Section 6 - Employer's Requirements

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ABBREVIATIONS

AC	-	Alternate Current
ADB	-	Asian Development Bank
BESS	-	Battery Energy Storage System
CAPEX	-	Capital Expenditure.
DC	-	Direct Current
FENAKA	-	the Utility responsible for electricity, water and sanitation
GUI	-	Graphical User Interface
MPP	-	Maximum Power Point
PCMS		PV-Diesel Hybrid Plant Control and Monitoring System
PV	-	Photovoltaic
RE	-	Renewable Energy.
SCADA	-	Supervisory control and data acquisition
SOC	-	State Of Charge
SWA	-	Steel wire armoured
SS	-	Substation
THD	-	Total Harmonics Distortion

WEIGHTS AND MEASURES

kW	–	Kilowatt
kWh	–	Kilowatt-hour
MW	–	Megawatt

1 Scope of Supply of Plant and Services (Lots 1 & 2)

1.1 General

The aim of the present tender is: *i)* to hybridize the existing diesel power plants **of 12 inhabited** islands located in the **Thaa atoll**, Maldives, by installing photovoltaic solar (PV) systems together with Lithium-ion battery systems and grid upgrades. The project also includes the upgrade of the existing diesel power plants into fully automated diesel power when necessary, and ii) to provide ice making plant powered by photovoltaic solar (PV) systems together with Lithium-ion battery systems.

The specific islands for the hybrid solar-storage minigrids are listed in Table 1-1.

Island Code	Atoll	Island Name
N02	Thaa	Vilufushi
N03	Thaa	Madifushi
N04	Thaa	Dhiyamigili
N05	Thaa	Guraidhoo
N06	Thaa	Kandoodhoo
N07	Thaa	Vandhoo
N08	Thaa	Hirilandhoo
N09	Thaa	Gaadhiffushi
N10	Thaa	Thimarafushi
N11	Thaa	Veymandoo
N12	Thaa	Kinbidhoo
N13	Thaa	Omadhoo

Table 1-1: List of islands for solar-storage minigrids with island code and atoll

Figure 1: Map of the islands of Thaa atoll

The specific islands for the solar powered ice making plants are listed in Table 1-2.

Island Code	Atoll	Island Name
A10	Haa Alif	Dhidhdhoo
N01	Thaa	Buruni
U02	Alifu Alifu	Rasdhoo
N02	Thaa	Vilufushi

Table 1-2: List of islands for solar powered ice making plants with island code and atoll

1.2 Scope of work

The scope of supply, works and services shall cover, but not limited to the following:

- assessment of the site and site characteristics.
- development, detailed design, engineering (including equipment specifications), coordination of sub bidders, permitting, procurement, manufacturing, factory testing, supply of all equipment (also including spare parts, consumable, special tools and handling equipment, etc.), transport to site, storage on site, erection, construction, commissioning and performance testing of the systems.

- works and services related to preparation, civil, mechanical, electrical, instrumentation and control (I&C) and communication works including all required equipment for the execution of these works and services,
- providing security on site during construction as per insurance requirements and the security technical specifications of the Employer and per all applicable codes and standards
- training of personnel according to Employer´s Requirements
- occupational health, safety and environment for construction and operation of the plant

The Contractor shall be responsible for detailed design, engineering and building of the overall system, consisting of:

- PV system with PV modules, grid tied inverters, mounting system, string combiner boxes, trenching, DC cabling, AC cabling, monitoring system and controller, UPS, communication cables, earthing and lightning protection, AC distribution boards, DC distribution boards, electricity meters, electrical connection to the existing system, provision of signals for the centralised SCADA system.
- Battery storage system with batteries, bidirectional battery inverters (if applicable grid building inverters), battery racks, monitoring system and controller, UPS, DC cabling, AC cabling, communication cables, earthing, AC distribution boards, DC distribution boards, electricity meters and sensors, electrical connection to the existing system, provision of signals for the centralised SCADA system.
- Diesel Generator system, if a replacement or revitalisation of the existing system is required as per Chapter 2, Site Specifications. The Diesel Generator system includes the Diesel Generators, fuel piping and storage, safety installations, fuel flow meters and sensors (also existing gensets shall be equipped), exhaust system, monitoring and genset controller (generator synchronization panel with automated system to synchronise gensets and run gensets in parallel on fuel optimized combination), UPS, AC cabling, communication cables, earthing, AC distribution boards, electricity meters, electrical connection to the existing system, provision of signals for the centralised SCADA system.
- Flake Ice making plants, suitable for seawater type with storage system.
- Upgrade the existing grid infrastructure as per the tender requirements which include but not limited to replacement of identified cables in the existing LV distribution network, replacement of identified distribution boxes to accomodate the revised cable sizes or to accommodate new in-feed from the proposed PV, replacement of existing main LV distribution board in Power house with new LV distribution board , modification of existing spare LV feeder in the main LV distribution board of the power house for direct connection of PV, extension of main LV distribution board of the power house for direct connection of PV, new DG incomer and a BESS incomer, modification of LV distribution boards of the 11/0.4kV distribution substations for direct connection of PV.

It is the sole responsibility of the Bidder to design, engineer and plan all related work and installations, buildings, sub-systems, elements, system facilities, equipment, services, including system hardware and software.

The Contractor shall collect and investigate all basic data which are needed for a proper design, planning and engineering. This includes, but is not limited to:

- conduct site visits and basic evaluation needed for a proper design and engineering
- survey of existing rooftops and installation locations with regards to condition and suitability for proposed installations
- review of static calculations and where such are not available static verification of the buildings / roof tops
- survey for suitability of proposed installation locations for equipment like batteries, inverters, controllers and other devices
- soil investigations in case buildings, ground mounted structures or foundations shall be built.
- survey related to the grid upgrade works which include but not limited to cable routes from PV plant site to powerhouse in each Island, condition assessment of low voltage distribution boxes, LV distribution boards in Power house, LV distribution boards in substations, MV distribution network (where applicable) etc.

The Contractor is responsible for import, transport, storage and handling of any equipment and material needed for installation and implementation of services.

The Contractor shall provide complete engineering data, calculations, drawings, reports, manuals for Employers review, approval and records.

The Contractor is responsible for the construction and implementation of the systems according to the design approved by the Employer. This includes, but is not limited to:

- PV system
- Battery energy storage system
- Diesel Generator system including automated generator synchronisation panel
- Flake Ice making plants, suitable for seawater type with storage system.
- Integration of the systems into the existing AC distribution panel. It is within the Contractors responsibility the change the actual AC distribution panel to be compliant with the new PV-Hybrid system
- Grid improvement
- Buildings
- Other works

The Bidder shall include in its scope all facilities and equipment necessary for the generation of power from the system and all works and services including workshop and store

equipment, special tools and handling equipment, spare parts, consumables, etc. necessary for complete, safe, reliable, and efficient operation and preventive and corrective maintenance of the system.

The scope includes also works not explicitly stated in Section 6 or elsewhere in the tender documents but which are reasonably required for the installation and operation of the systems according to good engineering practice.

All deliveries and works shall meet or exceed applicable requirements set forth by the latest edition of the following international and national codes and standards. In addition, all local rules and regulations shall be strictly adhered in all respects.

- ISO/IEC
- EN
- ISA (International Society of Automation)
- IEEE
- ITU (International Telecommunication Union)
- Maldives local regulations

No claims for extras will be considered in respect of failure by the Bidder to comply with any of the above.

Reputable manufacturers shall manufacture new equipment, which shall be subject to Employer's review and approval. Used, reconditioned or salvaged equipment or material shall not be allowed. All equipment used in connection with the project shall be of proven design for the intended use of the equipment. As a general principle, the latest, commercially proven, most modern and up-to-date technologies will be selected and licensing terms agreed with the objective of maximizing value to the Employer.

All parts of the plant shall be suitable in every respect for continuous operation at maximum efficiency as well as part loads and minimum load, under consideration of the climatic conditions peculiar to the site and environmental restrictions.

The Bidder shall apply a well-established component classification and identification system. The international SI system of units shall be used for design, drawings, diagrams, instruments, etc.

Project language is English. This applies also to any kind of documents, drawings, manuals, etc.

The individual islands are described in detail in Chapter 2. Any specification which is not provided in Chapter 2 but needed for a proper design, engineering, implementation, O&M services and any related work shall be investigated by the Bidder.

Disclaimer: Source of all satellite pictures shown in this Tender is Google Earth.

2 Hybrid Minigrid Site Specifications (Lot 1)

2.1 General

The following section describes the specific island and its site conditions as well as climate logical parameters for the atoll.

The Bidder is responsible for its own investigations to establish sufficient and accurate information for the design of the Plant. The Contractor shall visit the proposed sites and shall ascertain the nature and location thereof and all conditions which may affect design/layout of the PV plant, design of grid upgrade works and the project costs.

The Bidder shall make its own assessment of any and all of the information provided in this Bid and collect own information. Neither the Employer nor any representative or advisor is responsible for the accuracy or completeness of any such information.

2.2 Logistic

The Contractor is free to choose the seaport of entrance. There are three of these seaports. Upon arrival at one of these ports the Contractor shall take care of the clearance. However, Employer shall provide the relevant supporting documents to the Contractor. After clearance it is the Contractor's obligation to continue delivery up to the final destination at the respective islands.

2.3 Climatic conditions

This chapter describes the climatological conditions of the Thaa atoll, which should be applied for all islands within this tender.

The meteorological input data set for the simulation with PVsyst is mandatory to be used so that all Bidders base their yield forecast on the same irradiation and temperature values. The values of following table were obtained from NREL.

	Global Horizontal Irradiation (GHI)	Ambient temperature
	kWh/m²/day	°C
Jan	5.094	26.83
Feb	6.146	26.89
Mar	5.957	27.17
Apr	5.687	27.51
May	5.077	27.74
Jun	5.045	27.23
Jul	5.076	26.92
Aug	4.831	26.68
Sep	5.178	26.82
Oct	5.431	26.77
Nov	5.472	26.66
Dec	4.692	26.74
Year	5.31	27.00

Table 2-1: Solar resource and meteorological data

The following graphic representation confirms the very constant temperature and solar irradiation over the year. April and May are the warmest and sunniest months.

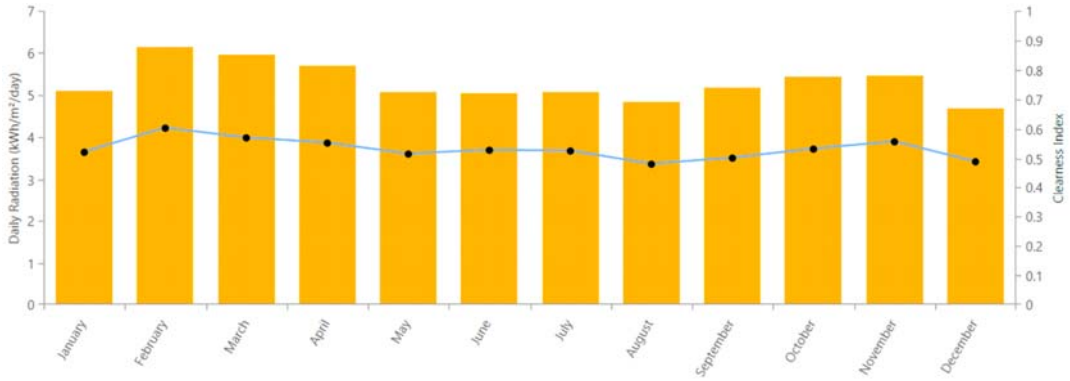


Figure 2: Global and Diffuse horizontal irradiation at the project location (NREL)

Figure 3: Ambient temperature at the project location (NREL)

2.4 Types of hybrid minigrid systems and general behaviour

From a conceptual point of view three different kinds of systems are defined (although this tender only considers 2 two of them. The three systems are:

- Type A: PV-Diesel
- Type B: PV- Diesel-Grid with support battery system
- Type C: PV-Diesel-Grid with forming battery system

2.4.1 Type A Hybrid system: PV-Diesel

This configuration is suitable for minigrids with a low renewable penetration and no energy storage. The diesel gensets are the grid-forming element acting as a voltage source that other sources (PV inverters) have to synchronize to, so at least one of them needs to be online. In this type of minigrid, power quality and system stability depend on the capacity of the gensets to respond to changes in power balance and other disturbances. The characteristics of the genset governor and excitation systems are key for the stability of systems with this configuration.

When a single genset is providing primary regulation for the whole minigrid (slack unit), this genset can function in synchronous (fixed speed) mode. This means that changes in the net load (demand – uncontrolled generation) initially translate on a speed (frequency) deviation until the governor control (usually based on a PI controller) restores the torque for the new power level at reference frequency. In case, the system stability is at risk due to high PV penetration, the PV power can be curtailed by frequency droop control and additionally commands via FOC connection (see Figure below).

With this control strategy, diesel generators balance their active and reactive power generation with the load based on the frequency and amplitude of the voltage in its terminals, respectively. Transient imbalances result in a steady state error of the voltage frequency and magnitude with respect to their reference values. A second slower control loop changes the parameters of the droop control to restore reference values in the steady state.

At least one Diesel will be always synchronized. Additionally, a data communication cable between the inverters and the Hybrid System Controller shall be installed for command and SCADA purposes.

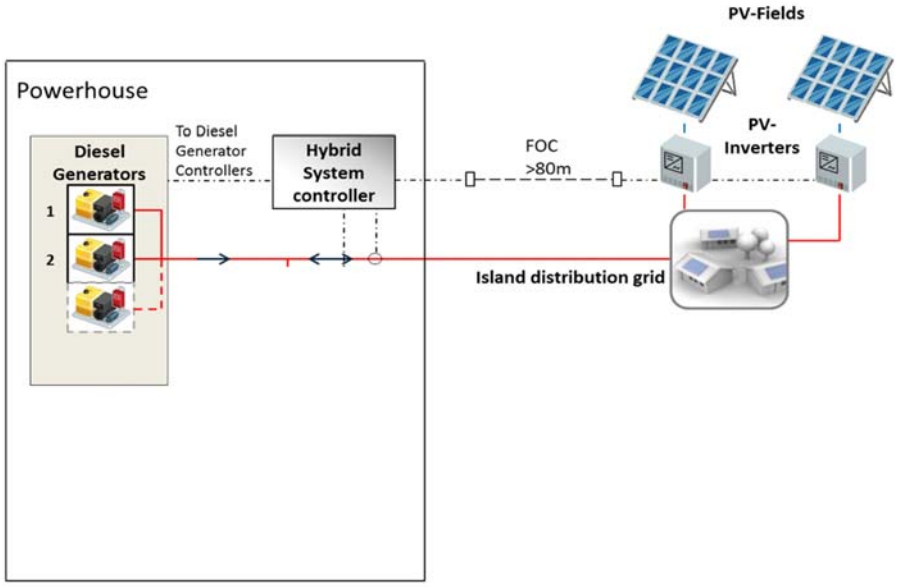


Figure 4: Schematic Block Diagram of Hybrid System

2.4.2 Type A: Energy distribution (typical day)

Type A islands are characterized by low PV penetration, therefore stability issues due to RES variability will have a limited impact and batteries will not be installed. When there is no PV (Region 1 and 3, Figure 2) diesels provide all the energy. The power plant controller selects the most efficient diesel genset for each given load.

Whenever PV starts to produce energy (Region 2, Figure 2) the load is fed by a combination of diesels gensets and RES. Contingencies and sudden variation of RES can be handled by droop controls at the Diesel GenSets.

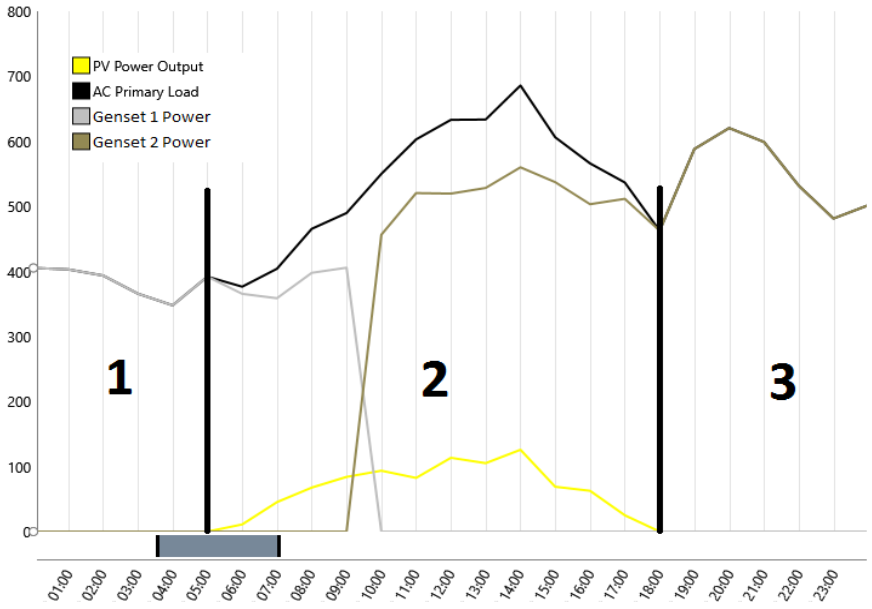


Figure 5: Simulation of energy distribution over one day (Type A: PV-Diesel Hybrid System)

2.4.3 Type B Hybrid system: PV-Diesel-Grid support battery

Diesel generator forms the grid and provides all ancillary system functions.

The PV plant is seen as a negative load by the Diesel Generators and injects its produced energy into the grid.

A hybrid system controller is installed to ensure grid stability and maintain the operation of Diesel Generators above a defined minimum load (usually 25-30%) by curtailing output power of the PV inverters when needed. The controller will constantly calculate the spinning reserve needed from the Diesel Generators and communicate with the genset system.

The communication between the hybrid system controller (located in the powerhouse) and the PV inverters is performed using Fibre Optic Cable (FOC) for large distance (above ~80m).

An additional short term power battery is included in the system (30 minutes to 2 hours energy reserve). The short term power battery increases grid stability and allows higher PV penetration by switching off generators when system stability allows it.

The battery is used to stabilize the grid when required (f/U) against sudden power fluctuation (from the load and/or the PV plant) and to have enough spinning reserve to start an additional Diesel Generator if needed.

2.4.4 Type C Hybrid system: PV-Diesel-Grid forming battery

During the day, the PV and battery system provides 100% of the load and charges the battery. If battery is fully charged and PV output power is higher than the loads in the system, the PV power can be curtailed by frequency droop control and additionally commands via FOC connection.

The battery is discharged during the night until the defined minimum State of Charge (SOC) is reached.

Diesel Generators are used as backup and started to provide energy to the load when the SOC_{min} of the battery is reached.

The communication between the hybrid system controller (located in the powerhouse) and the PV inverters can be performed via frequency droop to curtail the active power when needed.

Additionally, a data communication cable between the inverters and the Hybrid System Controller shall be installed for command and SCADA purposes.

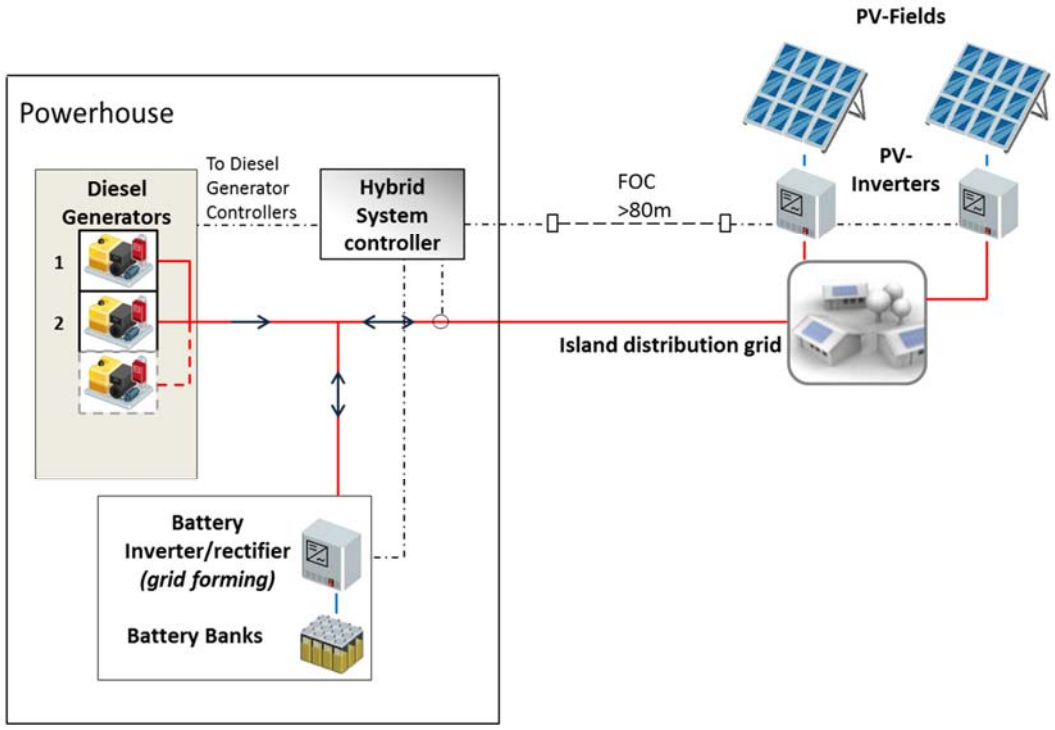


Figure 6: Schematic Block Diagram of Hybrid System

2.4.5 Type B and C: Energy distribution (typical day)

The following graphics present the power production from each energy source (PV, Diesel Generators, Battery) for type B and C of hybrid systems in order to help understanding the functioning of the controller simulated and how the energy is distributed between the different power sources. Two typical days of an island were chosen and are analysed.

