads can be delta on the 20 KV side and star on the 400V side.

Refer to technical specifications for detailed specs for transformer.

12.4 Additional Requirements

All the material and works must be in accordance with the most advance practice for this type of equipment. Other than specified hereafter all the materials and realized works will be in accordance with latest edition of the IEC recommendations.

The delivery and the equipment in it shall be designed to meet the requirements of the following codes and standards: International Electro-technical Commission (IEC)/National Electrical Code (NEC).The design, materials, manufacturing, transportation, inspection, tests and packaging of the equipment and systems supplied shall be carried out as per International practices.

12.5 Exceptions to this Specification

Any proposal for deviation from this Specification and all other documents and drawings referenced in this Specification, shall be clearly written, in a complete and explicit way. The form shall be signed and submitted for approval to Employer. Contractor shall not proceed with implementation of any deviation that has not been previously indicated and has not been approved in writing by Employer.

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The warranty period must be twelve months from the date of commissioning (provisional plant acceptance) or 24 months from the date pf delivery whichever is earlier.
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12.8 Documentation and Drawings

The system supplier has to provide the following drawings and documents:

- Detailed Single-Line Diagram
- Detailed Three-Line Diagrams
- Wiring diagrams
- Assembly/shop floor drawings
- General arrangement drawings
- Foundation plan
- Installation manual
- Operating and troubleshooting manual
- Software details for the control system
- Interface details for communication
- Test Certificates (Factory tests and Type test)

12.9 Factory Acceptance Tests

- All factory tests as per IEC or NEC
- For details check ANSI/IEEE Standard C57.12.90
- List of Tests
    - No-Load Losses
    - No-Load Excitation Current
    - Load Losses and Impedance Voltage
    - Dielectric Tests
    - Switching Impulse Test
    - Lightning Impulse Test
    - Partial Discharge Test
    - Insulation Power Factor
    - Insulation Resistance
    - Noise Measurement

  - o Temperature Rise (Heat Run)
- Measurement of voltage ratio and check for vector relationship,
- Measurement of winding resistance,
- Measurement of insulation resistance,
- Measurement of short circuit impedance and load loss,
- Measurement of no load losses and current, Induced overvoltage withstand test,
- separate source voltage withstand test,
- visual and dimensional check as per approved GA drawing ,
- Oil B.D.V. test

12.10 Type Tests

- Temperature rise test,
- short circuit test,
- Impulse test,
- Determination of transient (Impulse) voltage transfer characteristics,
- Noise level test,
- Zero phase sequence impedance test
- capacitance tan delta test, S.R.F.A test,
- Pressure and vacuum test on transformer tank,
- Magnetic balance test
- Option for factory inspection and witness test

12.11 Spare Parts

Two detailed spare parts lists shall be included. One list will include all recommended spare parts for commissioning and the other list with recommended spare part for ten (10) year operation. Both lists will include:

- Spare part description
- Quantity
- Unit Price

Furthermore, two-year operation spare parts list will include a recommended planning for equipment replacement (operation hours).

12.12 Bill of Quantities

Refer to the Bill of Quantity which will be separately attached in the design package.

13. MEDIUM VOLTAGE SWITCHGEAR/GRID CONNECTION SOLUTION

13.1 Codes and Standards

The delivery and the equipment in Medium-Voltage Switchgear shall be designed to meet the requirements of the following codes and standards:

- **IEC 60298** HV Metal-Enclosed Switchgear and Control gear.
- **IEC 60056** HV Alternating-Current Circuit Breakers.
- **IEC 60129** AC Disconnectors (Isolators) and Earthing Switches.
- **IEC 60044** Instrument Transformers.
- **IEC 60282** HV Fuses.
- **IEC 60071** Insulation Coordination.
- **IEC 60060** HV Test Techniques.
- **IEC 60529** Classification of Degrees of Protection Provided by Enclosures.
- **IEC 60694** Common Clauses for HV Switchgear and Control Gear Standards.
- **lEC 60099** Surge arresters.
- **lEC 60358** Surge Capacitor.
- **IEC 62271-200 IEC 62271-200** AC metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV
- **Other applicable standards**

The temperature rise of any part of the switchgear and control gear at an ambient air temperature not exceeding 40°C shall not exceed the temperature-rise limits specified in the appropriate standard, **IEC 62271-100** and **IEC 62271-1**.

The electrical life of the circuit breaker shall conform to **IEC 62271-100 class E2**, no maintenance of the circuit breaker interrupting parts for the life of the circuit breaker and only minimal maintenance of the other parts. As a minimum, the circuit breaker shall have not less than 20.000 make-break operations at full load without any maintenance or replacement of parts being necessary.

13.2 Design and Sizing

The Medium voltage switchgear is designed based on the generation capacity and load. We have selected a 20kA 600A grid-tie switchgear. The fault level of the utility is assumed to be 20kA. The switchgear is complete with synchronization capability that can be used in future when there is grid available.

A visible disconnect and a set of lightning arrestors have to be installed on the first pole as part of the reticulation system.

13.3 Configuration

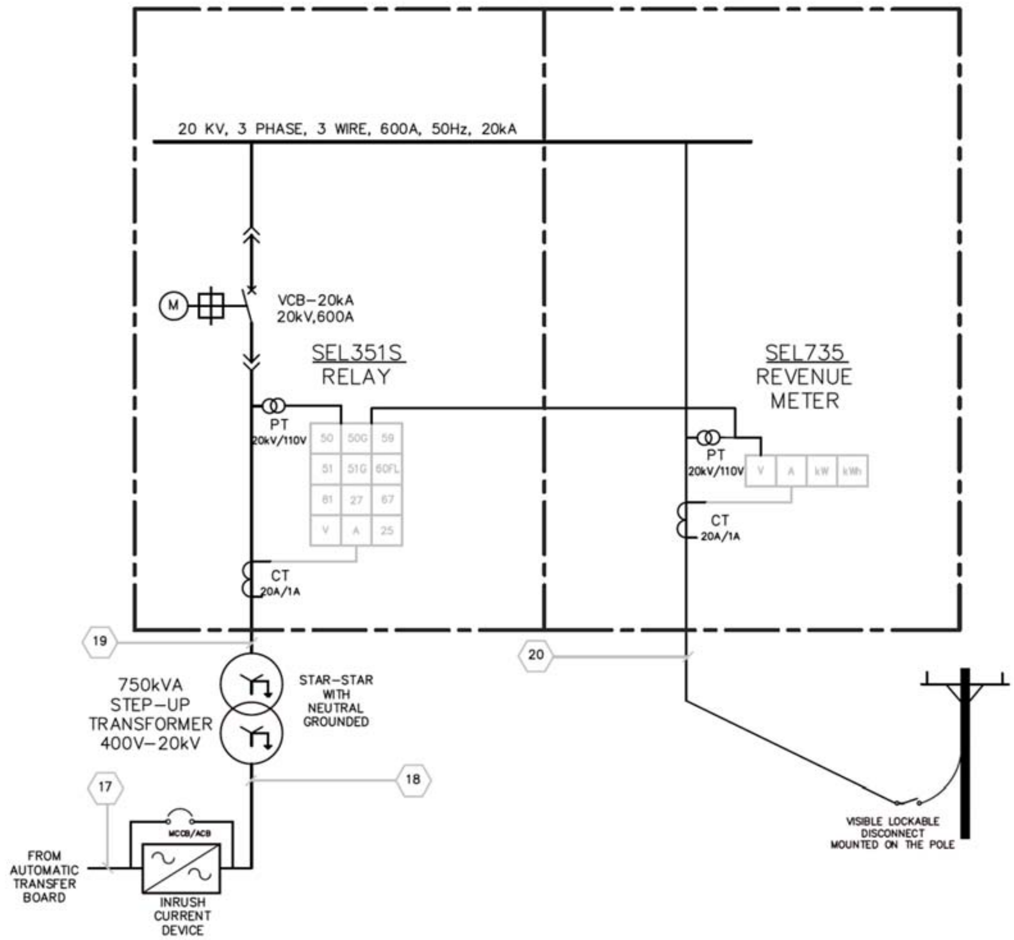

Figure 27: Medium Voltage switchgear details

Refer to technical specifications for detailed specs for medium voltage switchboard.

13.4 Total LV/MV Length

The total transmission routes for LV and MV are 20,578 meter. The following amount of cables are needed for both LV and MV routes:

- The total length of cable required for LV is 19,078 meter
- The total length of cables required for MV is 9043 meter

13.5 Additional Requirements

All the material and works must be in accordance with the most advance practice for this type of equipment. Other than specified hereafter all the materials and realized works will be in accordance with latest edition of the IEC recommendations.

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- Interface details for communication
- Test Certificates (Factory tests and Type test)

13.10 Factory Acceptance Tests

- All factory tests as per IEC or NEC
- MV switchgear shall be thoroughly tested at the factory to assure that there are no electrical or mechanical defects. Tests shall be conducted as per UL, ANSI and CSA Standards.
- Thoroughly test the switchgear at the factory with the circuit breakers in the connected position in their cubicles. The factory tests shall be in accordance with IEEE C37.09 and shall include the following tests:
    - Design Tests
    - Production Tests

13.10.1 Physical Inspection

1. Verify that the drawings and other project-specific documentations are correct, and make sure that the order number, customer name, and project name are consistent on all documents.
2. Verify component certifications, as required.
3. Verify that the product meets all applicable engineering and workmanship standards and specifications.
    - Verify paint quality.
    - Verify that all components are present, not damaged, and are correctly installed.
    - Verify structural integrity.
4. Verify that warning nameplates and isolation barriers are present to protect personnel and equipment.
    - Check for appropriate warning labels and nameplates to advise personnel of possible hazards.
    - Check that appropriate barriers are in place to isolate all medium voltage compartments. Barriers are to ensure that personnel cannot touch live medium voltage in a cell that is otherwise de-energized.

5. Verify that bus and bus connections have proper clearance, creepage, phasing, and torque.
    - Visually check to verify electrical clearances, creepage allowances, and bend radii.
6. Check the tightness of all control and power wires.
    - All hardware connections are torqued to standards and all crimps are proper.
    - Check for cross-threaded hardware.
7. Verify the mechanical interlocks.
    - Verify the operation of any isolation switches, mechanical interlocks & door interlocks.

13.10.2 Electrical

1. Functional checks are performed wherever possible; otherwise, inspection and continuity checks are made.
    - Continuity checks are performed on all parts of the control circuit that cannot be verified by cycling the equipment.
    - Trace or continuity checks are performed on all power wiring.
    - Verify the control wiring is identical to the electrical schematics.
2. A "HI-POT" dielectric withstand test is performed on all buswork and power cables from phase-to-phase and phase-to-ground (except solid-state components, low voltage controls, and instrument transformers). The voltage level that is used for this test depends on the nominal AC voltage of the product
3. Component devices are functionally operated in circuits as shown on electrical diagrams or as called for by specific test instructions.
    - Calibration of printed circuit boards according to specifications.
    - I/O checks
    - Programmable devices
4. Instruments, meters, protective devices, and associated controls are functionally tested by applying the specified control signals, current and/or voltages. Multi-function protective relays and like devices are not programmed – these types of devices are only functionally tested.
5. The product must function in accordance with the electrical diagram.

a. Medium voltage starters are inspected for the following:
- Electrical interlocking
- Overload protection and ground fault, if applicable

b. Medium voltage Smart Motor Controllers (SMCs) are inspected for the following:
- Electrical interlocking
- Motor protection and ground fault
- Motor start tests at rated voltage
- Motor stop tests (if applicable) at rated voltage

c. The following tests are performed on MV drives, as applicable:
- Control power failure test
- Rectifier gating checks
- Inverter gating checks
- Machine converter tests
- Load tests
- Power module failure tests

- Transformer over-temperature tests
- Cooling fan failure tests
- Remote control tests

Drives are accelerated to the test facility's nominal frequency of the motor, under load, and then decelerated to 10Hz. This cycle may be repeated continuously for up to 0.5 hour. Drives are tested under constant load at the nominal frequency of the test motor.

13.11 Spare Parts

Two detailed spare parts lists shall be included. One list will include all recommended spare parts for commissioning and the other list with recommended spare part for ten (10) year operation. Both lists will include:

- Spare part description
- Quantity
- Unit Price

Furthermore, two-year operation spare parts list will include a recommended planning for equipment replacement (operation hours).

13.12 Bill of Quantities

Refer to the Bill of Quantity which will be separately attached in the design package.

14. SCADA LAYOUT AND SPECIFICATIONS

14.1 SCADA Layout

SCADA layout document includes,

a. Overview of SCADA system for Microgrid application.
b. Detailed system block diagram shall be provided.

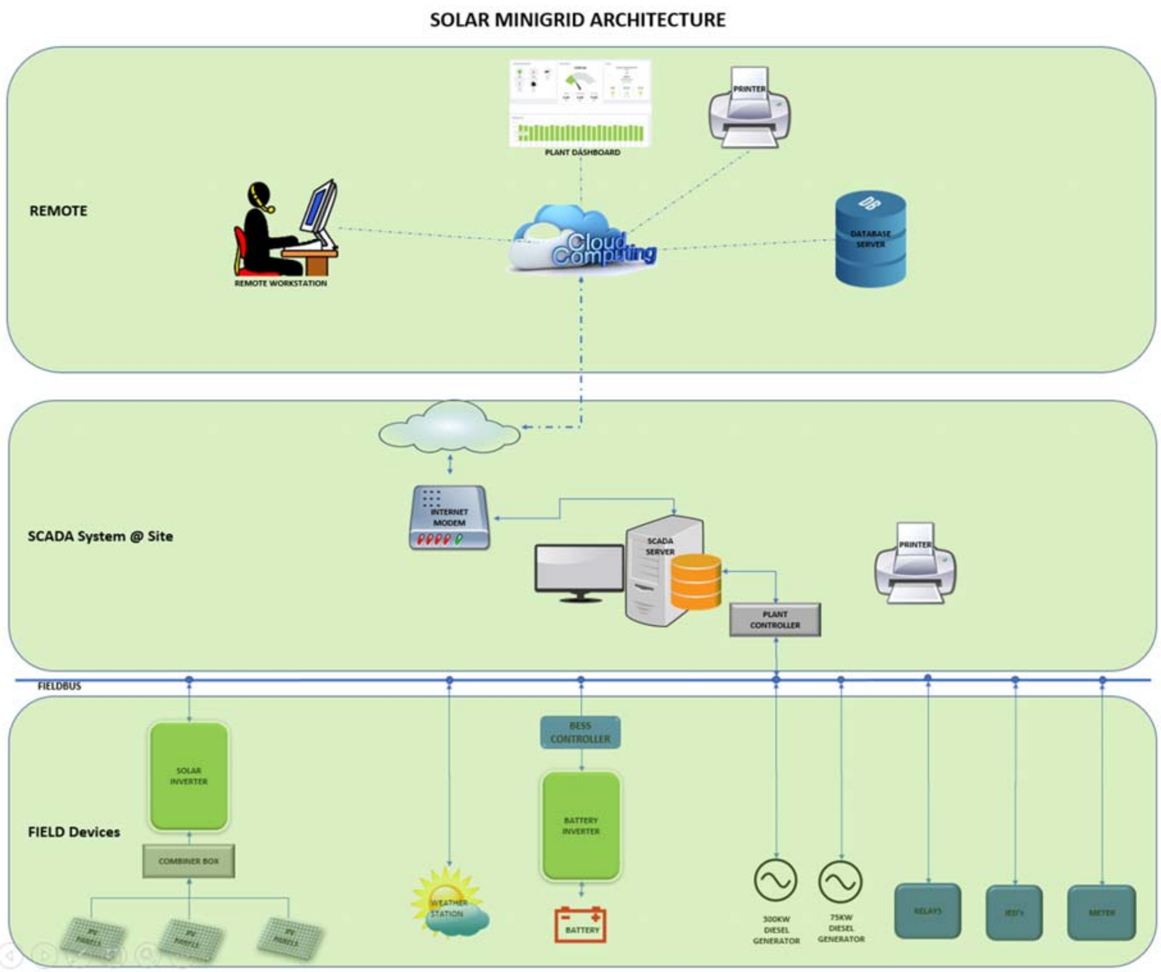


Figure 28: SCADA Architecture

Figure 28 represents overall SCADA architecture. SCADA vendor shall consider this for detailed design. SCADA vendor is responsible for providing minimum functionalities represented in the Figure 28.

a. PLANT CONTROLLER.
    i. PLC
        1. Necessary communication ports (Profibus / Profinet)
b. SCADA Server

1. Industrial Grade Box PC
2. 24” Monitor

ii. SCADA Software

1. User friendly GUI
2. Trends
3. Historian
4. Alarms
5. Multiple Protocol capability

iii. Printer (Laser)

c. Ethernet Switch with necessary copper and FO
d. All are enclosed in the enclosure.
e. Cloud
    i. Remote cloud computing functionality to be provided as an optional
    ii. SCADA shall be capable of remotely monitored (Offsite)
    iii. Remote maintenance workstation shall be provided
    iv. Long Term Historian shall be provided.

14.2 SCADA System Architecture

System architecture document consists of the following:

a. Network architecture.
b. Communication Protocol details
c. Communication Media (Ethernet / RS-485 / RS-232. Copper / Fiber)
d. Communication flow diagram
e. Hardware components (PLC, Servers, Media Converters, Ethernet Switches)
f. Software (Application Software for PLC, SCADA)

14.3 SCADA Data Flow Diagram

Data Flow diagram consists of list of data points from each system. Shall reflect how data is managed, monitored and controlled. Data log details.

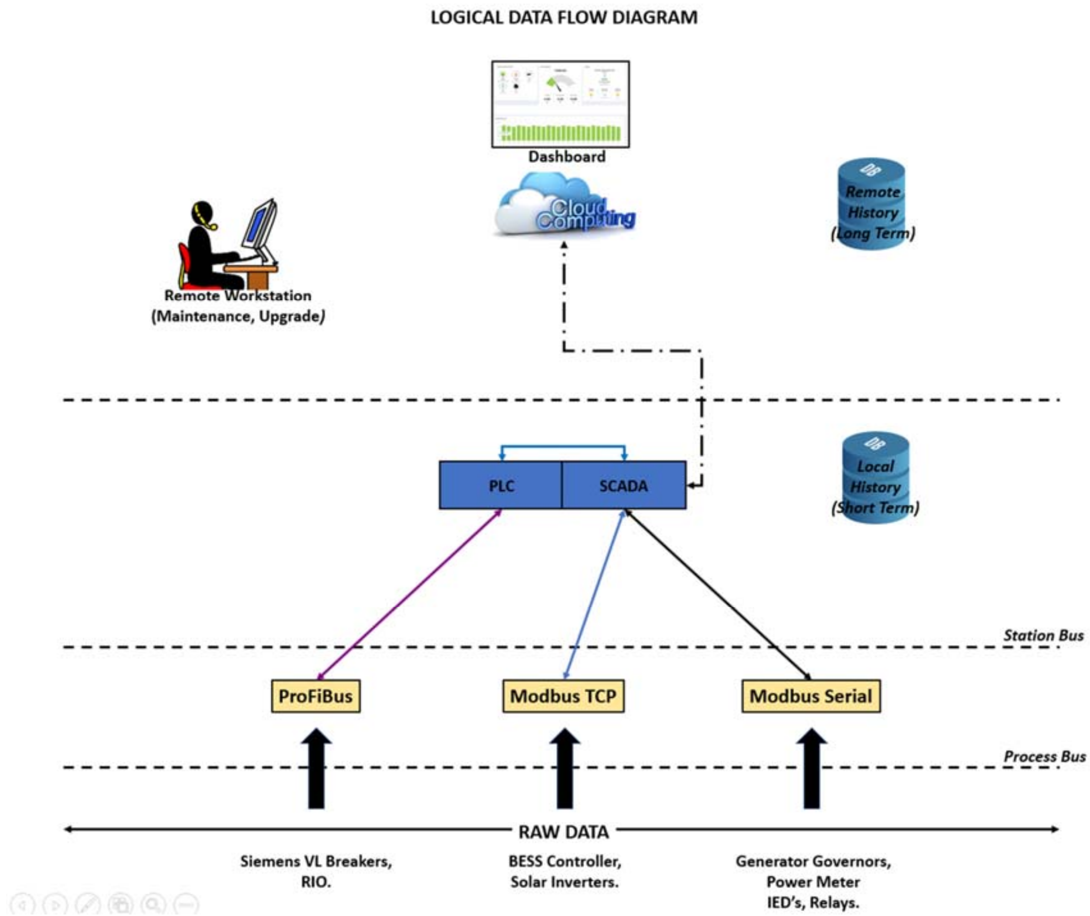


Figure 29: DATA Flow Diagram

Above Figure (29) represents Data Flow diagram for SCADA system.

AC Combiners, Battery Combiner, MV Switchgear, Main Combiner and Automatic Transfer Boards are equipped with VL Breakers with COM20 (Profibus) module. SCADA shall monitor and control these breakers. MV Switchgear has Power meter, SCADA shall read all power meter parameters.

BESS Controller monitor and control Battery Inverters. SCADA shall communicate to BESS Controller through Modbus.

Solar Inverters have Modbus TCP communication. SCADA system shall monitor and control Solar Inverter through Modbus TCP. All RIO are on Profibus / ProfNet nodes to SCADA system.