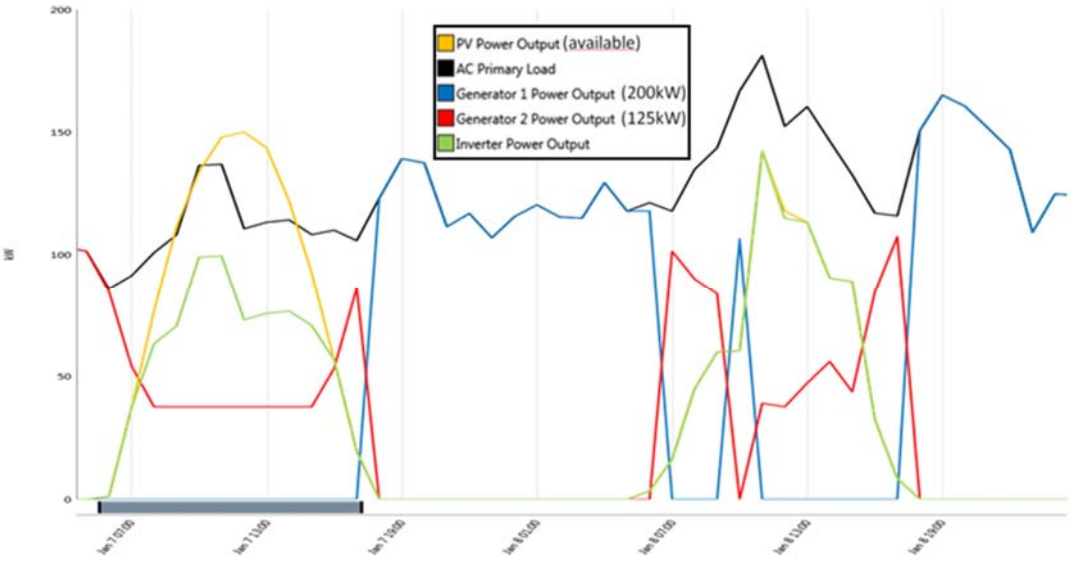


Figure 7: Simulation of energy distribution over 2 typical days (Type B: PV-Diesel-grid support battery)

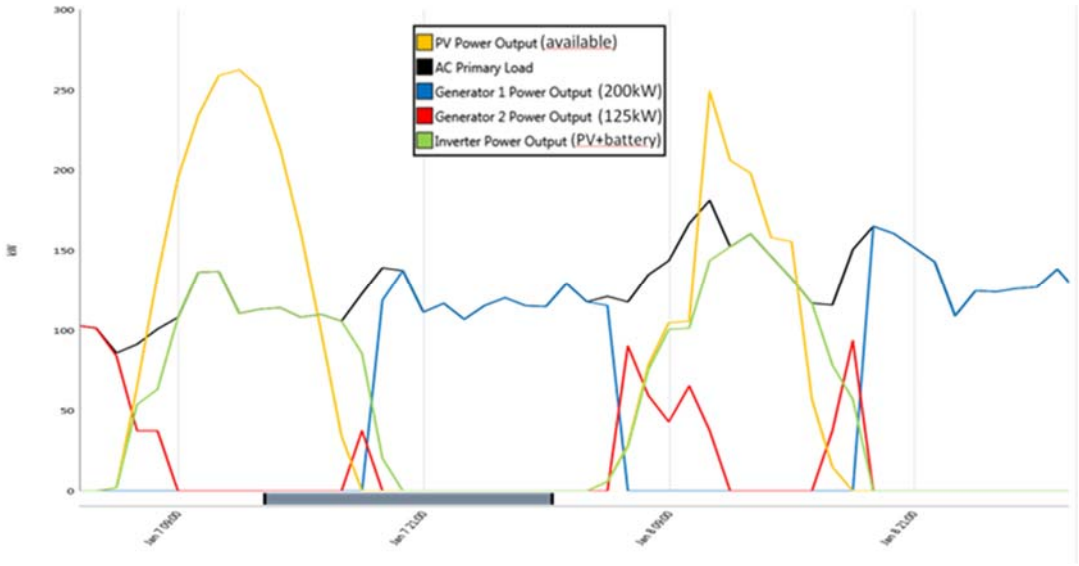


Figure 8: Simulation of energy distribution over 2 typical days (Type C: PV-Diesel-grid forming battery)

The functioning of the hybrid systems of Type B and the relative benefit provided by the grid supporting battery can be observed by comparing the two first figures:

- for the first day in both graphics there is enough PV power to possibly cover the whole load in the system. For Type B systems it is necessary to have a generator running at all times, as the grid building function of the battery inverters is not activated. It is to be noted that in Type C the generator power (red line) drops down to zero and the generator is completely shut down, whereas for Type B the generator remains running at its minimum partial load.
- for the second day represented on the figures, the following small difference can be observed: In the case of Type B (Figure 7) the grid support battery provides additional spinning reserve to the hybrid system and as a result the controller starts the smaller Diesel Generator (125kW) and preventing excess of energy in this specific case. This situation happens when the available PV power and the load are relatively high at the same time.
- The Type C (Figure 8) with a "small" grid forming battery inverter shows that the Diesel Generators can be turned off during the day as soon as the PV power exceeds the load and the battery State of Charge is high enough. Therefore higher diesel savings and significant running hour reductions of the Diesel Generators can be achieved.

2.4.6 Other technical characteristics

Regarding the energy management system and associated infrastructure, all islands should be readly available to future upgrade/downgrade to any of the types A, B or C.

Type C should also allow operation of multiple masters (grid forming entities such as Battery or Diesel generators) and only use PV as a slave. If one master fails the other master units should able to run the grid giving the system extra redundancy.

The Battery inverter must be synchronized to other voltage sources in both cases: *i)* Battery inverter is online first and the other voltage source (DG, Grid, other Battery Inverter) must be synched to the battery inverter, *ii)* Other voltage sources are first online (DG, other Battery Inverter), the battery inverter must be synchronized to them. Especially when a static (isochronous) voltage source such like an DG without synchronization capability the synchronization must be done with an external synch check and breaker. The measurement of the requirement parameters of voltage, frequency etc. must be done fast and accurate enough to guaranty synchronization.

2.5 Summary of the characteristics of the hybrid mingrid systems to be built

The Contractor shall implement the described systems on the 12 islands as summarized in the table below.

Island	Powerhouse relocation planned	System Type	Size PV (STC)	Battery and battery inverter requiered minimum power	Minimum required battery capacity (example given for a battery with a minimum nominal discharge rate of 1C)[1]
N02-Vilufushi		Type A	180 kWp	-	-
N03-Madifushi		Type A	140 kWp	-	-
N04-Dhiyamigili		Type A	90 kWp	-	-
N05-Guraidhoo		Type A	180 kWp	-	-
N06-Kandoodhoo		Type C	300 kWp	200 kW	400 kWh
N07-Vandhoo		Type C	300 kWp	200 kW	350 kWh
N08-Hirilandhoo		Type A	180 kWp	-	-
N09-Gaadhiffushi		Type C	150 kWp	150 kW	300 kWh
N10-Thimarafushi		Type A	220 kWp	-	-
N11-Veymandoo		Type A	250 kWp	-	-
N12-Kinbidhoo		Type C	300 kWp	225 kW	450 kWh
N13-Omadhoo		Type C	200 kWp	200 kW	400 kWh
Sum	**Total Powerhouses to be relocated: -**	**Type A: 7 Type C: 5 Total: 12**	**Total installed PV: 2.49 MWp**	**Total installed battery power: 0.975 MW**	**Total Battery capacity: 1.9 MWh (with at least 1C nominal discharge rate)**

Table 2-2: Summary of the hybrid system

[1] Manufacturers datasheet must be provided to confirm nominal discharge rate of offered battery. Technical specifications of battery and battery inverters (**Chapters 4.3.1 and 4.3.2**) shall be considered

2.6 Summary of auxiliary systems of the hybrid systems and Grid upgradation works to be done

Island	Type metrological station (see §4.2.6)	LVDB upgrade/replacement at Main Power house	Cable Works involved (Meters)*	Replacement of Existing DBs
N02-Vilufushi	Type 2	Replace Existing LVDB	75	0
N03-Madifushi	Type 2	Replace Existing LVDB	170	1
N04-Dhiyamigili	Type 2	Add BESS feeder and 2 outgoing feeders	50	0
N05-Guraidhoo	Type 1	Replace Existing LVDB	185	0
N06-Kandoodhoo	Type 2	Add BESS feeder and 2 outgoing feeders	420	1
N07-Vandhoo	Type 2	Replace Existing LVDB	495	1
N08-Hirilandhoo	Type 2	Replace Existing LVDB	355	0
N09-Gaadhiffushi	Type 2	Replace Existing LVDB	385	2
N10-Thimarafushi	Type 2	Replace Existing LVDB	40	0
N11-Veymandoo	Type 2	Replace Existing LVDB	635	2
N12-Kinbidhoo	Type 2	Replace Existing LVDB	95	0
N13-Omadhoo	Type 2	Replace Existing LVDB	185	0
Sum		**2/10**	**3090**	**7**

Table 2-3: Summary of the auxiliary system of the hybrid systems and Grid upgradation works

*For detail cable works refer network drawings.

Length of cables from LVDB to generators and BESS and length of communication cables are not included here. For details and proposed sizes refer to powerhouse SLD.

2.7 N02 Vilufushi Island

The island of Vilufushi is located in the Thaa Atoll. The general data of the island is shown in the following table:

Island code, name	N02 - Vilufushi
Atoll name	Thaa
Utility	FENAKA
GPS coordinates	2°30'14.07" N 73°18'32.55" E
Inhabitants (approx.)	1,200
Harbour type	Harbour, 80x350m

Table 2-4: N02 - Island identification and general data

Figure 9: N02 - Map of the island

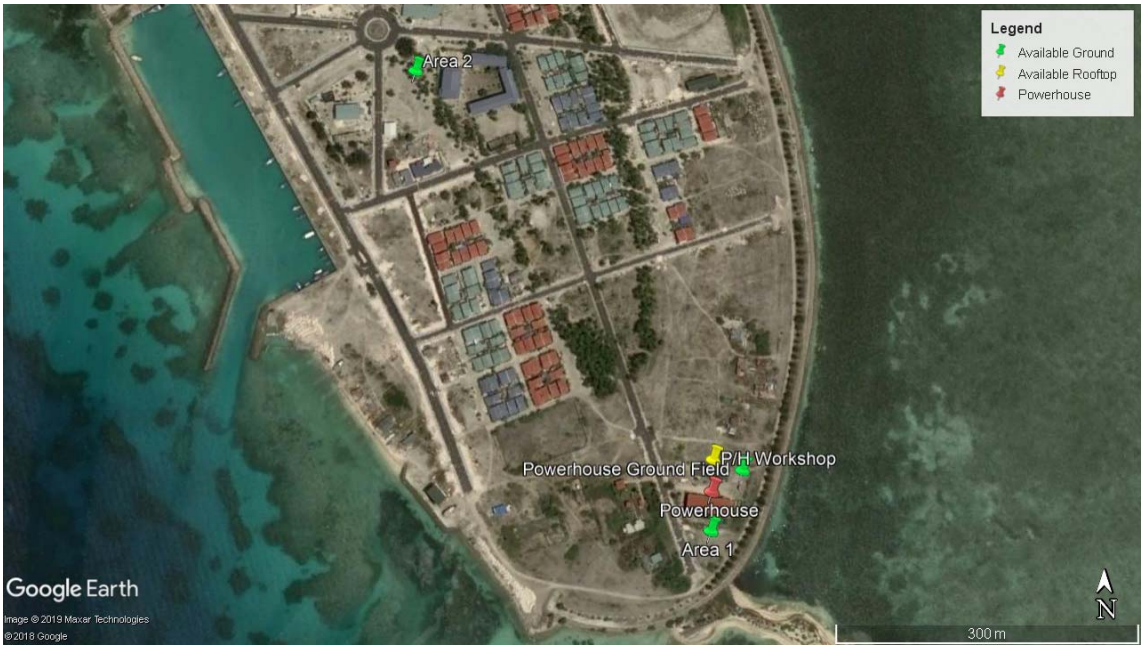


Figure 10: N02 - Location of the buildings with available roofs

2.7.1 Load profile

The island has a fluctuating energy consumption, which is shown in Figure 11 below.

The utility expect a steadily increase of the load by 7 %/year for the next 5 years.

The following load profiles for the year of 2024 shall be considered for sizing.

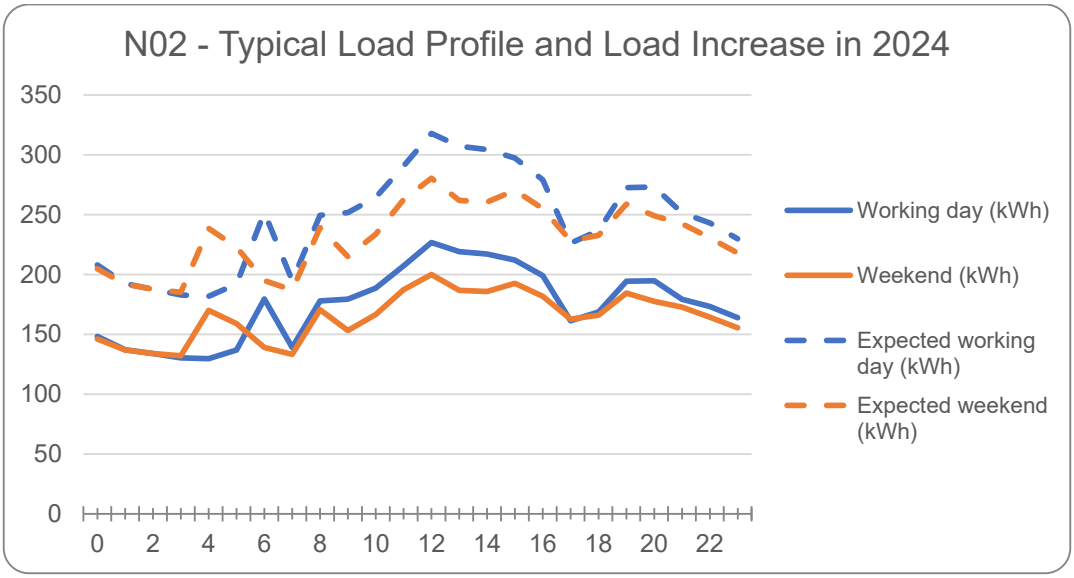


Figure 11: N02 - Typical daily load profile and evolution until 2024

	Average daily consumption [MWh/day]	Yearly consumption [MWh/yr]	Peak power [kW]
2019	4.20	1,533	320
2024	5.88	2,146	450

Table 2-5: N02 - Power consumption and peak power

2.7.2 Diesel Generators

4 Diesel Generators of different sizes are installed on the island.

The following table shows the existing Diesel Generators with specifications.

Item	Diesel Gen. 1	Diesel Gen. 2	Diesel Gen. 3	Diesel Gen. 4
Engine manufacturer & motor references	Cummins NTA-855G6	Cummins NTA-855G6	Cummins NTA-855G6	Cummins KTA19-G4
Engine power rating (continuous) [kW]	250	250	250	400
Available power under site temperature conditions [kW]	Damaged	160	180	150 (Under rated power cable)
Hours of operation / date of installation	38190	32772	36491	511
General maintenance performed [Yes/No] (if Yes, when)	Yes (Damaged after a week)	No	No	New
Diesel generator controller (if any) manufacturer and type (e.g.: Woodward GCP, Easygen, etc.)	-	Planned to install DSE8810	Planned to install DSE8810	Planned to install DSE8810
Relay for remote start available? [Yes/No]	No	No	No	No

Table 2-6: N02 - Diesel Generators currently installed

All Diesel Generators shall be integrated in the hybrid PV system.

2.7.3 Overview of possible installation locations for PV roof top systems

The table below shows the selected roofs for PV power plant installation and the estimated maximum PV power capacity installable on each roof. This estimation is based on a conservative approach considering standard 260Wp modules and enough margins in all directions. Roofs that were considered to be partially shaded most of the day were partially excluded from the estimation.

The Contractor shall however be responsible of checking the suitability of the roofs to install PV plants, optimize the design of each PV plant based on the available area, the electrical characteristics of its system and optimizing the yield (reduction of shading losses).

Building and name	Roof size X [m]	Roof size Y [m]	Area [m^2]	Slope [°]	Azimuth [°]	Distance to Powerhouse [m]	Proposed PV Capacity on selected roofs [kWp]	Comments
Powerhouse 1	8	44	352	12	8	25	40	
Powerhouse 2	8	44	352	12	188	25	40	
P/H Workshop 1	33	5	165	16	8	50	18	
P/H Workshop 2	33	5	165	16	188	50	18	
Area 1			1200	0		90	-	
Area 2			2400	0		-	-	
Powerhouse ground			1400	0		50	64	
Summary			6034				180	

Table 2-7: N02 - Analysis of the available roofs and proposed PV capacity for selected Roofs

2.7.4 Grid Infrastructure

2.7.4.1 *Electrical system*

- Generation: 400/230V
- Frequency: 50 Hz
- Phase and type: three phase Wye, earthed neutral, four wire system
- Distribution Network: Low Voltage (LV)

The power house in Vilufushi Island shall have four Diesel Generators that supply the complete load requirements of the island. The requirement related to existing and new Diesel Generators and associated systems are described in the above sections.

The island is fed through a 11 kV medium voltage and the low voltage distribution network connected to the main low voltage distribution board of the power house. The island is fed through LV distribution boxes located across the island and connected in a loop-in loop-out low voltage distribution network from the main low voltage distribution board of the power house.

Electrical supply to single phase consumers is commonly 230V, single phase, earthed neutral, two wire connections and for three phase consumers it is (400/230V) Wye, earthed neutral four wires.

2.7.4.2 *Grid infrastructure upgrade*

- The Contractor shall implement the grid upgrade works in Vilufushi Island in line with drawings listed below

S No.	Drawing Number	Title
1	G409-THAA-N02-SLD-1	NET WORK DIAGRAM FOR N02-VILUFUSHI POWER HOUSE
2	G409-THAA-N02-SLD-2	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (N02-VILUFUSHI)

Table 2-8: N02 - Drawings

This includes but not limited to the following works.

- Upgrade of the existing cable network from powerhouse to PV feed-in point.
- Modification or replacement of Distribution boxes to accommodate the proposed higher size cables connection.
- Modification or replacement of Distribution boxes to accommodate new connection of proposed PV.
- Replacement of existing Main LV Distribution board with the new LV Distribution board in the power house.

The modification / replacement of distribution boxes shall be designed to meet the final design kWp of the PV that will be approved by the Employer.

The new LV distribution board shall be designed in accordance with the latest international standards and shall include the automatic generator control systems and auto-synchronization systems.

The bidder shall closely coordinate with FENAKA to implement the critical changeover from the existing LV distribution board to the new LV distribution board in the power house without any disruption of power supply to the downstream feeders.

Bidder shall provide control cabling and junction boxes required for the proposed grid upgrade in the island.

Bidder shall provide necessary arrangements for safe dismantling, packaging of existing de-energized LV distribution board of the power house and distribution boxes and subsequent transportation of the same to a location identified by FENEKA.

2.7.4.3 *Schedule of Grid Infrastructure Modifications*

The following tables summarize the modifications related to the grid upgrade and PV plant connection in Vilufushi Island.

- Schedule of Proposed Grid/PV Connection Cables:

From	To	No. of Runs	Proposed Cable Size (Sq. mm)	Length (M)
Main LVDB (PH-FEEDER-RE1)	Fenaka Roof-PV	1	4C x 50	25
Main LVDB (PH-FEEDER-RE2)	Fenaka Free Field-PV	1	4C x 95	50

Table 2-9: N02 - Schedule of Proposed Grid/PV Connection Cables

- Installation of LV distribution equipment

Item Description	Quantity (Nos.)
Installation of New Distribution Box (DB)	0
Addition of RE Feeders to the Existing Main LV Distribution board in Power House	1

Table 2-10: N02 - Grid Upgradation

2.8 N03 Madifushi Island

The island of Madifushi is located in the Thaa Atoll. The general data of the island is shown in the following table:

Island code, name	N03 - Madifushi
Atoll name	Thaa
Utility	FENAKA
GPS coordinates	2°21'23.52" N 73°21'16.33" E
Inhabitants (approx.)	850
Harbour type	Harbour, 80 x 30m

Table 2-11: N03 - Island identification and general data

Figure 12: N03 - Map of the island

Figure 13: N03 - Location of the buildings with available roofs and powerhouse

2.8.1 Load profile

The island has a fluctuating energy consumption, which is shown in Figure 14 below.

The utility expect a steadily increase of the load by 10 %/year for the next 5 years.

The following load profiles for the year of 2024 shall be considered for sizing.

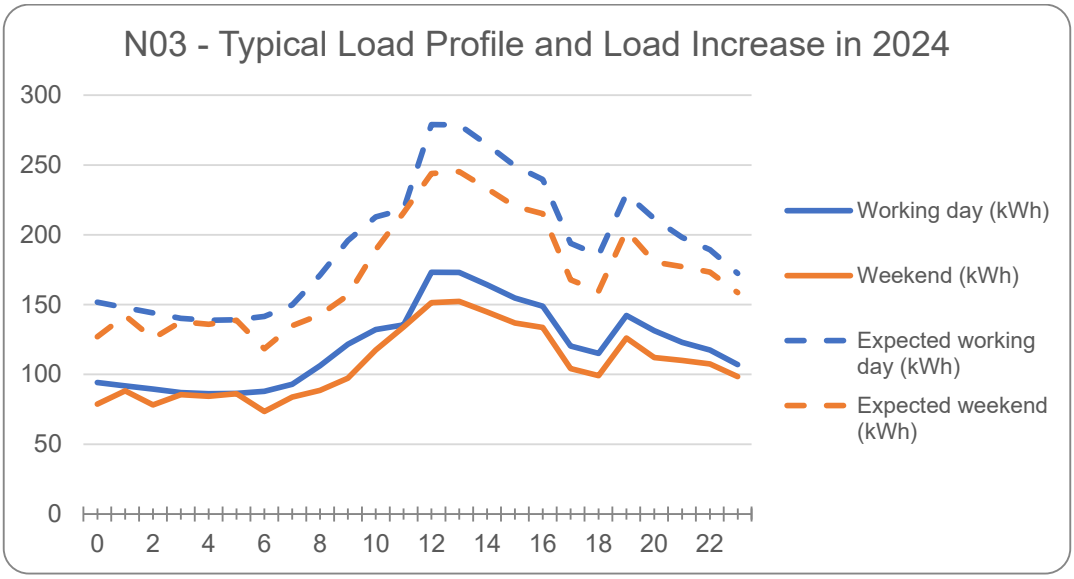


Figure 14: N03 - Typical daily load profile and evolution until 2024

	Average daily consumption [MWh/day]	Yearly consumption [MWh/yr]	Peak power [kW]
2019	2.88	1,051	300
2024	4.64	1,693	483

Table 2-12: N03 - Power consumption and peak power

2.8.2 Diesel Generators

2 Diesel Generators of different sizes are installed on the island.

The following table shows the existing Diesel Generators with specifications.

Item	Diesel Gen. 1	Diesel Gen. 2	Diesel Gen. 3
Engine manufacturer & motor references	Cummins NTA 855-G1B	Cummins 6CTAA8.3-G2	Cummins 6BTAA509G2
Engine power rating (continuous) [kW]	250	150	160
Available power under site temperature conditions [kW]	210	Damaged	85
Hours of operation / date of installation	Total: 28,289 18,647hrs after top overhaul		Total : 14563 hrs 1756hrs after overhaul
General maintenance performed [Yes/No] (if Yes, when)	Top overhaul done	Recently overhauled, however now valves are broken and now the generator is out of service.	No
Diesel generator controller (if any) manufacturer and type (e.g.: Woodward GCP, Easygen, etc.)	The old synchronize panel is retrofitted with DSE8810 controllers, however the out going feeders are overloaded and the generator main busbar also will be overloaded soon. Therefore the existing panel shall be replaced with a new panel.		
Relay for remote start available? [Yes/No]	Yes	Yes	Yes

Table 2-13: N03 - Diesel Generators currently installed

All Diesel Generators shall be integrated in the hybrid PV system.

2.8.3 Overview of possible installation locations for PV roof top systems

The table below shows the selected roofs for PV power plant installation and the estimated maximum PV power capacity installable on each roof. This estimation is based on a conservative approach considering standard 260Wp modules and enough margins in all directions. Roofs that were considered to be partially shaded most of the day were partially excluded from the estimation.

The Contractor shall however be responsible of checking the suitability of the roofs to install PV plants, optimize the design of each PV plant based on the available area, the electrical characteristics of its system and optimizing the yield (reduction of shading losses).

Building and name	Roof size X [m]	Roof size Y [m]	Area [m^2]	Slope [°]	Azimuth [°]	Distance to Powerhouse [m]	Proposed PV Capacity on selected roofs [kWp]	Comments
Powerhouse 1	27,8	8	222,4	15	25	25	30	
Powerhouse 2	27,8	8	222,4	15	205	25	30	
School A1	35	6	210	22	33	730	-	
School A2	35	6	210	22	213	730	-	
School B1	28	5,7	159,6	22	123	730	-	
School B2	28	5,7	159,6	22	303	730	-	
School C1	32	5,7	182,4	22	123	730	-	
School C2	32	5,7	182,4	22	303	730	-	
School D1	37	6	222	22	123	730	-	
School D2	37	6	222	22	303	730	-	
Health Centre A1	15	6	90	18		375	11	
Health Centre A2	15	6	90	18		375	11	
Health Centre B1	8,5	8,5	72,25	18		375	9	
Health Centre B2	8,5	8,5	72,25	18		375	9	
Health Centre C1	11	6	66	18		375	-	
Health Centre C2	11	6	66	18		375	-	
Area 1	29	10	290	0		50	40	
Area 2	23	10	230	0		50	-	

Table 2-14: N03 - Analysis of the available roofs and proposed PV capacity for selected Roofs

2.8.4 Grid Infrastructure

2.8.4.1 *Electrical system*

- Generation: 400/230V
- Frequency: 50 Hz
- Phase and type: three phase Wye, earthed neutral, four wire system
- Distribution Network: Low Voltage (LV)

The power house in Madifushi Island shall have three Diesel Generators that supply the complete load requirements of the island. The requirement related to existing and new Diesel Generators and associated systems are described in the above sections.

The island is fed through the low voltage distribution network connected to the main low voltage distribution board of the power house. The island is fed through LV distribution boxes located across the island and connected in a loop-in loop-out low voltage distribution network from the main low voltage distribution board of the power house.

Electrical supply to single phase consumers is commonly 230V, single phase, earthed neutral, two wire connections and for three phase consumers it is (400/230V) Wye, earthed neutral four wires.

2.8.4.2 *Grid infrastructure upgrade*

- The Contractor shall implement the grid upgrade works in Madifushi Island in line with drawings listed below.

S No.	Drawing Number	Title
1	G409-THAA-N03-SLD-1	NET WORK DIAGRAM FOR N03-MADIFUSHI POWER HOUSE
2	G409-THAA-N03-SLD-2	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (N03-MADIFUSHI)

Table 2-15: N03 - Drawings

This includes but not limited to the following works.

- Upgrade of the existing cable network from powerhouse to PV feed-in point.
- Modification or replacement of Distribution boxes to accommodate the proposed higher size cables connection.
- Modification or replacement of Distribution boxes to accommodate new connection of proposed PV.
- Replacement of existing Main LV Distribution board with the new LV Distribution board in the power house.

The modification / replacement of distribution boxes shall be designed to meet the final design kWp of the PV that will be approved by the Employer.

The new LV distribution board shall be designed in accordance with the latest international standards and shall include the automatic generator control systems and auto-synchronization systems.

The bidder shall closely coordinate with FENAKA to implement the critical changeover from the existing LV distribution board to the new LV distribution board in the power house without any disruption of power supply to the downstream feeders.

Bidder shall provide control cabling and junction boxes required for the proposed grid upgrade in the island.

Bidder shall provide necessary arrangements for safe dismantling, packaging of existing de-energized LV distribution board of the power house and distribution boxes and subsequent transportation of the same to a location identified by FENEKA.

2.8.4.3 Schedule of Grid Infrastructure Modifications

The following tables summarize the modifications related to the grid upgrade and PV plant connection in Madifushi Island.

- Schedule of Proposed Grid/PV Connection Cables:

From	To	No. of Runs	Proposed Cable Size (Sq.mm)	Length (M)
Main LVDB (PH-FEEDER-RE)	Power House Roof-PV	1	4C x 70	50
DB-D01	Health Centre-PV	1	4C x 50	120

Table 2-16: N03 - Schedule of Proposed Grid/PV Connection Cables

- Modification/Replacement of LV distribution equipment :

Item Description	Quantity (Nos.)
Replacement of Existing Distribution Box (DB)	1
Modification of existing of Distribution Box (DB)	-
Replacement of Existing Main LV Distribution board in Power House	1

Table 2-17: N03 - Grid Upgradation

2.9 N04 Dhiyamigili Island

The island of Dhiyamigili is located in the Thaa Atoll. It stretches over 1.800 meters in length at a width of 700m. The general data of the island is shown in the following table:

Island code, name	N04 - Dhiyamigili
Atoll name	Thaa
Utility	FENAKA
GPS coordinates	2°20'23.19" N 73°20'15.88" E
Inhabitants (approx.)	1,000
Harbour type	Harbour, 200x90m

Table 2-18: N04 - Island identification and general data

Figure 15: N04 - Map of the island

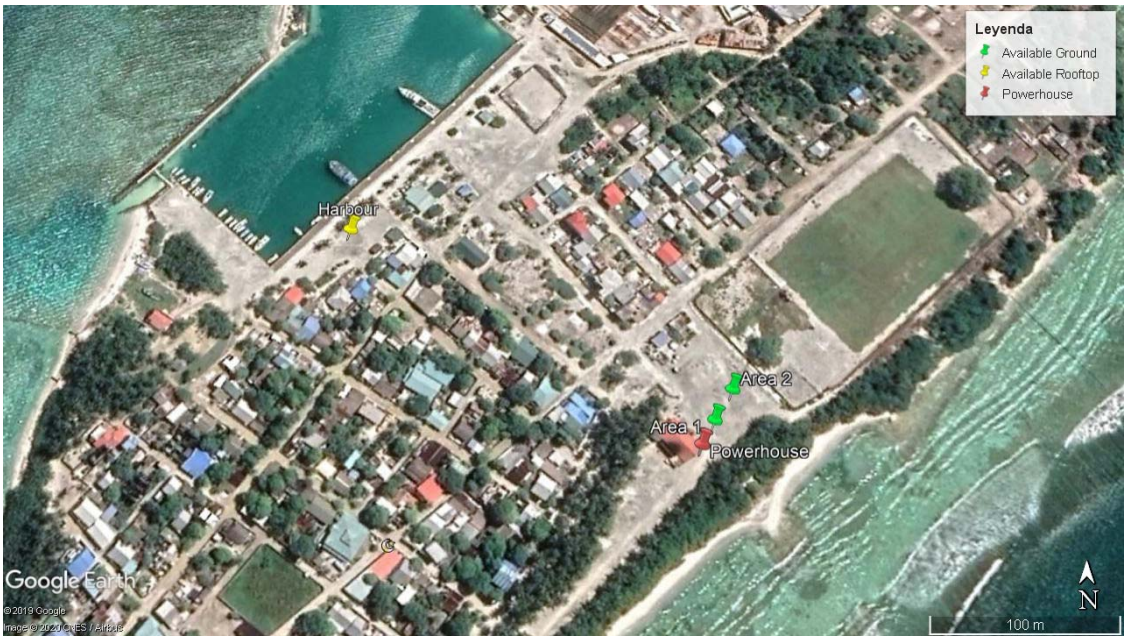


Figure 16: N04 - Location of the buildings with available roofs and powerhouse

2.9.1 Load profile

The island has a fluctuating energy consumption, which is shown in Figure 17

The utility expect a steadily increase of the load by 12 %/year for the next 5 years.

The following load profiles for the year of 2024 shall be considered for sizing.

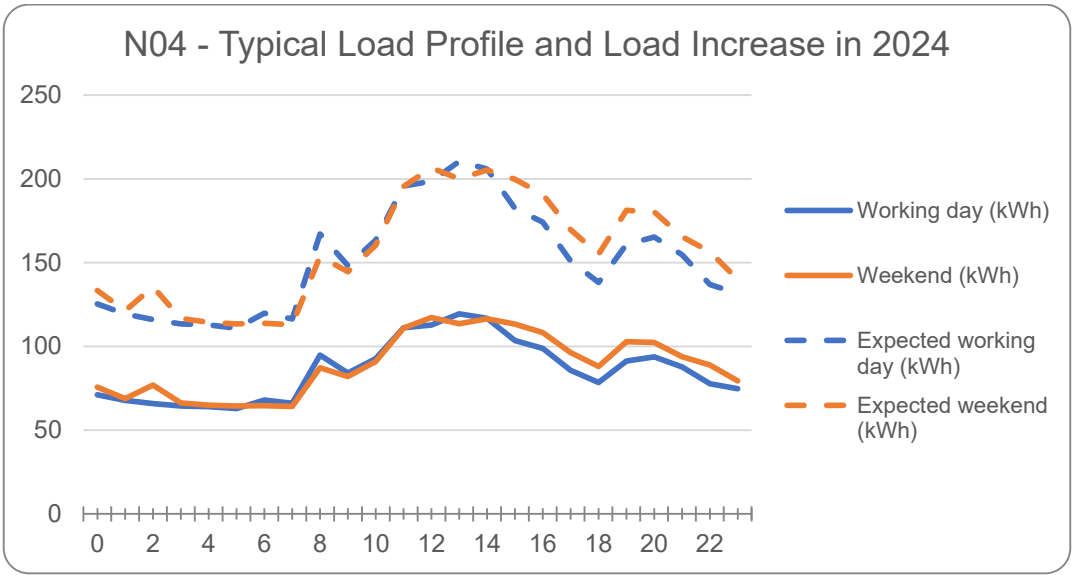


Figure 17: N04 - Typical daily load profile and evolution until 2024

	Average daily consumption [MWh/day]	Yearly consumption [MWh/yr]	Peak power [kW]
2019	2.05	749	170
2024	3.62	1,320	300

Table 2-19: N04 - Power consumption and peak power

2.9.2 Diesel Generators

3 Diesel Generators of different sizes are installed on the island.

The following Diesel Generators are currently used.

Item	Diesel Gen. 1	Diesel Gen. 2	Diesel Gen. 3
Engine manufacturer & motor references	Cummins 6CTA8.3.G2	Cummins NTA855.G1B	Cummins 6CTA8.3.G2
Engine power rating (continuous) [kW]	150	250	140
Available power under site temperature conditions [kW]	60kW	Max demand (170kW)	80kW
Hours of operation / date of installation	Data not available	20,217hrs	Data not available
General maintenance performed [Yes/No] (if Yes, when)	No	No	No
Diesel generator controller (if any) manufacturer and type (e.g.: Woodward GCP, Easygen, etc.)	DSE8810	DSE8810	DSE8810
Relay for remote start available? [Yes/No]	Yes	Yes	Yes

Table 2-20: N04 - Diesel Generators currently installed

All Diesel Generators shall be integrated in the hybrid PV system.

2.9.3 Overview of possible installation locations for PV roof top systems

The table below shows the selected roofs for PV power plant installation and the estimated maximum PV power capacity installable on each roof. This estimation is based on a conservative approach considering standard 260Wp modules and enough margins in all directions. Roofs that were considered to be partially shaded most of the day were partially excluded from the estimation.

The Contractor shall however be responsible of checking the suitability of the roofs to install PV plants, optimize the design of each PV plant based on the available area, the electrical characteristics of its system and optimizing the yield (reduction of shading losses)

Building and name	Roof size X [m]	Roof size Y [m]	Area [m^2]	Slope [°]	Azimuth [º]	Distance to Powerhouse [m]	Proposed PV Capacity on selected roofs [kWp]	Comments
CouncilFree Field Area 2	32	27	864			50	90	
Summary			**864**				**90**	

Table 2-21: N04 - Analysis of the available roofs and proposed PV capacity for selected Roofs

2.9.4 Grid Infrastructure

2.9.4.1 *The Electrical system*

- Generation: 400/230V
- Frequency: 50 Hz
- Phase and type: three phase Wye, earthed neutral, four wire system
- Distribution Network: Low Voltage (LV)

The power house in Dhiyamigili Island shall have three Diesel Generators that supply the complete load requirements of the island. The requirement related to existing and new Diesel Generators and associated systems are described in the above sections.

The island is fed through the low voltage distribution network connected to the main low voltage distribution board of the power house. The island is fed through LV distribution boxes located across the island and connected in a loop-in loop-out low voltage distribution network from the main low voltage distribution board of the power house.

Electrical supply to single phase consumers is commonly 230V, single phase, earthed neutral, two wire connections and for three phase consumers it is (400/230V) Wye, earthed neutral four wires.

2.9.4.2 *Grid infrastructure upgrade*

- The Contractor shall implement the grid upgrade works in Dhiyamigili Island in line with drawings listed below.

S No.	Drawing Number	Title
1	G409-THAA-N04-SLD-1	NET WORK DIAGRAM FOR N04-DHIYAMIGILI POWER HOUSE
2	G409-THAA-N04-SLD-2	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (N04-DHIYAMIGILI)

Table 2-22: N04 - Drawings

This includes but not limited to the following works.

- Upgrade of the existing cable network from powerhouse to PV feed-in point.
- Modification or replacement of Distribution boxes to accommodate the proposed higher size cables connection.
- Modification or replacement of Distribution boxes to accommodate new connection of proposed PV.
- Replacement of existing Main LV Distribution board with the new LV Distribution board in the power house.

The modification / replacement of distribution boxes shall be designed to meet the final design kWp of the PV that will be approved by the Employer.

The new LV distribution board shall be designed in accordance with the latest international standards and shall include the automatic generator control systems and auto-synchronization systems.

The bidder shall closely coordinate with FENAKA to implement the critical changeover from the existing LV distribution board to the new LV distribution board in the power house without any disruption of power supply to the downstream feeders.

Bidder shall provide control cabling and junction boxes required for the proposed grid upgrade in the island.

Bidder shall provide necessary arrangements for safe dismantling, packaging of existing de-energized LV distribution board of the power house and distribution boxes and subsequent transportation of the same to a location identified by FENEKA.

2.9.4.3 Schedule of Grid Infrastructure Modifications

The following tables summarize the modifications related to the grid upgrade and PV plant connection in Dhiyamigili Island.

- Schedule of Proposed Grid/PV Connection Cables:

From	To	No. of Runs	Proposed Cable Size (Sq.mm)	Length (M)
Main LVDB (PH-FEEDER RE1)	Island Council Free Field-PV	1	4C x 120	50

Table 2-23: N04 - Schedule of Proposed Grid/PV Connection Cables

- Modification/Replacement of LV distribution equipment

Item Description	Quantity (Nos.)
Replacement of Existing Distribution Box (DB)	0
Modification of Existing Main LV Distribution board in Power House	0

Table 2-24: N04 - Grid Upgradation

2.10 N05 Guraidhoo Island

The island of Guraidhoo is located in the Thaa Atoll. The general data of the island is shown in the following table:

Island code, name	N05 - Guraidhoo
Atoll name	Thaa
Utility	FENAKA
6°21'36.39" N 73°02'55.53" E	2°19'30.18" N 73°19'04.87" E
Inhabitants (approx.)	2,132
Harbour type	Harbour, 215 x 80m

Table 2-25: N05 - Island identification and general data

Figure 18: N05 - Map of the island

Figure 19: N05 - Location of the buildings with available roofs and powerhouse

2.10.1 Load profile

The island has a fluctuating energy consumption, which is shown in Figure 20.

The utility expect a steadily increase of the load by 12 %/year for the next 5 years.

The following load profiles for the year of 2024 shall be considered for sizing.

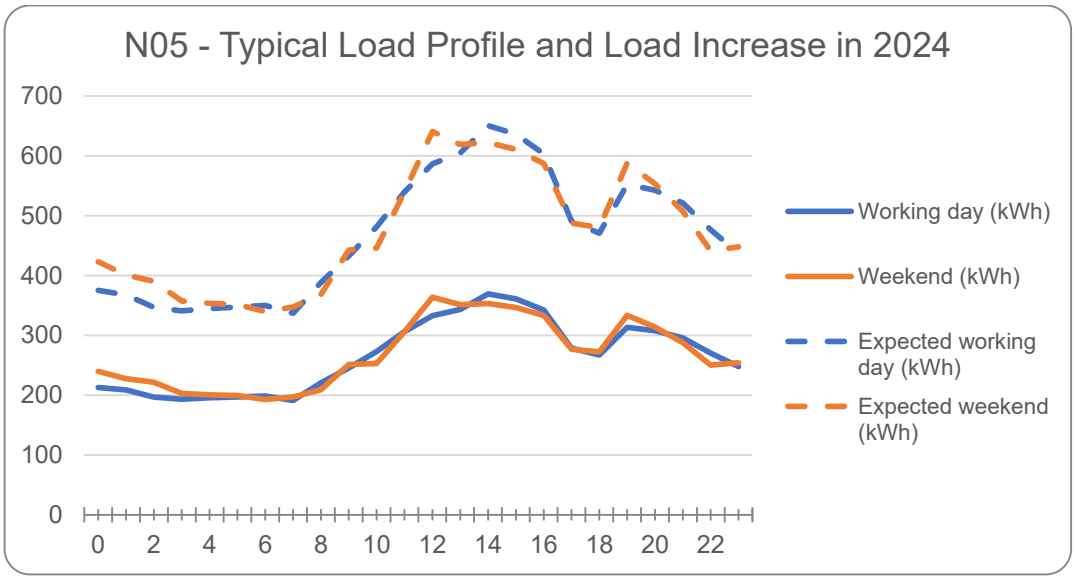


Figure 20: N05 - Typical daily load profile and evolution until 2024

	Average daily consumption [MWh/day]	Yearly consumption [MWh/yr]	Peak power [kW]
2019	6.37	2,324	759
2024	11.22	4,095	1,337

Table 2-26: N05 - Power consumption and peak power

2.10.2 Diesel Generators

3 Diesel Generators of different sizes are installed on the island.

The following Diesel Generators are currently used.

Item	Diesel Gen. 1	Diesel Gen. 2	Diesel Gen. 3
Engine manufacturer & motor references	Cummins KTA19-G3	Cummins KT38-GA	DEUTZ BF8M1015CP
Engine power rating (continuous) [kW]	360	600	800
Available power under site temperature conditions [kW]	240	470	700
Hours of operation / date of installation	24200	1 year	New

General maintenance performed [Yes/No] (if Yes, when)	No	New	No
Diesel generator controller (if any) manufacturer and type (e.g.: Woodward GCP, Easygen, etc.)	Panel to be Replaced	Panel to be Replaced	Panel to be Replaced
Relay for remote start available? [Yes/No]	Panel to be Replaced	Panel to be Replaced	Panel to be Replaced

Table 2-27: N05 - Diesel Generators currently installed

All Diesel Generators shall be integrated in the hybrid PV system.

2.10.3 Overview of possible installation locations for PV roof top systems

The table below shows the selected roofs for PV power plant installation and the estimated maximum PV power capacity installable on each roof. This estimation is based on a conservative approach considering standard 260Wp modules and enough margins in all directions. Roofs that were considered to be partially shaded most of the day were partially excluded from the estimation.

The Contractor shall however be responsible of checking the suitability of the roofs to install PV plants, optimize the design of each PV plant based on the available area, the electrical characteristics of its system and optimizing the yield (reduction of shading losses).

Building and name	Roof size X [m]	Roof size Y [m]	Area [m^2]	Slope [°]	Azimuth [°]	Distance to Powerhouse [m]	Proposed PV Capacity on selected roofs [kWp]	Comments
Powerhouse 1	25	5,2	130	16	135	25	20	
Powerhouse 2	25	5,2	130	16	315	25	20	
Powerhouse GM	25	6	150			25	20	
School A1	31	6,75	209,25	15	234	150	25	
School A2	31	6,75	209,25	15	54	150	25	
School B1	16	6,5	104	15	143	150	10	
School B2	16	6,5	104	15	323	150	10	
School C1	32	5,5	176	22	143	150	25	
School C2	32	5,5	176	22	323	150	25	
Health Centre A1	14,4	4,7	67,68	16	230	170		
Health Centre A2	14,4	4,7	67,68	16	50	170	-	
Health Centre B1	24,6	8,2	201,72	16	230	170	30	
Health Centre B2	24,6	8,2	201,72	16	50	170	30	
Health Centre C1	7,3	3,25	23,725	16	230	170	-	
Health Centre C2	7,3	3,25	23,725	16	50	170	-	
Health Centre D1	12,8	4,45	56,96	16	230	170	-	
Health Centre D2	12,8	4,45	56,96	16	50	170	-	
Sewerage Plant 1	14	7	98	12	230	35	-	
Sewerage Plant 2	14	7	98	12	50	35	-	
Summary							180	

Table 2-28: N05 - Analysis of the available roofs and proposed PV capacity for selected Roofs

2.10.4 Grid Infrastructure

2.10.4.1 *Electrical system*

- Generation: 400/230V
- Frequency: 50 Hz
- Phase and type: three phase Wye, earthed neutral, four wire system
- Distribution Network: Low Voltage (LV)

The power house in Guraidhoo Island shall have three Diesel Generators that supply the complete load requirements of the island. The requirement related to existing and new Diesel Generators and associated systems are described in the above sections.

The island is fed through the low voltage distribution network connected to the main low voltage distribution board of the power house. The island is fed through LV distribution boxes located across the island and connected in a loop-in loop-out low voltage distribution network from the main low voltage distribution board of the power house.

Electrical supply to single phase consumers is commonly 230V, single phase, earthed neutral, two wire connections and for three phase consumers it is (400/230V) Wye, earthed neutral four wires.

2.10.4.2 *Grid infrastructure upgrade*

- The Contractor shall implement the grid upgrade works in Guraidhoo Island in line with drawings listed below.

S No.	Drawing Number	Title
1	G409-THAA-N05-SLD-1	NET WORK DIAGRAM FOR N05-GURAIDHOO POWER HOUSE
2	G409-THAA-N05-SLD-2	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (N05-GURAIDHOO)

Table 2-29: N05 - Drawings

This includes but not limited to the following works.

- Upgrade of the existing cable network from powerhouse to PV feed-in point.
- Modification or replacement of Distribution boxes to accommodate the proposed higher size cables connection.
- Modification or replacement of Distribution boxes to accommodate new connection of proposed PV.
- Replacement of existing Main LV Distribution board with the new LV Distribution board in the power house.

The modification / replacement of distribution boxes shall be designed to meet the final design kWp of the PV that will be approved by the Employer.

The new LV distribution board shall be designed in accordance with the latest international standards and shall include the automatic generator control systems and auto-synchronization systems.

The bidder shall closely coordinate with FENAKA to implement the critical changeover from the existing LV distribution board to the new LV distribution board in the power house without any disruption of power supply to the downstream feeders.

Bidder shall provide control cabling and junction boxes required for the proposed grid upgrade in the island.

Bidder shall provide necessary arrangements for safe dismantling, packaging of existing de-energized LV distribution board of the power house and distribution boxes and subsequent transportation of the same to a location identified by FENEKA.

2.10.4.3 Schedule of Grid Infrastructure Modifications

The following tables summarize the modifications related to the grid upgrade and PV plant connection in Guraidhoo Island.

- Schedule of Proposed Grid/PV Connection Cables:

From	To	No. of Runs	Proposed Cable Size (Sq.mm)	Length (M)
Main LVDB (PH-FEEDER-RE1)	Power House Free Field-PV	1	4C x 35	35
Main LVDB (PH-FEEDER-RE2)	School-PV	1	4C x 150	150

Table 2-30: N05 - Schedule of Cables Power House

- Modification/Replacement of LV distribution equipment

Item Description	Quantity (Nos.)
Replacement of Existing Distribution Box (DB)	-
Modification of existing of Distribution Box (DB)	-
Replacement of Existing Main LV Distribution board in Power House	1

Table 2-31: N05 - Grid Upgradation

2.11 N06 Kandoodhoo Island

The island of Kandoodhoo is located in the Thaa Atoll. The general data of the island is shown in the following table:

Island code, name	N06 – Kandoodhoo
Atoll name	Thaa
Utility	FENAKA
GPS coordinates	2°19'18.01" N 72°55'02.88" E
Inhabitants (approx.)	671
Harbour type	Harbour, 120x75m

Table 2-32: N06 - Island identification and general data

Figure 21: N06 - Map of the island

Figure 22: N06 - Location of the buildings with available roofs and powerhouse

2.11.1 Load profile

The island has a fluctuating energy consumption, which is shown in Figure 23

The utility expect a steadily increase of the load by 7 %/year for the next 5 years.