14.4 SCADA Hardware Design and Layout

Vendor shall provide, detailed SCADA enclosure design. Consists of

a. Bill of Material
b. Layout drawing.
    i. Mechanical (Dimensions, gross weight etc.).
    ii. Environmental properties of the system.
    iii. Mounting arrangement
    iv. Thermal Management
    v. General Arrangement drawing

14.5 SCADA Server, Workstation and Monitoring System

Provide detailed specification of

i. Servers
    a. Box PC
ii. Workstations
    a. Desktop / Laptop
iii. Layout drawings

14.6 SCADA Communication and Network Architecture

Vendor shall provide detailed communication architecture diagram.

a. Detailed drawing of communication network Architecture diagram
b. Communication components
    vi. Media Convertors
    vii. Ethernet Switches
    viii. Network type (Copper / Fiber / Wireless)
    ix. Hardwired I/O details
    x. Shall provide type of connectors
    xi. Calculation of attenuation

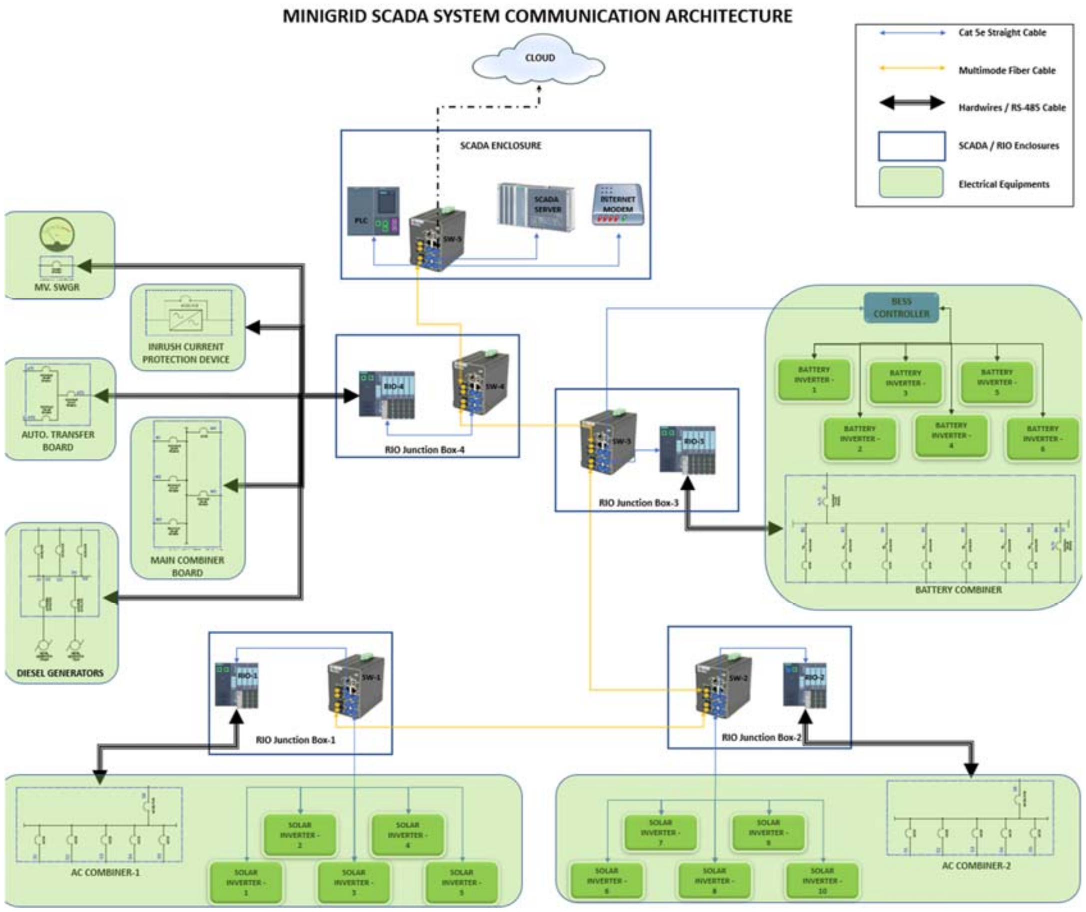


Figure 30: SCADA Communication Architecture

Above Figure (30) represents communication Architecture of Mini Grid SCADA system.

a. Solar Inverters
    i. Modbus TCP Communication
b. AC Combiners
    i. Capable of Profibus Communication
c. RIO Junction Boxes (4 Numbers)
    i. RIO Module with Profibus Communication Module
    ii. OLM for ProFiBus
    iii. Ethernet Switch
d. SCADA Enclosure
    i. SCADA Server PC
    ii. Master PLC
    iii. Ethernet Switch
    iv. Internet Modem.
    v.

14.7 SCADA Functional Specifications

14.7.1 Functionality

Following are minimum functionality to be provided by SCADA vendors.

- All hardware equipment shall have minimum 10 years replacement support.
- Software update service to be provided minimum of 2 years
- ANSI standard electrical schematics (AUTOCAD) shall be provided for
  - Electrical Schematics
  - Communication Network Diagram
- SCADA GUI as per ANSI standards
- SCADA vendor shall provide all necessary hardware and software to meet the requirements in the following sections. Prior approval is required if there is a deviation.
- SCADA system shall be consists of PLC and HMI software.
- Standalone PLC and SCADA with multiple communication protocol capability are necessary. Including Profibus, Profinet, Modbus RTU, Modbus TCP and CANBUS.
- Vendor is providing necessary gateways, media converters if necessary.
- RIO junction boxes shall be outdoor enclosures for AC combiners.
- Communication media between Main PLC and RIO shall be Fiber Optic. Vendor shall provide necessary FO cable and connector details.
- All DI/DO are 24 VDC, interposing relays to be provided control circuits.
- Site will provide 230VAC (single phase) max 60 Amps as an incoming power. Vendor shall provide necessary Power Supply units in the system.

14.7.2 Preferred Manufacturers

a) PLC
   - Provide Ethernet Communications
   - Provide Profinet Communications
   - Provide Profibus Communications

b) RIO
   - Power Supply (230VAC / 24VDC)
   - Provide Profinet Communications
   - Provide Profibus Communications
   - OLM
   - Digital Inputs (24VDC)
   - Ethernet Switch

c) SCADA HMI Software
   - Provide Ethernet Communication
   - Server Client Architecture

- Remote Monitoring and Control Functionality
- Data Logging
- Alarm Management
- Historical Data
- Trending
- Faceplate / Library functionality
- User Administration

d) Cloud / Remote Monitoring (Optional)
- Remote Data Logging
- Long term historian
- Remote Support workstation
- Data Analytics
- Dashboard.

14.7.3 Field Equipment

Mini Grid SCADA system shall be designed to perform following functions.

- Minigrid devices
- Solar Inverters
- AC Combiners
- Battery system
    - BESS Controller
    - Battery Inverters
    - Batteries
- Battery Combiners
- Diesel Generators
    - Generator Controller
    - Diesel Combiner
- Automatic Transfer Board
- Inrush Current Protection Device
- MV Switchgear
    - Power Meter
- Auxiliary Panel Board
- Weather Station.

SCADA vendor shall provide complete system which will monitor and control all above field equipment.

1. Solar Inverters:

There are 10 solar inverters in the system. Group of 5. SCADA shall monitor and control all inverters parameters through Modbus TCP communication. SCADA system shall monitor alarm / events and reports to operators through email / SMS.

2. AC Combiners:
   There are two AC combiners, consists of VL breakers (Without metering function). With Profibus COM20 module. SCADA shall monitor and control AC combiners.
3. Battery system:
   Battery system consists of Batteries, Battery Inverters and BESS controller. BESS controller controls battery inverters. SCADA shall communicate to BESS controller for monitoring and controlling charge and discharge commands through Modbus TCP. If Modbus RTU is provided by BESS controller, SCADA vendor shall provide necessary gateways. SCADA shall also monitor BESS controller for any alarms / events and reports to operator.
4. Battery Combiners:
   Battery combiner, consists of VL breakers (Without metering function). With Profibus COM20 module. SCADA shall monitor and control Battery combiners.
5. Diesel Generators:
   There are two generators. (300kW and 75kW). Each Diesel Generator consists of Generator Controller. SCADA shall issue Start / Stop commands to Generator Controllers through Modbus TCP. Vendor shall provide necessary gateway if required. SCADA monitors status of generators. Diesel generator has Diesel Combiner. Equipped with VL breakers (Without Metering function). SCADA shall monitor and control combiner breakers through Profibus communication channel. SCADA system shall report alarms / events to operator.
6. Automatic Transfer Board:
   Consists of VL breakers (Without metering function). With Profibus COM20 module. SCADA shall monitor and control Automatic Transfer Board.
7. Inrush Current Protection Device:
   SCADA system shall monitor and control this equipment.
8. MV Switchgear:
   Consists of VL breakers (With metering function). With Profibus COM20 module. SCADA shall monitor meter data from VL breaker. Also controls. MV Switchgear equipped with Power Meter. SCADA shall monitor all power meter data through Modbus TCP. Necessary gateway to be provided by vendor.
9. Auxiliary Panel Board:
   Consists of VL breakers (Without metering function). With Profibus COM20 module. SCADA shall monitor and control VL Breakers.
10. Weather Station:
    SCADA system shall monitor weather station and records data. Weather station shall be communicated through Modbus TCP. Necessary gateway to be provided by SCADA vendor if required.

14.8 Design and Functions

1. Introduction:
   SCADA system shall monitor and control all connected devices. Provide alarm notifications for immediate assistance of the plant status.
   - Dashboards for visualization of data
   - Communication status of devices
   - Alarm and Event for smooth pant operation
   - Realtime Data of plant

2. Monitoring Functions:
   The following capabilities shall be implemented into SCADA system.
   - Realtime data: System shall be implemented to see real time data from each connected device.
   - Alarm / Event Notification: Shall be capable of alerting operator any critical alarms through email and SMS.
   - System Efficiency: SCADA shall have analytics to display system efficiency.

3. Online Configuration:
   SCADA system shall be upgraded without interrupting the system. Any changes / modification to system can be implemented white system is online / running.

4. Navigation:
   Navigation Structure shall be shown in the left part of the screen in a logical tree view to provide a quick and friendly access to following screens. It must be organized using folders for proper navigation:
   - General: Linked to “General View” display.
   - Weather Stations: Linked to “Weather Station View” display.
   - Inverters: Linked to “Inverters View” display.
   - BESS: Linked to “Battery System Views” display
   - Generators: Linked to “Generator System Views” display
   - General Communication: Linked to the “General Communication View” display.
   - Medium Voltage: Folder containing access to specific art of the Medium Voltage.
   - Alarms and Events (A&E): Folder containing the following A&E groups. Alarm and events are shown in an additional Tab.

5. Access Control:
   In order to provide a secured access to the system, the login process should be implemented with following roles:

- Administrator has all privileges. This role can be grant to another user and could create users with any role. There is no restriction in the data or configuration access to this role.
- Engineer can change signal database structure and create or modify trends, menus and displays.
- Operator can see data and set orders but is not allowed to change any database parameter.
- View only can see data and trends (default user at login).

6. Parameters to be monitored:
   Any device subjected to be monitored shall be connected to the SCADA system and relevant signals sampled, registered and displayed on the correspondent SCADA screen as required by the Employer in order to provide adequate Plant information for trouble shouting, commissioning and plant operation.
   Sampling timing must be implemented according to the variance of the variable. Variable records shall be shown as instantaneous values or cumulated values at selected intervals selected by the user.
   The following variables, parameters and signals are just an example. The SCADA system shall not only restrict to them if more signals are available and convenient for monitoring and reporting purposes:

   a. Energy Counter

      The following data is obtained from the tariff meter located at the electric room by MODBUS Communication (or similar).
      - Total Energy: Total amount of energy in kWh.
      - Energy Day: Total amount of energy produced in the current day in kWh.
      - Output Power: Instant output power in kW.

   b. Inverter Stations

      The following data is gathered from individual meters located at each MV incomer.
      - Total Energy. Total amount of energy produced measured from the meter in kWh.
      - Energy Day: Total amount of energy produced in the current day for all energy meters in kWh.
      - Output Power: Output power from all energy meters in kW.

c. Weather Stations

Tilt Irradiation. Irradiation measured at the POA pyranometer in W/m2.

- Average of the cells located at tilt plane considering the following method:
- Only the available cells or equipment are considering for this calculation.
- If no cell or equipment is available, the value is set to null and appears as “Non-Available”.
- If weather station is present and available, its cells are considered for this calculation.

Global Horizontal Irradiation. Global irradiation measured in W/m2 by the horizontal pyranometer.

- Average of the pyranometers considering the following method:
- Only the available pyranometer or equipment is considered for this calculation.
- If no pyranometer or equipment is available, the value is set to null and appears as “Non-Available”.
- If weather station is present, its pyranometer is considered for this calculation.

Environment temperature. External temperature measured in ºC.

- Average of the meters considering the following method:
- Only the available meters or equipment is considered for this calculation.
- If no meter or equipment is available, the value is set to null and appears as “Non-Available”.
- If weather station is present, its meter is considered for this calculation.

Cell temperature. Tilt Cell temperature measured in ºC.

- Average of the temperature cell meters considering the following method:
- Only the available meters or equipment are considered for this calculation.
- If no meter or equipment is available, the value is set to null and appears as “Non-Available”.
- If weather station is present, its meters are considered for this calculation.

Weather Stations View

The weather Stations View provides the values from radiation and temperature sensors from the Stations present in the plant. The communication status with all of them could also be checked using this display.

d. Input Status

Communication Status: Alarm flag to indicate the communication status with the Weather Station. The alarm symbol will turn red when the Control System is not able to connect to the equipment and green when the communication is working.

e. Input Values

- Fixed Radiation. Value of radiation for the current day from the pyranometer cell at horizontal plane of the weather station in in Wh/m2.
- Tilt Radiation. Value of radiation for the current day from the tilt calibrated cell 1 of the weather station in Wh/m2.
- Global Irradiation. Value of irradiation from the pyranometer of the weather station at horizontal plane in W/m2.
- Global Radiation. Value of radiation for the current day from the pyranometer of the weather station at horizontal plane in Wh/m2.
- Cell Temperature. Value from the cell temperature probe of the weather station in ºC.
- Ambient Temperature. Value from the external temperature probe of the weather station in ºC.

f. Inverters View

The inverters View provides some values of all plant inverters as well as an indication of general alarm.
Input Status

- Inverter Communication Status. This flag indicates the inverter communication status. The led symbol will turn red when there is a communication alarm and green when the communication success.
- Inverter General Fault. This flag indicates any inverter fault. The led symbol will turn red when there is a fault in the inverter and green when the inverter is working properly.

Input Values

- Output Power. Output power from inverter in kW.
- Energy Day. Total day amount of energy from inverter in kWh.

g. Medium Voltage Views

MV plant information will be shown trough the following types of views.

- MV View. The Medium Voltage View shows the single line diagram of the Medium Voltage system of the plant including the actual breaker status.

h. Inverter stations general view

The General View of the inverter stations (IS) provides an overview of this part of the plant including all combiner boxes (CNs) connected to the IS. The information displayed of the CNs includes last value read and status.
This view is particularly useful to verify the communication status with the CNs. Also, to check if there is any anomaly in the CN, the status of the breaker or an overvoltage fault.
Input Values

- Combiner Current. The sum of all string currents in A.
- Combiner Voltage. The average of measuring equipment voltage in V. Only available equipment is considered for this calculation.
- IS Tilt Irradiation. The value from the calibrated cell of the weather station located in the IS area in W/m2.
- IS Global Irradiation. The value from the pyranometer of the weather station located in the IS area in W/m2.
- IS Cell Temperature. The value from the cell temperature meter of the weather station located in the IS area in ºC.
- IS External Temperature. The value from the external temperature meter of the weather station located in the IS area in ºC.
- Inverter Energy Total. Total amount of energy in kWh.
- Inverter Energy Day. Total amount of energy day in kWh.
- Inverter Output Power. The current active output power in kW.
- DC Meter Energy Total. Total amount of energy in kWh.
- DC Meter Energy Day. Total amount of energy day in kWh.
- DC Meter Output Power. The current active output power in kW.
- Energy Meter Energy Total. Total amount of energy in kWh.
- Energy Meter Energy Day. Total amount of energy day in kWh.
- Energy Meter Output Power. The current active output power in kW.

i. Calculations

- IS Energy Total. The sum of all IS energy meters total energy in kWh.
- IS Energy Day. The sum of all IS energy meters daily energy in kWh.
- IS Output Power. The sum of all IS energy meters active output power in kW

j. Trends screen

Trends views aim to trace Plant behavior during a time frame using a chart utility provided by the Control System SCADA.
Following are typical trend views:

- Inverters. Including one trend per inverter containing the following measures:
  - Output Energy in kWh.
  - Performance ratio trend of each inverter Kwh output
  - Input Active Power in kW.
  - Input Voltage in V.
  - Input Current in A.
  - Output Active Power in kW.
  - Reactive Power in kVAr.
  - Output Voltage in V.
  - Output Current in A
  - Power factor
  - Daily load profiles,
  - Diversity factors,
  - Load factors,
  - Capacity factors
  - Internal Temperature.
- Weather Station. Including one trend per equipment with the following measures:
  - Irradiations at Tilt Plane in W/m2.
  - Insolation at Plane of Array in Wh/m2
  - Cell temperature in ºC.
  - Environment temperature in ºC.
  - Global irradiation in W/m2.
  - Global Insolation in Wh/m2
- Generation Meter:
  - Total generation in Kwh. o Total AC Power in Kw. o AC voltage.
  - AC Current.
  - AC frequency.

14.9 RIO Junction Box Specifications

There are four junction boxes required. Two junction boxes are installed in outdoor environment near AC combiners. Two are installed indoor. One closer to BESS Controller and another closer to other switchgears.

Purpose of the RIO junction box is to create distributed architecture. Connect and communicate to distributed field devices. Minimize hardwires running from devices to main controller.
Typical junction box consists of following components.

1. Enclosure (Two Outdoor and Two Indoor)
2. Power Supply (230VAC / 24VDC)
3. Interface Module with Profibus
    a. Profibus is used for communication to VL Breaker COM20 (or similar)
        i. Daisy chain configuration shall be implemented for all Profibus slave devices.
4. Digital Input (24 VDC) (8 DI's) for future expansion
5. Digital Output Modules (24 VDC) (8 DO's) for future expansion
6. OLM module (Profibus copper to Fiber). For connecting to Main Controller.
    a. All RIO's are connected to Main controller through Fiber Optic media.
7. Industrial grade ethernet switch with wide operating temperature
    a. Ethernet switch with minimum 6 copper and two multimode Fiber ST ports.
    b. Capable of Modbus TCP protocol
    c. Copper ports are connected to Solar Inverters, BESS controller, Generator Controller for Modbus TCP communication
    d. Fiber ports are used for communication to SCADA system.

Note:
1. All cables between RIO junction boxes and Main PLC / SCADA enclosure shall be multimode fiber.
2. All VL breakers to RIO junction box shall be Profibus two wire cable
3. All Solar Inverters to Ethernet Switch are Cat5e ethernet cable
4. Generator controller to Ethernet switch. Vendor shall provide Modbus RTU to Modbus TCP gateway.
5. Power meter at MV Switchgear to Ethernet switch. Vendor shall provide Modbus RTU to Modbus TCP gateway
6. BESS controller to Ethernet Switch. Vendor shall provide Modbus RTU to Modbus TCP gateway
7. Profibus OLM with two fiber ports shall be installed in each RIO junction box.

14.10 Scope of Work

SCADA vendor/supplier shall provide the following:

- PLC based plant controller
- SCADA hardware
- Communication cables

- RIO Junction box
- Programming of Junction Box, PLC controller and SCADA.
- Documentation
- Onsite commissioning
- System integration support to BESS system vendor

15. CIVIL DESIGNS WITH CALCULATIONS, INCLUDING ROADS, WALKWAYS AND FLOOD CONTROLS

15.1 List of Codes and Technical Criteria

The following codes and technical criteria and those referenced therein shall be required for this project.

References within each reference below shall be required and adhered to. If there is conflict in the criteria the most stringent requirement shall be applied. This list is not exhaustive and is not necessarily complete. The publications to be taken into consideration shall be those of the most recent editions.

ACI 318	Building Code Requirements for Structural Concrete (latest edition), American Concrete Institute
ACI 530/ASCE 5/TMS 402	Building Code Requirements for Masonry Structures (latest edition)
AISC 360	Specification for Structural Steel Buildings (latest edition), American Institute of Steel Construction
ASCE 7	Minimum Design Loads for Buildings and Other Structures (latest edition)
ASTM	American Society for Testing and Materials
ASTM-D-1586	Standard Test Method for Standard Penetration Test
ASTM-D-5299	Standard Guide for Decommissioning Ground Water Wells
AWS D1.1	Structural Welding Code – Steel (latest edition), American Welding Society
BS 7671	British Standards Requirements for Electrical Installations (IEE Wiring regulations, 17th Edition)
EIA ANSI/TIA/EIA-607	(1994) Commercial Building Grounding/Bonding Requirement Standard
IBC	International Building Codes, 2009 edition (and its referenced codes including those inset below)
IEEE C2	National Electrical Safety Code (NESC), latest edition
IMC	International Mechanical Code, latest edition
IPC	International Plumbing Code, latest edition

Fire Protection and Life Safety:

NFPA 1	General Fire Protection, latest edition
NFPA 10	Portable Fire Extinguishers, latest edition

NFPA 72	National Fire Alarm Code, latest edition
NFPA 80	Fire Rated Doors and Windows, latest edition
NFPA 101	Life Safety Code, latest edition
ANSI TIA/EIA 607-A	Commercial Building Grounding (Earthing) and Bonding Requirements for Telecommunications, (latest edition)
ANSI TIA/EIA 607-A	Commercial Building Grounding (Earthing) and Bonding Requirements for Telecommunications, (latest edition)

USACE-AED Design Requirements:
In addition, technical criteria provided in USACE-AED Design Requirements (most recent version) shall be required for use in design and construction specifications as indicated in the following documents.

The following design criteria shall be used:
AED Design Requirements – Voltage Drop Calculations Process, latest version
AED Design Requirements - Site Layout Guidance, latest version
AED Design Requirements - Well Pumps & Well Design/Specifications, latest version
AED Design Requirements – Water Tank and Water Distribution Systems, latest version
AED Design Requirements - Booster Pumps, latest version
AED Design Requirements – Chlorinators, latest version
AED Design Requirements - Hydro-Pneumatic Tanks, latest version
AED Design Requirements - Jockey Pumps, latest version
AED Design Requirements - Water Tanks, latest version
AED Design Requirements – Hydrology, latest version
AED Design Requirements - Sanitary Sewer and Septic Systems, latest version
AED Design Requirements - Grease Trap, latest version
AED Design Requirements - Oil-Water Separator, latest version
AED Design Requirements – Geotechnical Investigations for USACE Projects, latest version

All codes listed are used as a design guide. Other standards may apply.

15.2 Building System Descriptions

15.2.1 Architectural Components

Codes:

- 2003 International Building Code (IBC)
- UNIFORM BUIDLING CODE (UBC)
- NeuFert 2006 (Architecture Design Data)
- Force Protection: D regulation UFC-4-010-01, 31 July 2002
- Architect standards 6th Edition
- National Fire Protection Association (NFPA 101): Life Safety Plan Only

- Local building codes: there are no known applicable local building codes for this project.
- Other applicable standards

All Building Major Construction Components:

Office building	Concrete structure with Brick wall
Power house	Equipment room Brick wall with RCC columns and RCC ceiling system
	Open yard for containerized battery and inverters
	And steel canopy for generator, fuel tank and transformer shade
Guard Room	Brick wall with RCC columns and RCC ceiling system
Water tank /Towers	Brick wall and RCC ceiling system for the guard room

15.2.2 Plumbing

Codes:

- International Plumbing Code
- Uniform Plumbing Code
- American Society of heating, Refrigerating, and air Conditioning Engineers (ASHRAE) handbooks
- American society of mechanical Engineers
- American society of testing and materials
- American welding society

Materials:

- Domestic water pipe **Polyvinyl Chloride per ASTM D 1784 and 1785 50psi hydrostatic test.**
- Waste and vent PVC ASTM D2665
- Hot Water 90 Degrees C

15.2.3 Electrical

Codes:

- National fire protection association, NFPA 70 (national Electrical Code, 2002)
- National Fire Protection Association Life Safety Code NFPA 101
- Illuminating Engineering society of North America (IES)

Power Distribution Design Loads:

- Each electrical panel shall have a short circuit withstand rating of 65kA ISC/0.5 Sec.
- Voltage drop for branch circuit home runs shall not exceed 2% and 3% for main feeder and total 5%.
- A ground grid system is provided as indicated in the drawings.

- See drawings for electrical load calculations.

Lighting Design:

- Fluorescent lighting is provided as per calculation based on the lux required. Switches are provided to control the lighting for all rooms.
- Emergency/egress lighting is provided only as required by NFPA 101.
- Lighting is seismically braced.
- Exterior building mounted security lighting is provided.
- Lighting levels meet the following:
    - General office Space 400 Lux
    - Dining room 200 Lux
    - Sleeping room 300 Lux
    - Meeting room 300 Lux
    - Living Quarters 300 Lux
    - Hall 300 Lux
    - Kitchen 500 Lux
    - Storage 200 Lux
    - Maintenance/Repair room 400 Lux
    - Lobbies 150 Lux
    - Lounges 150 Lux
    - Mechanical & Electrical rooms 200 Lux
    - Toilets 200 Lux
    - Exterior lighting 5 Lux

Outdoor Area and Street Lighting is not Provided, building exterior light are enough for exterior lightings around the buildings.

15.2.4 Mechanical criteria

Outdoor Design Conditions:

Summer	36 C (97^{o} F) db and 23.8^{o} C (75^{o} F) WB.
Winter	-5.00 C db
Range of DB	Summer 36
Average Extreme wind”	40 km/h (25mph)
Winter heating	all areas should be maintained at 20^{o} C (68^{o} F) db.

Ventilation:

Office	37 CMH/m^{2} with ceiling fans
Mechanical/Electrical rooms	Mechanical ventilation sufficient to remove heat to 42^{o} C (100^{o} F)

Toilet and Wash Area	Min 37 CMH/m2 (2 CFM/Ft^2) or 85 CMH per water closet, whichever is greater.

Air Intakes:
Size for maximum velocity of 2.5 m/s (500 fpm) through the free area.

Filtration:
Weatherproof louvers with a bird screen.

Seismic:
Meet requirements of IBC 2000 for ductwork, equipment, and piping.

Codes:

- American society of heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) Handbooks American society of mechanical Engineers
- American society for testing and materials
- American welding society
- Sheet metal and Air conditioning contractor's national association
- Underwriter's laboratories (UL)

15.3 Office Building

15.3.1 Architectural Layout

The office space is design for 6 staff, working during the day to operate the plant.
Interior space consists of following rooms.

Office room-1	=	10sqm
Officer room-2	=	12sqm
Hall/lobby	=	15sqm
Kitchen	=	12sqm
Meeting/dining RM	=	15sqm
Sleeping room	=	20sqm
Toilets#1	=	4sqm
Toilet#2	=	4sqm

First floor Consist of 2 High officer rooms, one junior officer room, one hall for waiting area and meeting and dining room, one sleeping room and two toilets.

Building size:
This is one story building which have rectangular shape.

Total net area	=	150sqm
Gross area	=	171sqm

Code Reference Information:
2003 IBC – International Building Code

Occupancy Type:
IBC (chap 3) Barracks, Group (R)
Occupancy separation (Table 302.3.2)

Construction Type:

IBC (601)	Type A 11

Allowable Area:

IBC (Table 503)	=	111m^2
Actual Area	=	171m^2

Minimum Number of Exits Required:

IBC (Table 1018.1)	2 exits (building G.B) Occupants <1-500 < occupants Exist provided = 2 (Complies)

Maximum Exit Travel Distance Limit:

IBC (Table 1018.2) 100 feet	=	30.4m
Actual travel maximum distance to exit	=	11m (Complies)

15.4 Site Development

Final Adjustment to grading and utility connections are performed on-site.

15.4.1 Utilities

Water:
Building connections are taken to 1.5 meters beyond the building; from that point they are connected to main water distribution system.

Sanitary Sewer:
Building connection are taken to 1.5 meters beyond the building; from that point they are connected to the septic tank and then connected to drain field or leach field.

15.4.2 Architectural Components

Exterior Materials:
- Walls: 350mm brick masonry wall plastered and painted. The total width becomes 400mm for insulation.
- Doors and frames: steel, painted.

- Windows: PVC fixed insect screen.
- Roofing: 130mm RCC slab with insulation.

Interior Materials:

- Floor covering: Sealed concrete.
- Walls: under beam 350mm Burnt Brick Masonry plastered and painted.
- Walls: under slab as partition wall 15mm
- Doors and frames: steel, painted and PVC door for wet areas.
- Safety Equipment: fire extinguishers provided.
- Signage: Exit signs provided

15.4.3 Structural Systems

Office building is class –I frame system of RCC beams and columns, the walls are not bearing, it is used as partition inside the building and weather proof outside the building. Ring beam is provided at ground surface level to provide sufficient strength for the building frame, Minimum steel areas based on ACI code -318-08 are provided.
All other building is the same system as above mentioned.

- The Flat roof system is a RCC Slab painted with local insulation and bituminous liquid waterproofing on top, plaster at the bottom, applied immediately after the slab.
- The exterior finish of the structures is mortar plaster applied immediately after installation mesh over insulations boards over brick wall. The 50mm thick insulation board is fasten by plaster mesh 1mm thick @ 25mm opening size by 150mm long , and Ø12mm expansion PVC Bolt into wall, The bolt shall be installed 4-6 per sqm area of wall and on edges as necessary.
- The interior walls finish is plaster, applied immediately after the completion brick masonry wall.
- In wet areas (kitchen, toilet and showers): the interior low partition walls brick masonry with plaster and ceramic tile all up to 1.2 m, floors are ceramic tile.
- Other floors are painted concrete.
- All components listed in the design Criteria are contractor Furnished/Contractor installed unless otherwise noted. Furniture, Equipment, are not part of this contract, and are in the drawings to show how we met the requirements for number of occupants, cup boards and other wood board in kitchen is part of the contract.

15.4.4 Mechanical Systems

Plumping Design:
System demands are established in accordance with listed applicable codes and standards. All new plumbing fixtures are at commercial or industrial grade as appropriate

Sanitary Drainage System:
The sanitary drainage system consists of regular waste systems. All piping systems are provided with clean out located as required. The proposed regular waste system consists of

Waste and vent piping to all plumbing fixtures. All drainage connections are drained by gravity through soil waste stacks and the house drains to site sanitary sewer. All piping is PVC

Domestic Water System:
The building domestic water supply is connected to the network main water supply system. Domestic water system shall include double check backflow prevention, and building water distribution to all plumbing fixtures and water heater. Drinking fountains are provided. All piping is schedule 25 galvanized or schedule PPR PVC or PVC. Water heaters are solar water heater.

Mechanical Design:
Ceiling fans and fire wood heaters with vent through roof are provided in all rooms.
Toilet and kitchen are exhausted. Make – up air is transferred from outside through filtered louvers.

- Heating is provided for personal comfort in dining, sleeping and other common areas via wood fired local heater, vent is provided for and heater will be installed by customer.
- Ceiling fans are provided for air in sleeping areas and offices.
- Calculations for heating and ventilation loads have been made based on brick walls and insulated roofs and wall, R=20 for walls and R=30 for roof.
- Domestic water is heated via electric water heaters. Water heaters are located in inside the wet areas depending or their numbers and size.
- Fire alarm, stand-alone smoke detector is provided.
- Fire extinguisher is provide as required by code, 1/100sqm

Indoor Design Conditions:

Office Building	Heating only in the office 20^{o} C (68^{o} F) by fire wood heaters Ceiling fans only in the offices for summer ventilation
Toilet/Shower Areas	Exhaust fans at ventilation rate of 2 cfm/sf or 37 CMH/M^{M} No heating.
Guard Room	Heating only 20^{o} C (68^{o} F) by fire wood stove.

	Ceiling fans for summer ventilation.
Guard Tower	Heating only 20° C (68° F) by fire wood stove Ceiling fans for summer ventilation

Outdoor Air Ventilation Rate:

Office and Sleeping Areas	Windows plus ceiling fan ventilation 37 CMH/M^2 of floor area or 85
Toilet and Wash Areas	CMH/WC, whichever is larger 19CMH/M^2 for kitchen

15.4.5 Electrical Systems

Power Distribution Design Loads:
Electric outlets are provided. See Design Calculation for load calculation and design analysis.

Lighting Design:
- Fluorescent lighting is provided, water proof light is provided in wet location.
- Switches are provided to control lighting in all rooms.
- Egress lighting is provided
- Lighting is seismically braced.
- See Design Calculation for lighting calculations.

Grounding:
A ground grid system is provided as indicated in the drawings.

15.5 Powerhouse Building

This building has three parts
- **Part one**: is for equipment room and storage
- **Part two**: is for containerized battery yard
- **Part three**: is for generators, fuel tank and transformers canopy

15.5.1 Architectural Layout

Part one - Total gross Area	=	279.3sqm
Part two - Total gross Area	=	342sqm
Part three - Total gross Area	=	138.7sqm
Shape	=	Regular Rectangular Shape.
No of floor	=	1 floor
Structure	=	Steel canopy structure over steel pipe column and metal truss and GI roof.

Total floor area = 123.95sqm

The facility consists of following rooms:

1. Space for two Generators, one 425kW and 75kW, 7.65mx6.7m
2. Space for one fuel tank Ø2.5m, 5m length, Space Room 6.7mx4.5m
3. Space for two step transformer, MV breakers, MTS and MDB, 6.35mx6.7m
4. Space for storages and equipment rooms

Code Reference Information:
2003 IBC – International Code Building

Occupancy Type:

- IBC (chap 3) Power House- not classified in any specific occupancy –group U Incidental
- Generator Room (N/A) = group U
- Occupancy separation (Table 302.3.2) no requirement.

Construction Type:
BC (601) Type llB

Allowable Area:
IBC (Table 503) = Following spacing in between equipment not less than 70cm
Actual provided space = 100cm (complies)

Minimum Number of Exits Required:
IBC (Table 1018.2 = 1 exits (building G.R U) Occupants <50 Travel Distance < 22,8m
Exits Provided = 3 (Complies)

Maximum Exit Travel Distance Limit:
IBC (Table 1015.1) = 22.86 meter
Actual travel maximum distance to exit = 6.7m (Complies)

Site Development:
Final adjustments to grading and utility connections are performed on-site.

15.5.2 Utilities

Water”
Not used.

Sanitary Sewer:
Not used.

15.5.3 Architectural Components

Exterior Materials:

- Walls: chain link fence for generator, fuel tank and transformer, 350mm thick brick masonry for control room
- Doors and frames: chain link fence gates for generator, fuel tank and transformer, steel double door for equipment room
- Windows: PVC window for equipment room
- Roofing: Steel structure canopy for generator, fuel tank and transformer
- Fuel tank: containment concrete wall 1m high all around

Interior Materials:

- Floor covering: Sealed concrete.
- Walls: chain link fence for generator, fuel tank and transformer, 350mm thick brick masonry for control room
- Ceilings: Steel structure canopy for generator, fuel tank and transformer, concrete slab for equipment room
- Doors and frames: Steel door
- Safety Equipment: One fire extinguisher provided.
- Signage: not used.

15.5.4 Structural Systems

The building is a single story rectangular building with no walls around and steel roof structure supported by pipe column, design for snow, wind and other loads
Isolated footing is provided for each column.

Control Room and Storage Areas Structures:
Part of the facilities is for equipment room, the building is a single story rectangular building with 350mm thick bearing Brick masonry walls with RCC columns at each corner. The building is designed as wall bearing with RCC frame.

The RCC Columns is designed to bear the load and to limit the eccentricity between the center of stiffness and the current center of mass and reduce the major twisting effects on the building. The roof consists of 130mm thick RCC slab supported by the bearing walls and RCC columns.
The foundation of this building is square footing foundation for columns and continuous foundation for wall type 800mm below finished floor level perimeter ground beam according to design. Minimum steel area as per ACI code is provided for columns, ring beam, top beam and foundation footings.

The containerized batteries are place on open yard and place on open area on concrete pads.

15.5.5 Mechanical Systems

Mechanical Design:

- Fuel piping is provided to supply fuel from fuel to generators, black steel welded type is considered supply pipe is Ø20mm and return pipe Ø20mm to fuel tank.
- The fuel pipe is directly connected to generator fuel pump and discharge pipe is back connected to fuel tank.

Sanitary Drainage System:
Not used

Domestic Water System:
Not used

15.5.6 Electrical Systems

Power Distribution Design Loads:
Electric outlets are provided. See Design Calculation for load calculations and design analysis.

Lighting Design:

- Fluorescent dust proof G type lighting fixture is provided.
- Switches are provided to control lighting in all rooms.
- Egress lighting is provided
- Lighting is seismically braced.
- See Design Calculation for lighting calculations.

Grounding:
A ground grid system is provided as indicated in the drawings.

Communications:
Not used

15.6 Guard Room

15.6.1 Architectural Layout

The room consists of one room and a toilet.

Total Floor Area of the Room = 18.25 m2

Code Reference Information:
2003 IBC – International Code Building

Occupancy Type:

- IBC (chap. 3) Guard Room –not classified in any specific occupancy- Group U
- Guard Room (N/A) = group U
- Occupancy separation (table 302. 3.2): No requirements

Construction Type:
IBC (table 601) Type ll B

Allowable Area:
IBC (Table 503) = 18qsm
Actual area = 20sqm (Complies)

Minimum Number of Exits Required:
IBC (Table 1018.2) = 1 exit (Building Group U. occupants <50, travel distance < 22.8m)
Exits Provided = 1 (Complies)

Maximum Exit Travel Distance Limit:
IBC (table 1015.1) = 91.44 meters
Actual maximum travel distance to exit = 3.5 meters (complies)

Site Development:
Final adjustments to grading and utility connections are performed on-site.

15.6.2 Utilities

Water:
Building connections are taken to 1.5 meters beyond the building; from that point they are connected to main water distribution system.

Sanitary Sewer:
Building connections are taken to 1.5 meters beyond the building; from that point they are connected to main water distribution system.

15.6.3 Architectural Components

Exterior Materials:
Walls: 350mm brick masonry wall with plaster surface, painted.
Doors and frames: steel door, painted.
Windows: PVC, with metal sill and screen.
Roofing: 130mm RCC slab and local insulation and Tar sheet final surface aggregate.

Interior Material:
Floor coverings: Sealed concrete.
Walls: 250mm
Ceilings: 130mm RCC slab with plaster, painted.
Safety Equipment: one fire extinguishers provided.
Signage: Not Used

15.6.4 Structural Systems

The building is a single story rectangular building with 350mm thick bearing Brick masonry walls with RCC columns at each corner. The building is designed as wall bearing with RCC frame.

The RCC Columns is designed to bear the load and to limit the eccentricity between the center of stiffness and the current center of mass and reduce the major twisting effects on the building. The roof consists of 130mm thick RCC slab supported by the bearing walls and RCC columns.

The foundation of this building is square footing foundation for columns and continuous foundation for wall type 800mm below finished floor level perimeter ground beam according to design

Minimum steel area as per ACI code is provided for columns, ring beam, top beam and foundation footings.

15.6.5 Mechanical Systems

Mechanical Design:
Wooden heaters are provided for heating and ceiling fan for ventilation.

Plumbing Design:
System demands are established in accordance with listed applicable codes and standards. All new plumbing fixtures are at commercial or industrial grade as appropriate

Sanitary Drainage System:
The sanitary drainage system consists of regular waste systems. All piping systems are provided with cleanout located as required. The proposed regular waste system consists of waste and vent piping to all plumbing fixtures. All drainage connections are drained by gravity through soil waste stacks and the house drains to site sanitary sewer. All piping is PVC

Domestic Water System:
The building domestic water supply is connected to the compound's main water supply system. Domestic water system shall include double check backflow prevention, and building water distribution to all plumbing fixtures and water heater. Drinking fountains are provided. All piping is schedule 25 PVC. Water heaters are electric

15.6.6 Electrical

Power Distribution Design Loads:
Electric outlets are provided. See Design Calculation for load calculations and design analysis.

Lighting Design:

- Fluorescent lighting is provided.
- Switches are provided to control lighting.
- Lighting is seismically braced.
- See Design Calculation for lighting calculations.

Grounding:
A ground grid system is provided as indicated in the drawings.

Communications:
The communication system is not required in this contract.

15.7 Water Tower and Water Tank Structure

15.7.1 Architectural Layout

The tower has 7m height and 3m height of tank, total height of 10m

Water Tank Capacity:
Total inner volume = 30 m^3

Code Reference Information:
2003 IBC – International Code Building

Occupancy Type:

- IBC (chap. 3) water tank tower – not classified in any specific occupancy - Group U
- Water tank tower (N/A) = group U
- Occupancy separation (table 302. 3.2): No requirements

Construction Type:
IBC (table 601) Type ll B

Site Development:
Final adjustments to grading and utility connections are performed on-site.

15.7.2 Utilities

Water
Water is connected to water tank above tower from water well and then distribution to building.

Sanitary Sewer
NA

15.7.3 Architectural Components

Exterior Material:
Walls: NA
Doors and frames: NA
Windows: NA
Roofing: RCC SLAB 15CM thick.

Interior Material:
Floor coverings: Sealed concrete.
Walls: 350mm RCC
Ceilings: 150mm RCC slab with plaster, painted.
Safety Equipment: NA.
Signage: Not Used

15.7.4 Structural Systems

The Tower facility is a 7m high above ground and 3m is water tank height, total height for the facilities is 10m. The tower is located on high area which has 6m for down facilities. The structure is concrete with 6 RCC columns at each corner. The building is designed RCC frame.

The RCC Columns is designed to bear the load and to limit the eccentricity between the center of stiffness and the current center of mass and reduce the major twisting effects on the building. The roof consists of 150mm thick RCC slab supported by the bearing walls and RCC columns. The foundation of this building is mat foundation for columns 800mm below finished floor level perimeter ground beam according to design

Minimum steel area as per ACI code is provided for columns, ring beam, top beam and foundation footings.

15.7.5 Mechanical Systems

Mechanical Design:
N/A

Plumbing Design:
Over flow, inlet, out let, drain and other piping is provided for the water tanks

Sanitary Drainage System:
N/A

Domestic Water System:
N/A

15.7.6 Electrical

Power Distribution Design Loads:
Electric outlets are provided. See Design Calculation for load calculations and design analysis.

Lighting Design:

- Flood light is provided on 4 faces.
- Lighting is seismically braced.
- See Design Calculation for lighting calculations.

Grounding:
A ground rod is provided as indicated in the drawings.

15.8 Civil Standards and Codes

The Civil Works shall comply as a minimum with International Standards ISO, IEE, DIN, BS Standards (International Standards Organization: European Norm: EN; German Standards: DIN; British Standards: BS; American Standard: ASM).

Works of any nature, not specifically mentioned in the Contract, however necessary for the Works subject of this Contract, shall be executed as per state of the art.

Where there is conflict between this General Specification and the relevant Norm, the Specifications shall take precedence.

Materials supplied and work performed shall comply with these Standards and regulations as a minimum. If other Standards are used, the Standards shall be equal or superior to those specified and full details of the difference shall be supplied to the Engineer if requested.

When standards are referred to, the edition shall be the current at the time of issue of tender documents, together with any amendments issued to that date. In case any standard is superseded, the later relevant standard shall be adhered to.

If requested by the Engineer, the Contractor shall supply at his own expense one copy of any standard, which is applicable to the contract.

System of Units:
The International System of Units (SI) applies to all aspects of the project.

Loading and Structural Design Standards:
For civil structural design, the following codes and standards have been used for determining the design loads and calculating required dimension of the sections:

- IS 1893: 1970 Criteria for earthquake resistant design of structures
- BS 8110: 1985 Structural Use of Concrete
- BS 8007: 1987 Design of Reinforced Concrete Structures for Retaining Aqueous Liquids
- BS 4466: 1987 Specification for Bending Dimension and Scheduling of Reinforcement for Concrete
- BS 6031: 1981 Code of Practice for Earthquakes.

15.9 Concrete

The structural concrete shall comply with the general specifications and the construction drawings. For the analysis purpose, the following values were adopted:

Unit Weight:

Reinforced concrete	=	25 kN/m³
Plain concrete	=	24 kN/m³

Characteristic Strength:

C15	=	15Mpa
C25	=	25Mpa
Concrete		ASTM C 39 and ACI 318; f''_c = 25 MPa (3625 psi) minimum specified compressive strength @ 28 days
Water-cement ratio	=	0.45 (maximum)
Steel Reinforcement Deformed bar		ASTM A 615 (ASTM A 706 for weldable rebar); f_y= 420 MPa (60 ksi) yield strength
Welded Wire Fabric		ASTM A 185
Non-Shrink Grout		35 MPa (5000 psi) min compressive strength at 28 days, ASTM C827

Mortar	ASTM C 270; Cement-Lime Type S, minimum 12.4 MPa (1800 psi) average compressive strength at 28 days
Grout	ASTM C 476; minimum 14 MPa (2,000 psi) compressive strength @ 28 days
Stone Masonry	f_{st}=300 kg/cm^2 (4350 psi) required for general walls foundation

The design concrete strength is derived from the characteristic strength multiplied by a coefficient 0.67 which is a material partial safety factor. The material partial safety factor (0.67 = 1/1.5, where 1.5 is material partial safety factor) in flexure and axial load takes account of differences between and laboratory values, local conditions and inaccuracies.