The following load profiles for the year of 2024 shall be considered for sizing.

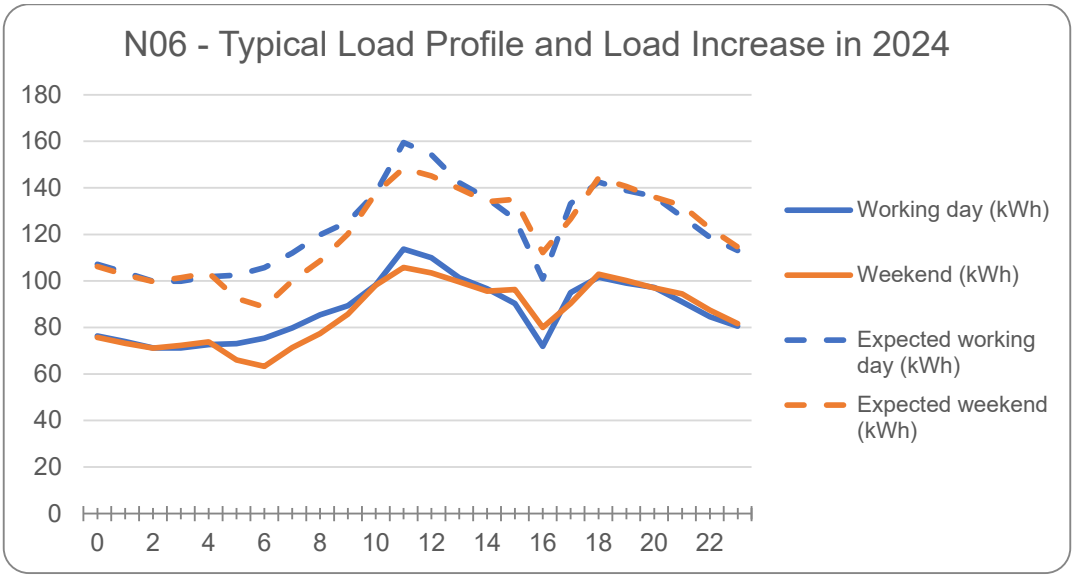


Figure 23: N06 - Typical daily load profile and evolution until 2024

	Average daily consumption [MWh/day]	Yearly consumption [MWh/yr]	Peak power [kW]

2019	2.10	766	125
2024	2.94	1,074	175

Table 2-33: N06 - Power consumption and peak power

2.11.2 Diesel Generators

3 Diesel Generators of different sizes are installed on the island.

The following Diesel Generators are currently used.

Item	Diesel Gen. 1	Diesel Gen. 2	Diesel Gen. 3
Engine manufacturer & motor references	Cummins 6ACTAA8.3-G2	Komatsu S6D125-1	Cummins 6CTAA8.3-G2
Engine power rating (continuous) [kW]	160	220	160
Available power under site temperature conditions [kW]	160	120 (radiator too small)	90 (water leakage and radiator issues)
Hours of operation / date of installation			
General maintenance performed [Yes/No] (if Yes, when)	New Genset	No	No
Diesel generator controller (if any) manufacturer and type (e.g.: Woodward GCP, Easygen, etc.)	DSE8810	DSE8810	DSE8810
Relay for remote start available? [Yes/No]	Yes	Yes	Yes

Table 2-34: N06 - Diesel Generators currently installed

All Diesel Generators shall be integrated in the hybrid PV system.

2.11.3 Overview of possible installation locations for PV roof top systems

The table below shows the selected roofs for PV power plant installation and the estimated maximum PV power capacity installable on each roof. This estimation is based on a conservative approach considering standard 260Wp modules and enough margins in all directions. Roofs that were considered to be partially shaded most of the day were partially excluded from the estimation.

The Contractor shall however be responsible of checking the suitability of the roofs to install PV plants, optimize the design of each PV plant based on the available area, the electrical characteristics of its system and optimizing the yield (reduction of shading losses)

Building and name	Roof size X [m]	Roof size Y [m]	Area [m^2]	Slope [°]	Azimuth [º]	Distance to Powerhouse [m]	Proposed PV Capacity on selected roofs [kWp]	Comments
Powerhouse 1	25	5,5	137,5	16	180	25	20	
Powerhouse 2	25	5,5	137,5	16	0	25	20	
Area 1 A	10	45	450			25	65	
Area 1 B	10	15	150			25	20	
Area 2	30	20	600			70	90	
Harbour Area	65	9	585			350	85	
Summary			**1475**				**300**	

Table 2-35: N06 - Analysis of the available roofs and proposed PV capacity for selected Roofs

2.11.4 Grid Infrastructure

2.11.4.1 *Electrical system*

- Generation: 400/230V
- Frequency: 50 Hz
- Phase and type: three phase Wye, earthed neutral, four wire system
- Distribution Network: Low Voltage (LV)

The power house in Kandoodhoo Island shall have three Diesel Generators that supply the complete load requirements of the island. The requirement related to existing and new Diesel Generators and associated systems are described in the above sections.

The island is fed through the low voltage distribution network connected to the main low voltage distribution board of the power house. The island is fed through LV distribution boxes located across the island and connected in a loop-in loop-out low voltage distribution network from the main low voltage distribution board of the power house.

Electrical supply to single phase consumers is commonly 230V, single phase, earthed neutral, two wire connections and for three phase consumers it is (400/230V) Wye, earthed neutral four wires.

2.11.4.2 *Grid infrastructure upgrade*

- The Contractor shall implement the grid upgrade works in Kandoodhoo Island in line with drawings listed below.

S No.	Drawing Number	Title
1	G409-THAA-N06-SLD-1	NET WORK DIAGRAM FOR N06-KANDOODHOO POWER HOUSE
2	G409-THAA-N06-SLD-2	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (N06-KANDOODHOO)

Table 2-36: N06 - Drawings

This includes but not limited to the following works.

- Upgrade of the existing cable network from powerhouse to PV feed-in point.
- Modification or replacement of Distribution boxes to accommodate the proposed higher size cables connection.
- Modification or replacement of Distribution boxes to accommodate new connection of proposed PV.
- Replacement of existing Main LV Distribution board with the new LV Distribution board in the power house.

The modification / replacement of distribution boxes shall be designed to meet the final design kWp of the PV that will be approved by the Employer.

The new LV distribution board shall be designed in accordance with the latest international standards and shall include the automatic generator control systems and auto-synchronization systems.

The bidder shall closely coordinate with FENAKA to implement the critical changeover from the existing LV distribution board to the new LV distribution board in the power house without any disruption of power supply to the downstream feeders.

Bidder shall provide control cabling and junction boxes required for the proposed grid upgrade in the island.

Bidder shall provide necessary arrangements for safe dismantling, packaging of existing de-energized LV distribution board of the power house and distribution boxes and subsequent transportation of the same to a location identified by FENEKA.

2.11.4.3 Schedule of Grid Infrastructure Modifications

The following tables summarize the modifications related to the grid upgrade and PV plant connection in Kandoodhoo Island.

- Schedule of Proposed Grid/PV Connection Cables:

From	To	No. of Runs	Proposed Cable Size (Sq.mm)	Length (M)
Main LVDB (FEEDER RE1)	Powerhouse-PV	1	4C x 70	25
Main LVDB (FEEDER RE1)	Free Field (Infront of Powerhouse)-PV	1	4C x 70	45
Main LVDB (FEEDER RE1)	DB	1	4C x 240	200
DB	Harbour Free Field	1	4C x 240	150

Table 2-37: N06 - Schedule of Proposed Grid/PV Connection Cables

- Modification/Replacement of LV distribution equipment

Item Description	Quantity (Nos.)
Replacement of Existing Distribution Box (DB)	1
Modification of existing of Distribution Box (DB)	-
Modification of Existing Main LV Distribution board in Power House	1

Table 2-38: N06 - Grid Upgradation

2.12 N07 Vandhoo Island

The island of Vandhoo is located in the Thaa Atoll. The general data of the island is shown in the following table:

Island code, name	N07 - Vandhoo
Atoll name	Thaa
Utility	FENAKA
GPS coordinates	2°17'29.81" N 72°56'32.56" E
Inhabitants (approx.)	700
Harbour type	Harbour, 90m wide inner harbour

Table 2-39: N07 - Island identification and general data

Figure 24: N07 - Map of the island

Figure 25: N07 - Location of the buildings with available roofs and powerhouse

2.12.1 Load profile

The island has a fluctuating energy consumption, which is shown in

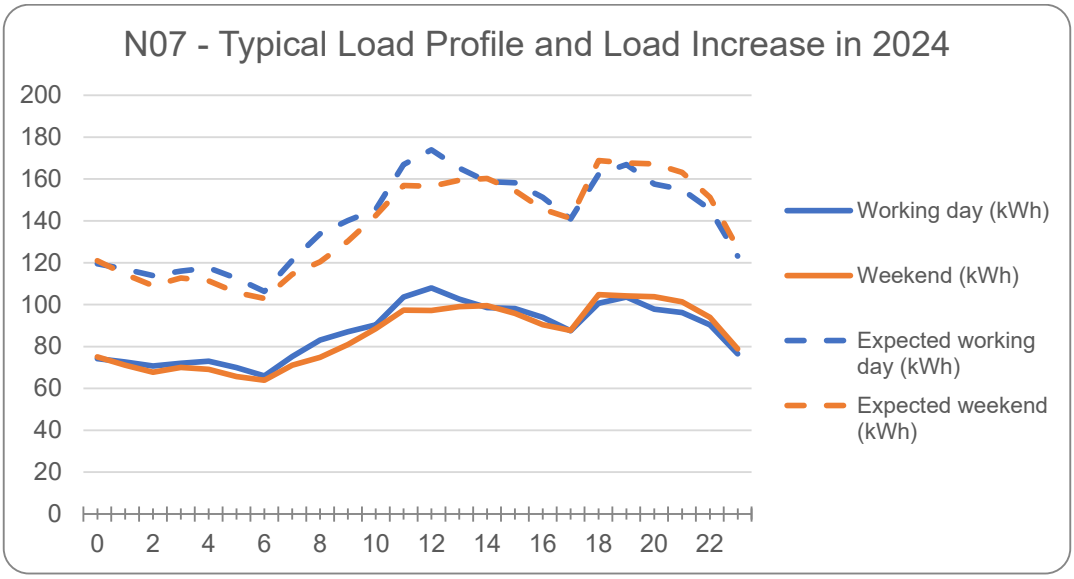


Figure 26.

The utility expect a steadily increase of the load by 10 %/year for the next 5 years.

The following load profiles for the year of 2024 shall be considered for sizing.

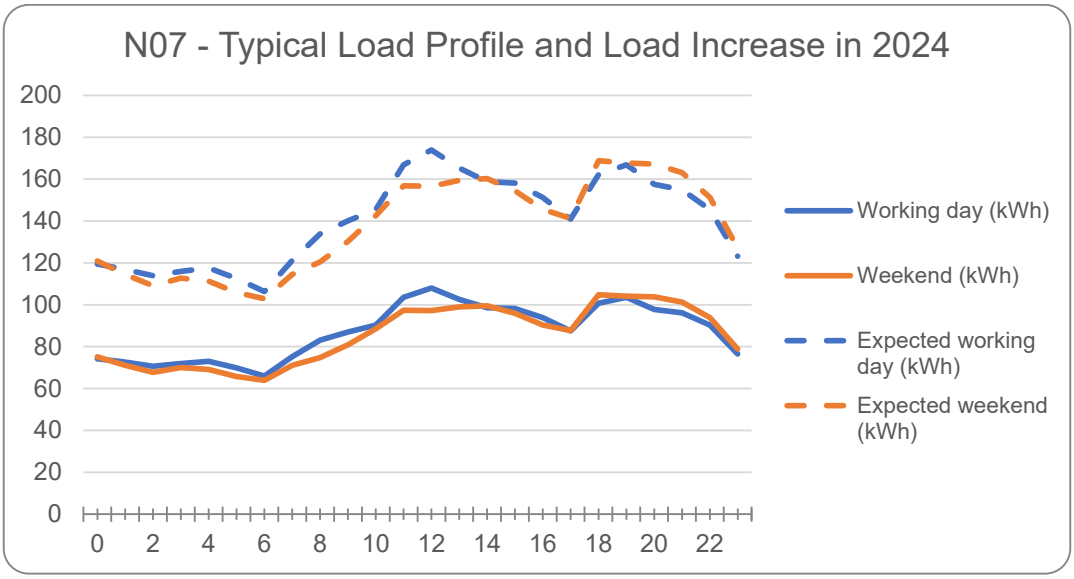


Figure 26: N07 - Typical daily load profile and evolution until 2024

	Average daily consumption [MWh/day]	Yearly consumption [MWh/yr]	Peak power [kW]
2019	2.09	763	120
2024	3.37	1,229	193

Table 2-40: N07 - Power consumption and peak power

2.12.2 Diesel Generators

3 Diesel Generators of different sizes are installed on the island.

The following Diesel Generators are currently used.

Item	Diesel Gen. 1	Diesel Gen. 2	Diesel Gen. 3
Engine manufacturer & motor references	Cummins 6CTAA8.3G2	Cummins 6CTAA8.3G2	Cummins TD720GE
Engine power rating (continuous) [kW]	160	160	112
Available power under site temperature conditions [kW]	150	150	55
Hours of operation / date of installation	data not available	data not available	data not available
General maintenance performed [Yes/No] (if Yes, when)	data not available	data not available	data not available
Diesel generator controller (if any) manufacturer and type (e.g.: Woodward GCP, Easygen, etc.)	N/A	N/A	N/A
Relay for remote start available? [Yes/No]	No	No	No

Table 2-41: N07 - Diesel Generators currently installed

All Diesel Generators shall be integrated in the hybrid PV system.

2.12.3 Overview of possible installation locations for PV roof top systems

The table below shows the selected roofs for PV power plant installation and the estimated maximum PV power capacity installable on each roof. This estimation is based on a conservative approach considering standard 260Wp modules and enough margins in all directions. Roofs that were considered to be partially shaded most of the day were partially excluded from the estimation.

The Contractor shall however be responsible of checking the suitability of the roofs to install PV plants, optimize the design of each PV plant based on the available area, the electrical characteristics of its system and optimizing the yield (reduction of shading losses).

Building and name	Roof size X [m]	Roof size Y [m]	Area [m^2]	Slope [°]	Azimuth [º]	Distance to Powerhouse [m]	Proposed PV Capacity on selected roofs [kWp]	Comments
Powerhouse 1	11,5	5,45	62,675	16	166	25	-	
Powerhouse 2	11,5	5,45	62,675	16	346	25	8	
Area 1 A	20	12	240	0		25	35	
Area 1 B	7	15	105	0		25	15	
Area 2	32	16,20	550	0		260	77	
Area 3	18	62	1116			180	165	
Summary			**720**				**300**	

Table 2-42: N07 - Analysis of the available roofs and proposed PV capacity for selected Roofs

2.12.4 Grid Infrastructure

2.12.4.1 *Electrical system*

- Generation: 400/230V
- Frequency: 50 Hz
- Phase and type: three phase Wye, earthed neutral, four wire system
- Distribution Network: Low Voltage (LV)

The power house in Vandhoo Island shall have three Diesel Generators that supply the complete load requirements of the island. The requirement related to existing and new Diesel Generators and associated systems are described in the above sections.

The island is fed through the low voltage distribution network connected to the main low voltage distribution board of the power house. The island is fed through LV distribution boxes located across the island and connected in a loop-in loop-out low voltage distribution network from the main low voltage distribution board of the power house.

Electrical supply to single phase consumers is commonly 230V, single phase, earthed neutral, two wire connections and for three phase consumers it is (400/230V) Wye, earthed neutral four wires.

2.12.4.2 *Grid infrastructure upgrade*

- The Contractor shall implement the grid upgrade works in Vandhoo Island in line with drawings listed below.

S No.	Drawing Number	Title
1	G409-THAA-N07-SLD-1	NET WORK DIAGRAM FOR N07-VANDHOO POWER HOUSE
2	G409-THAA-N07-SLD-2	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (N07-VANDHOO)

Table 2-43: N07 - Drawings

This includes but not limited to the following works.

- Upgrade of the existing cable network from powerhouse to PV feed-in point.
- Modification or replacement of Distribution boxes to accommodate the proposed higher size cables connection.
- Modification or replacement of Distribution boxes to accommodate new connection of proposed PV.
- Replacement of existing Main LV Distribution board with the new LV Distribution board in the power house.

The modification / replacement of distribution boxes shall be designed to meet the final design kWp of the PV that will be approved by the Employer.

The new LV distribution board shall be designed in accordance with the latest international standards and shall include the automatic generator control systems and auto-synchronization systems.

The bidder shall closely coordinate with FENAKA to implement the critical changeover from the existing LV distribution board to the new LV distribution board in the power house without any disruption of power supply to the downstream feeders.

Bidder shall provide control cabling and junction boxes required for the proposed grid upgrade in the island.

Bidder shall provide necessary arrangements for safe dismantling, packaging of existing de-energized LV distribution board of the power house and distribution boxes and subsequent transportation of the same to a location identified by FENEKA

2.12.4.3 Schedule of Grid Infrastructure Modifications

The following tables summarize the modifications related to the grid upgrade and PV plant connection in Vandhoo Island.

- Schedule of Proposed Grid/PV Connection Cables:

From	To	No. of Runs	Proposed Cable Size (sq.mm)	Length (m)
Main LVDB (PH-FEEDER-RE1)	Powerhouse-PV	1	4C x 50	25
Main LVDB (PH-FEEDER-A)	DB-A1	1	4C x 150	240
DB-A1	Harbour(North) Free Field-PV	1	4C x 70	50
Main LVDB (PH-FEEDER-RE2)	Harbour(West) Free Field-PV	1	4C x 185	180

Table 2-44: N07 - Schedule of Grid/PV Connection Cables

- Modification/Replacement of LV distribution equipment

Item Description	Quantity (Nos.)
Replacement of Existing Distribution Box (DB)	1
Modification of existing of Distribution Box (DB)	-
Addition of BESS and RE Feeders to Existing Main LV Distribution board in Power House	1

Table 2-45: N07 - Grid Upgradation

2.13 N08 Hirilandhoo Island

The island of Hirilandhoo is located in the Thaa Atoll. The general data of the island is shown in the following table:

Island code, name	N08 - Hirilandhoo
Atoll name	Thaa
Utility	FENAKA
GPS coordinates	2°16'18.17" N 72°55'53.94" E
Inhabitants (approx.)	1,170
Harbour type	Harbour, 186x55m

Table 2-46: N08 - Island identification and general data

Figure 27: N08 - Map of the island

Figure 28: N08 - Location of the buildings with available roofs and powerhouse

2.13.1 Load profile

The island has a fluctuating energy consumption, which is shown in Figure 29.

The utility expect a steadily increase of the load by 10 %/year for the next 5 years.

The following load profiles for the year of 2024 shall be considered for sizing.

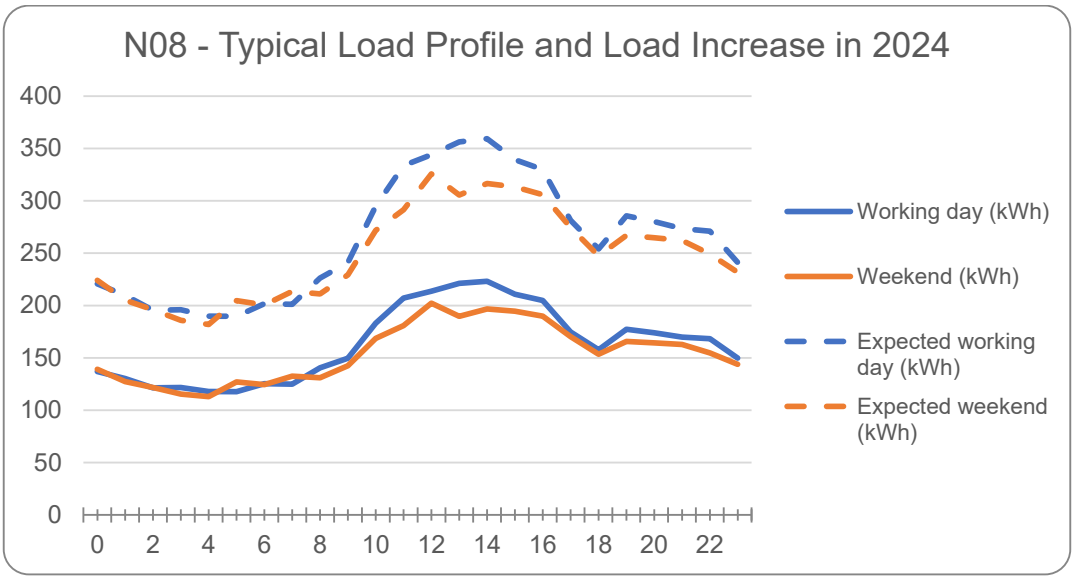


Figure 29: N08 - Typical daily load profile and evolution until 2024

	Average daily consumption [MWh/day]	Yearly consumption [MWh/yr]	Peak power [kW]
2019	3.92	1,431	-
2024	6.32	2,305	-

Table 2-47: N08 - Power consumption and peak power

2.13.2 Diesel Generators

3 Diesel Generators of different sizes are installed on the island. All Diesel Generators shall be integrated in the hybrid PV system.

Item	Diesel Gen. 1	Diesel Gen. 2	Diesel Gen. 3
Engine manufacturer & motor references	Cummins KTA19	Cummins NT855G1-A	Cummins NT855G1-B
Engine power rating (continuous) [kW]	400	250	250
Available power under site temperature conditions [kW]	New / Max demand	180	140
Hours of operation / date of installation	New	Generators are in bad shape as maintenance was not carried out on time	Generators are in bad shape as maintenance was not carried out on time
General maintenance performed [Yes/No] (if Yes, when)	-	No	No
Diesel generator controller (if any) manufacturer and type (e.g.: Woodward GCP, Easygen, etc.)	Deep Sea 8810	Deep Sea 8810	Deep Sea 8810
Relay for remote start available? [Yes/No]	Yes	Yes	Yes

Table 2-48: N08 - Diesel Generators currently installed

All Diesel Generators shall be integrated in the hybrid PV system.

2.13.3 Overview of possible installation locations for PV roof top systems

The table below shows the selected roofs for PV power plant installation and the estimated maximum PV power capacity installable on each roof. This estimation is based on a conservative approach considering standard 260Wp modules and enough margins in all directions. Roofs that were considered to be partially shaded most of the day were partially excluded from the estimation.

The Contractor shall however be responsible of checking the suitability of the roofs to install PV plants, optimize the design of each PV plant based on the available area, the electrical characteristics of its system and optimizing the yield (reduction of shading losses).

Building and name	Roof size X [m]	Roof size Y [m]	Area [m^2]	Slope [°]	Azimuth [º]	Distance to Powerhouse [m]	Proposed PV Capacity on selected roofs [kWp]	Comments
Area 1	29	13,5	391,5	0		170	40	
Area 2	22,2	20	444	0		150	50	
Area 3 A	22	14	308	0		35	30	
Area 3 B	31	18	558	0		35	60	
Summary							**180**	

Table 2-49: N08 - Analysis of the available roofs and proposed PV capacity for selected Roofs

2.13.4 Grid Infrastructure

2.13.4.1 *Electrical system*

- Generation: 400/230V
- Frequency: 50 Hz
- Phase and type: three phase Wye, earthed neutral, four wire system
- Distribution Network: Low Voltage (LV)

The power house in Hirilandhoo Island shall have three Diesel Generators that supply the complete load requirements of the island. The requirement related to existing and new Diesel Generators and associated systems are described in the above sections.

The island is fed through the low voltage distribution network connected to the main low voltage distribution board of the power house. The island is fed through LV distribution boxes located across the island and connected in a loop-in loop-out low voltage distribution network from the main low voltage distribution board of the power house.

Electrical supply to single phase consumers is commonly 230V, single phase, earthed neutral, two wire connections and for three phase consumers it is (400/230V) Wye, earthed neutral four wires.

2.13.4.2 *Grid infrastructure upgrade*

- The Contractor shall implement the grid upgrade works in Hirilandhoo Island in line with drawings listed below.

S No.	Drawing Number	Title
1	G409-THAA-N08-SLD-1	NET WORK DIAGRAM FOR N08-HIRILANDHOO POWER HOUSE
2	G409-THAA-N08-SLD-2	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (N08-HIRILANDHOO)

Table 2-50: N08 - Drawings

This includes but not limited to the following works.

- Upgrade of the existing cable network from powerhouse to PV feed-in point.
- Modification or replacement of Distribution boxes to accommodate the proposed higher size cables connection.
- Modification or replacement of Distribution boxes to accommodate new connection of proposed PV.
- Replacement of existing Main LV Distribution board with the new LV Distribution board in the power house.

The modification / replacement of distribution boxes shall be designed to meet the final design kWp of the PV that will be approved by the Employer.

The new LV distribution board shall be designed in accordance with the latest international standards and shall include the automatic generator control systems and auto-synchronization systems.

The bidder shall closely coordinate with FENAKA to implement the critical changeover from the existing LV distribution board to the new LV distribution board in the power house without any disruption of power supply to the downstream feeders.

Bidder shall provide control cabling and junction boxes required for the proposed grid upgrade in the island.

Bidder shall provide necessary arrangements for safe dismantling, packaging of existing de-energized LV distribution board of the power house and distribution boxes and subsequent transportation of the same to a location identified by FENEKA.

2.13.4.3 Schedule of Grid Infrastructure Modifications

The following tables summarize the modifications related to the grid upgrade and PV plant connection in Hirilandhoo Island.

- Schedule of Proposed Grid/PV Connection Cables:

From	To	No. of Runs	Proposed Cable Size (sq.mm)	Length (M)
Main LVDB (PH-FEEDER-RE1)	Powerhouse Free Field-PV	1	4C x 70	35
Main LVDB (PH-FEEDER-RE2)	Ferry Terminal Area Free Field-PV	1	4C x 50	150
Main LVDB (PH-FEEDER- RE3)	Council Free Field	1	4C x 50	170

Table 2-51: N08 - Schedule of Proposed Grid/PV Connection Cables

- Modification/Replacement of LV distribution equipment

Item Description	Quantity (Nos.)
Replacement of Existing Distribution Box (DB)	1
Modification of existing of Distribution Box (DB)	-
Replacement of Existing Main LV Distribution board in Power House	1

Table 2-52: N08 - Grid Upgradation

2.14 N09 Gaadhiffushi Island

The island of Gaadhiffushi is located in the Thaa Atoll. The general data of the island is shown in the following table:

Island code, name	N09 - Gaadhiffushi
Atoll name	Thaa
Utility	FENAKA
GPS coordinates	2°15'09.52" N 73°12'46.57" E
Inhabitants (approx.)	730
Harbour type	Harbour, 85x50m

Table 2-53: N09 - Island identification and general data

Figure 30: N09 - Map of the island

Figure 31: N09 - Location of the buildings with available roofs and powerhouse

2.14.1 Load profile

The island has a fluctuating energy consumption, which is shown in Figure 32.

The utility expect a steadily increase of the load by 9 %/year for the next 5 years.

The following load profiles for the year of 2024 shall be considered for sizing.

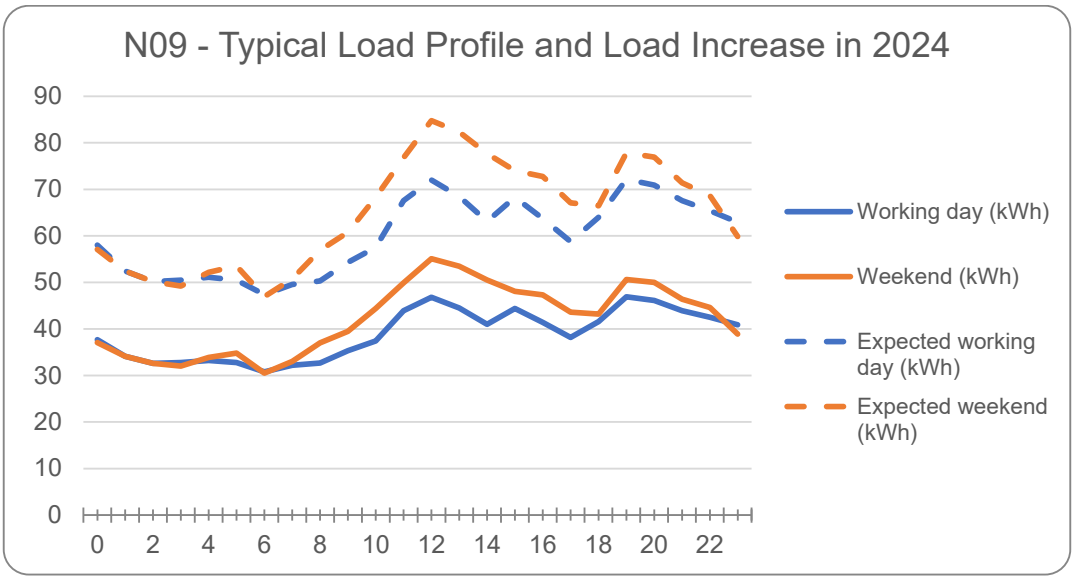


Figure 32: N09 - Typical daily load profile and evolution until 2024

	Average daily consumption [MWh/day]	Yearly consumption [MWh/yr]	Peak power [kW]
2019	0.93	341	65
2024	1.43	524	100

Table 2-54: N09 - Power consumption and peak power

2.14.2 Diesel Generators

3 Diesel Generators of different sizes are installed on the island.

The following Diesel Generators are currently used.

Item	Diesel Gen. 1	Diesel Gen. 2	Diesel Gen. 3
Engine manufacturer & motor references	Cummins 6BTAA5.9-G13	Cummins 6BTAA5-9G	Cummins 6CTA8-3-G2
Engine power rating (continuous) [kW]	60	100	140
Available power under site temperature conditions [kW]	65	80	100
Hours of operation / date of installation	In good Condition	In good Condition	In good Condition
General maintenance performed [Yes/No] (if Yes, when)	No (Service due date: Jan 2019)	No (Service due date: Jan 2019)	No (Service due date: Jan 2019)
Diesel generator controller (if any) manufacturer and type (e.g.: Woodward GCP, Easygen, etc.)	DSE8810	DSE8810	DSE8810
Relay for remote start available? [Yes/No]	Yes	Yes	Yes

Table 2-55: N09 - Diesel Generators currently installed

All Diesel Generators shall be integrated in the hybrid PV system.

2.14.3 Overview of possible installation locations for PV roof top systems

The table below shows the selected roofs for PV power plant installation and the estimated maximum PV power capacity installable on each roof. This estimation is based on a conservative approach considering standard 260Wp modules and enough margins in all directions. Roofs that were considered to be partially shaded most of the day were partially excluded from the estimation.

The Contractor shall however be responsible of checking the suitability of the roofs to install PV plants, optimize the design of each PV plant based on the available area, the electrical characteristics of its system and optimizing the yield (reduction of shading losses).

For this specific island the area for free field PV installation still has to be cleared by the Contractor. This is to be done in close contact and only with permission of local council and PMU.

Building and name	Roof size X [m]	Roof size Y [m]	Area [m^2]	Slope [°]	Azimuth [°]	Distance to Powerhouse [m]	Proposed PV Capacity on selected roofs [kWp]	Comments
Powerhouse 1	22	5,5	121	16	128	25	-	
Powerhouse 2	22	5,5	121	16	308	25	-	
Preschool 1	26	7	182	0		350	-	Coconut trees to be removed
Preschool 2	26	18	468	0		350	-	
School	15	28,5	427,5	0		365	-	
Harbour	16,5	65	1072,5	0		350	120	Some trees to be moved to another area
Fenaka	6	29,5	177	0		35	30	
Summary							150	

Table 2-56: N09 - Analysis of the available roofs and proposed PV capacity for selected Roofs

2.14.4 Grid Infrastructure

2.14.4.1 *Electrical system*

- Generation: 400/230V
- Frequency: 50 Hz
- Phase and type: three phase Wye, earthed neutral, four wire system
- Distribution Network: Low Voltage (LV)

The power house in Gaadhiffushi Island shall have three Diesel Generators that supply the complete load requirements of the island. The requirement related to existing and new Diesel Generators and associated systems are described in the above sections.

The island is fed through the low voltage distribution network connected to the main low voltage distribution board of the power house. The island is fed through LV distribution boxes located across the island and connected in a loop-in loop-out low voltage distribution network from the main low voltage distribution board of the power house.

Electrical supply to single phase consumers is commonly 230V, single phase, earthed neutral, two wire connections and for three phase consumers it is (400/230V) Wye, earthed neutral four wires.

2.14.4.2 *Grid infrastructure upgrade*

- The Contractor shall implement the grid upgrade works in Gaadhiffushi Island in line with drawings listed below.

S No.	Drawing Number	Title
1	G409-THAA-N9-SLD-1	NET WORK DIAGRAM FOR N09-GAADHIFFUSHI POWER HOUSE
2	G409-THAA-N9-SLD-2	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (N09-GAADHIFFUSHI)

Table 2-57: N09 - Drawings

This includes but not limited to the following works.

- Upgrade of the existing cable network from powerhouse to PV feed-in point.
- Modification or replacement of Distribution boxes to accommodate the proposed higher size cables connection.
- Modification or replacement of Distribution boxes to accommodate new connection of proposed PV.
- Replacement of existing Main LV Distribution board with the new LV Distribution board in the power house.

The modification / replacement of distribution boxes shall be designed to meet the final design kWp of the PV that will be approved by the Employer.

The new LV distribution board shall be designed in accordance with the latest international standards and shall include the automatic generator control systems and auto-synchronization systems.

The bidder shall closely coordinate with FENAKA to implement the critical changeover from the existing LV distribution board to the new LV distribution board in the power house without any disruption of power supply to the downstream feeders.

Bidder shall provide control cabling and junction boxes required for the proposed grid upgrade in the island.

Bidder shall provide necessary arrangements for safe dismantling, packaging of existing de-energized LV distribution board of the power house and distribution boxes and subsequent transportation of the same to a location identified by FENEKA.

2.14.4.3 Schedule of Grid Infrastructure Modifications

The following tables summarize the modifications related to the grid upgrade and PV plant connection in Gaadhiffushi Island.

- Schedule of Proposed Grid/PV Connection Cables:

From	To	No. of Runs	Cable Size (sq.mm)	Length (M)
Main LVDB (FEEDER RE1)	Powerhouse - PV	1	4C x 35	35
Main LVDB (FEEDER RE2)	Harbour Area Free Field-PV	1	4C x 240	350

Table 2-58: N09 - Schedule of Proposed Grid/PV Connection Cables

- Modification/Replacement of LV distribution equipment

Item Description	Quantity (Nos.)
Replacement of Existing Distribution Box (DB)	2
Modification of existing of Distribution Box (DB)	-
Addition of BESS and RE Feeder to Existing Main LV Distribution board in Power House	1

Table 2-59: N09 - Grid Upgradation

2.15 N10 Thimarafushi Island

The island of Thimarafushi is located in the Thaa Atoll. The general data of the island is shown in the following table:

Island code, name	N10 - Thimarafushi
Atoll name	Thaa
Utility	FENAKA
GPS coordinates	2°12'22.68" N 73°08'34.39" E
Inhabitants (approx.)	1,190
Harbour type	Harbour, 210 x 90m

Table 2-60: N10 - Island identification and general data

Figure 33: N10 - Map of the island

Figure 34: N10 - Location of the buildings with available roofs and powerhouse

2.15.1 Load profile

The island has a fluctuating energy consumption, which is shown in Figure 35.

The utility expect a steadily increase of the load by 5 %/year for the next 5 years.

The following load profiles for the year of 2024 shall be considered for sizing.

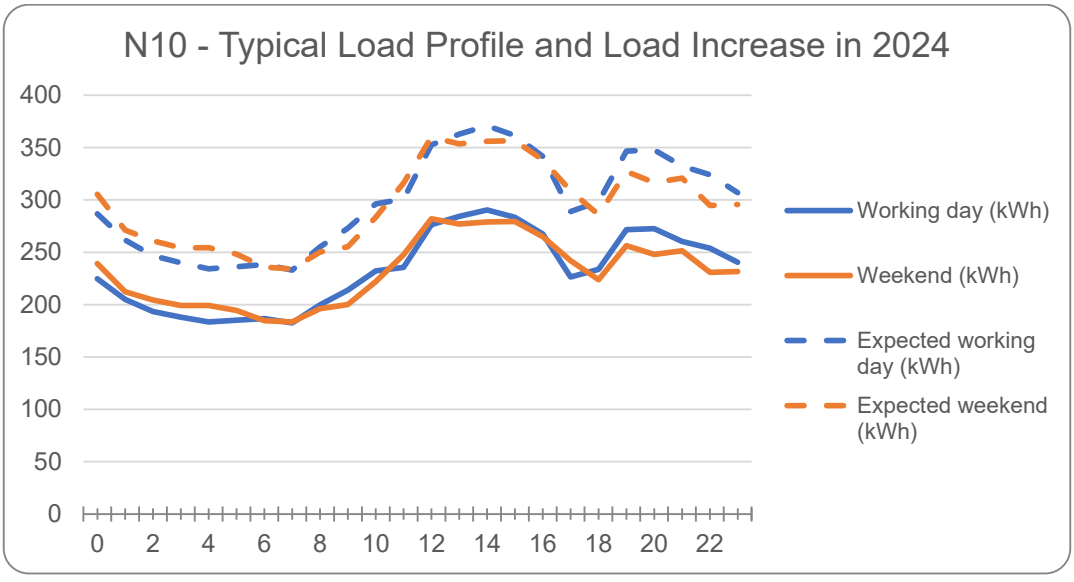


Figure 35: N10 - Typical daily load profile and evolution until 2024

	Average daily consumption [MWh/day]	Yearly consumption [MWh/yr]	Peak power [kW]
2019	5.59	2,041	420
2024	7.14	2,604	536

Table 2-61: N10 - Power consumption and peak power

2.15.2 Diesel Generators

3 Diesel Generators of different sizes are installed on the island.

The following Diesel Generators are currently used:

Item	Diesel Gen. 1	Diesel Gen. 2	Diesel Gen. 3
Engine manufacturer & motor references	Cummins NTA855G1A	Cummins	Cummins
Engine power rating (continuous) [kW]	250kW	400kW	600kW
Available power under site temperature conditions [kW]	140kW	360	500
Hours of operation / date of installation	N/A	N/A	N/A
General maintenance performed [Yes/No] (if Yes, when)	Generator is in bad shape and shall be replaced.	New	New
Diesel generator controller (if any) manufacturer and type (e.g.: Woodward GCP, Easygen, etc.)	DSE8810	DSE8810	DSE8810
Relay for remote start available? [Yes/No]	The panel shall be replaced as most of the circuit breakers are overloaded. Some modifications are done to increase circuit breaker ratings, however the connection cables and plates and main busbar are under rated.		

Table 2-62: N10 - Diesel Generators currently installed

All Diesel Generators shall be integrated in the hybrid PV system.

2.15.3 Overview of possible installation locations for PV roof top systems

The table below shows the selected roofs for PV power plant installation and the estimated maximum PV power capacity installable on each roof. This estimation is based on a conservative approach considering standard 260Wp modules and enough margins in all directions. Roofs that were considered to be partially shaded most of the day were partially excluded from the estimation.

The Contractor shall however be responsible of checking the suitability of the roofs to install PV plants, optimize the design of each PV plant based on the available area, the electrical characteristics of its system and optimizing the yield (reduction of shading losses).

Building and name	Roof size X [m]	Roof size Y [m]	Area [m^2]	Slope [°]	Azimuth [º]	Distance to Powerhouse [m]	Proposed PV Capacity on selected roofs [kWp]	Comments
Powerhouse 1	22,4	4,85	108,64	16	28	25	-	
Powerhouse 2	22,4	4,85	108,64	16	208	25	-	
Area 1	68	15	1020	0		35	120	
Area 2	30	12	360	0		35	40	
Area 3	50	12	600	0		40	60	
Summary			**2197**				**220**	

Table 2-63: N10 - Analysis of the available roofs and proposed PV capacity for selected Roofs

2.15.4 Grid Infrastructure

2.15.4.1 *Electrical system*

- Generation: 400/230V
- Frequency: 50 Hz
- Phase and type: three phase Wye, earthed neutral, four wire system
- Distribution Network: Low Voltage (LV)

The power house in Thimarafushi Island shall have four Diesel Generators that supply the complete load requirements of the island. The requirement related to existing and new Diesel Generators and associated systems are described in the above sections.

The island is fed through the low voltage distribution network connected to the main low voltage distribution board of the power house. The island is fed through LV distribution boxes located across the island and connected in a loop-in loop-out low voltage distribution network from the main low voltage distribution board of the power house.

Electrical supply to single phase consumers is commonly 230V, single phase, earthed neutral, two wire connections and for three phase consumers it is (400/230V) Wye, earthed neutral four wires.

2.15.4.2 *Grid infrastructure upgrade*

- The Contractor shall implement the grid upgrade works in Thimarafushi Island in line with drawings listed below.

S No.	Drawing Number	Title
1	G409-THAA-N10-SLD-1	NET WORK DIAGRAM FOR N10-THIMARAFUSHI POWER HOUSE
2	G409-THAA-N10-SLD-2	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (N10-THIMARAFUSHI)

Table 2-64: N10 - Drawings

This includes but not limited to the following works.

- Upgrade of the existing cable network from powerhouse to PV feed-in point.
- Modification or replacement of Distribution boxes to accommodate the proposed higher size cables connection.
- Modification or replacement of Distribution boxes to accommodate new connection of proposed PV.
- Replacement of existing Main LV Distribution board with the new LV Distribution board in the power house.

The modification / replacement of distribution boxes shall be designed to meet the final design kWp of the PV that will be approved by the Employer.

The new LV distribution board shall be designed in accordance with the latest international standards and shall include the automatic generator control systems and auto-synchronization systems.

The bidder shall closely coordinate with FENAKA to implement the critical changeover from the existing LV distribution board to the new LV distribution board in the power house without any disruption of power supply to the downstream feeders.

Bidder shall provide control cabling and junction boxes required for the proposed grid upgrade in the island.

Bidder shall provide necessary arrangements for safe dismantling, packaging of existing de-energized LV distribution board of the power house and distribution boxes and subsequent transportation of the same to a location identified by FENEKA.

2.15.4.3 Schedule of Grid Infrastructure Modifications

The following tables summarize the modifications related to the grid upgrade and PV plant connection in Thimarafushi Island.

- Schedule of Cables-Power House:

From	To	No. of Runs	Proposed Cable Size (sq.mm)	Length (M)
Main LVDB (PH-FEEDER-RE)	Powerhouse Free Field-PV	1	4C x 185	40

Table 2-65: N10 - Schedule of Cables Power House

- Modification/Replacement of LV distribution equipment

Item Description	Quantity (Nos.)
Replacement of Existing Distribution Box (DB)	0
Modification of existing of Distribution Box (DB)	-
Replacement of Existing Main LV Distribution board in Power House	1

Table 2-66: N10 - Grid Upgradation

2.16 N11 Veymandoo Island

The island of Veymandoo is located in the Thaa Atoll. The general data of the island is shown in the following table:

Island code, name	N11 – Veymandoo
Atoll name	Thaa
Utility	FENAKA
GPS coordinates	2°11'17.22" N 73°05'43.81" E
Inhabitants (approx.)	1,454
Harbour type	Harbour, 1200ft

Table 2-67: N11 - Island identification and general data

Figure 36: N11 - Map of the island

Figure 37: N11 - Location of the buildings with available roofs

2.16.1 Load profile

The island has a fluctuating energy consumption, which is shown in Figure 38.

The utility expect a steadily increase of the load by 7 %/year for the next 5 years.

The following load profiles for the year of 2024 shall be considered for sizing.

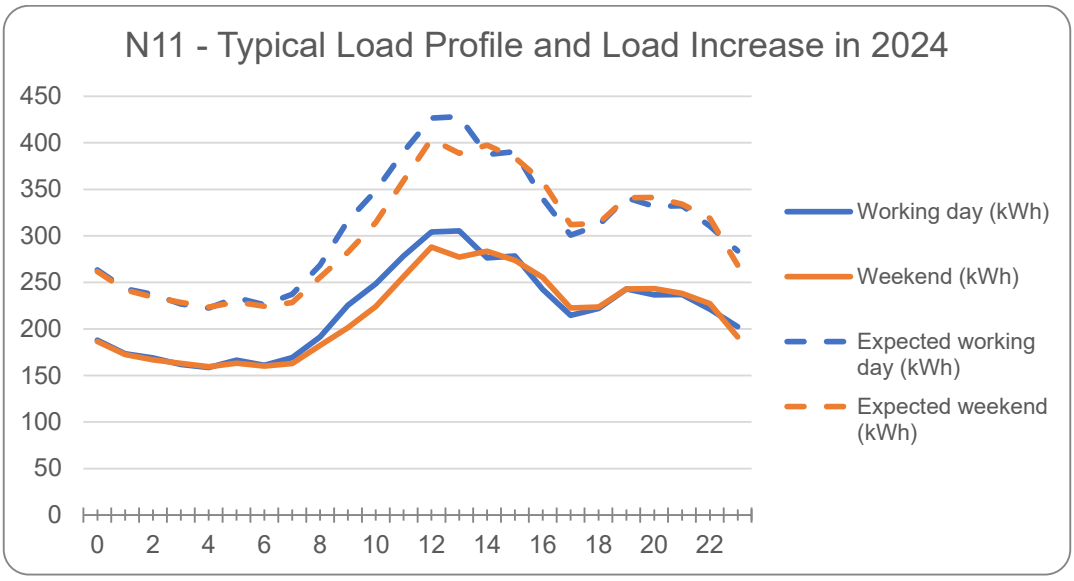


Figure 38: N11 - Typical daily load profile and evolution until 2024

	Average daily consumption [MWh/day]	Yearly consumption [MWh/yr]	Peak power [kW]
2019	5.27	1,924	476
2024	7.40	2,700	667

Table 2-68: N11 - Power consumption and peak power

2.16.2 Diesel Generators

3 Diesel Generators of different sizes are installed on the island.

The following Diesel Generators are currently used:

Item	Diesel Gen. 1	Diesel Gen. 2	Diesel Gen. 3
Engine manufacturer & motor references	Cummins NTA855-G1A	Cummins	Cummins KTA38-G2
Engine power rating (continuous) [kW]	250	400	600
Available power under site temperature conditions [kW]	140	360	500
Hours of operation / date of installation			
General maintenance performed [Yes/No] (if Yes, when)	No	New	New
Diesel generator controller (if any) manufacturer and type (e.g.: Woodward GCP, Easygen, etc.)	DSE8810	DSE8810	DSE8810
Relay for remote start available? [Yes/No]	Yes	Yes	Yes

Table 2-69: N11 - Diesel Generators currently installed

All Diesel Generators shall be integrated in the hybrid PV system.