15.10 Metal Canopy and Steel Structure

15.10.1 Steel Structure

Plates, Shapes & Bars	ASTM A 36; F_y = 250 MPa (36 ksi) minimum yield strength
Hollow Sections	ASTM A 500, Grade B; F_y = 318 MPa (46 ksi) minimum yield Strength
High Strength Bolts	ASTM A 325
Standard Bolts	ASTM A 307
Anchor Bolts	ASTM F 1554; Grade 36 steel
Welding	AWS D1.1 (American Welding Society)
Welding Electrodes	E70XX
Sheets	ASTM A 653; Grade 340 (50), Class Z275 (G90) for galvanized coating

15.10.2 Welding (for Canopy)

All major load bearing steel members shall be pre-engineered structural steel manufactured by a reputable foreign steel firm according to ASTM and AWS requirements.
For minor structural members of small steel structures (tanks, sheds, stairs.), the following shall apply. As there are no established testing labs and procedures in Afghanistan, we used an additional 2.0 safety factor to account for Afghanistan welders' deficiencies and inability to conduct proper testing. We used 500 kg.cm^2 for f_y permissible instead of 1000 kg/cm^2 allowed by AWS D1.1-98. We substituted testing with visual inspection by at least 10 year experienced afghan welder.

15.10.3 Reinforcement steel

The reinforcement design is based on the following specifications

- Complies with the requirements of BS 8110
- TMT steel having ultimate tensile strength of 420 MPa (Fe 420).

The reinforcement steel also uses a material partial safety factor of 1.15.

Minimum Bend Diameter:
All reinforcement shall be bent at cold temperatures. Hooks are calculated at follows:

- A 180° bend plus an extension of at least 4db (diameter of bar) but not less than 64.00 mm
- A 90° bend plus an extension of at least 12db or
- Ties and stirrups either 90° or 135° bend plus an extension of at least 6db but not less than 64 mm.

The following minimum bending diameters should be used

Table 21: Minimum bending diameter

#	Bar Size	Minimum Diameter of Bend
1	#3 through #8	6 d_b
2	#9, #10 and # 11	8 d_b
3	#14 and #18	10 d_b

Clear Cover of Concrete Structures:
Minimum concrete cover of reinforced concrete is compiled in Table 22.

Table 22: Clear cover of concrete structures

#	Description	Minimum Cover (mm)
1	Concrete cast against & permanently exposed to earth	75.00
2	Concrete exposed to earth or weather	
	#6 through#18 bars	50.00
	#5 and smaller bars	35.00
3	Concrete not exposed to weather or in contact with ground	
Slabs, walls	#14 and #18 bars	35.00
	#11 and smaller bars	2000
Beams, Columns	Primary reinforcement, Ties, Stirrups	40.00
NOTE: Until unless otherwise mentioned, 75mm thick C15 concrete shall be used for blinding • For footings • For columns		

- For beams
- For slab/staircase

Reinforcement Spacing:
Reinforcement spacing of the main longitudinal bars can also be controlled by size of aggregate. The minimum spacing required is compiled in Table 23.

Table 23: Minimum bending diameter

#	Description	Minimum Spacing
1	Clear distance between Bars in a layer	d_b or 25.0 mm
2	Two or more Layers in parallel, distance between layers	25 mm
3	In column clear distance between bars	$1.5d_b$ or 40.0 mm
4	In walls and slabs, primary reinforcement shall be spaced farther than 3 time thickness of wall or slab	460.0 mm

Reinforcement Spacing of Ties:
Compression members shall be enclosed by lateral bars such as:

#3 in size for longitudinal bars #10 and less
#4 in size for longitudinal bars #11, #14, #18

Vertical Spacing of ties shall not exceed the following:

16 multiply by diameter of longitudinal bars
48 multiply by diameter of ties bars
48 multiply by least dimension of the compression members
Compression reinforcement in beams shall be enclosed with ties satisfying the size and spacing as discussed above.

Minimum Reinforcement:
Area of longitudinal reinforcement for compression members shall not be less than 0.01 nor more than 0.08 times the gross area of the section.
At any section of flexural member where positive reinforcement is required by analysis, the ratio provided shall not be less than $200/f_y$.

Minimum reinforcement shall be provided at least of the following ratios of reinforcement area to gross concrete area but not less than 0.0014.

- Where grade 40 or 50 deformed bars are used 0.0020

- Where grade 60 deformed bars are used 0.0018

15.10.4 Adopted Soil Parameters

The following values were adopted for the properties of soil during foundation design:

Unit weight of dry soil	=	18 kN/m³
Unit weight of saturated soil	=	21 kN/m³
Unit weight of submerged soil	=	11.2 kN/m³
Angle of repose for the soil	=	30^o-35^o (based on soil properties)
Allowable bearing pressure	=	96 kN/m²

Other parameters:

Modulus of elasticity for C15/C25	=	19,365/25,000 MPa
Poisson's ratio	=	0.25
Coefficient of thermal expansion	=	0.00001 per °C.

Foundation:
Allowable bearing pressures: 0.75 kg/sq cm based on the technical requirements listed in soil report. However, we designed the footing based on AMERCAN CONCRETE INSTITUTE (ACI), 318 Strength Design 318-08

15.10.5 Loads

Reference used for USACE project in Afghanistan.

Wind Loads:
Basis ASCE 7-98
Basic Wind Speed = 80 mph (122Km/hr)
Exposure category "C" (Open Terrain)
Importance Factors 1w = 1.0

W =Ce*Cq*qs*Lw		
Exposure factor Ce =	1.06	for exposure Category C , Open Terrain
and Cq =	0.8	
qs for wind speed 122 KM/PH =	0.08	t/m2

Table 24: is used to determine wind load

Seismic Loads:
Basis 2010 IBC Section 1614 "Earthquake loads- general"
Ss = 2.29g

S1 =0.869g
Group “1”
Site Class “D”
Importance Factor 1 = 1.0
Fa = 1.0 (table 1615.1 (1))
Fv = 1.5

Sms = Fa Sa	(2.29g)
Sds = 2/3 Sms	(1.1g)
Sm1= Fv S1	(1.5g)
SD1 = 2/3 Sm1	(1.0g)

Seismic Use Groups for all buildings is (l), no true hospitals or schools or buildings with over 300 occupants are anticipated. See table 1604.5, seismic design category based on short period response table 1616.3 (1)

Seismic design category = E (Based on footnote a.)
Section 1616.6.3 (if the structures have period T < 0.5sec, Sds & Sd1 need not be based on a value of Ss> 1.5g and S1>.6g) therefore Sds =1.0g and Sd1=0.4g
Table 1617.6 is used to determine R = 2 1/2, Q=2. Cant. Column system max ht. <35’. Walls act as nonbearing for all buildings except in Generator room and Well house
Cs =.156g based on EQ 16-35 therefore V_{base} = Cs (w) EQ 16-34

For Components:
Out of wall for design, the RCC frame themselves is controlled by section 1620.1.7 EQ 16-63
Fp =0.41 Sds therefore F_p =0.4*(1.0)*1*W_w

The following Calculation is used for frame system (Special RCC frames)	
Response Modification coefficient R	6.5
System Over strength factor Ω	2.5
$C_S = S_{DS}/(R/I_E)$, Equation 16-35	0.15385
V_{base} = CS*(Weight of the structure) , Equation 16-35	0.15*W

Table 25: Is used to determine design coefficients and factors for relevant building System

Vertical loading:

Snow loading	=	200 kg/sq/ meter
Roof live load	=	200 kg/sq meter
Office live load	=	350 kg/sq meter
Barracks live load	=	195 kg/sq meter
Ground floor live load 490	=	kg/sq meter
Corridors live load	=	490 kg/sq/ meter
Mechanical room live load	=	735 kg/sq/ meter

Storage area live load = 612 Kg/sq meter

Geotechnical investigation – the geotechnical investigation analysis for the site is completed. The report recommends the site for building construction and the bearing is in the range of 0.75-1.2 Kg/cm2. The test results for the borings are submitted with design submittal.

16. SITE FACILITIES

16.1 Hydrology/Weather Kandahar – Site Storm Water Management

The project location as show is near to Panjwayee, the rainfall intensity estimated from the following figures. The indoor design for heating and cooling found based on outside weather conditions. The outside condition is found in the following figures.

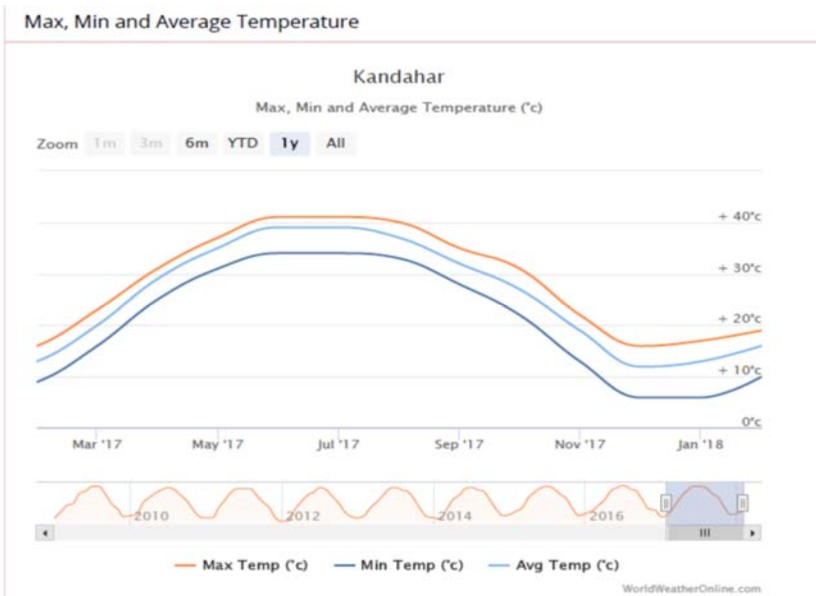


Figure 31: Annual Average Temperature Study for Kandahar

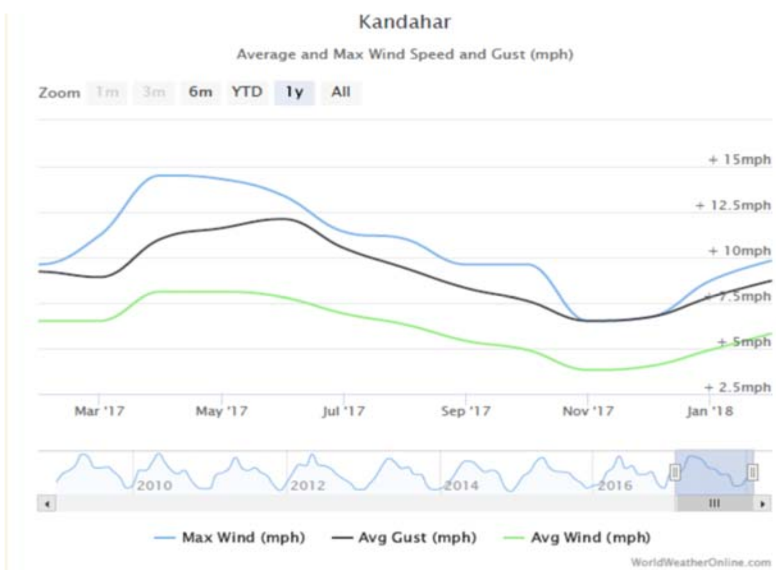


Figure 32: Annual Average and Maximum Wind Speed and Gust (mph) for Kandahar

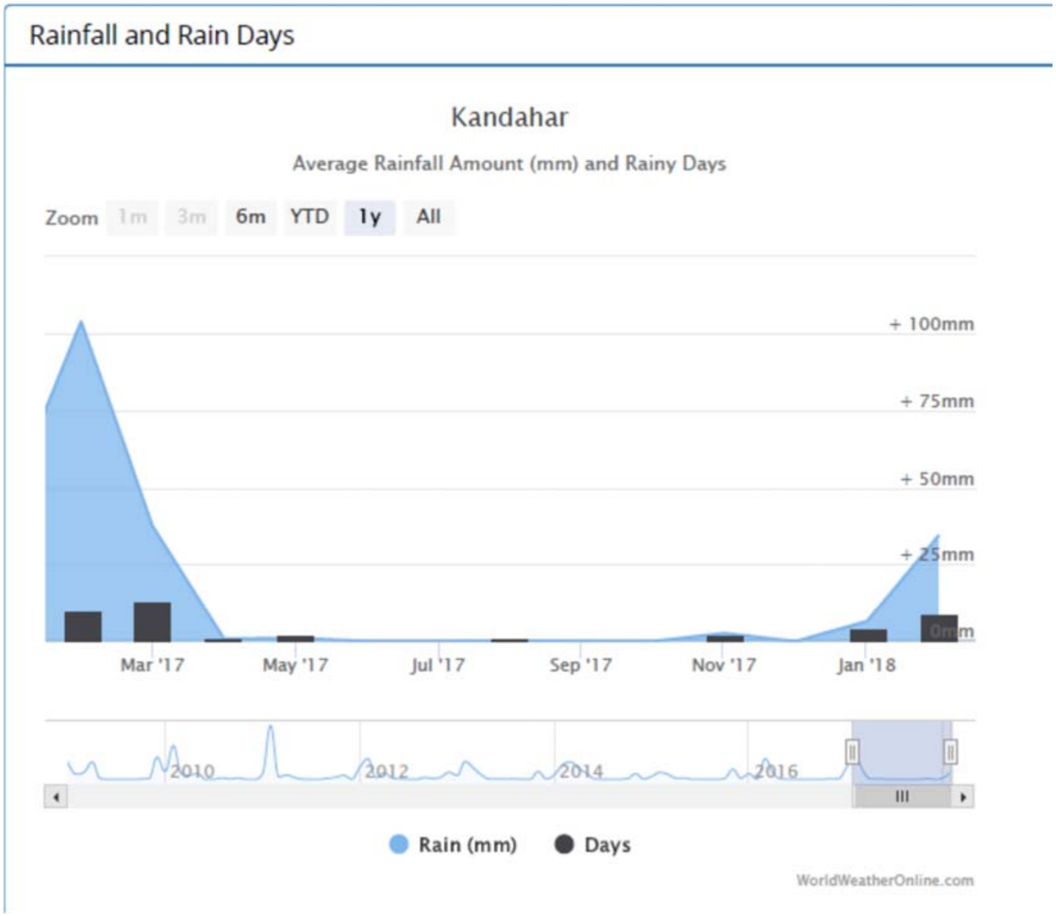


Figure 33: Rain intensity chart

The site is divided in basin and area slope to trench and runoff water is estimated based on ground surface materials than the trench size is estimated. Open V type trenches are considered which are the most cost effective, easy for construction and good for water flow. Two type trenches are considered earth channel for low slope up to 0.5% and stone patching surface trenches are considered for high slope above 0.5% to control erosion on trenches sides. The storm water is calculated based on the above table and site trenches and culverts are provided as per natural slope and required at site. Drainage plan is provided showing finished floor of building and slope and grade the site to trenches that no rain water will be standing on site.

16.2 Security Fence and Gate

Security fence is provided around power house facilities and panel yards selected site, the total area is 21,500m2 as indicated in drawings.

Foundation stone wall is provided under Fence to prevent excavating under fence by mates, dogs or steeling the panel form site. The stone wall is 80cm in ground and 40cm above grade level to prevent flooding into the site as well. Fence post is fixe on stone wall. Fence gate is provided at entrance 3.5m wide and 2.4m high.

16.3 Roads and parking space

Concrete surface road, parking and walkway are considered to prevent dust for Panels.
The ADT is not much but concrete surface is good to control dust on sites.
The road layer considered as follows:

- Sub graded natural ground compacted to 90%
- Sub base course 150mm layer compacted to 95%
- Base course 150mm compacted to 98%

Concrete walk way is considered to control dust control. Walkway layer consist of sub graded compacted to 90% base course compacted to 98% and 10cm concrete 20Mpa

16.4 Mounting frame for PV Panels

Metal frame for PV panel is provided as unit base; each unit has space for 18 PVC panels and has four posts in ground. Each unit is set side by side to provide a uniform row for PV panels. The frame structure includes vertical columns, rafters, purlins and other component which are provided for fixing the panel. The frame can be adjusted to different tilt angles for different seasons. Details of angles and tilts are given in the drawings. Cold farm frame have been used in the frame structure and all nuts and bolts are standards. The concrete foundations are provided for each post.

The frame, designed, withstand all the natural calamity/forces such as wind load, quake load and other vertical loads of panels. The calculation is provided for the frame are done manually as well as by software.

16.5 Site Lighting System

Site lighting is provided in the perimeter fence line on the pole at 7m height. The lights are directed to perimeter line only and the purpose of lighting is to control and guard the site perimeter for the compound. The lights are controlled and switched on and off from the Guard. Underground PVC conduits Ø50mm pipe and cables are provided for each light fixtures mounted on the pole. Two circuits (one in the lift and one in the right) are provided which cover the whole site perimeter light fixtures. Total of 8 Poles and 16 light fixtures are provided. The pole will be constructed from steel pipe 100mm at the bottom and 75mm at the top. Two lights and two cameras will be installed in each pole.
The light fixture is LED 4000K 230V, Rated luminous flux: 3866lm, Rated input power: 40W, Luminaries efficacy: 84lm/W, Electronic ballast 120÷240V 50Hz. Cable insertion place is

provided at base of the pole. The cables are run from inside the pole pipe to the fixture point.
The lighting pole calculation is provided to withstand all natural calamity/forces.

16.6 Sewer System and Leach Field

Gravity sewer line is provided for office building and guard room toilets. All sewer line flown by gravity to septic tank and then connected to leach field. Excess water will flow to leach field and will be absorbed. Septic materials will need low maintenance once a year. Leach field will not affect any nearby wells or water facilities. This is the most economic system for septic system implemented by USACE in most of their projects and they are working very well. The septic tank design and calculation provided. Refer to the calculation sheets for more information.

Sanitary Sewer laterals run from the new buildings by gravity to the new sanitary sewer collection system constructed as part of this project. Because of the small number of occupants, the sanitary sewer collection system is mainly 100mm PVC pipes. The sanitary sewer collection system has been designed for 80% of the water usage of 10 person compounds, using 155 Lit per day per person, and having a peaking factor of 1.5 times the average daily flow. Manholes and/or cleanouts are provided as indicated at each change in direction of the new sewer lateral line. We have no manholes that are spaced more than 120m.

The septic tank is considered for waste water which is connected to the leach field. The septic is sized for 10 individuals for the duration of two days. The leach field is designed for 10 individuals, assuming 80% of 155 lit of water per head per day; the scope determine the size of the leach field as indicated in drawing. Size of septic tank and leach field is calculated - refer the calculations. The leach field is a good system for treatment of sewerage system disposal and it is used by USACE in some of its projects. It can work for long times. Some are still working but few are blocked due to large amount of waste or improper construction. The design is based on design requirement attached in design standard package.

16.7 CCTV and Video Security System

Site Video and Camera system are provided to for site surveillance, security check, control of theft and other security issues through perimeter fence and other parts of the compound. The cameras are installed at the light pole along the perimeter fence. A total of 16 cameras are provided and installed. Each camera has the capacity to observe/see up to 50m and the site distance is around 40m.

16.8 Concrete Pad

Concrete pads are provided for containerized Battery Energy Storage System, the transformers, generators and the fuel tanks. The pads are all interior pads and there are no isolated exterior pads. All the pads are supported and jointed with grade slab. The BESS, the fuel tank and generators have same loading and weight therefore only one type is calculated and te transformer is less in weight and it is calculates separately. The pad consist of 150mm grade slab and then 100-150mm additional concrete poured over grade slab. The overall thickness of pad is 25cm and the grade slab is 15cm with reinforcement bars.

16.9 Fuel Tank

Steel sheet fuel tank is considered for fueling generators. The fuel tank is sized based on the fuel consumption for 6 months for the two generators. The generators are not running all the time. They are operating in coordination with PV panels. The tank can hold 25000 Liter fuel which is enough for 6 months as calculated in DPR report. The fuel tank is designed round type shape to have the best strength against collapsing. The circular tanks are the most cost effective with strong strengths against fuel and other forces. The tank is supported by steel saddle and saddle is anchored in the concrete. The calculation is provided for all sheeting, anchors and pad and the slab foundation. The tank is inside the canopy with containment wall around to hold leakage fuel during leakage of tank. The containment is sufficient to hold all fuel in the tank. A sump and valve is provided for cleaning purpose and flow of water out of the containment. The valves shall be closed all the time and shall be opened as/when required.

16.10 Master plan

Building Connections – Land scope and building connection based on usage is considered, comfortable design and setting facilities location are considered in site layout plan. The site utilities are connected to the buildings as required. This includes connection to the water main, sanitary sewer collection system, and electrical service.

Land Disturbance Limits –the sites is not in rectangular shape, the total area is 20000m2 ranges. The site-specific topography will determine the direction of storm water flow.

16.11 Survey and topographic plan

Site survey is performed and topo plan is included in drawing showing all exist feature at site as indicated. The survey plan for distribution system also shows all roads and exist culverts and houses.

16.12 Site grading

Site grading is considered to slope the site as per natural slope and drain water from site and the finish floor elevation for building and other facilities is considered above 40cm above grade that shall prevent flooding during flooding.

16.13 Site drainage

Storm Drains and culverts – the design utilities surface runoff features through grading plan that will be developed based on site specific plans. We expect to construct trenches and culverts to drain surface flood water out compound, the site will be graded and culvert will be constructed at natural slop direction. Tow kind of culverts are considered. The PVC pipe culverts design for closed areas within the compound to collect water from closed area to main culvert and main culvert are designed of stone masonry to drain the storm water out of the compound.