2.16.3 Overview of possible installation locations for PV roof top systems

The table below shows the selected roofs for PV power plant installation and the estimated maximum PV power capacity installable on each roof. This estimation is based on a conservative approach considering standard 260Wp modules and enough margins in all directions. Roofs that were considered to be partially shaded most of the day were partially excluded from the estimation.

The Contractor shall however be responsible of checking the suitability of the roofs to install PV plants, optimize the design of each PV plant based on the available area, the electrical characteristics of its system and optimizing the yield (reduction of shading losses).

Building and name	Roof size X [m]	Roof size Y [m]	Area [m²]	Slope [°]	Azimuth [º]	Distance to Powerhouse [m]	Proposed PV Capacity on selected roofs [kWp]	Comments
Powerhouse 1	24	6,5	156	16	188	25	-	
Powerhouse 2	24	6,5	156	16	8	25	-	
School A1	41	6	246	24	196	565	30	
School A2	41	6	246	24	16	565	30	
School B1	18	6	108	24	196	565	0	
School B2	18	6	108	24	16	565	0	
School C1	25	6	150	24	102	565	-	Small trees which can be trimmed
School C2	25	6	150	24	282	565	-	
School D1	25	6	150	24	196	565	20	
School D2	25	6	150	24	16	565	20	
Health Centre A1	22	8,25	181,5	16	85	640	-	
Health Centre A2	22	8,25	181,5	16	265	640	-	
Health Centre B1	13	9,5	123,5	16	85	640	-	
Health Centre B2	13	9,5	123,5	16	265	640	-	
Area 1 A	45	18	810	0		35	90	Trees which can be trimmed
Area 1 B	20	15	300	0		35	30	
Area 1 C	15	20	300	0		35	30	
Summary			3640				250	

Table 2-70: N11 - Analysis of the available roofs and proposed PV capacity for selected Roofs

2.16.4 Grid Infrastructure

2.16.4.1 *Electrical system*

- Generation: 400/230V
- Frequency: 50 Hz
- Phase and type: three phase Wye, earthed neutral, four wire system
- Distribution Network: Low Voltage (LV)

The power house in Veymandoo Island shall have three Diesel Generators that supply the complete load requirements of the island. The requirement related to existing and new Diesel Generators and associated systems are described in the above sections.

The island is fed through the low voltage distribution network connected to the main low voltage distribution board of the power house. The island is fed through LV distribution boxes located across the island and connected in a loop-in loop-out low voltage distribution network from the main low voltage distribution board of the power house.

Electrical supply to single phase consumers is commonly 230V, single phase, earthed neutral, two wire connections and for three phase consumers it is (400/230V) Wye, earthed neutral four wires.

2.16.4.2 *Grid infrastructure upgrade*

- The Contractor shall implement the grid upgrade works in Veymandoo Island in line with drawings listed below.

S No.	Drawing Number	Title
1	G409-THAA-N11-SLD-1	NET WORK DIAGRAM FOR N11-VEYMANDOO POWER HOUSE
2	G409-THAA-N11-SLD-2	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (N11-VEYMANDOO)

Table 2-71: N11 - Drawings

This includes but not limited to the following works.

- Upgrade of the existing cable network from powerhouse to PV feed-in point.
- Modification or replacement of Distribution boxes to accommodate the proposed higher size cables connection.
- Modification or replacement of Distribution boxes to accommodate new connection of proposed PV.
- Replacement of existing Main LV Distribution board with the new LV Distribution board in the power house.

The modification / replacement of distribution boxes shall be designed to meet the final design kWp of the PV that will be approved by the Employer.

The new LV distribution board shall be designed in accordance with the latest international standards and shall include the automatic generator control systems and auto-synchronization systems.

The bidder shall closely coordinate with FENAKA to implement the critical changeover from the existing LV distribution board to the new LV distribution board in the power house without any disruption of power supply to the downstream feeders.

Bidder shall provide control cabling and junction boxes required for the proposed grid upgrade in the island.

Bidder shall provide necessary arrangements for safe dismantling, packaging of existing de-energized LV distribution board of the power house and distribution boxes and subsequent transportation of the same to a location identified by FENEKA.

2.16.4.3 *Schedule of Grid Infrastructure Modifications*

The following tables summarize the modifications related to the grid upgrade and PV plant connection in Veymandoo Island.

- Schedule of Cables-Power House:

From	To	No. of Runs	Proposed Cable Size (Sq.mm)	Length (M)
Main LVDB (PH-FEEDER-RE1)	Powehouse-PV	1	4C x 95	50
Main LVDB (PH-FEEDER-D)	DB-D1	1	4C x 240	365
DB-D1	DB-D2	1	4C x 240	160
DB-D2	School-PV	1	4C x 240	60

Table 2-72: N11 - Schedule of Cables Power House

- Modification/Replacement of LV distribution equipment

Item Description	Quantity (Nos.)
Replacement of Existing Distribution Box (DB)	2
Modification of existing of Distribution Box (DB)	-
Replacement of Existing Main LV Distribution board in Power House	1

Table 2-73: N11 - Grid Upgradation

2.17 N12 Kinbidhoo Island

The island of Kinbidhoo is located in the Thaa Atoll. The general data of the island is shown in the following table:

Island code, name	N12 – Kinbidhoo
Atoll name	Thaa
Utility	FENAKA
GPS coordinates	2°10'07.59" N 73°03'58.34" E
Inhabitants (approx.)	1,469
Harbour type	Harbour, 155x75m

Table 2-74: N12 - Island identification and general data

Figure 39: N12 - Map of the island

Figure 40: N12 - Location of the buildings with available roofs

2.17.1 Load profile

The island has a fluctuating energy consumption, which is shown in Figure 38.

The utility expect a steadily increase of the load by 4 %/year for the next 5 years. In addition, there is a seasonal increase of the load in March and April, due to the hot weather condition.

The following load profiles for the year of 2024 shall be considered for sizing.

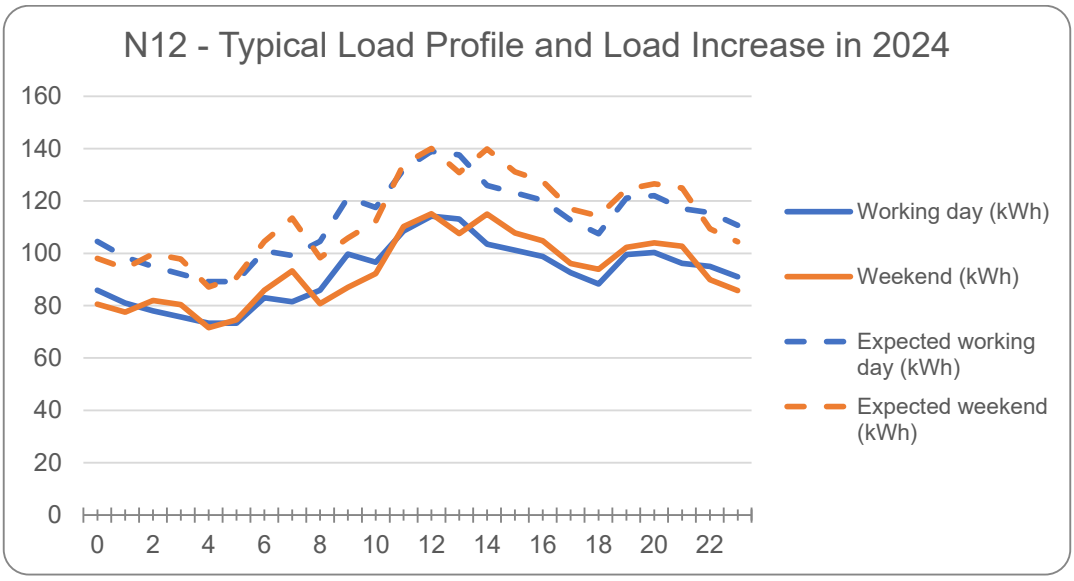


Figure 41: N12 - Typical daily load profile and evolution until 2024

	Average daily consumption [MWh/day]	Yearly consumption [MWh/yr]	Peak power [kW]
2019	2.21	809	180
2024	2.70	984	220

Table 2-75: N12 - Power consumption and peak power

2.17.2 Diesel Generators

3 Diesel Generators of different sizes are installed on the island.

The following Diesel Generators are currently used:

Item	Diesel Gen. 1	Diesel Gen. 2	Diesel Gen. 3
Engine manufacturer & motor references	Cummins 6LTAA8.9-G2	Cummins 6CTA8.3-G2-1	Cummins 6CTAA8.3-G2
Engine power rating (continuous) [kW]	200	140	160
Available power under site temperature conditions [kW]	150	100	140
Hours of operation / date of installation	To be serviced in 2019	To be serviced in 2019	Good
General maintenance performed [Yes/No] (if Yes, when)			
Diesel generator controller (if any) manufacturer and type (e.g.: Woodward GCP, Easygen, etc.)	DSE8810	DSE8810	DSE8810
Relay for remote start available? [Yes/No]			

Table 2-76: N12 - Diesel Generators currently installed

All Diesel Generators shall be integrated in the hybrid PV system.

2.17.3 Overview of possible installation locations for PV roof top systems

The table below shows the selected roofs for PV power plant installation and the estimated maximum PV power capacity installable on each roof. This estimation is based on a conservative approach considering standard 260Wp modules and enough margins in all directions. Roofs that were considered to be partially shaded most of the day were partially excluded from the estimation.

The Contractor shall however be responsible of checking the suitability of the roofs to install PV plants, optimize the design of each PV plant based on the available area, the electrical characteristics of its system and optimizing the yield (reduction of shading losses).

Building and name	Roof size X [m]	Roof size Y [m]	Area [m^2]	Slope [°]	Azimuth [º]	Distance to Powerhouse [m]	Proposed PV Capacity on selected roofs [kWp]	Comments
Powerhouse 1	25	5,5	137,5	16	174	35	15	
Powerhouse 2	25	5,5	137,5	16	354	35	15	
Area 1 A	45	20	900	0		35	120	
Area 1 B	25	14	350	0		35	50	
Area 2 (Behind Powerhouse)	45	16	720			60	100	
Summary			**1525**				**300**	

Table 2-77: N12 - Analysis of the available roofs and proposed PV capacity for selected Roofs

2.17.4 Grid Infrastructure

2.17.4.1 *Electrical system*

- Generation: 400/230V
- Frequency: 50 Hz
- Phase and type: three phase Wye, earthed neutral, four wire system
- Distribution Network: Low Voltage (LV)

The power house in Kinbidhoo Island shall have three Diesel Generators that supply the complete load requirements of the island. The requirement related to existing and new Diesel Generators and associated systems are described in the above sections.

The island is fed through the low voltage distribution network connected to the main low voltage distribution board of the power house. The island is fed through LV distribution boxes located across the island and connected in a loop-in loop-out low voltage distribution network from the main low voltage distribution board of the power house.

Electrical supply to single phase consumers is commonly 230V, single phase, earthed neutral, two wire connections and for three phase consumers it is (400/230V) Wye, earthed neutral four wires.

2.17.4.2 *Grid infrastructure upgrade*

- The Contractor shall implement the grid upgrade works in Kinbidhoo Island in line with drawings listed below.

S No.	Drawing Number	Title
1	G409-THAA-N12-SLD-1	NET WORK DIAGRAM FOR N12-KINBIDHOO POWER HOUSE
2	G409-THAA-N12-SLD-2	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (N12-KINBIDHOO)

Table 2-78: N12 - Drawings

This includes but not limited to the following works.

- Upgrade of the existing cable network from powerhouse to PV feed-in point.
- Modification or replacement of Distribution boxes to accommodate the proposed higher size cables connection.
- Modification or replacement of Distribution boxes to accommodate new connection of proposed PV.
- Replacement of existing Main LV Distribution board with the new LV Distribution board in the power house.

The modification / replacement of distribution boxes shall be designed to meet the final design kWp of the PV that will be approved by the Employer.

The new LV distribution board shall be designed in accordance with the latest international standards and shall include the automatic generator control systems and auto-synchronization systems.

The bidder shall closely coordinate with FENAKA to implement the critical changeover from the existing LV distribution board to the new LV distribution board in the power house without any disruption of power supply to the downstream feeders.

Bidder shall provide control cabling and junction boxes required for the proposed grid upgrade in the island.

Bidder shall provide necessary arrangements for safe dismantling, packaging of existing de-energized LV distribution board of the power house and distribution boxes and subsequent transportation of the same to a location identified by FENEKA.

2.17.4.3 *Schedule of Grid Infrastructure Modifications*

The following tables summarize the modifications related to the grid upgrade and PV plant connection in Kinbidhoo Island.

- Schedule of Cables-Power House:

From	To	No. of Runs	Proposed Cable Size (Sq.mm)	Length (M)
Main LVDB (PH-FEEDER-RE1)	Powerhouse-PV	1	4C x 150	35
Main LVDB (PH-FEEDER-RE2)	Council Free Field-PV	1	4C x 150	60

Table 2-79: N12 - Schedule of Cables Power House

- Modification/Replacement of LV distribution equipment

Item Description	Quantity (Nos.)
Replacement of Existing Distribution Box (DB)	0
Modification of existing of Distribution Box (DB)	-
Addition of BESS and RE Feeders to Existing Main LV Distribution board in Power House	1

Table 2-80: N12 - Grid Upgradation

2.18 N13 Omadhoo Island

The island of Omadhoo is located in the Thaa Atoll. The general data of the island is shown in the following table:

Island code, name	N13 – Omadhoo
Atoll name	Thaa
Utility	FENAKA
GPS coordinates	2°10'04.94" N 73°01'27.75" E
Inhabitants (approx.)	800
Harbour type	Harbour

Table 2-81: N13 - Island identification and general data

Figure 42: N13 - Map of the island

Figure 43: N13 - Location of the buildings with available roofs

2.18.1 Load profile

The island has a fluctuating energy consumption, which is shown in Figure 38.

The utility expect a steadily increase of the load by 7 %/year for the next 5 years.

The following load profiles for the year of 2024 shall be considered for sizing.

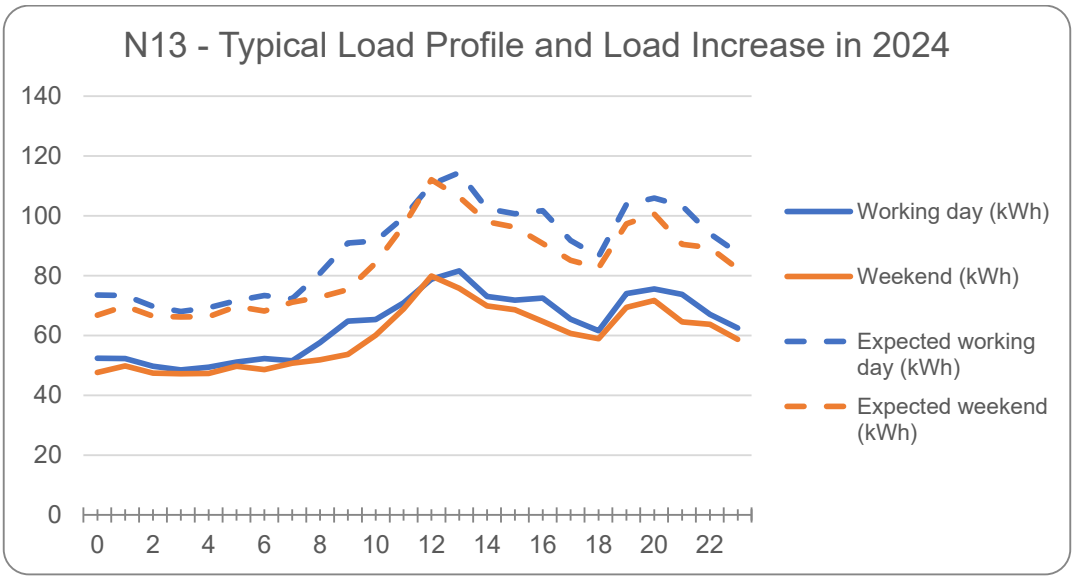


Figure 44: N13 - Typical daily load profile and evolution until 2024

	Average daily consumption [MWh/day]	Yearly consumption [MWh/yr]	Peak power [kW]
2019	1.52	556	320
2024	2.14	780	450

Table 2-82: N13 - Power consumption and peak power

2.18.2 Diesel Generators

3 Diesel Generators of different sizes are installed on the island.

The following Diesel Generators are currently used:

Item	Diesel Gen. 1	Diesel Gen. 2	Diesel Gen. 3
Engine manufacturer & motor references	Cummins 6CTA8.3	Deutz BF6M1013E	Cummins 6CTAA8.3G2
Engine power rating (continuous) [kW]	128	112	160
Available power under site temperature conditions [kW]	100	70	128
Hours of operation / date of installation	Data not available	Data not available	Data not available
General maintenance performed [Yes/No] (if Yes, when)	New	Genset to be replaced	No. Scheduled for this year.
Diesel generator controller (if any) manufacturer and type (e.g.: Woodward GCP, Easygen, etc.)	No (New synchronizing panel is required for this island)	No (New synchronizing panel is required for this island)	No (New synchronizing panel is required for this island)
Relay for remote start available? [Yes/No]	No	No	No

Table 2-83: N13 - Diesel Generators currently installed

All Diesel Generators shall be integrated in the hybrid PV system.

2.18.3 Overview of possible installation locations for PV roof top systems

The table below shows the selected roofs for PV power plant installation and the estimated maximum PV power capacity installable on each roof. This estimation is based on a conservative approach considering standard 260Wp modules and enough margins in all directions. Roofs that were considered to be partially shaded most of the day were partially excluded from the estimation.

The Contractor shall however be responsible of checking the suitability of the roofs to install PV plants, optimize the design of each PV plant based on the available area, the electrical characteristics of its system and optimizing the yield (reduction of shading losses).

Building and name	Roof size X [m]	Roof size Y [m]	Area [m²]	Slope [°]	Azimuth [º]	Distance to Powerhouse [m]	Proposed PV Capacity on selected roofs [kWp]	Comments
Powerhouse A1	11,5	4,9	56,35	16	0	25	7	
Powerhouse A2	11,5	4,9	56,35	16	180	25	7	
Powerhouse B1	6,5	4,9	31,85	16	0	25	3	
Powerhouse B2	6,5	4,9	31,85	16	180	25	3	
Area 1 A	17	18	306	0		35	40	
Area 1 B	15	30	450	0		35	60	
Area 2 (Next to School)	27	20	540				80	
Summary			932.4				200	

Table 2-84: N13 - Analysis of the available roofs and proposed PV capacity for selected Roofs

2.18.4 Grid Infrastructure

2.18.4.1 *Electrical system*

- Generation: 400/230V
- Frequency: 50 Hz
- Phase and type: three phase Wye, earthed neutral, four wire system
- Distribution Network: Low Voltage (LV)

The power house in Omadhoo Island shall have three Diesel Generators that supply the complete load requirements of the island. The requirement related to existing and new Diesel Generators and associated systems are described in the above sections.

The island is fed through the low voltage distribution network connected to the main low voltage distribution board of the power house. The island is fed through LV distribution boxes located across the island and connected in a loop-in loop-out low voltage distribution network from the main low voltage distribution board of the power house.

Electrical supply to single phase consumers is commonly 230V, single phase, earthed neutral, two wire connections and for three phase consumers it is (400/230V) Wye, earthed neutral four wires.

2.18.4.2 *Grid infrastructure upgrade*

- The Contractor shall implement the grid upgrade works in Omadhoo Island in line with drawings listed below.

S No.	Drawing Number	Title
1	G409-THAA-N13-SLD-1	NET WORK DIAGRAM FOR N13-OMADHOO POWER HOUSE
2	G409-THAA-N13-SLD-2	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (N13-OMADHOO)

Table 2-85: N13 - Drawings

This includes but not limited to the following works.

- Upgrade of the existing cable network from powerhouse to PV feed-in point.
- Modification or replacement of Distribution boxes to accommodate the proposed higher size cables connection.
- Modification or replacement of Distribution boxes to accommodate new connection of proposed PV.
- Replacement of existing Main LV Distribution board with the new LV Distribution board in the power house.

The modification / replacement of distribution boxes shall be designed to meet the final design kWp of the PV that will be approved by the Employer.

The new LV distribution board shall be designed in accordance with the latest international standards and shall include the automatic generator control systems and auto-synchronization systems.

The bidder shall closely coordinate with FENAKA to implement the critical changeover from the existing LV distribution board to the new LV distribution board in the power house without any disruption of power supply to the downstream feeders.

Bidder shall provide control cabling and junction boxes required for the proposed grid upgrade in the island.

Bidder shall provide necessary arrangements for safe dismantling, packaging of existing de-energized LV distribution board of the power house and distribution boxes and subsequent transportation of the same to a location identified by FENEKA.

2.18.4.3 *Schedule of Grid Infrastructure Modifications*

The following tables summarize the modifications related to the grid upgrade and PV plant connection in Omadhoo Island.

- Schedule of Proposed Grid/PV Connection Cables-Power House:

From	To	No. of Runs	Proposed Cable Size (sq.mm)	Length (M)
Main LVDB (PH-FEEDER-RE1)	Powerhouse-PV	1	4C x 70	35
Main LVDB (PH-FEEDER-RE2)	Near School Free Field-PV	1	4C x 120	150

Table 2-86: N13 - Schedule of Proposed Grid/PV Connection Cables Power House

- Modification/Replacement of LV distribution equipment

Item Description	Quantity (Nos.)
Replacement of Existing Distribution Box (DB)	0
Modification of existing of Distribution Box (DB)	-
Addition of BESS and RE Feeders to Existing Main LV Distribution board in Power House	1

Table 2-87: N13 - Grid Upgradation

3 Solar Powered Ice making Plant Site Specifications (Lot 2)

3.1 General

The following section describes the specific island and its site conditions.

The Bidder is responsible for its own investigations to establish sufficient and accurate information for the design of the Plant. The Contractor shall visit the proposed sites and shall ascertain the nature and location thereof and all conditions which may affect design/layout of the solar powered ice making plant, design of grid upgrade works and the project costs.

The Bidder shall make its own assessment of any and all of the information provided in this Bid and collect own information. Neither the Employer nor any representative or advisor is responsible for the accuracy or completeness of any such information.

3.2 Logistic

The Contractor is free to choose the seaport of entrance. There are three of these seaports. Upon arrival at one of these ports the Contractor shall take care of the clearance. However, Employer shall provide the relevant supporting documents to the Contractor. After clearance it is the Contractor's obligation to continue delivery up to the final destination at the respective islands.

3.3 Solar powered Ice making plant configuration and general behaviour

The solar-powered ice making plant operation is next described.

3.3.1 System Architecture and Operation modes

An schematic block diagram of solar powered ice making plant and it connection to the main grid is next depicted.

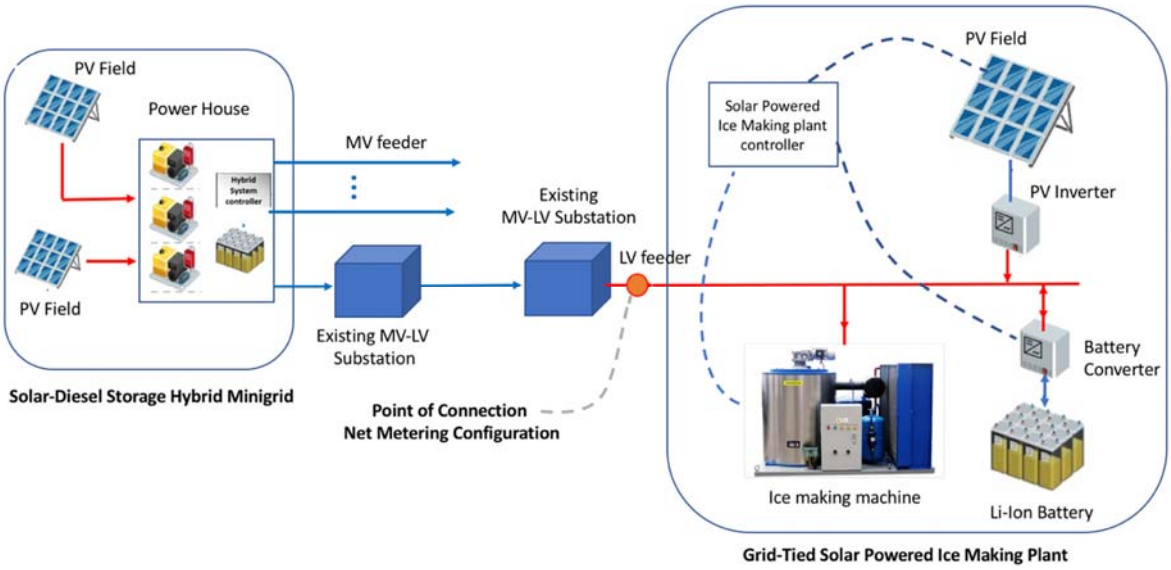


Figure 45: Schematic Block Diagram of Solar Powered Ice Making Plant (SPIMP)

The SPIMP controller will be responsible for the smooth operation of the SPIMP. A data communication cable between the PV and battery converters, and the ice making machine shall be installed for command. The SPIMP will collect necessary data for an efficient operation.

During sunny hours the PV plant will provide energy to the ice making plant and any PV excess will be evacuated to the the main distribution grid following Net Metering regulations. The battery will provide support to the PV to avoid sharp fluctuations in the power injected to the distribution grid. The contractor shall provide a set of battwery inverter and battery fast enough to compensate PV fluctuations. For those periods when there is no enough PV energy, the ice making machine will be also fed from the main distribution grid.

3.3.2 Other technical characteritics

This proposed configuration should allow operation of multiple masters (grid forming entities such as Battery or Diesel generators) and only use PV as a slave. If one master fails the other master units should able to run the grid giving the system extra redundancy.

The Battery inverter must be synchronized to other voltage sources in both cases: *i)* Battery inverter is online first and the other voltage source (DG, Grid, other Battery Inverter) must be synched to the battery inverter, *ii)* Other voltage sources are first online (DG, other Battery Inverter), the battery inverter must be synchronized to them. Specially when a static (isochronous) voltage source such like an DG without synchronization capability the synchronization must be done with an external synch check and breaker. The measurement of the requirement parameters of voltage, frequency etc. must be done fast and accurate enough to guaranty synchronization.

3.4 Summary of the characteristics of the Solar Ice making plants to be built

The Contractor shall implement the described systems on the 4 islands as summarized in the table below.

Island	Ice Machine Plant Capacity (Tons / kW)	PV plant (kWp)	Battery Capacity (kW / kWh)	EMS	Grid
A10 Dhidhdhoo	15T/day 80 kW	295 kWp	100 / 150	1 unit-	1 lot
N01 Buruni	5T/day 30 kW	100 kWp	100 / 50	1 unit-	1 lot
U02 Rasdhoo	15T/day 80 kW	295 kWp	100 / 150	1 unit-	1 lot
N02 Vilufushi	15T/day 80 kW	295 kWp	100 / 150-	1 unit-	1 lot
TOTAL		985 kWp	400 / 500		

Table 3-1: Summary of the hybrid system to Ice Plant

3.5 Summary of auxiliary systems of the hybrid systems and Grid upgradation works to be done

A summary of Grid upgradation works can be found in each island section

3.6 A10 Dhidhdhoo Island

The island of Dhidhdhoo is located in the Haa Alif Atoll. The general data of the island is shown in the following table:

Island code, name	N13 – Omadhoo
Atoll name	Haa Alif
Utility	FENAKA
GPS coordinates	6° 53' 19.1184" N and 73° 6' 48.8484" E
Inhabitants (approx.)	4500
Harbour type	Harbour

Table 3-2: A10 - Island identification and general data

A map of the island is given in the next Figure.

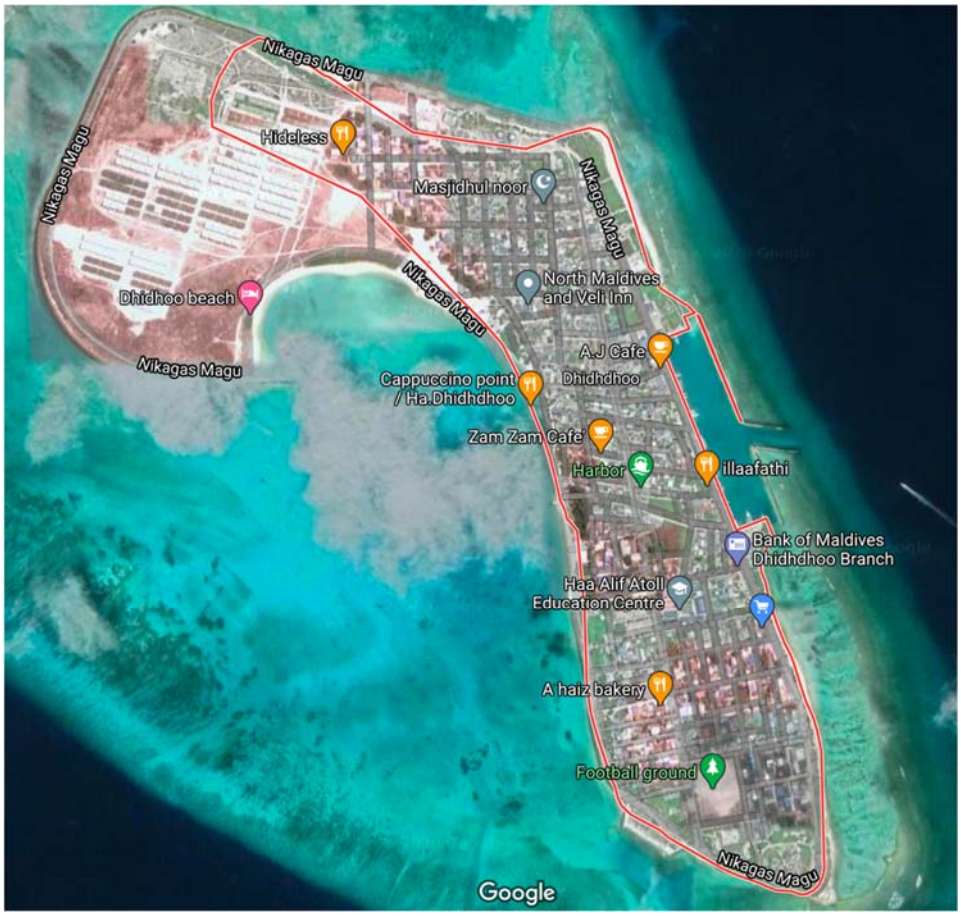


Figure 46: N13 - Map of the island

The Figure below shows the selected sites for the Ice making plant and PV power plant installation and the estimated required area.

Figure 47 Ice making plant and PV power plant sitting & connection to distribution grid.

The Contractor shall however be responsible of checking the suitability of the sites and optimize the design of the ice making plant and PV/BESS power plant plant based on the available area, the electrical characteristics of its system and optimizing its performance.

The general characteristics of the system to be installed are:

Island	Ice Machine Capacity	Store Room Capacity	PV size (kWp)	Battery (kW / kWh)	Solar Powered Ice plant Controller	Grid
Dhidhdhoo	15 T/day	35 T	295 kWp	100 / 150	1unit	1 lot

The PV power plant and the ice making machine will be controlled and operated by it own energy mangament system following this system architecture (see Figure 48).

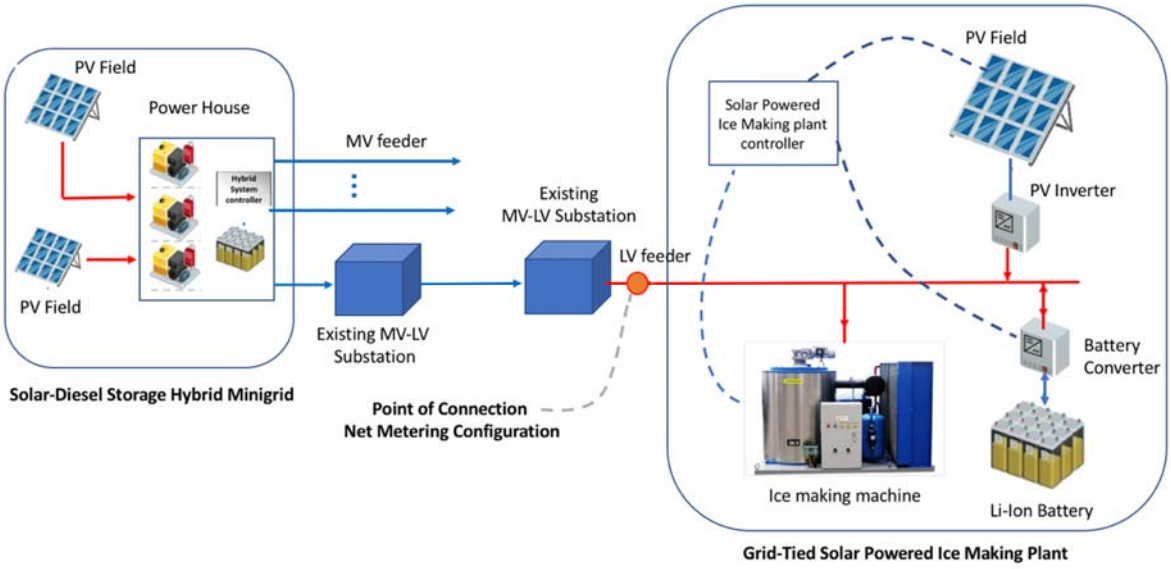


Figure 49: Ice making plant and PV power plant Schematic for Dhidhdhoo.

A detailed analysis of the integration of the PV power plant and its impact on the operation of the existing hybrid energy system shall be provided by the bidder.

The island is fed through a 11 kV / 0,4 kV distribution network. The island is fed through distribution boxes located across the island and connected in a loop-in loop-out low voltage distribution network from the main low voltage distribution board of the power house.

Figure 50 above includes schematically the proposed grid interventions. The following tables summarize the modifications related to the grid upgrade, PV plant and ice plant connection in Dhidhdhoo Island.

- Schedule of Proposed Substation:

From	No. of trafo
Proposed 500 kVA, 11 kV / 0,4 kV substation	1

Table 3-3: A10 - Schedule of Proposed Substation

- Schedule of Proposed Medium Voltage Connection Cables:

From	To	No. of Runs	Proposed Cable Size (sq.mm)	Length (M)
Proposed 500 kVA, 11 kV / 0,4 kV substation	Existing subesation (see Figure 51)	1	3cx x 70mm2	800

Table 3-4- Schedule of Proposed Cable Connection Cables

- LV distribution cables and equipment

Item Description	Type	Length (M)
PV Feeders to Main LV Distribution board in the proposed new substation	To be defined by the bidder	
Ice Power plant feeder to Main LV Distribution board in the proposed new substation	4cx 70mm2	30
Upgrade of protection devices at powerhouse or any other point of the network	1 lot	

Table 3-5: A10 - Grid Upgradation

The Contractor shall implement the grid upgrade works in Dhidhdhoo Island considering all necessary action for an smooth an reliable operation of the ice making plant and PV power plant.

The modification / replacement of distribution boxes shall be designed to meet the final design kWp of the PV that will be approved by the Employer.

The MV-LV distribution substation shall be designed in accordance with the latest international standards

The bidder shall closely coordinate with FENAKA to implement the critical changeover from the existing MV-LV distribution board to the new MV-LV distribution board in the substation without any disruption of power supply to the downstream feeders.

The Bidder shall provide control cabling and junction boxes required for the proposed grid upgrade in the island.

Bidder shall provide necessary arrangements for safe dismantling, packaging of existing de-energized MV-LV distribution board of the power house and distribution boxes and subsequent transportation of the same to a location identified by FENEKA.

3.7 N01 Buruni Island

The island of Buruni is located in Thaa Atoll. The general data of the island is shown in the following table:

Figure 52 Ice making plant and PV power plant sitting & connection to distribution grid.

The Contractor shall however be responsible of checking the suitability of the sites and optimize the design of the ice making plant and PV/BESS power plant plant based on the available area, the electrical characteristics of its system and optimizing its performance.

The general characteristics of the system to be installed are:

Island	Ice Machine Capacity	Store Room Capacity	PV size (kWp)	Battery (kW / kWh)	Solar Powered Ice plant Controller	Grid
Buruni	5 T/day	15 T	295 kWp	100 / 100	1 unit	1 lot

The PV power plant and the ice making machine will be controlled and operated by it own energy mangament system following this system architecture (see Figure 53).

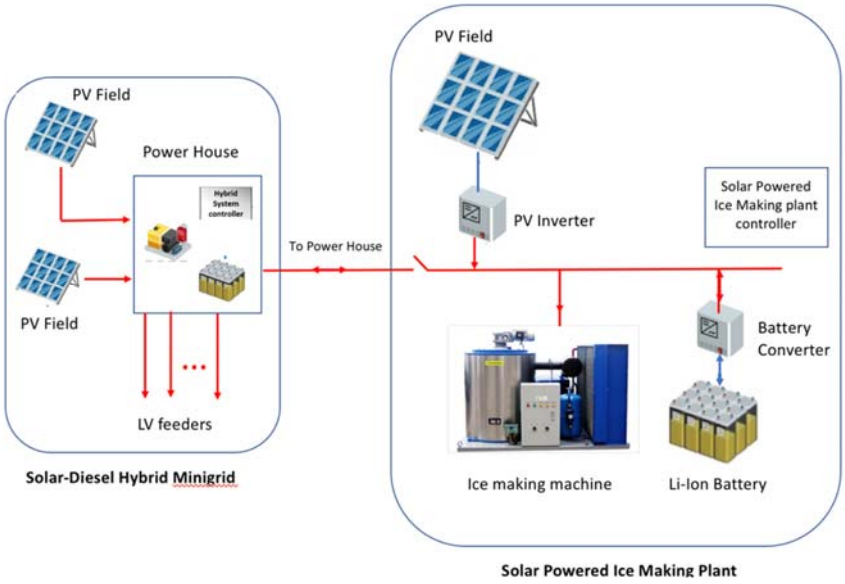


Figure 54: Ice making plant and PV power plant Schematic for Buruni.

A detailed analysis of the integration of the PV power plant and its impact on the operation of the existing hybrid energy system shall be provided by the bidder.

The island is fed through a LV distribution network. The island is fed through distribution boxes located across the island and connected in a loop-in loop-out low voltage distribution network from the main low voltage distribution board of the power house.

Figure 55 above includes schematically the proposed grid interventions. The following tables summarize the modifications related to the grid upgrade, PV plant and ice plant connection in Buruni Island.

Addtionaly, in Buruni island two extra interventions are considered:

i) Distribution automation investment to improve LV network resilience The contractor shall provide design including necessary devices to make it more resilient including.

1. Remote monitor power consumption of each distribution box
2. Remotely Control breakers in each distribution box
3. Communication system from boxes to powerhouse
4. Basic cusotm SCADA software for distribution monitoring and control.

The single line diagrams and network information is also provided.

S No.	Drawing Number	Title
1	04_GRID_BURUNI_CABLE ROUTE & DB LOCATIONS	04_Grid_Buruni_Cable Route & DB Locations
2	04_BURUNI_NETWORK_TABLE	04_BURUNI_network_table

ii) Smart Meter design improvement: Buruni is currently operating a smartmeter infrastructure. The objective under this intervention is to optimize the powerline communications required to ensure that AMI systems meet the required SLAs and increase network reachability.

provide and install blocking filters and signal repeaters at appropriate locations as required during implementation.

The blocking filters for smart grid applications are designed to reduce all kinds of noise coming from end user equipment via household wiring to ensure more reliable PLC communication while the repeaters amplify the PLC signal for those customer located far away from the data concentrator.

PLC Filter	Single phase (40 A)	Three Phase (80 A)
Blocking Filters Attenuation 40-60 dB	50 units	8 units

PLC Repeaters	Three Phase
PLC Signal repeater	10 units

3.8 U02 Rasdhoo Island

The island of Rasdhoo is located in the Alif Alif Atoll. The general data of the island is shown in the following table:

Island code, name	N13 – Omadhoo
Atoll name	Alif Alif
Utility	STELCO
GPS coordinates	6° 53' 19.1184" N and 73° 6' 48.8484" E
Inhabitants (approx.)	4500
Harbour type	Harbour

Table 3-6: A10 - Island identification and general data

A map of the island is given in the next Figure.

Figure 56: N13 - Map of Rasdhoo island

The Figure below shows the selected sites for the Ice making plant and PV power plant installation and the estimated required area.

Figure 57: Ice making plant and PV power plant sitting & connection to distribution grid.

The Contractor shall however be responsible of checking the suitability of the sites and optimize the design of the ice making plant and PV power plant plant based on the available area, the electrical characteristics of its system and optimizing its performance.

The general characteristics of the system to be installed are:

Island	Ice Machine Capacity	Store Room Capacity	PV size	Battery (kW / kWh)	Solar Powered Ice plant Controller	Grid
Rasdhoo	15 T/day	35 T	295 kWp	100 / 150	1 lot	1 lot

The PV power plant and the ice making machine will be controlled and operated by it own energy mangament system following this system architecture (see Figure 7).

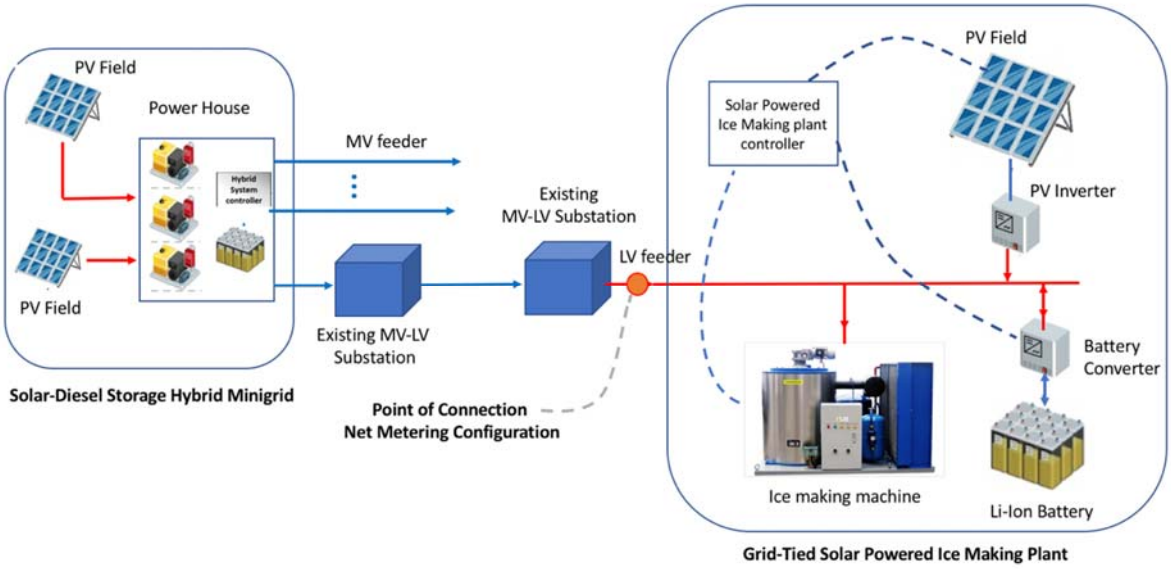


Figure 58: Ice making plant and PV power plant Schematic for Rasdhoo.

A detailed analysis of the integration of the PV power plant and its impact on the operation of the existing hybrid energy system shall be provided by the bidder.

The island is fed through a 11 kV / 0,4 kV distribution network. The island is fed through distribution boxes located across the island and connected in a loop-in loop-out low voltage distribution network from the main low voltage distribution board of the power house.

Figure 59 above includes schematically the proposed grid interventions. The following tables summarize the modifications related to the grid upgrade, PV plant and ice plant connection in Rasdhoo Island.

- Schedule of Proposed Substation:

From	No. of trafo
Proposed 500 kVA, 11 kV / 0,4 kV substation	1

Table 3-7: A10 - Schedule of Proposed Substation

- Schedule of Proposed Medium Voltage Connection Cables:

From	To	No. of Runs	Proposed Cable Size (sq.mm)	Length (M)

Proposed 500 kVA, 11 kV / 0,4 kV substation	Existing subesation (see Figure 60)	1	3cx x 70mm2	630

Table 3-8- Schedule of Proposed Cable Connection Cables

- LV distribution cables and equipment

Item Description	Type	Length (M)
PV Feeders to Main LV Distribution board in the proposed new substation	To be defined	
Ice Power plant feeder to Main LV Distribution board in the proposed new substation	4cx 95mm2	170
Upgrade of protection devices at powerhouse or any other point of the network	1 lot	

Table 3-9: A10 - Grid Upgradation

The Contractor shall implement the grid upgrade works in Rasdhoo Island considering all necessary action for an smooth an reliable operation of the ice making plant and PV power plant.

The modification / replacement of distribution boxes shall be designed to meet the final design kWp of the PV that will be approved by the Employer.

The MV-LV distribution substation shall be designed in accordance with the latest international standards

The bidder shall closely coordinate with FENAKA to implement the critical changeover from the existing MV-LV distribution board to the new MV-LV distribution board in the substation without any disruption of power supply to the downstream feeders.

The Bidder shall provide control cabling and junction boxes required for the proposed grid upgrade in the island.

Bidder shall provide necessary arrangements for safe dismantling, packaging of existing de-energized MV-LV distribution board of the power house and distribution boxes and subsequent transportation of the same to a location identified by FENEKA.

3.9 N02 Vilufushi Island

The island of Vilufushi is located in the Thaa Atoll. The general data of the island is shown in the following table:

Island code, name	N02 - Vilufushi
Atoll name	Thaa
Utility	FENAKA
GPS coordinates	2°30'14.07" N 73°18'32.55" E
Inhabitants (approx.)	1,200

Harbour type	Harbour, 80x350m

Table 3-10: N02 - Island identification and general data

Figure 61: N02 - Map of the island

The Figure below shows the selected sites for the Ice making plant and PV power plant installation and the estimated required area.

Figure 62: Ice making plant and PV power plant sitting & connection to distribution grid.

The Contractor shall however be responsible of checking the suitability of the sites and optimize the design of the ice making plant and PV power plant plant based on the available area, the electrical characteristics of its system and optimizing its performance.

The general characteristics of the system to be installed are:

Island	Ice Machine Capacity	Store Room Capacity	PV size	Battery (kW / kWh)	Solar Powered Ice plant Controller	Grid
Vilufushi	15 T/day	35 T	295 kWp	100 / 150	1 lot	1 lot

The PV power plant and the ice making machine will be controlled and operated by it own energy mangament system following this system architecture (see Figure 63).