16.14 Water distribution system

The water is being provided to each building and to solar panel from the water distribution system. The solar panel needs washing on a time basis which needs water to wash the dirt. The distribution system consists of network around building, piping inside building and reservoir water tanks. The one-day demand is calculated as 20000Lit for domestic demand and washing, therefore 27000 Lit is provided, and the water storage tanks are located on 4m high concrete water tower structure. The water storage tanks are connected with water pump and well pump. Water tower is provided to provide pressure to all fixtures. The tank provides water as down fed system to the building fewer amounts of head lose. Sufficient pressure is provided to all fixtures including showers.

The water will be pumped from the new water well to water storage tank. The one day water demand including washing is stored in the water tanks. The water tanks are connected with compound network. Each building which needs water is connected with network distribution system. The new water well, new water pump will be located in the bore well. The well is located on high elevation, While the septic tank is located at the low elevation, furthest point from the well and water tank. The water distribution network is 25-50 mm PVC or PPR pipes running to the buildings for the water usage of max 6 individuals, using 150 Lit per day per person, having a peaking factor of 1.5 times the average daily flow, as we assumed the office will work in one shifts around the clock. Water lines are PVC pressure rated pipe. Blow Valves are provided at low elevation and air valve are provided at high elevation as required, also other valves are provided to isolated buildings from the water distribution piping system.

Washing panel, paths or spraying garden stand up tapes are provided in the main network system. Hose bib tapes are provided, 25 mm stands up pipe at 1.2m elevation is provided to supply sufficient water for washing panels, paths spraying gardens and etc. total of xx stands up tape including. 1 stands up tape are also provided for Guard rooms.

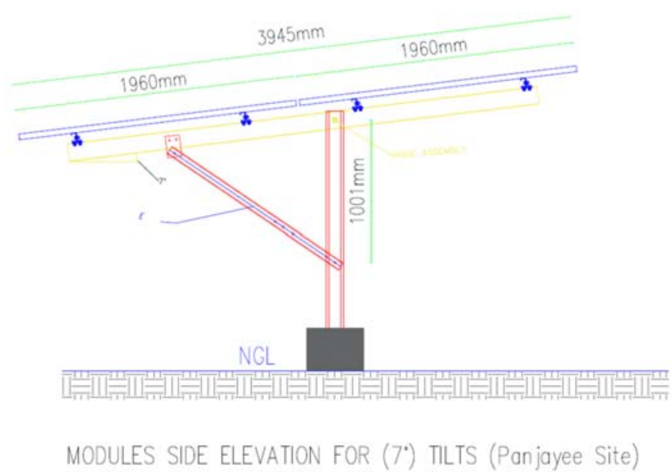
16.15 Public Lightings

The public lighting design is provided in the main roads near main shopping areas and crowded places where people have walking during the night. The light fixture is mounted on the concrete poles at 4-5 m height from ground level and is fed from nearest meter box at the pole with auto photocell switch on the fixture. The lighting fixture's spacing is 120m at the site which can be provided more than 5 lux lighting illumination which is required as per NEC code. NEC Code recommends 5 lux for street lights. LED fixture with 100w power consumption and luminosity of 13200 lm is selected which can provide sufficient luminosity for the roads. There may be flood light installed in front of the shops and houses' gates by individual households and shop owners as well which can help to increase the light illumination during the night time.

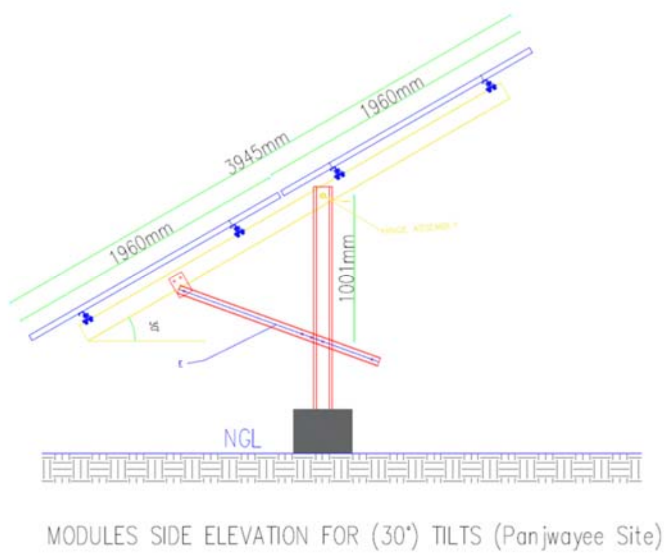
Substation lighting is provided by projector type LED light fixture with 50W power and luminosity of 2400 lm which can provide sufficient illumination for the transformer and its surrounding areas. 10lux illumination is provided as per NEC Code. Two light fixtures per substation is provided to light up all direction and the projectors are also movable that can be adjusted to direct lights at specific locations as required. The street type light fixtures are big and need 1m spacing in front and may touch with MV wires. Therefore, the projector type LED lights are selected for substations.

17. MECHANICAL DESIGNS OF RACKING SYSTEMS, INCLUDING ALL CALCULATIONS

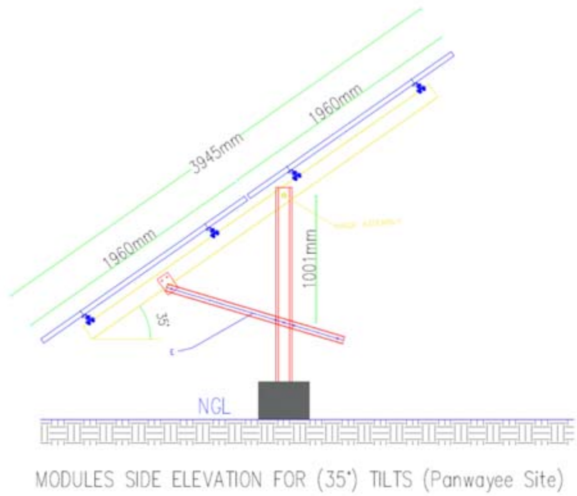
The pole mounts will be made of steel with a concrete foundation and associated racking system. The racking system is installed on the poles. Every set of four poles will carry 20 solar panels. A row of solar panels and rows are sized in line with the PV park layout and the string size. Steel structures are made of galvanized steel protected against corrosion for up to 50 years. The structures shall be tilted at three angles for three seasons, in line with the drawings.



(a-I)



(a-II)



(a-III)

Figure 34: Modules side elevation for (a-I) 7°, (a-II) 30°, (a-III) 35°.

17.1 Codes and Standards

Manufacture and installation of steel works shall be as indicated in drawings and specs. Where there is a conflict between various regulations, codes and standards and the priority of those documents is not spelled out in this specification the contractor should request for clarification in writing from the Engineer.

All regulations, codes and standards referred to in this specification refer to the latest editions of those regulations, codes and standards unless otherwise approved by the Engineer.

S.N.	Code/ Regulation	Description
1	ANSI/API Spec 2B	Specification for Fabricated Structural Steel Pipe
7	ASTM A312	Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes
12	ASTM F593	Standard Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs
13	ASTM F594	Standard Specification for Stainless Steel Nuts
14	AWS D1.1	Structural Welding Code Steel (2008)
15	IS 2062	Steel for General Structural Purpose
16	IS 10748	Hot-rolled Steel Strip for Welded Tubes and Pipes
17	ISO 630	Structural steels -- Plates, wide flats, bars, sections and profiles
18	ISO 898	Mechanical Properties of Fasteners
19	ISO 1461	Hot Dip Galvanized Coatings on Fabricated Iron and Steel Articles.
20	ISO 3506	Mechanical Properties of Corrosion-Resistant Stainless Steel Fasteners

Table 26: Applicable External Specifications, Codes and Standards

17.2 Structural Materials

For valves and pipelines, the manufacture shall conform to use of steel and polymer in accordance with the following guideline as shown in table 27.

Table 27: Material specifications for Steel Equipment & Structures

S.N.	Material Type	Equipment or Structure	Steel Grade
1	Stainless Steel	Fasteners and Anchor Bolts	ASTM F593/F594 Alloy Grade-A
2	Hot Rolled Steel	Plates Structural and Flat Bars	ASTM A36, Grade 60
3	Hot Rolled Steel	Penstock pipe, easily weldable	IS:2062, ASTM A106
4	Cold Rolled Steel	Shafting for tandem lifts Radial gate pins.	ASTM A108, Grade 1045
5	Ductile Iron	Bearings and Rollers	ASTM A536 Grade 60-40-18

17.2.1 Bolted Connections

Bolts, nuts and washers and other demountable fastenings of all galvanized parts and also Aluminium alloy parts shall be in stainless steel to the appropriate DIN Standard and shall remain unpainted. P.T.F.E. washers shall be flatted beneath bolt-head and washer when fastening galvanized and aluminium alloy parts.

All nuts shall be secured by pre-stressing, lock or counter nuts or similar methods. Spring washers are not allowed in structural members. Washers shall be used at both bolt head and nut. No welding is allowed on either item as galvanizing must remain intact. Bolts shall not be reused. Pre-stressing tolls shall be applied when utilizing torque stress techniques. The grease shall be non-corrosive and must not contain sulphur.

All holes for bolted connections up to 18 mm shall be approximately 1mm larger than the bolts used. For bolts above 18 mm the holes shall be 1.5 mm larger unless otherwise specified.

Bolts heads and nuts shall rest squarely against the base material, and bolts shall be a length that will extend entirely through and up to a maximum of 6mm beyond the nuts.

Bolts with pre-installed tension control may be used subject to Engineer’s approval.

17.2.2 Bolts in Shear and Tension Connections

Bolts in structural members from 12 mm and above shall be pre-stressed to 50% of yield strength unless otherwise specified by the Engineer. Bolts in joints exposed to wave loads shall be pre-stressed to 75%of yield strength.

17.2.3 Friction Grip Connections

Bolts shall be pre-stressed and documented as specified on design drawings or as approved by the Engineer. Enlarging of holes for high stress bolts shall be by reaming only. Holes shall be clean-cut without torn or ragged edges. Outside burrs resulting from drilling or reaming operations shall be removed with a tool making a 2 mm bevel. All holes shall be drilled and reamed as necessary prior to application of protective coating.

17.2.4 Hand Railing

Unless otherwise specified all rails shall be fabricated from 32 mm bore galvanized medium weight steel tube. Hand railing shall be provided along every edge of all metalwork and concrete walkways, stairs or accessible open areas where the drop beyond the edge exceeds 700 mm. Hand railing shall consist of Standards at regular intervals not exceeding 1.5 m, and two rails. The upper rail shall be 1.0 m above the adjacent finished floor level, and 900 mm above the nosing line on stairways. The lowest rail shall be midway between floor and upper rail. The hand railing fixing and anchorages shall be designed to withstand a continuous horizontal load at the top rail of 750 N/m. Hand railing shall be flush jointed. Hand railing terminating against a wall shall have a suitable wall fixing.

Where required ladders, stairways or other openings shall be guarded on three sides by hand railing conforming to the requirements stated above. Access to the ladders or openings shall be guarded by two removable galvanized hanging chains secured to eyes at top and middle levels. Hand railing shall be of uniform appearance and manufacture.

17.2.5 Module mounting structure

The array mounting systems and overall installation must meet all applicable local building codes, and shall have attachment points, which are consistent with the module manufacturer’s installation instructions, and the requirements of ANSI/ASCE 7-98.

The array support structure shall be fabricated using corrosion resistant GI (40 mm x 40 mm x 5 mm) or anodized aluminum or equivalent metal sections. Minimum thickness of galvanization shall be 80 microns. Array support structure fabricated from alternate material shall have equivalent degree of protection The Contractor shall submit respective certificates from an approved laboratory latest at commissioning.

Array mounting hardware supplied for this installation shall be compatible with the site considerations and environment. Special attention shall be paid to minimize the risk from exposed fasteners, sharp edges, and potential damage to the modules or support structure. Corrosion resistance and durability of the mechanical hardware is emphasized. All materials shall be selected to avoid corrosion and degradation. The use of any wood or plastic components is strongly discouraged.

These are high profile, publicly visible installations, and the aesthetics of the overall installations are extremely important. To create a uniform appearance of the array, spacing between individual modules and panels shall be kept to a minimum, and the overall layout keeping in consistency with the overall architectural features of the buildings and properties. As much as possible, all mechanical hardware, conduit, junction boxes and other equipment shall be concealed beneath and/or behind the array, and all other electrical work performed neatly and as inconspicuously as possible.

The array layout shall be consistent with the electrical ordering (and labeling) of source circuits in the array combiner boxes. Ease of access for array troubleshooting and maintenance is provided by allowing access to the back of the array for module junction box servicing, and removal/replacement of individual source circuits (panels) and modules if necessary.

The support structure shall be free from corrosion when installed; array support structure welded joints and fasteners shall be adequately treated to resist corrosion.

PV modules shall be secured to support structure using screw fasteners and/or metal clamps. Module fasteners/clamps shall be adequately treated to resist corrosion.

The support structure shall withstand wind loading of up to 150 km/h and operating environmental conditions for a period of minimum 25 years.

The junction boxes shall be of IP54 (for outdoor) as per IEC 529.

The mounting structures are fixed in reinforced concrete foundations, designed to withstand all loads including weight, wind, snow, and earthquake. The Contractor shall design the foundations and propose standard mounting structures and shall submit the documents including structural analyses, drawings, plans, etc. to the Employer for approval.

18. RETICULATION SYSTEM

18.1 Codes and Standards

1. American National Standards Institute – ANSI

2. ASTM International - ASTM

- ASTM D92 Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester
- ASTM D445 Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (the Calculation of Dynamic Viscosity)
- ASTM D664 Standard Test Method for Acid Number of Petroleum Products by Potentiometric Titration
- ASTM D877 Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids using Disk Electrodes
- ASTM D923 Standard Practices for Sampling Electrical Insulating Liquids
- ASTM D924 Standard Test Method for Dissipation Factor (or Power Factor) and Relative Permittivity (Dielectric Constant) of Electrical Insulating Liquids
- ASTM D971 Standard Test Method for Interfacial Tension of Oil against Water by the Ring Method
- ASTM D974 Standard Test Method for Acid and Base Number by Color-Indicator Titration
- ASTM D1298 Standard Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
- ASTM D1500 Standard Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)
- ASTM D1524 Standard Test Method for Visual Examination of Used Electrical Insulating Oils of Petroleum Origin in the Field
- ASTM D1533 Standard Test Methods for Water in Insulating Liquids by Coulometric Karl Fischer Titration
- ASTM D1816 Standard Test Method for Dielectric Breakdown Voltage of Insulating Oils of Petroleum Origin Using VDE Electrodes
- ASTM D2029 Standard Test Methods for Water Vapor Content of Electrical Insulating Gases by Measurement of Dew Point
- ASTM D2129 Standard Test Method for Color of Clear Electrical Insulating Liquids (Platinum-Cobalt Scale)
- ASTM D2284 Standard Test Method of Acidity of Sulfur Hexafluoride

- ASTM D2285 Standard Test Method for Interfacial Tension of Electrical Insulating Oils of Petroleum Origin against Water by the Drop-Weight Method
- ASTM D2477 Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Insulating Gases at Commercial Power Frequencies
- ASTM D2685 Standard Test Method for Air and Carbon Tetra fluoride in Sulfur Hexafluoride by Gas Chromatography
- ASTM D2759 Standard Practice for Sampling Gas from a Transformer under Positive Pressure
- ASTM D3284 Standard Test Method for Combustible Gases in the Gas Space of Electrical Apparatus Using Portable Meters
- ASTM D3612 Standard Test Method for Analysis of Gases Dissolved in Electrical Insulating Oil by Gas Chromatography
- ASTM D3613 Standard Practice for Sampling Electrical Insulating Oils for Gas Analysis and Determination of Water Content
- **Other applicable standards**

3. Association of Edison Illuminating Companies - AEIC

4. Canadian Standards Association - CSA

5. Electrical Apparatus Service Association - EASA
ANSI/EASA AR100 Recommended Practice for the Repair of Rotating Electrical Apparatus

6. Institute of Electrical and Electronic Engineers - IEEE

- ANSI/IEEE C2 National Electrical Safety Code
- ANSI/IEEE C37 Compilation Guides and Standards for Circuit Breakers, Switchgear, Relays, Substations, and Fuses
- ANSI/IEEE C57 Compilation Distribution, Power, and Regulating Transformers
- ANSI/IEEE C62 Compilation Surge Protection
- ANSI/IEEE C93.1 Requirements for Power-Line Carrier Coupling Capacitors and Coupling Capacitor Voltage Transformers (CCVT)
- ANSI/IEEE 43 IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery
- ANSI/IEEE 48 IEEE Standard Test Procedures and Requirements for Alternating Current Cable Terminations 2.5 kV through 765 kV
- IEEE 81 IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System Part I: Normal Measurements
- ANSI/IEEE 81.2 IEEE Guide for Measurement of Impedance and Safety Characteristics of Large, Extended or Interconnected Grounding Systems

- ANSI/IEEE 95 IEEE Recommended Practice for Insulation Testing of Large AC Rotating Machinery with High Direct Voltage
- IEEE 100 The Authoritative Dictionary of IEEE Standards Terms
- IEEE 141 IEEE Recommended Practice for Electrical Power Distribution for Industrial Plants (IEEE Red Book)
- ANSI/IEEE 142 IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (IEEE Green Book)
- ANSI/IEEE 241 IEEE Recommended Practice for Electric Power Systems in Commercial Buildings (Gray Book)
- ANSI/IEEE 242 IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (Buff Book)
- ANSI/NETA ATS-2009 IEEE 386 IEEE Standard for Separable Insulated Connectors System for Power Distribution Systems above 600 V
- ANSI/IEEE 399 IEEE Recommended Practice for Power Systems Analysis (Brown Book)
- ANSI/IEEE 400 IEEE Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems
- ANSI/IEEE 400.2 IEEE Guide for Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF)
- ANSI/IEEE 421.3 IEEE Standard for High-Potential-Test Requirements for Excitation Systems for Synchronous Machines
- ANSI/IEEE 446 IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications (Orange Book)
- ANSI/IEEE 450 IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications
- ANSI/IEEE 493 IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems (Gold Book)
- ANSI/IEEE 519 IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems
- ANSI/IEEE 602 IEEE Recommended Practice for Electric Systems in Health Care Facilities (White Book)
- ANSI/IEEE 637 IEEE Guide for the Reclamation of Insulating Oil and Criteria for Its Use IEEE 644 Procedures for Measurement of Power Frequency Electric and Magnetic Fields from AC Power Lines
- ANSI/IEEE 739 IEEE Recommended Practice for Energy Management in Commercial and Industrial Facilities (Bronze Book)
- ANSI/IEEE 902 IEEE Guide for Maintenance, Operation and Safety of Industrial and Commercial Power Systems (Yellow Book)
- IEEE 1015 IEEE Recommended Practice for Applying Low-Voltage Circuit Breakers Used in Industrial and Commercial Power Systems (Blue Book)

- IEEE 1100 IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment (Emerald Book)
- ANSI/NETA ATS-2009 ANSI/IEEE 1106 IEEE Recommended Practice for Maintenance, Testing, and Replacement of Nickel-Cadmium Batteries for Stationary Applications
- ANSI/IEEE 1159 IEEE Recommended Practice on Monitoring Electrical Power Quality
- ANSI/IEEE 1188 IEEE Recommended Practice for Maintenance, Testing, and Replacement of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Applications
- IEEE 1584 IEEE Guide for Arc-Flash Hazard Calculations
- **Other applicable standards**

7. Insulated Cable Engineers Association – ICEA

- ANSI/ICEA S-93-639/NEMA WC 74 5-46 kV Shielded Power Cable for Use in the Transmission and Distribution of Electric Energy
- ANSI/ICEA S-94-649 Standard for Concentric Neutral Cables Rated 5,000 - 46,000 Volts
- ANSI/ICEA S-97-682 Standard for Utility Shielded Power Cables Rated 5,000 - 46,000 Volts
- **Other applicable standards**

8. International Electrical Testing Association –

- NETA ANSI/NETA ETT Standard for Certification of Electrical Testing Technicians
- ANSI/NETA MTS 7.2.1.1 Standard for Electrical Maintenance Testing of Dry-Type Transformers
- ANSI/NETA MTS 7.2.1.2 Standard for Electrical Maintenance Testing of Liquid-Filled Transformers
- NETA MTS Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems
- **Other applicable standards**

9. National Electrical Manufacturers Association - NEMA

- NEMA AB4 Guidelines for Inspection and Preventive Maintenance of Molded-Case Circuit Breakers Used in Commercial and Industrial Applications
- ANSI/NEMA 84.1 Electrical Power Systems and Equipment Voltage Ratings (60 Hz)
- NEMA MG1 Motors and Generators
- **Other applicable standards**

10. National Fire Protection Association - NFPA

- ANSI/NFPA 70 National Electrical Code
- ANSI/NFPA 70B Recommended Practice for Electric Equipment Maintenance
- ANSI/NFPA 70E Standard for Electrical Safety in the Workplace ANSI/NFPA 99 Standard for Healthcare Facilities
- ANSI/NFPA 101 Life Safety Code ANSI/NFPA 110 Emergency and Standby Power Systems
- ANSI/NFPA 780 Installation of Lightning Protection Systems
- **Other applicable standards**

11. Occupational Safety and Health Administration - OSHA

12. State and local codes and ordinances

13. Underwriters Laboratories, Inc. - UL

18.2 Transmission and Distribution System

The transmission line conveys the power from the power house to the villages. It consists of a 20kV conductor line installed on both, concrete poles ranging from 9 to 12 m height and respective sub-stations in each village. The average span is 60 m, maximum span should not exceed 80 m.

The distribution networks (0.4 kV LV network) connect the consumers with the sub-stations via ABC cables fixed on 9 m concrete poles. Average span is 50 m while maximum span shall not exceed 60 m. Clearance shall be provided according to National and International Standards.

Service lines of at minimum $4x4mm^2$ to $4x16mm^2$ based on distance from main service lead from the 0.4 kV distribution network to the consumers premises where house connection boxes including short circuit fuses and RCBOs are installed.

Split pre-paid electronic meter are considered at the consumers premises and in public meter boxes to allow pre-payment and to protect meters against manipulation. The proposed pre-paid metering systems are described in section 19.

All transformer stations (main and all step-down or substations) are equipped with separate earthing systems for MV and LV voltage. In addition, LV earthing is required at each meter box or consumer and at each dead end of feeder and at every 10^{th} pole.

The system lay-out is based on the daily load pattern as compiled drawing and one line diagram. The number and type of consumers per village and transformer capacity per village is compiled in Table 28.

The maximum capacity includes margins for technical losses as calculated is (3-4%) and for future expansion (10%). The technical loses includes energy losses in transformers and cables. The transformers have two types of losses, winding losses which are independent of loads and other is loading losses which depend on loads. Cable losses are due to loading which depends on size of the cable and the flow of current through it. All losses are calculated and reported in details. However, at present, losses will decrease as 200w per family are used instead of 1000w per family.

NEC code and other parameters suggest considering 25% future loads but as per site analysis, population growth of 10% is considered for this project.

The load flow and short circuit analyses (single and three-phase) are considered in calculation, sizing of breakers, MCB and conductor/cable sizes and verification of maximum voltage drops and power losses will be based on calculation and not more than 4% losses.

The mechanical and electrical design of the T&D network is optimized with respect to cost and quality.
Site LV Electrical Distribution- Electrical power is distributed in underground PVC duct banks to meter boxes at various locations on the site.

Voltage drop
The voltage drop is calculated by ETAP software based on IEC standard and IEEE Guidelines. The Maximum voltage drop is not more than 8% in total and the allowance in main service line is 4-5% and 1-3% in branch lines and circuits.

The total transmission routes for LV and MV are 20,578 meter. The following amount of cables is needed for both LV and MV routes:

- The total length of cable required for LV is 19,078meter
- The total length of cables required for MV is 9043 meter

18.3 Power Poles

Concrete power poles are provided for MV and LV distribution, 4 type of pole is considered in design as follow:

P1- is normal concrete power pole, 12m high and used for MV lines, while it is able to carry LV line as well under MV lines. This pole design is stipulated for tension load of 400kg at top

P2- is secure concrete power poles, 12m high and used for MV line, while it can carry LV lines as well. P2 poles are stronger than P1 and used in places where it faces higher strain or potential external harm, such as near corners or near roads etc. This pole is design for tension load of 800kg at the top.

P3 - is normal concrete pole used for LV lines, it can carry one to two or more LV circuits and used only for LV lines. This pole is designed for tension load of 300kg at the top

P4 - is 15m concrete pole used for crossing over fuel tank station or main roads, to ensure adequate clearance. This pole is design for tension load of 1100kg at the top.

Pole calculation and analysis is provided to check if the applied loads are in line with this project. The supported structure such as pole top cable structure, distribution panel structure, transformer structure and fuse and surge arrester structure are analyzed and calculated to check if it can withstand the applied loads. Due to the calculation, changes have been made and the final design and drawing are corrected and submitted.

The foundation of poles is based on soil condition (soil bearing pressure of 0.75kg/cm2) and change in direction at different angles. The foundation is simple stone and earth backfill at straight line, with no concrete foundation (only stone and soil can be used). At 0-6 degrees, concrete foundation is required and at 6-30 degrees, type 2 foundations is required, while at 30-90 degrees, guy wire will be used.

Where there is no place to install a guy wire, a tension pole is considered to be used instead, a tension pole for P2 with total allowable loads of 800kg at top and concrete foundation, calculation have been performed to check if the P2 can work, calculation show that tension is less than 800kg and P2 is good in such cases and used at site.

18.4 Reticulation and Household Connection System

The power supplied to the households is fixed at around 195 Watt, which would imply that, the wiring from the households to the meters and from the meters to the transformer and to the power plant would have to be sized accordingly. However, in designing the reticulation system, we deferred to the general national standard for rural electrification, which assumes between 1-2.5 kW per household, with diversity factor of 80% at the transformer level. Thus, the wiring is sized somewhat larger than at 200 Watt per household. The additional cost is justified as follows:

1) The lifespan of the PV plant is 25 years, while the life span of the reticulation system is significantly more at close to 50-years. During this time frame, the villages are expected to receive grid connection, given the fact that they are located around 40 km from the provincial capital of Kandahar and about 10 km from the existing 20 kV grid system. Additionally, the South East Power System (SEPS) is expected to pass through the district center of Panjwayee, which will enable Grid connection of the system. Hence, it makes sense to size the system with a clear understanding of the future grid connection.

2) The commercial, institutional and residential customers are typically on the same overhead wiring system. Whereas the residential loads are limited to 200 Watt, commercial and institutional loads are not limited. If the designed wiring size were to be set for 200 Watt residential customers, commercial and institutional customers would need to be connected through alternative wiring system, which would double the overhead wiring costs.
3) There is always a likelihood that one neighbor will settle for a 200 Watt connection, while another neighbor, connected to the same meter will want to receive a 1 kW connection. If the power produced in the plant allows for such connectivity and the customer is willing to pay for power, the mini-grid would set the metering for the desired output. This would require that the sizing of the system is able to transmit the minimum of 1 kW power.

In view of these circumstances, the complete reticulation system design was based on 1 kW residential load.

The surveyed load demand is in excess of 1 kW per household. Due to supply limitations, the actual connected power for the interim period will be at 200 Watts for low income households and more than 200 Watts for affluent households, should sufficient power be available. Additionally, the system is within 3.5 km of the grid system, which in the reasonably foreseeable future will also be able to connect to the PV utility system. This implies that in foreseeable future, the supply of power will be significantly in excess of 200 Watts. This requires that the transmission and household connection system should be sufficiently sized to meet this future demand and supply. This also translates to the World Bank's Multi-Tier Framework tiers 3 and 4, possibly 5, which should be a long-term objective of the design. As such the household connections have been sized for 1 kW, which is in line with normal practice in Afghanistan.

Power connection to house and businesses are through step down transformers, LV distribution and meter boxes. Total of 10 transformers are considered based on location and concentration of house and shops and other connection to masque, etc. For each transformer surge arrester and fuse cut off is provided to increase protection for the system. The transformer is distributed based on the table and as indicated in the site plan.

No	Name of Village	Estimated No of House Holds	Institutional loads	commercial loads	Substation & transformers	Size of substation	Meter box	
			No	No	No	KVA	MB9	MB6
1	Haji Malem Kalia	69	20	80	1	315	27	2
	Haji Mamor Kalai	71						

2	Haji Khalifa Kalai	36	25	90	2	400	35	0
	Haji Sardar Street	100						
	Haji Shir Gull Kalai	57						
3	Pump street	206	5	6	3	400	56	2
	Doctor Sayed Agha St	181						
	Toryalai Agha street	117						
4	Molla Obaidullah St	97	5	50	4	500	43	9
	Jami De Sha Street	93						
	Janan Oil street	64						
	Aslam Jan Agha street	129						
5	Omer Street	0	15	40	5	400	31	0
	Amara kalai	33						
	Usmani street	121						
	Hamam Street	69						
6	Loya Nachara and mian bazar	154	10	75	6	160	26	1
7	Wara Nachara/loya nachara	43	2	40	7	160	9	2
8	Torgi Kalai	14	2	20	8	160	0	20
	Haji Lalo Kalai	61						
9	Haji Rostam Kalai	46	1	10	9	200	7	8
	Haji Rahmatullah Kalai	10						
	Charkhab Kalai							
10	Charkhab Kalai	89	1	5	10	315	33	4
	Akbar Kalai	137						
	Destagiri Kalai	84						
	Total	**2081**	**86**	**416**			267	48
	Grand total	**2583**					**2691**	

Table 28: Transformer and Substations

The transformers are located at proper location to provided branches to all routes and roads, The LV circuits from each transformer is distributed on all routes and the maximum distance is 800m and minimum is 250m, based on the load and distance double line are also considered. Voltage drop is calculated in MV line and also in LV lines.

18.5 LV Distribution

LV distribution is from Transformer to meter boxes, the longest LV line is around 400-800m and shortest is about 100m. In most of LV overhead lines, two line are considered to minimize the voltage drop and ensure cost affective distributions. The LV distribution is on concrete pole with 9m height in total height of 7.5m from the ground. The LV lines are connected to meter boxes located at poles and also at pad far from pole. Most of the meter boxes are located at poles but some are located far from poles based on location of houses. Some meter boxes are located 80m, 120m, 150m and 200m far from pole connected with underground Copper 4-core cable in PVC conduits.

ABC aluminum cables size of 25, 35, 50, 70, 95, 120 and 150mm2 are used in LV distribution. Each LV circuits is control by LV breaker at MDB located under each transformer. The MDB controls each circuit separately and can be used during maintenance.

The distribution is mostly in level surface area with maximum ground slope up to 2%, there is no big slope in distribution site to affect the distribution system for MV and LV lines.

Crossing over road: Crossing over road is critical issue for MV line and also for LV lines, in most cases there are loads required at both side of roads and these loads cannot be feed from one side of road since crossing road for many LV lines are not possible therefore in some places where required, a separate circuits branches from circuits are provided on the other side of the road

18.6 Overhead Line Clearance

Clearance shall be provided according to the National or International Standard. There is no such national standard available and the national utility company accepted to use the 12m pole for MV lines with 1.8m embedded in ground and 9m LV pole with 1.5m embedded in ground. With these poles' heights, the required clearance for both MV and LV as per NESC or other international code are good and is easily obtainable at the site. The clearing are based on the National Electrical Safety Codes on Overhead Line Clearances and they are shown in the table below which is a good clearance at the site.

Using 12m pole for MV lines, which is 10m above the ground, is an acceptable height and has enough clearance for all type of features exist on the ground. Also using 9m pole for LV lines is an acceptable height for all existing features on the ground. Also the distribution area is platen and level with 1-2% slope which will not affect the overhead lines going through a slope.

Clearance for MV lines

Minimum Vertical clearance	Required per Code	Available at Project Site
Ground accessible to pedestrians only	6.5m	9m
open country site	6m	10m
Roads and streets	7m	10m
Fence line	5m	7m
Walls	4m	6m
Building , accessible points , flat roofs upon Power line may stand		
power line above trees	2.5m	3m
Power line above steel structure	3m	NA
Power line above telecommunication lines	2.5m	NA

Horizontal distance from building	2.3m	5M
Exist light or pole	2.3m	NA
Normal span	60m	
Maximum span	90m	
Minimum depth of pole foundation	1.5m	
Minimum horizontal phase to phase separation	0.4m	

LV Lines

open country site	4m	7.5M
Roads and streets	4.3m	7.5M
Fence line	4.3m	5M
Walls	3m	4M
Allowance for Creep		
ABC cable	600mm	
ACSR	600MM	

All the existing features under the overhead line are met as per the above clearance table. All vertical and horizontal clearance are met at the site as per above table.

18.7 Meter Boxes

The Meter Boxes (MBs) are for use in the low voltage distribution system to achieve simple and cost-effective means of providing single phase and three phase connections to the customers. Meter boxes will be installed at poles from the secondary network to provide service connections to small groups of houses in their vicinity.

18.7.1 Types of Meter Boxes

Two type of meter box are designed for this project. MB9 type is used to house 9 meters for 9 households, while MB6 type is used to house 6 meters for 6 households. Each meter box has main breaker and switch and sub breaker for each meter. The main breaker can off and on based on the routine power connection to house and businesses. RCBO breakers are used for each house connection to protect the system from short circuits and human touch.

18.8 Distribution Construction Materials

The following materials and structure are used in MV and LV distributions. Drawing for each structure in detail is provided. All the items are detailed in MV and LV distribution standards. Appendix –A

MV UNDERGROUD CABLES / ACCESSORIES

C1 MV UNDERGROUND CABLE 12/20kV, N2XS2Y, single core, copper, XLPE
T1 OUTDOOR TERMINATION KIT 20kV, XLPE insulation
T2 INDOOR TERMINATION KIT 20kV, XLPE insulation

J1 STRAIGHT JOINT KIT 20kV, XLPE insulation
C2 SHRINK CAP, XLPE insulation
J3 BRANCH JOINT KIT 20kV, XLPE insulation according to Chapter C

MV COVERED CONDUCTORS & ACCESSORIES

E1 MV COVERED CONDUCTORS
E2 ARC PROTECTION DEVICE
E3 INSULATION PIERCING CONNECTOR
E4 HELICAL (PREFORMED) TIES

LV UNDERGROUD CABLES / ACCESSORIES

C3 LV UNDERGROUND CABLE 0.6kV/1kV, NYCWY, concentric copper conductor
C4 LV UNDERGROUND CABLE 0.6kV1kV, NYY-J, three core
T3 OUTDOOR TERMINATION KIT 0.6/1kV
J2 UNDERGROUND STRAIGHT JOINT- KIT 0.6/1kV
C5 END CAP 0.6/1kV, according to Chapter D (Technical Specification)

OVERHEAD MV CONDUCTOR / ACCESSORIES

C6 ALUMINIUM CONDUCTOR STEEL REINFORCED (ACSR)
S1 COMPRESSION SPLIES, full tension for ACSR
S2 REPAIR SLEEVE, for ACSR conductors
C7 COMPRESION TAP CONNECTOR, Type H
S3 COMPRESSION STIRRUP CONNECTOR for ACSR
C8 HOT LINE CLAMP, for installation on compression stirrups

ABC LV CABLES & ACCESSORIES

C9 ABC CABLES (QUADRUPLEX) 0.6/1V, aluminum conductor
S4 SPIRAL (PIG TAIL) HOOK
N1 NUT HOOK
N2 NUT HOOK (EXTERNAL ANGLE)
C10 DEAD END CLAMP, for non-insulated neutral AAAC with cutting
C11 DEAD END CLAMP, for non-insulated neutral AAAC without cutting
C12 SUSPENSION CLAMP (UP TO 30º)
Y1 YOKE UNIVERSAL
S5 PRE-INSULATED SLEEVES
S6 COMPRESSION SLEEVES (FULL TENSION)
C13 INSULATION PIERCING CONECTOR
C14 SEALING CAP 0.6/1kV

INSULATORS & ACCESSORIES

I1 SUSPENSION INSULATOR, porcelain, ball& socket according to Chapter Q

I2 PIN TYPE INSULATOR, porcelain according to Chapter Q (Tech. Spec.)
C15 WEDGE TYPE TENSION CLAMP
C16 WEDGE TYPE TENSION CLAMP, for ACSR conductor with current loop
B4 BALL CLEVIS
N3 EYE NUT
E1 SOCKET EYE STRAIGHT
P1 POLE TOP PIN
P2 SHORT SHANK PIN
P3 OFFSET POLE TOP PIN
P4 DOUBLE ARMING PLATE

MISCELLANEOUS
A1 SURGE ARRESTER
B1 DOUBLE ARMING BOLT
B2 MACHINE BOLT
B5 BUCKLE FOR STRAPS
C17 COPPER CONDUCTOR
C18 NOT IN USE
C19 GROUND STUD CONNECTOR (SPILT BOLT)
G1 GROUND WIRE MOULDING GUARD
R1 GROUND ROD
S7 STRAP
S8 STRAPS
S9 FACADE SADLES
W1 ROUND WASHER
W2 SQUARE WASHER
W3 SPRING LOCK WASHER

GUY
A2 CONE ANCHOR, concrete
G2 GUY HOOD, ductile iron, hot dip galvanized
G3 GUY END, galvanized steel
G4 TAPERED GUY (GUARD)
N4 THIMBLEYENUT, galvanized steel
R3 THIMBLEYE ANCHOR ROD, galvanized steel
R4 TWINEYE ANCHOR ROD, galvanized steel
S12 SPLIT BOLT, copper to galvanized
W4 GUY WIRE

ASSEMBLIES

AS-01	SINGLE CROSS ARM STEEL (2000 mm)

AS-02	SINGLE CROSS ARM STEEL (3200 mm)
AS-03	DOUBLE CROSS ARM STEEL (2000 mm)
AS-04	DOUBLE CROSS ARM STEEL (3200 mm)
AS-05	SINGLE SUPPORT ON CROSS ARM (TANGENT)
AS-06	DOUBLE SUPPORT ON CROSS ARM (ANGLE)
AS-07	SINGLE SUPPORT ON TOP POLE
AS-08	DOUBLE SUPPORT ON TOP POLE
AS-09	DEAD END ON CROSS ARM
AS-10	DEAD END ON POLE
AS-11	LV-SINGLE SUPPORT
AS-12	LV-SINGLE DEADEND
AS-13	LV-SINGLE DEADEND (existing spiral hook)
AS-14	LV-DOUBLE SUPPORT (angle up to 60º)
AS-15	LV-SINGLE SUPPORT (external angle)

MV STRUCTURES

MV-301C	STRUCTURE M1, ALIGNMENT
MV-302C	STRUCTURE M2, ALIGNMENT, SMALL ANGLE
MV-303C	STRUCTURE M3, TENSION, LARGE ANGLE
MV-304C	STRUCTURE M4, TENSION, BRANCH
MV-305C	STRUCTURE M5, TENSION, DEADEND
MV-306C	STRUCTURE M6, TENSION, SHACKLE
MV-601C	STRUCTURE MM1, ALIGNMENT, DOUBLE CIRCUIT
MV-602C	STRUCTURE MM2, ALIGNMENT, SMALL ANGLE, DOUBLE CIRCUIT
MV-603C	STRUCTURE MM3, TENSION, LARGE ANGLE, DOUBLE CIRCUIT
MV-604C	STRUCTURE MM4, TENSION, BRANCH, DOUBLE CIRCUIT
MV-605C	STRUCTURE MM5, TENSION, DEADEND, DOUBLE CIRCUIT
MV-606C	STRUCTURE MM6, TENSION, SHACKLE, DOUBLE CIRCUIT
TR-01	POLE MOUNTED TRANSFORMER

LV STRUCTURES

LV-101 STRUCTURE L1, ALIGNMENT (angle 0º to 30º)

LV-102 STRUCTURE L2, TENSION, SHACKLE

LV-103 STRUCTURE L3, TENSION, BRANCH

LV-104 STRUCTURE L4, TENSION, SHACKLE & BRANCH

LV-105 STRUCTURE L5, ALIGNMENT, LARGE ANGLE (angle 30º to 60º)

LV-106 STRUCTURE L6, TENSION, RIGHT ANGLE (angle 60º to 90º)

LV-107 STRUCTURE L7, TENSION, DEAD END

TRENCHES

T-001	TRENCHES FOR DIRECT BURIAL CABLES – Low Voltage
T-002	TRENCHES FOR DIRECT BURIAL CABLES – Medium Voltage
T-003	TRENCHES FOR DIRECT BURIAL CABLES – Low & Medium Voltage
T-004	STREET CROSSING IN CONCRETE ENCASED DUCT
T-004.1	STREET CROSSING IN CONCRETE ENCASED DUCT
T-005	STREET CROSSING IN CONDUIT Special case
T-006	STREET CROSSING & SECTIONS

SWITCHING EQUIPMENT

PR-01	RECLOSER WITH BYPASS SWITCH
PR-02	RECLOSER WITHOUT BYPASS SWITCH
PR-03	LOAD BREAK SWITCH
PR-04	SINGLE SUPPORT ON CROSS ARM DISCONNECTING SWITCH
CT-1	MV CABLE TERMINATION TO OVERHEAD LINE FROM TRANSFORMER
CT-2	MV CABLE TERMINATION TO OVERHEAD LINE FROM GRID/ JUNCTION

MISCELLANEOUS

M-001 CONDUIT INSTALLATION

M-002 PAD-MOUNTED FEEDER PILLER & METER BOX

CX-01 CONCRETE TRENCH

CABLES AND CONDUCTORS

C-001 TABLE OF CABLE AND CONDUCTORS ASSIGNATION

C-002 OVERHEAD LINE DESIGN CRITERIA

C-003 WEATHER CASE

C-004 SAG TENSION CALCULATIONS – EXAMPLE

19. LOAD GROWTH SCENARIO

The mini-grid proposed and discussed here will be a definite positive and huge step in the direction of providing the people with reliable and cleaner electricity. The impacts that it will have in the lives of the generations to come will be tremendous. Even though, this mini-grid will be a huge leap in the right direction, this is not the all end of the electricity infrastructure.

As it was discovered during the course of this study, and discussed in this report, the energy produced by a 1MW Solar PV system is not enough to support all the demands and needs of the people of these villages. This is a very good starting point by setting up the infrastructure and reaching the end customer. But, this system provides about 30% of the total energy requirements. As people get more dependent on the reliable electricity they will explore other options of businesses and livelihoods and this will definitely increase the demand for more electricity.

There are multiple ways to expand the reach and impact of this mini-grid. Some of them are discussed below:

- Once the transmission and distribution infrastructure is established, more solar PV and battery energy storage system (BESS) can either be added at the same location or at a different location and tied into the existing infrastructure.
- As the loads and demands at village level increase, smaller decentralized PV+BESS systems can be added at village level and tied into the infrastructure.
- After a stable operation of the mini-grid is established and proven, it can be proposed to tie into the Utility grid. This will allow more and more such mini-grids to be established with a future prospect of interconnecting into the Utility grid. This will reduce the impact of new loads on the Utility grid and will add clean and renewable energy produced purely using solar resources.
- On the commercial front, the proposed 1MW mini-grid cannot support loads like the irrigation pumps, lathe machines, flour mills, machine shops and a number of other users that are rated 7.5 kW and more. Either completely off-grid irrigation pumps or decentralized solar systems can be setup in order to support clusters of irrigation pumps. For other users, there are no other options but to either add new capacity to the system or to wait for the grid connection to be available.
- On the residential front, with the availability of electricity people will be able to use equipment like space heaters, water heaters, iron, etc. to help increase the quality and comfort of their households.

During the system design, we have assumed a relatively higher diversity factor, which slightly increases the designed system size. The system is not expected to provide excess energy and as such the system is not expected to feed the grid but the grid, when in place, will be expected to supplement the power demand within the communities. The system, as designed, will cater to a reduced power supplied to residential customers of 195 Watts per household as compared to a demanded 1.1 kW per household. The power provided to commercial customers have also been limited from demanded 989kW to 173kW. Additionally, access to residential customers has been limited to 5 pm to 9 am and to commercial customers from 9 am to 5 pm. Thus, the utility has additional 816kW of commercial clients as Anchor customers and additional demand by the residential customers, coupled with the potential overlap of power provided to residential, commercial and institutional customers. This by itself will require a system size more than twice the existing system size.

In addition to existing unmet demand that can be part of the demand growth potential over the coming years, we will also face a generic demand growth, which is based on population growth, refugee resettlement from Pakistan and other related factors. Since growth in power because of the beneficiaries' preference cannot be effectively quantified, we have opted to use the population growth as one indicator for the demand growth. According to the World Bank's population growth data, Afghanistan's population growth rate is 2.7%, with varying averages since the 1960s. Because of the future evolution of Afghanistan's demographic and recent years' tendencies for reducing population growth, we have selected 2.5% as our estimated population growth rate.

Additionally, we have assumed a demand growth of 5% on an annualized basis, which is primarily due to resettlement into the area, start of new businesses and an inherent need to require more energy as the economic condition of the population improves. There is no scientific or experiential value that the designers can use to estimate this growth as such growth is dependent on factors that are specific to the location. There is no data available for the targeted communities and as such the future demand can at best be estimated. At this level, the load growth of 7.5% per annum will be as shown in Table 30.

Year	Population	Energy Consumption (kWh/yr)	Energy per capita (kWh/yr)	Growth y/y	Increase in Energy Consumption (kWh)	Estimated amount of Solar PV needed to meet the growth (kW)		
0	25,000	1,456,089	58.24					
1	25,625	1,492,491		2.5%	36,402	19.95		
2	26,266	1,529,804		2.5%	37,312	20.45		
3	26,922	1,568,049		2.5%	38,245	20.96		
4	27,595	1,607,250		2.5%	39,201	21.48		
5	28,285	1,647,431		2.5%	40,181	22.02	104.84	kW of PV
6	28,992	1,688,617		2.5%	41,186	22.57		
7	29,717	1,730,832		2.5%	42,215	23.13		
8	30,460	1,774,103		2.5%	43,271	23.71		
9	31,222	1,818,456		2.5%	44,353	24.30		
10	32,002	1,863,917		2.5%	45,461	24.91	118.62	kW of PV
11	32,802	1,910,515		2.5%	46,598	25.53		
12	33,622	1,958,278		2.5%	47,763	26.17		
13	34,463	2,007,235		2.5%	48,957	26.83		
14	35,324	2,057,416		2.5%	50,181	27.50		
15	36,207	2,108,851		2.5%	51,435	28.18	134.21	kW of PV
16	37,113	2,161,572		2.5%	52,721	28.89		
17	38,040	2,215,612		2.5%	54,039	29.61		
18	38,991	2,271,002		2.5%	55,390	30.35		
19	39,966	2,327,777		2.5%	56,775	31.11		
20	40,965	2,385,971		2.5%	58,194	31.89	151.85	kW of PV
21	41,990	2,445,621		2.5%	59,649	32.68		
22	43,039	2,506,761		2.5%	61,141	33.50		
23	44,115	2,569,430		2.5%	62,669	34.34		
24	45,218	2,633,666		2.5%	64,236	35.20		
25	46,349	2,699,508		2.5%	65,842	36.08	171.80	kW of PV

Table 30: Load profile growth over 25 years

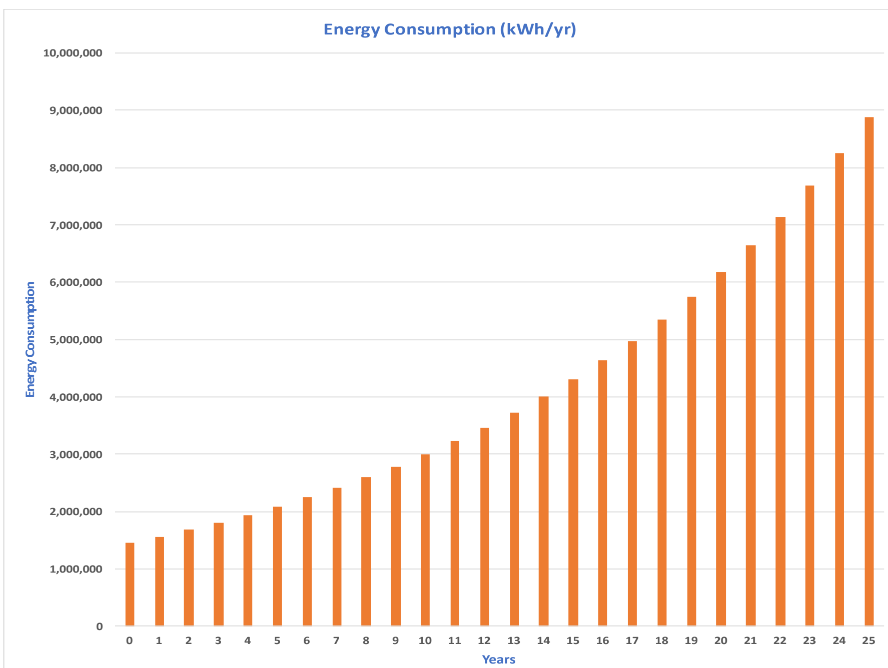


Figure 35: Load profile growth over 25 years

This indicates that after the first five years, 348 kW-DC of extra generation will be needed to meet the demand. In the subsequent five years, additional 499 kW-dc, 716kW-dc, 1,028kW-dc and 1.476kW-dc respectively will need to be added to the system to ensure that additional demand is met.

20. TARIFF COLLECTION & PAY AS YOU GO SOLUTION

20.1 Tariff Calculation

For the proposed mini-grid configuration, based on the preliminary design, the PV-system costs, reticulation system cost as well as maintenance and operation costs, component replacement costs and other associated cost factors have been taken into consideration. A basic method for calculating the tariff of a solar power project is to use a basic Levelized Cost of Energy (LCoE) approach. A simplified LCoE calculation can be made using the following formula:

$$\mathrm{LCoE} = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

Where,

t: The year of calculation, which varies for every one of the 25 years

n: The whole lifetime of the system, which is 25 years

r: Discount rate of 10%

It: Investment expenditures (CAPEX) in the year t=1,

Mt: Operational and maintenance expenditures in the year t=1 plus (under worst case scenario) additional annual set-aside is considered to cover the cost of replacement of BESS and inverters every ten years. The personnel estimated for a properly functioning system is estimated to be structured as per table below.

Ft: Fuel expenditures, has been included in the O&M cost calculation (Mt). So, Ft=0.

Et: Electricity yield in the year t=1, which translates to 1,456,089 kWh.

20.2 O&M Personnel Requirement

Description	QTY	Months	Unit Cost	Annual Pay
Personnel:				
Project Manager & Site Engineer	1	12	$700	$8,400
Admin/Finance Officer	1	12	$450	$5,400
Technicians	3	12	350	$12,600
Service Personnel	4	12	200	$9,600

Table 31: Operation and Maintenance Personnel Requirements

When considering a one-time investment in year one with no further consideration for opportunity cost in the following years, the expected tariff is calculated at US$ 0.53 (equivalent of AFA 37.20) per kWh.

However, a tariff rate of US$ 0.53 (AFA 37.20) per kWh is unreasonable and will, based on the surveyed household payment capability, provide only around 12.10 kWh of power per household per month, which is not sufficient to entice population to pay for power.

The client is willing to possibly subsidize most or all of the CAPEX related to the mini-grid. At a CAPEX of US$0, the LCoE is calculated to be US$0.14 per kWh or equivalent of AFA 9.83 per kWh.

The project owner is, furthermore, evaluating the possibility of subsidizing the cost of replacement of the BESS and the inverter system every ten-years (worst-case scenario), which allows the tariff to further reduce to US$ 0.07 (AFA 5.17) per kWh.

Additionally, it is normal to have a tiered tariff system, charging residential customers a fixed rate and marking up the power to institutional and commercial customers. The utility would be well-advised to initiate such a tiered tariff system.

20.3 General Framework of Pay as You Go (PAYG) Requirement

The typical O&M constraint in rural electrification systems is focused on collection of tariffs and with it, recovering of the investment and financing the operation and maintenance costs of the system.

Figure 36: Micro Grid Major Challenges

On the qualitative side, where reliability of the grid becomes a significant consideration, load control, consumer indexing and meter faults are critical.

Load control can make the difference between system overloads and system reliability. The system stipulates that every residential customer will receive about 200 Watts of power up to a total energy consumption of around 1kWh from 5 pm to 9 am. Commercial customers receive power as per their need from 9 am to 5 pm, while institutional customers receive 24 hours of power as needed. The metering system must be able to regulate these variabilities and ensure that the demand side behavior can be effectively controlled and managed, thus minimizing risk of system overload.

Customer indexing help to develop a good understanding of the number of customers is always known, and transformer load analysis can be effectively done before giving new connections, power leakages on the grid is detected in a timely manner and is effectively addressed. Furthermore, customer indexing ensures that consumer mapping data is accurate and that wrong feeder/transformer is not mapped to the wrong meter. Smart meters, provide integrated, low cost solutions to intelligently manage and organize power distribution throughout a mini-grid.

Meter faults can be avoided by installing reliable digital meters that eliminate incorrect usage/billing, avoids incorrect low line voltage operation and protects against general unreliability of the meter as a whole.

On the quantitative side, where revenue is lost due to incorrect billing, theft of power, inaccurate meter reading and other losses, the reliability and effective use of a sound metering system will avoid lost revenue and ensure a sustainable mini-grid.

Smart meters enable prepaid and postpaid payments for electricity consumption. Wireless, real time, prepaid payment system using cell phones allows consumers to make payments at their doorsteps or in the neighborhood store and monitor their energy consumption. Complete billing system is online and can be changed at any time without replacing meter.

Smart meters enable use of variable pricing, so that the price of power on the meter can be changed depending on demand, time of day, type of customers or even source of generation.

Smart meters also help to minimize theft and facilitate fault detection through the intelligent wireless network formed by the meters, which informs the grid operator of the location of power theft, faults or overload on the distribution lines.

Smart meters automatically shut off when any consumer crosses their load limit. Domestic, agricultural, and commercial consumers can be provided meters with different limits. Online remote monitoring technology allows real time control and monitoring of every meter on the grid.

All meters communicate over RF mesh networks. The wireless network is controlled by a Data Concentrator. The Data Concentrator is intelligently managed by the associated provider operated cloud servers.

The Smart Metering System as recommended in this document includes the Pay-As You-Go (PAYG) system, handheld point of sale systems, etc. Discussions with wireless phone companies will be initiated by the Contractor to ensure that adequate Internet connectivity and networks are provided to facilitate the operation of the system.

20.4 Codes and Standards:

Meters must comply with applicable international standards, including:

- IEC 62052-11 standard in combination with IEC 62053-11, 62053-21, 62053-22 and 62053-23 as well as to the European (MID harmonized) standards EN50470-1, EN50470-2 and EN50470-3 and other relevant standards.
- The compliance to these standards must have been done by independent laboratories that have been accredited to ISO 17020/17025. The relevant tests include: mechanical requirements, insulation properties, accuracy requirements, influence quantities, electrical requirements, electromagnetic compatibility, and the effect of climatic environments.
- Other standards may also apply.

Prepayment System must comply with STS standards. The Standard Transfer Specification ("STS") has become recognized as the only globally accepted open standard for prepayment systems. It is a secure message system ensuring the appropriate encryption key management for protecting the security of prepayment transactions of utilities. STS is centered on the information transferred between a point-of-sale and a pre-payment meter - this includes the manner in which the vending station encodes the token with the information, and the way in which the meter interprets the information. STS provides the facility of generating (e.g. credit transfer) tokens which can only be used by the intended meter, and furthermore in the case of credit tokens, can only be used once in that meter.

The servers and related IT infrastructure must be equipped with accreditations such as VeriSign or equivalent that provide necessary security measures such as firewalls and other VeriSign security measures to prevent unauthorized network access from outside the MDM environment. A changing entrance key prevents automatic "key" generation machines to break into the system.

20.5 Pre-Paid Meter

Split-type compact DIN-Rail mounted Class 1 accuracy single phase electricity meter built in 35mm (or equivalent) international standard housing made of poly-carbonate flame retardant material. The meter adopts Power Line Carrier (PLC) communication between the meter and keypad. Double circuit measurement and relay are also available on request for reinforced tamper prevention.

Refer to technical specifications for detailed specs for metering system.

20.6 Hand-Held Point of Sale Device

The hand-held portable, standalone POS device shall be designed for use over cellular communication networks for the selling of credit for prepayment meters. The device provides on-line vending via the utility's MDMS. PCPOS5000S enables a utility to set up flexible vending points that are fully mobile, cost-effective and automatic communications with the central Utility Vending Database. The unit shall comprise of an external power supply, internal
Rechargeable battery, integrated modem, thermal printer for printing the STS token number, swipe card reader, and is designed for stationary use.
FEATURES

- 128*64 LCD Display, 24 keys, menu operation interface, easy operation
- Platen removal mechanism, easy loading paper and maintenance
- Prints SMS message
- Standalone device, no need to connect to PC
- Keeps 50 SMSs in memory
- Sends SMS if required
- Generates calls (hands free)
- Paper: Thermal paper roll, 58mm /2inch wide
- Effective printing area: 48mm
- Character: 12*24 dots
- Number of columns: 32 columns/line
- Printing Head Life: Paper traveling distance 50KM

Refer to technical specifications for detailed specs for hand held point sale device system.

21. OPERATION AND MAINTENANCE PLAN

A utility scale PV system is always faced with different types of maintenance and operation issues. Some key products and system related O&M issues are as follows:

21.1 Critical O&M Issues for PV Power Plant

The contractor will be required to develop a detailed maintenance and operational schedule, which will be approved by the Engineer. The schedule will be based on the actual make and model of panels, inverters and other associated components. The manufacturer recommended O&M schedule will be incorporated into their plan and then approved by the Engineer. The Engineer will also develop a detailed O&M contract, which will be signed with the contractor shortly before the testing and commissioning of the system, and will address all critical issues related to the O&M activities.

The following sub-sections will describe some critical O&M related issues that the contractor will need to address in their O&M plan:

21.1.1 Panel cracking

Different components of PV solar plant may fail during the operation. First, panels might crack, even in the new once, if they have been damaged in the manufacturing process. The micro-cracks are not always obvious, and that's why the new panels must be inspected and a warranty must be secured. The cracks may lead to the failure of panels or losses of optimal efficiency.

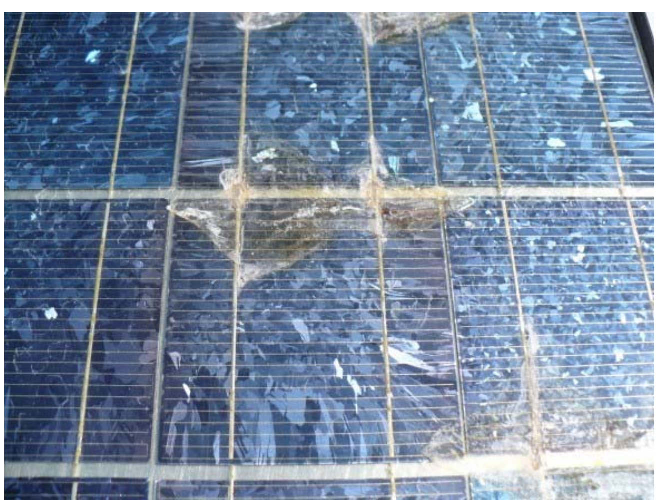


Figure 37: Panel failure due to cracking

21.1.2 Visual discoloration

Visual discoloration is another common defect that reduces the amount of sunlight that penetrates into a solar cell. As a result, solar cells are less exposed to solar irradiation, and generate less energy. The reason it leads to loss of efficiency is because different color panels changes the wavelength of light that can be absorbed. As in the case with panel cracking, not much can be done once the panel became discolored, hence the solar panels must be carefully operated and maintained.

21.1.3 Hotspots

Contrary to the common misleading opinion, solar panels are most efficient when they gain maximum solar irradiance, not maximum temperature. Quite the contrary, high temperatures can actually damage solar panels, leading to the emergence of the hot spots. Hot spots occur when a panel is shaded, damaged, or electrically mismatched and decrease power output. Since solar cells are attached in strings, just one hot spot can lead to multiple cells functioning poorly. To solve this problem, all shading should be negated, and electrical connections should be optimized.

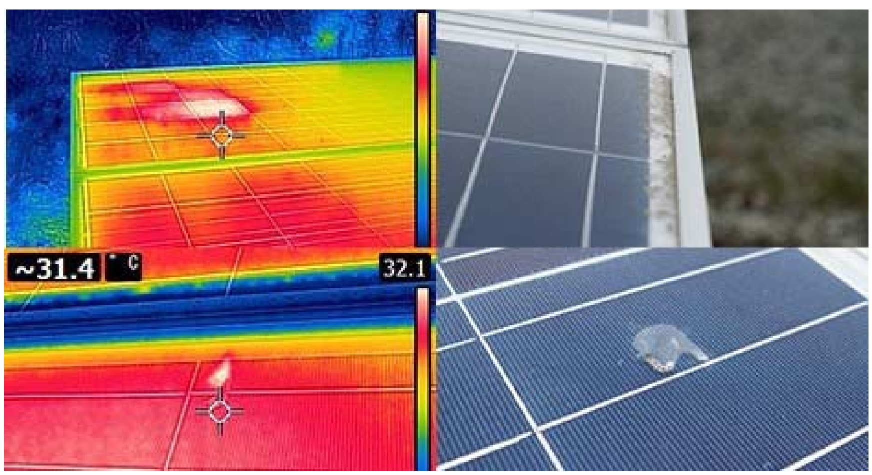


Figure 38: PV Hotpots

21.1.4 Inverters failure

Generally, inverter faults are the most common cause of system downtime in PV power plants. Therefore, the scheduled maintenance of inverters should be treated as a centrally important part of the O&M strategy.

21.1.5 Trackers and Panel Orientation

Panel orientation is an issue for static PV solar systems. It requires due diligence on the consumer's part to make sure the installer is taking the proper steps necessary to determine an ideal panel orientation. Similarly, tracking systems also require maintenance checks. These checks will be outlined in the manufacturer's documentation and defined within the warranty conditions. In general, the checks will include inspection for wear and tear on the moving parts, servicing of the motors or actuators, checks on the integrity of the control and power cables, servicing of the gearboxes and ensuring that the levels of lubricating fluids are appropriate. The alignment and positioning of the tracking system should also be checked to ensure that it is functioning optimally. Sensors and controllers should be checked periodically for calibration and alignment.

21.1.6 Structural Integrity

The module mounting assembly, cable conduits and any other structures built for the solar PV power plant should be checked periodically for mechanical integrity and signs of corrosion. This will include an inspection of support structure foundations for evidence of erosion from water run-off.

21.1.7 Weather Conditions (snow, wind, soiling)

Finally, depending on the environmental conditions, the panels must be protected from wind, snow, and soiling (in dusty areas). Regular cleaning and maintenance will be enough in these cases. Solar DAO uses durable crystalline silicon panels that are built of lead-free, optically transparent, anti-reflective glass, which can withstand the tested shot of an ice ball with 35mm diameter at a speed of 30 m/s. Their serviceable life is up to 25 years, with 10 years of guaranteed performance.

Figure 39: Effects of weather condition

21.1.8 Other Issues

Other common unscheduled maintenance requirements include but are not limited to:

- Tightening cable connections that have loosened.
- Replacing blown fuses.
- Repairing lightning damage.
- Repairing equipment damaged by intruders or during module cleaning.
- Rectifying SCADA faults.
- Repairing mounting structure faults.
- Rectifying tracking system faults.

21.2 Maintenance Checklist for Electrical Distribution Systems:

21.2.1 Intrusive LV Switchboards

❒ Check function of all power meters before shutdown.
❒ Check function of lamps and indicators.
❒ Inspect locking devices for signs damage or worn.
❒ Clean thoroughly, vacuum and full visual inspection of exterior and interior of all LV switchboards.
❒ Inspect control wiring, relays, power supply units, timers, etc. where applicable.
❒ Check electronic surge protection is intact where installed.
❒ Verify control circuit fuse rating and continuity.
❒ Check and torque test bolted electrical connections as necessary to specified levels.
❒ ACB maintenance withdrawable or fixed, check contacts, arc chutes secondary injection, etc.
❒ Visual inspection for signs of overheating or deterioration.
❒ Final visual inspection to insure all clear after work completed.
❒ Inspection of all panels for paint work damage and signs of corrosion.
❒ Check battery tripping packs, battery integrity, signs of defects, etc.

21.2.2 Non-Intrusive LV Switchboards

Note: These maintenance procedures require no shutdowns.

❒ Check function of all power meters before shutdown.
❒ Check function of lamps and indicators.
❒ Inspect locking devices for signs damage or worn.
❒ Clean thoroughly, vacuum and full visual inspection of exterior only.
❒ Visual inspections of control wiring, relays, power supply units, timers and fuse carriers.
❒ Check electronic surge protection is intact where installed.

❒ Visual inspection for signs of overheating or deterioration.
❒ Inspection of all panels for paint work damage and signs of corrosion.
❒ Check battery tripping, battery integrity, signs of defects.

21.2.3 ACB Chassis

❒ Rack out ACB.
❒ Clean/ vacuum internal chassis.
❒ Check operation of safety shutters closing.
❒ Check shutter locking devices are intact.
❒ Check operation and position of contacts.
❒ Operate padlocking system.
❒ Grease clusters as necessary.

21.2.4 ACB's

❒ Check general condition of the device.
❒ Clean with diluents Henkel 273471, vacuum ACB.
❒ Check filters clean/vacuum arc-chutes.
❒ Visual check for contact wear.
❒ Check auxiliary wiring insulation.
❒ Check ACB locking devices.
❒ Open/close manually.
❒ Charge the device manually.
❒ Secondary injection with FFT Kit, produce trip curve report.
❒ Check earth fault protection/earth leakage protection.
❒ Grease disconnect contacts as necessary.
❒ MCCB trip test with report.

21.2.5 Busbar & Accessories

❒ Visual inspection all Power bar runs
❒ Check supports
❒ Check alignment, straight runs, joint packs and directional change pieces
❒ Check panel flanges, earth continuity etc.
❒ Thermal image survey of complete runs

21.2.6 Meters

❒ Voltage connections
❒ CT connections
❒ Modbus connections

21.2.7 MCCB checks

❒ Motor operator
❒ Under voltage release
❒ Power supply unit
❒ Control relays
❒ Fuse and fuse holders

21.2.8 PDU

❒ Clean thoroughly exterior and interior PDU switchboards
❒ Check function of all power meters
❒ Verify control circuit fuse rating and continuity
❒ Check function of lamps and indicators
❒ Check and torque test bolted electrical connections as necessary to specified levels
❒ Check all cable connections for tightness and torque terminals
❒ Visual inspection for signs of overheating or deterioration
❒ Inspection of all panels for paint work damage and signs of corrosion
❒ Inspection to insure all clear after work completed before fitting covers
❒ All labeled secure in place

21.2.9 Thermal Imaging Surveys

Thermal imaging is becoming more common within preventive maintenance programs to help detect excess heat in electrical components. It can be carried out while the system is under a full load with no impact to operations.

Thermal imaging technology can detect loose connections, corroded elements, short circuits, overloaded circuits and busway-joint analysis. This non-invasive technique also allows to gather data from a remote location, away from potentially dangerous situations.

21.3 O&M Approaches and Activities

Maintenance can be broken down in two parts:

- **Scheduled maintenance:** Planned in advance and aimed at fault prevention, as well as ensuring that the plant is operated at its optimum level.
- **Unscheduled maintenance:** Carried out in response to failures.

Another way to classify the PV O&M approaches is to break them down into three categories, each with different cost-benefit tradeoffs and risk profiles:

- **Preventative maintenance (PM)** encompasses routine inspection and servicing of equipment — at frequencies determined by equipment type, environmental conditions, and warranty terms in an O&M services agreement — to prevent breakdowns and unnecessary production losses. This approach is becoming increasingly popular because of its perceived ability to lower the probability of unplanned PV system downtime. However, the upfront costs associated with PM programs are moderate and the underlying structure of PM can engender superfluous labor activity if not optimally designed.

- **Corrective or reactive maintenance** addresses equipment repair needs and breakdowns after their occurrence and, as such, is instituted to mitigate unplanned downtime. The historical industry standard, this "break-fi x" method allows for low upfront costs, but also brings with it a higher risk of component failure and accompanying higher costs on the backend (perhaps placing a premium on negotiating extended warranty terms). Though a certain amount of reactive maintenance will likely be necessary over the course of a plant's 20-year lifetime, it can be lessened through more proactive PM and condition-based maintenance (CBM) strategies.

- **Condition-based maintenance (CBM)** uses real-time data to anticipate failures and prioritize maintenance activities and resources. A rising number of third party integrators and turnkey providers are instituting CBM regimes to offer greater O&M efficiency. The increased efficiency, however, comes with a high upfront price tag given communication and monitoring software and hardware requirements. Moreover, the relative novelty of CBM can produce maintenance process challenges caused in part by monitoring equipment malfunction and/or erratic data collection.

Preventative Maintenance (PM) includes the following activities:

- Panel Cleaning
- Water Drainage
- Vegetation Management
- Retro-Commissioning (identifies and solves problems that have developed during the course of the PV system's life.)
- Wildlife Prevention
- Upkeep of Data Acquisition and Monitoring Systems (e.g., electronics, sensors)

- Upkeep of Power Generation System (e.g., Inverter Servicing, BOS Inspection, Tracker Maintenance)
- Site maintenance (e.g., security, road/fence repair, environmental compliance, snow removal, etc.).

Corrective/Reactive Maintenance typically includes:
- On-Site Monitoring
- Non-Critical Reactive Repair (addresses production degradation issues)
- Critical Reactive Repair (high priority, addresses production losses issues)
- Warranty Enforcement

Condition-Based Maintenance (CBM) usually consists in Active Monitoring — Remote and On-Site Options Equipment Replacement (Planned and Unplanned) and Warranty Enforcement (Planned and Unplanned).

21.4 Contracts & Obligations

21.4.1 Key Contractual Provisions (KCP)

KCPs in O&M contracts impact the O&M budgeting considerations and approaches, and typically include:

- **Service-level agreements (SLA)** — specify compliance timeframes for responding to and resolving a range of plant conditions, based on equipment type and issue severity level.
- **Availability or "uptime" guarantees** — define the percentage of time that a system must be fully able to produce electricity. Availability guarantees are typically set at 97–99% per year.
- **Performance ratio and yield guarantees** — stipulate plant performance levels (e.g., a minimum amount of energy delivered) according to measured solar irradiation at a site, based on system design and modeled plant behavior — which can be variable, thus introducing risks. These guarantees account for Force Majeure events and warranty defects.
- **Production guarantees** — state annual plant production levels, independent of weather conditions. Insurance coverage can be used to mitigate weather risk, though it can be an expensive policy to underwrite.
- **Performance incentives** — reward/penalize for plant performance that misses, meets, or exceeds projected production levels.
- **Energy-based contracts** — links plant production (kWh/yr) with O&M service provider revenues so that associated expenses are calibrated according to low (fall/winter) and high (spring/summer) revenue periods.

21.4.2 O&M Contract Contents

The purpose of an O&M contract is to optimize the performance of the plant within established cost parameters. To do this effectively, the O&M contract should clearly set out:

- Services to be carried out by, and obligations of, the contractor.
- Frequency of the services.
- Obligations of the owner.
- Standards, legislation and guidelines with which the contractor must comply.
- Payment structure.
- Performance guarantees and operational targets.
- Methodologies for calculating plant availability and/or performance ratio.
- Methodologies for calculating liquidated damages/ bonus payments in the event of plant under- or over-performance.
- Terms and conditions.
- Legal aspects.
- Insurance requirements and responsibilities.

21.4.3 O&M Contractor Services and Obligations

The O&M contract should list the services to be performed by the contractor, including the following entries:

- Plant monitoring requirements.
- Scheduled maintenance requirements.
- Unscheduled maintenance requirements.
- Agreed targets and/or guarantees (for example, response time or system availability figure) Reporting requirements (including performance, environmental, health and safety, and labor relations reporting).
- The contractor should also be contractually obliged to optimize plant performance. Additionally, it should be stipulated that all maintenance tasks should be performed in such a way that their impact on the productivity of the system is minimized.

21.4.4 O&M Terms of the Contract

The O&M contract will also typically define the terms by which the contractor is to:

- Provide, at intervals, a visual check of the system components for visible damage and defects.
- Provide, at intervals, a functional test of the system components.
- Ensure that the required maintenance will be conducted on all components of the system. As a minimum, these activities should be in line with manufacturer recommendations and the conditions of the equipment warranties.

- Provide appropriate cleaning of the modules and the removal of snow (site-specific).
- Make sure that the natural environment of the system is maintained to avoid shading and aid maintenance activities.
- Replace defective system components and system components whose failure is deemed imminent.
- Provide daily (typically during business hours) remote monitoring of the performance of the PV plant to identify when performance drops below set trigger levels.

In an O&M contract, the obligations of the owner/ developer are generally limited to granting the O&M contractor access to the system and all the associated land and access points, obtaining all approvals, licenses and permits necessary for the legal operation of the plant providing the O&M contractor with all relevant documents and information, such as those detailed above, that are necessary for the operational management of the plant.

The cost factors that will be included in the O&M activities are estimated to consist of the following:

- Personnel cost, consisting of
  - One project Manager/site engineer
  - One Admin/Finance Officer
  - Three technicians
  - Four Service personnel
  - Guards and other personnel
- Operational costs include:
  - Fuel for generator based on calculated LoLP
  - Fuel for diesel generators on cloudy days, estimated for 60 days per year
  - Diesel Generator repair and maintenance costs
  - Spare parts for PV Plant and reticulation system.

21.5 Quad Pod Jack for Tilt Angle Adjustment User Manual

This manual describes the operation of this unit. Please read this manual carefully before operations. This manual provides safety and as well as information on operation.

21.5.1 Safety Instructions

1. Before using the unit, read all instructions, the brace channel and all appropriate sections of this manual.
2. To reduce risk of injury, use an assistant while lifting up the unit because of its heavy weight.
3. Do not disassemble the unit. Take it to a qualified service center when service or repair is required.

4. Please strictly follow operation procedure when you want to mount and dismount the quad pod jack from the PV frame.
5. Warning!! Only qualified service persons are able to service this unit. If malfunction occurred, please send this unit back to local dealer or service center for maintenance.

21.5.2 Introductions

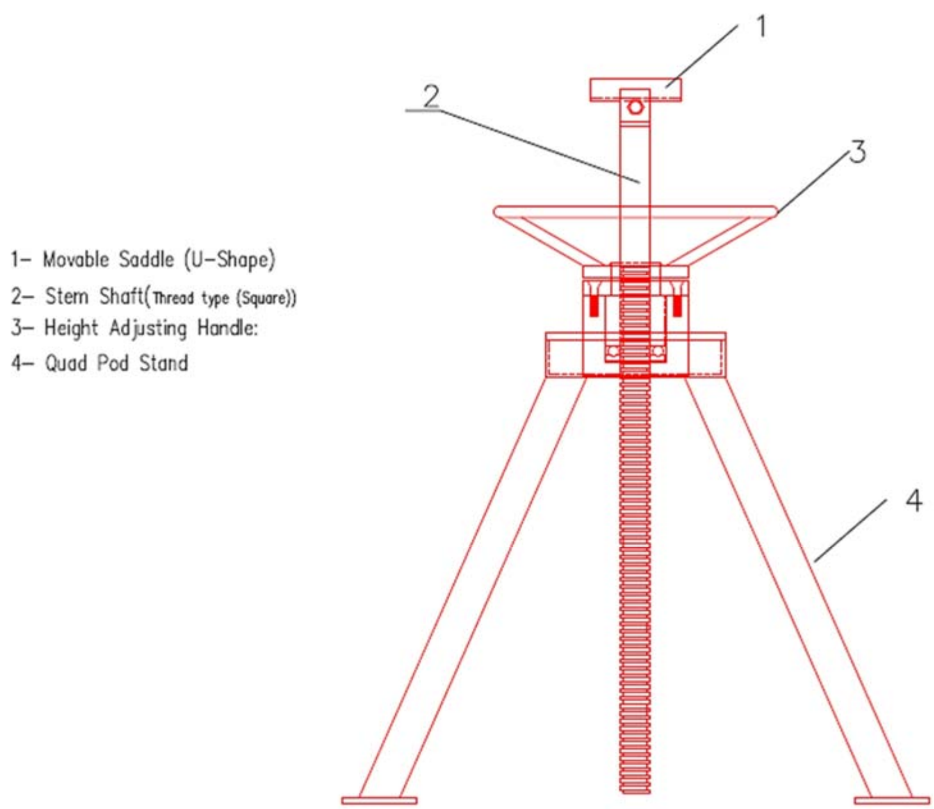
This is a quad pod jack for the adjustment of the PV support structure tilt angles for 7°, 12°, 30°, 35° and 40°. Its movable jack and adjustable brace chamber allows a user to change angles in the most reliable way possible.

Features

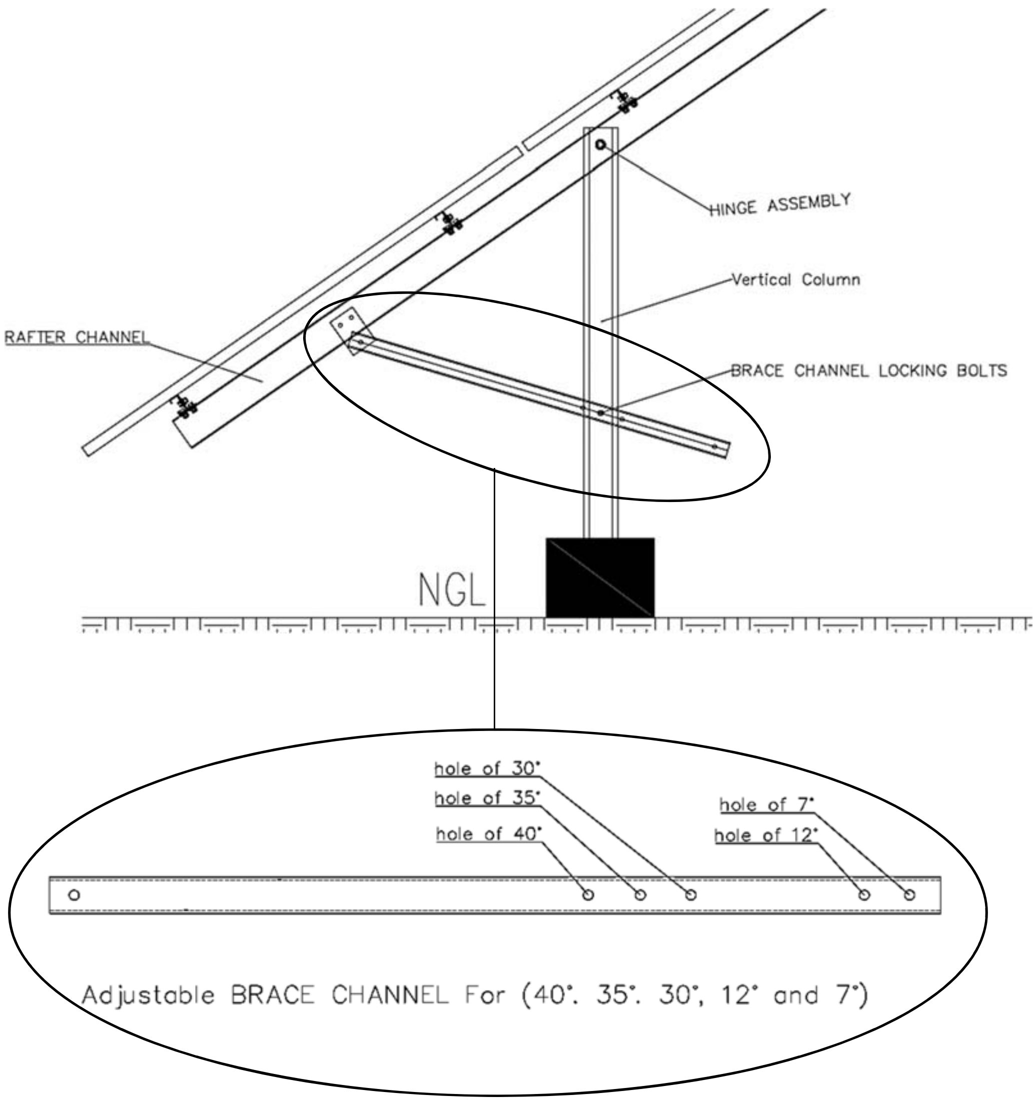
- Adjustable brace channel
- Portable quad pad jack
- Easy to use
- Easy to maintain
- Accessible by a minimum of one operator
- Cost effective device for manual tracking

21.5.3 Product Overview

1. **Quad Pad Jack**



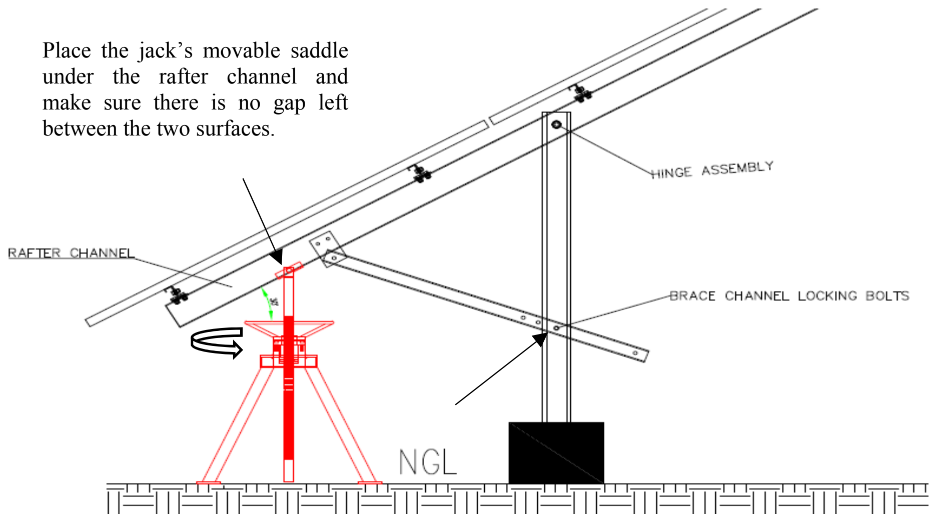
2. Adjustable Tilt Angle Mechanism



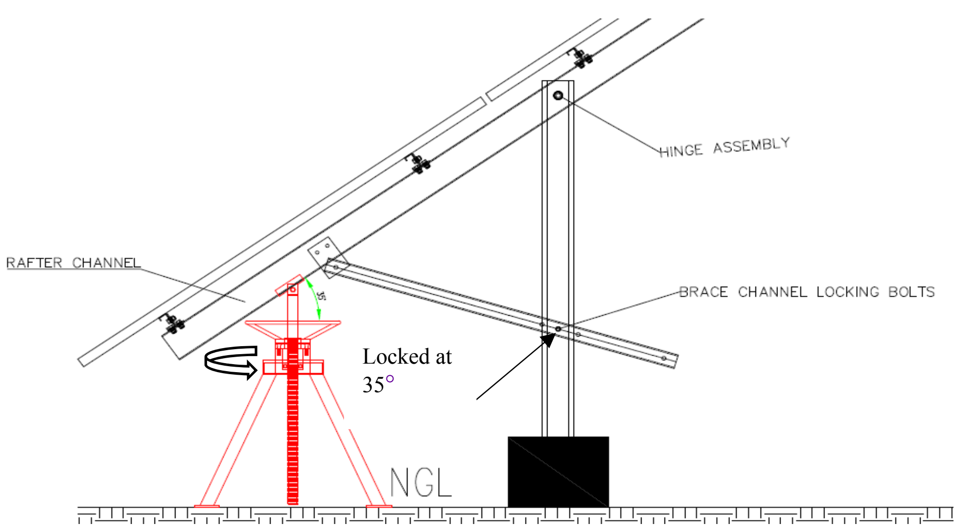
21.5.4 Quad Pad Jack Operation

Changing the Angle

The following illustration shows basic operation for changing the tilt angles. As described above the support structure has the ability to change its tilt angel from a different range of degrees. The illustrated figure shows the tilt angle changed from 30° to 35° tilt.



1. As shown above the brace channel is locked at the 30°, in-order to adjust the tilt to 35° place the quad pad jack under the rafter channel as illustrated in the above figure.
2. After placing the jack's movable saddle firmly under the rafter channel, start undoing the nut and bolt which holds the brace channel at 30°.
3. The brace channel is fixed with a pin at the top end with the rafter channel as shown in the figure, now check for any jams and see if the brace channel moves freely along its own axis.
4. As show in the figure, turn the jack's wheel anti clock wise this will allow the shaft along with the rafter to move downwards. While turning the wheel, with the aid of the second operator (it can be fully operated with a single person, but for a quicker operation two persons are recommended) check if the brace channel's bolt hole for 35° is in position for locking and at this point stop turning the wheel.
5. Once, at the position for locking please tie up the nut and bolt before removing the jack.
6. After the bolt is locked remove the jack and to avoid any jams turn the wheel even further so the shaft is not in contact with the rafter anymore.



22. ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT

During the assessment, a detailed social and environmental assessment of the site and associated reticulation path was carried out in all cluster villages. The assessment established that no social, community, institutional or political structures of the area are negatively impacted by the project. At the same time, the individual and family structures are not negatively impacted by the project. Similarly, community resources such as common spaces, gathering areas, and other similar resources are not negatively impacted. As a matter of fact, the arrival of electricity in the communities, such resources are expected to be enhanced and to better serve the population of the area.

22.1 Noise Pollution

The project is expected to be completed without any significant noise during the construction phase and even less so post construction and during normal operations. However, a back-up generator system will be installed that will operate during prolonged cloudy days and where necessary. These generators will cause some noise pollution. However, they will be installed in a closed space and will be away from residential and commercial neighborhoods close to the main street and surrounded by agricultural land. Hence the effect of the noise on the villages will be minimum. The pollution as affected by the diesel generator fumes is also minimum, taking into consideration the fact that there are not many other sources of pollution in the area. The minimum pollution is also offset by the great benefit of the system to the population and the prosperity of the communities.

22.2 Impact on Water and Air

There will be no negative impact on the quantity and quality of surface or sub-surface water or the soil. Solar power is an environmentally sound technology that uses the abundance of natural sun light to produce electricity. However, where diesel generators will be installed some impact will be noticeable on air. This impact will be minimal, as the generators will operate only during scarce multiple cloudy days and as needed.

22.3 Impact on Forests and Trees

At the project site and throughout the reticulation path, there are no forests, no orchards that will, in any shape or form, be negatively impacted by the project. No trees have to be removed to clear path for the reticulation system, even though some trees branches will need to be clipped to facilitate the passing of the overhead power cables. In addition to that, the designated solar power plant site contains some small saplings that will need to be removed. This impact will be insignificant. Otherwise, no damage will be caused to any natural resources.

22.4 Impact on Agriculture, Flora & Fauna

The cluster of villages that build the project site is mostly agricultural land. Except for the actual site of the solar power plant, which requires that rain-fed agricultural land be de-scoped to an industrial land, there will be no impact on the agricultural land in the cluster of villages. The flora and fauna will not be negatively impacted and grazing land, which is not part of the geography of the cluster villages, will also not be impacted.

22.5 Impact on Historic Heritage

The project site and the surrounding areas, including the reticulation path do not have any historic heritage, archaeological sites or other similar sites. Therefore, there is no impact on these facilities. Access to electricity will enable the population to have ready access to mass media, which in turn enhances the level of awareness of the population towards many aspects of life, including the preservation of cultural heritage and historic structures.

22.6 Impact on Wildlife & Protected Wildlife

The township and neighboring communities, where the project site and the reticulation path are located do not impact any wildlife in any way possible. Protected wildlife is not prevalent on the project site and are therefore not affected by the project.

22.7 Impact on Irrigation Systems

The irrigation system will not be affected by the project, as there are no irrigation channels at the site of the solar power plant. The reticulation path may cross some irrigation channels but do not affect their operation. The only impact on agricultural land will be through de-scoping of 10 jeribs of land from agricultural land to industrial land and the effective construction of the solar power plant. Other than that, the project can only have a positive impact on irrigation systems, by enabling the use of electric powered irrigation pumps to increase the quantity of irrigated land.

22.8 Social Impact

The project may demonstrate some negative impact on the social fabric of the target community, especially as it relates to the neighboring communities. Some of the neighboring communities are located fairly close to the project site, yet they will not have access to the power from the project. This may create resentment against the population of the target villages and may have some negative impact on the social fabric of the area.

As a whole, the project has a net positive impact on the social, natural resources and environmental condition of the target area or at a minimum no negative impacts at all.