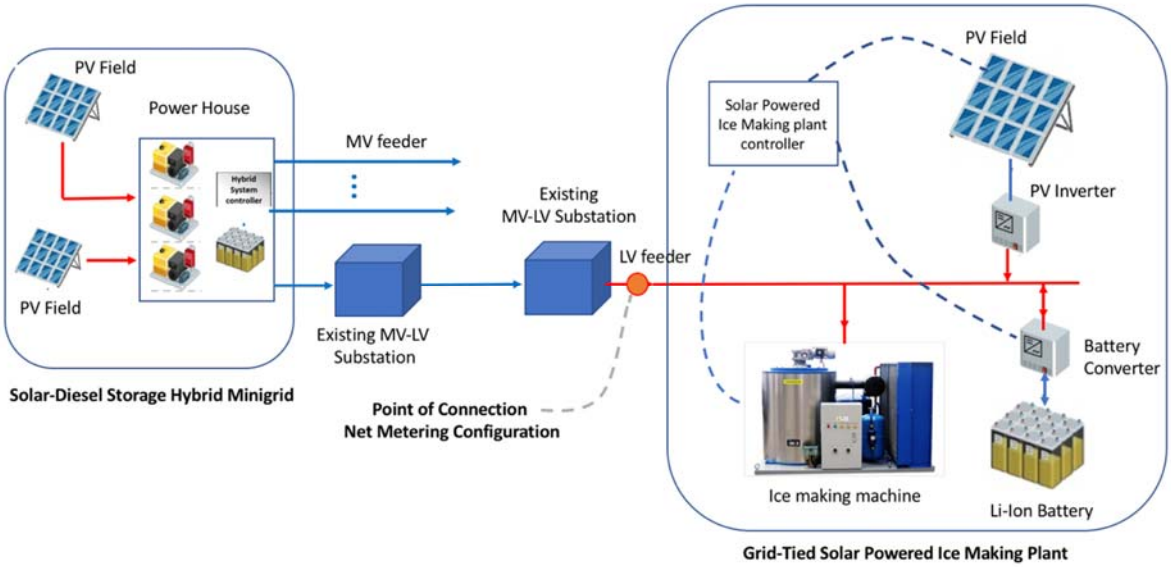


Figure 64: Ice making plant and PV power plant Schematic for Rasdhoo.

A detailed analysis of the integration of the PV power plant and its impact on the operation of the existing hybrid energy system shall be provided by the bidder.

The island is fed through distribution boxes located across the island and connected in a loop-in loop-out low voltage distribution network from the main low voltage distribution board of the power house.

Figure 65 above includes schematically the proposed grid interventions. The following tables summarize the modifications related to the grid upgrade, PV plant and ice plant connection in Rasdhoo Island.

The following tables summarize the modifications related to the grid upgrade and PV plant connection in Vilufushi Island.

- LV distribution cables and equipment

Item Description	Type	Length (M)
PV Feeders to Main LV Distribution board in the proposed new substation	4c x 300 mm2	160 m
Ice Power plant feeder to Main LV Distribution board in the proposed new substation	4c x 95 mm2	160 m
Upgrade of protection devices at powerhouse or any other point of the network	1 lot	

Table 3-11: A10 - Grid Upgradation

The Contractor shall implement the grid upgrade works in Vilufushi Island considering all necessary action for an smooth an reliable operation of the ice making plant and PV power plant.

The modification / replacement of distribution boxes shall be designed to meet the final design kWp of the PV that will be approved by the Employer.

The MV-LV distribution board shall be designed in accordance with the latest international standards

The bidder shall closely coordinate with FENAKA to implement the critical changeover from the existing LV distribution board to the new LV distribution board in the substation without any disruption of power supply to the downstream feeders.

The Bidder shall provide control cabling and junction boxes required for the proposed grid upgrade in the island.

Bidder shall provide necessary arrangements for safe dismantling, packaging of existing de-energized MV-LV distribution board of the power house and distribution boxes and subsequent transportation of the same to a location identified by FENEKA.

4 Technical specifications

4.1 General

The following sections describe the general requirements for design, manufacturing, installation, testing and commissioning of all components related to the photovoltaic solar system, grid improvement and ice making plants.

Beside all the component specific documentation to be delivered, the Bidder shall also provide at least:

- For minimum technical requirements, Section 4, "Data Sheets".
- A general Layout showing the overall design of the PV solar system including positioning of PV modules on each location separate with mounting structure, positioning of inverters, controllers, transformer, meteorological measurement station and grid connection of PV solar system. A two-dimensional drawing in PDF format is required.
- Prosposed daily operation for the hybrid systems
- A general Single Line Diagram (SLD)
- A Single Line Diagram (SLD) of generator control panel and distribution panel
- Main distribution network diagram
- MV distribution network layout, if applicable
- Sizing calculations
- Cable schedules
- Modification design

4.2 Photovoltaic Power plant

4.2.1 Photovoltaic Modules

4.2.1.1 *General*

This Chapter describes the requirements for design, manufacturing, installation, testing and commissioning of the PV modules to be provided for the PV solar system. The Bidder shall complete the data sheet "PV Module" in Section 4 Data Sheets with all missing information for the proper planning, execution of construction work, commissioning, operation and maintenance.

The nominal cumulative DC power (STC conditions) of the PV systems shall amount at least to 2.49 + 0.985 MWp (+2.5%/-0%), distributed on 12 + 4 islands (+/- 10% DC power variation is allowed on the specific islands as long as the total contractual amount is within the above given range).

Monocrystalline or Polycrystalline Module technologies shall be used.

Moreover, the Contractor is requested to deliver at least 1% additional PV modules as spare part equipment.

4.2.1.2 *Codes and Standards*

The PV Module shall be designed, manufactured and tested in full compliance with the latest edition of the following, but not limited to, standards, codes, rules and regulations:

- EN 50262 Cable glands for electrical installations
- EN 50380 Datasheet and nameplate information for photovoltaic modules
- EN 60695-1-1 Fire hazard testing
- IEC 60216-1 Electrical insulating materials - Properties of thermal endurance - Part 1: Ageing procedures and evaluating of test results
- IEC 60529 Degrees of protection provided by enclosures (IP code)
- IEC 60891 Procedures for temperature and irradiance corrections to measured I-V characteristics of photovoltaic devices
- IEC 60904-1 Photovoltaic Device, Part 1: Measurement of Photovoltaic Current-Voltage Characteristics
- IEC 60904-3 Measurement principles for terrestrial Photovoltaic (PV) solar devices with reference spectrum irradiance data.
- IEC 60943 Guidance concerning the permissible temperature rise for parts of electrical equipment, in particular for terminals
- IEC 60990 Methods of measurement of touch current and protective conductor current
- IEC 61140 Protection against electric shock - Common aspects for installation and equipment
- IEC 61215 Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval
- IEC 61345 UV test for Photovoltaic (PV) modules
- IEC 61701 Salt mist corrosion testing of photovoltaic (PV) modules
- IEC 61730-1 Photovoltaic (PV) module safety qualification - Part 1: Requirements for construction

- Manufacturing facilities must be certified ISO9001 and ISO14001
- CE Certification

4.2.1.3 *Product and Power Warranty*

The PV modules product warranty shall be guaranteed for minimum ten (10) years.

The following minimum power warranties shall be guaranteed:

- 90% of the rated power output after 10 years.
- 80% of the rated power output after 25 years.

Linear output power warranty characteristic is preferred.

4.2.1.4 *Quality*

Modules shall be of silicon cristaline type (mono-cristaline or poly-crystaline).

The quality certificate to IEC 61215 shall be provided. The flash data of each PV module shall be submitted to Employer.

The Bidder shall give attention for the compliance to IEC standard 61701 Salt mist corrosion testing of photovoltaic (PV) modules.

The quality management system of PV modules manufacturer shall be certified according to ISO 9001 and ISO 14001 by an internationally recognized Certification Authority.

The Bidder shall demonstrate a track record for the selected PV module of at least 50 MWp.

The Bidder has to deliver a quality control report. This report shall include the flash data and electroluminescence test of each module.

Modules shall be PID free. A certificate form an independent third party is required.

Modules shall not require any positive or negative grounding.

4.2.1.5 *Efficiency of PV modules*

Individual modules shall be at least 260Wp in power output under STC conditions. The tolerance of rated output of the PV modules offered may not be larger than 2.5%, and all tolerance shall be greater than rated. No negative tolerances are permitted.

4.2.1.6 *Construction requirements*

All PV modules for all installation locations shall be of the same make, type and size.

The PV modules shall be installed according to manufacturer standards and guidelines using only manufacturer approved components.

The covers shall be resistant against environmental influences like UV and salt-laden air.

Each module must be labelled indicating at a minimum:

- Manufacturer
- Type
- Serial Number
- Power rating under STC conditions
- Wp ± tolerance
- Maximum Power Point Current
- Maximum Power Point Voltage
- Open Circuit Voltage
- Short Circuit Current

The module framing (if applicable) should be such that it permits secure connection to the mounting structure, prevents edge damage and has the longevity to withstand environmental factors for the duration of the module warranty period.

The module framing and modules shall be compatible with both the roof mount structure, and compatible with the earthing requirements of section 4.10 Earthing.

PV Modules shall be provided with 14-12 AWG (2.5mm² - 4mm²) fly leads and a cable length sufficient for interconnection of modules into strings without any additional wiring. Connectors shall full fill he requirements of IEC 62852.

Integrated bypass diodes shall be installed in the junction box of every PV module.

Each PV module shall be provided with a unique identification code by the manufacturer as per their standards.

4.2.1.7 *Tests*

- Factory Acceptance Tests (FAT)

The test program for the Factory Acceptance Tests (FAT) shall be submitted to Employer for approval at least 4 weeks prior to start of the tests. The test report shall be submitted prior to the shipment.

The Employer reserves the right to visit the PV modules factory at any time during manufacturing process to verify quality and timely production.

- Type Tests

Type tests and verifications according to applicable codes and standards is not required to repeat, if a copy of the type test certificate is provided for same model.

- Additional Independent Test

Additional independent certified Third Party tests of the PV modules shall be performed. The Contractor shall propose competent Third Party testing laboratory for Employer's approval. The

Contractor shall organize and facilitate the Employer visit and/or testing in the factory if required. The Employer reserves the right to select PV modules randomly (limited to 1% of total amount of PV modules to be provided for all islands) for the following tests as minimum:

- Module performance tests
- Module behaviour test (irradiation and temperature)
- Module electroluminescence tests

All relevant costs for the above shall be borne by the Contractor.

- Site Tests

The PV modules shall be tested at site to ensure their performance during:

- Pre-commissioning
- Commissioning and test on completion

The site tests shall be witnessed by Employer. The commissioning test program shall be submitted at least 2 weeks prior to start of the tests.

- Manufacturing

All PV modules for this PV solar system shall be manufactured in the same factory. However, if there is any reason that modules are manufactured in more than one factory the Bidder shall obtain prior approval from Employer and ensure that all concerned factories have the same quality standards.

4.2.1.8 *Documentation*

Complete documentation shall be provided for the design, manufacturing, testing, installation, commissioning, start-up, operation, maintenance, repair and disposal of the PV modules and their components.

The Contractor shall provide as minimum the following documentation:

- Technical data sheets
- Reports of tests and commissioning with protocols
- Flash Report
- Installation and maintenance manual
- Factory testing quality protocol
- Guarantee
- CE Conformity Declaration.

4.2.2 DC Cabling

4.2.2.1 *General*

All DC string cables shall be of PV1-F type.

DC Cables shall be designed to have losses less than 1.5 % for the whole DC cabling system, starting from PV array till inverter DC input. Cable loss calculation is subject to prior approval by the Employer.

Any cabling shall be firmly attached to the mounting structure or lay down in cable ducts out of direct sunlight and away from access by vandals.

All DC cables shall be installed to provide as short runs as possible. Moreover, positive and negative cables of the same string or main DC supply shall be bundled together to avoid the creation of loops in the system (reduction of the induced voltage surge due to lightning).

Long DC cable runs to be in earthed metallic cable trays to attenuate surge suppression.

All DC cables shall be permanently shaded from UV radiation. Between mounting structure or PV modules a tube shall be used for protection of the cabling.

The conductors of the cables shall be made of annealed copper in accordance with IEC 60228 in flexible UV resistant sheath.

The arrangement of modules on the mounting structure, and their interconnection shall be designed to enhance servicing and inspection.

All string and main cables must be permanently labelled on both ends. Cables shall be labelled in such way that corresponding string and inverter can be identified.

4.2.2.2 *Cable Connections*

DC cable connections on string level shall be realized with connectors MC4, TYCO or equivalent of the same type and same manufacturer.

Only one type of connector for the positive (+) and negative (-) side shall be used for all installations.

Any additional connectors plus the necessary crimping tools shall be provided.

Connectors shall fulfil the requirements of IEC 62852.

All connectors shall be of the same brand. Connectors which are compatible but not of the same brand shall be not allowed.

4.2.3 Mounting Structure

4.2.3.1 *General*

This Section describes the requirements for design, manufacturing and installation of the suitable mounting structure that shall be provided as supporting structure for the PV modules.

For minimum technical requirements reference shall be made to the data sheet "Mounting Structure" in Section 4 "Data Sheets". The Bidder shall complete the data sheet with all missing information for the proper planning, execution of construction work and maintenance.

The PV module mounting structure shall meet and comply with the requirements of the PV module manufacturer.

The PV module mounting structure shall be installed on buildings, roof tops and other installation locations as defined in Chapter 2.

The typical installation location is on top of existing roofs. However in a few cases (if the available roof space is not sufficient) a free standing mounting structure may be considered..

4.2.3.2 *Materials and InstallationRooftop installation*

Roof coverings are generally made out of corrugated sheets of standing-seam type or trapezoidal/box type profile. Most roofs are Lysaght Trapezoidal Steel Sheets (0.47mm thick) with the following dimensions, but the selected systems shall be selected by the Bidders to be flexible enough to adapt to roofs sheets with potentially different measures:

Figure 66: Typical Trapezoidal Roof Sheet

The roof covering shall be refurbished / renewed before the installation of PV modules mounting structure starts in cases there the roof covering shows signs of corrosion or any other signs of deformation.

Roof fasteners shall be multiple mountings onto the corrugated roof sheet profiles for better weight distribution. A clamp type system or specialised system compatible with the trapezoidal roof sheet profiles shall be used with inbuilt waterproofing mechanisms. The array mounting superstructure shall be bolted to roof fasteners.

The roof fasteners as well as fixing method are subject to prior approval of Employer. Any attachments requiring drilling into the roof sheets, purlins or trusses shall require special prior approval of Employer.

The PV module mounting system shall be standard anodised aluminium structure or profile for clamp-mounting installation of modules. All aluminium parts shall be anodised.

All nuts, bolts, screws and other fasteners shall be made out of stainless steel, suitable to withstand the environmental conditions for 25 years.

Any contact between unlike metals shall be avoided by use of suitable insulation materials like plastic or rubber separation strips.

The PV module mounting structure shall be designed to withstand all environmental loads (wind speed of 100 km/h) and specified design loads.

An adequate corrosion protection shall be applied for the mounting structure.

The PV module mounting structure with PV modules shall be installed with sufficient (>0,5m) space from edges, eave, ridge and verge so there is ease access and a maintenance walkway.

The PV module mounting structure shall provide at least a distance of 100 mm to the roof in order to provide a sufficient natural ventilation of the PV modules.

4.2.3.3 *Ground mounted installation*

The grounding mounting structure shall be designed to withstand all environmental loads (wind speed of 100 km/h) considering the soil properties and design loads. Reinforced concrete foundation shall be used to support the main structure and the minimum height of the concrete base above the ground level shall be 300mm and cross sectional area shall be same as the steel structure flange touching the concrete base. Roofing sheets suitable for coastal area shall be used in all ground mounting structures.

The PV module mounting system shall be standard anodised aluminium structure with profile for clamp-mounting installation of modules. All aluminium parts shall be anodised.

All nuts, bolts, screws and other fasteners shall be made out of stainless steel, suitable to withstand the environmental conditions for 25 years.

The main structure may be made out of galvanized steel and shall withstand the corrosion category C5. The minimum thickness of the galvanized coat shall be 120micron.

Any contact between unlike metals shall be avoided by use of suitable insulation materials like plastic or rubber separation strips.

An adequate corrosion protection shall be applied for the mounting structure and foundation.

Minimum distance between two rows imposed: 2.8m allowing a small vehicle to drive between the rows without risk of damaging the modules. The size of the tables will actually be defined by the size of PV modules considering as well the orientation and the tilt. The Contractor shall ensure that the table size meet the recommendation from the PV module manufacturer (i.e. gap between the modules) and the site boundary conditions such as distances to roads, fences and adjacent tables.

The dimension of the tables will be defined by the size of the PV modules considering as well the azimuth and the tilt. The Contractor shall propose its mounting structure concept for Employers approval.

The Contractor shall optimize the number of the PV modules connected into one string and likewise the number of PV modules per table considering the maximum allowed DC system voltage of 1,000 V.

The Contractor is responsible to clear the installation area from any kind of vegetation as well as removal or cutting of vegetation nearby which could cause shading on the module tables. Any removal or cutting of vegetation needs to be approved by the Employer. Furthermore the Contractor is responsible for an adequate building ground preparation.

4.2.3.4 *Azimuth & Inclination*

The mounting structure shall be fixed mounted (no tracking system) and shall be, in case of roof top installations, orientated in the orientation of the roof slope as well as in the plane of the roof. In case of ground mounted systems the installation shall be optimized for yield and easy operation and maintenance.The Bidder shall submit the PV modules installation arrangement for Employer's approval.

4.2.3.5 *Cabling*

The mounting structure shall be provided with the adequate size/number of cable ducts for the installation of the cables between PV modules and the junction boxes or inverters.

The installation of the cable ducts shall facilitate easy maintenance work.

The mounting structure shall be connected to the earthing system by an appropriate arrangement.

4.2.4 PV Inverters

4.2.4.1 *General*

This Section describes the requirements for design, manufacturing, installation, testing and commissioning of the inverter to be provided for the PV solar system. For minimum technical requirements reference shall be made to the data sheet "Inverter" Section 4 "Data Sheets". The Bidder shall complete the data sheet with all missing information for the proper planning (data column), execution of construction work, commissioning, operation and maintenance. The technical data of inverter shall provide detailed information for a proper planning, execution of construction work, commissioning, service and maintenance.

The cumulative installed nominal AC output power of the inverters shall be suitable for PV module output in all ambient conditions without clipping of system output.

The inverters shall be selected and sized by the Bidder to ensure a safe and efficient functioning together with the PV solar system electrical characteristics (among others for the Maximum Power Point (MPP) range in accordance to the climatic conditions prevailing on the islands).

The Bidder shall use string inverter concepts. The Bidder is requested to deliver at least 5% additional inverter power as spare part equipment and minimum 1 inverter of each type.

4.2.4.2 *Codes and Standards*

The inverter shall be designed, manufactured and tested in full compliance with the latest edition of the following, but not limited to, standards, codes, rules and regulations:

- DIN / VDE 0126-1-1 Automatic disconnection device between a generator and the public low-voltage grid
- DIN EN 50178 Electronic equipment for use in power installations
- DIN EN 50524 Data sheet and name plate for photovoltaic inverters
- EN 50530 Overall efficiency of photovoltaic inverters
- EN 61000-6-4/A1 Electromagnetic compatibility (EMC) - Part 6-4: Generic standards - Emission standard for industrial environments
- IEC 60146-1-1 Semiconductor convertors - General requirements and line-commutated convertors - Part 1-1: Specifications of basic requirements
- IEC 60529 Degrees of protection provided by enclosures (IP code)
- IEC 61140 Protection against electric shock - Common aspects for installation and equipment
- IEC 61183 Electro acoustics - Random-incidence and diffuse-field calibration of sound level meters
- IEC 61683 Photovoltaic systems - Power conditioners - Procedure for measuring efficiency
- IEC 61727 Photovoltaic (PV) systems – Characteristic of the utility interface
- IEC 62093 Balance-of-system components for photovoltaic systems - Design qualification natural environments
- IEC 62109-2 Safety of power converters for use in photovoltaic power systems - Part 2: Particular requirements for inverters
- IEC 62116 Testing procedure of islanding prevention measures for utility interactive photovoltaic inverters
- IEC 61000-6-2 Electromagnetic compatibility (EMC) - Part 6-2: Generic standards - Immunity for industrial environments
- IEC 61000-6-4 Electromagnetic compatibility (EMC) - Part 6-4: Generic standards – Emission standard for industrial environments
- IEC 61400-21 Harmonics
- UL 1741 Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources

4.2.4.3 *Warranties and Certifications*

A product warranty of minimum five (5) years shall be provided. In addition it should be possible to purchase an extended warranty up to 10 years.

4.2.4.4 *Components*

All components of the inverters shall be selected considering easy maintenance, simple and quick diagnosis and long maintenance intervals.

All components and equipment shall be designed for continuous operation at nominal feed-in under the given climatic conditions.

All additional inverter components required to full fill the applicable standards requirements shall be provided by the Contractor. These components are not limited to inverter inside installations.

4.2.4.5 *Euro-Efficiency of Inverter*

The minimum euro-efficiency of the proposed inverter shall be at least 97% (according to DIN EN 50524).

4.2.4.6 *Operating Conditions*

The inverters shall be designed and constructed for continuous operation under the climatic and environmental conditions at site.

The system of protection shall be selected and coordinated in line with the feeding network data and the connected component requirements:

- To guarantee personnel and system safety.
- To ensure a sufficient protection against damages of the components, that might arise from the internal and external short circuits as well as from possible atmospheric discharges.
- To ensure as far as possible the continuity of operation for those parts not concerned by the fault. This will be achieved by selecting the setting in a way such that in case of a fault the closest protection device to the fault trips first.
- Overvoltage protection devices / function shall be included.

All components and devices shall have a durable, long term stable, high quality protection coat according to environmental requirements.

Damages, caused by transport, installation, cabling or commissioning shall be repaired in a way, that the original protection quality is restored.

4.2.4.7 *Technical Concept*

Only string inverter concepts are allowed. The Bidder shall propose the most technically and economically suitable concept (taking into account the operation and maintenance requirement over the PV solar system lifetime). The local environmental conditions but also the remoteness of the islands shall be considered. The chosen inverter technology must be fully compliant with the proposed PCMS to provide an optimized control of the PV-Diesel hybrid system and a reliable power supply.

The maximum DC/AC ratio of the inverter for the design of the PV system shall be 1.2 or less. Additionally the Bidder must ensure that there is no clipping of the PV power due to missing inverter capacity.

Selected PV inverters shall have a maximum nominal AC rating of 30 kVA

For ease of operation and maintenance the following requirements shall be followed:

- all PV inverters types shall be provided by a single manufacturer
- The number of different models of PV inverter shall be limited as much as possible, with a maximum of 6 different types

All PV inverters installed must provide the capability to control the active power by frequency droop control.

4.2.4.8 *Inverter Housing*

The inverters have to be installed in order to withstand prevailing climate conditions. The following concepts shall be considered, preferred concepts in descending order:

- Indoor installation in existing building: String inverter shall be installed indoor wherever locations are available. The Contractor shall install the inverters in rooms which are assigned by the Employer. Wall mounted as well as ground mounted installation may be considered.
- Outdoor installation in case where no existing building / room is available the Contractor shall install the inverters on outside walls of suitable buildings close to the installations and grid connection points at an appropriate height to allow easy maintenance. Walls will be defined together with the Employer. Moreover:
    - The PV inverters shall be protected by the rain and direct solar irradiation with a corrugated roof sheet (lower edge: minimum 2m, minimum slope 10°).
    - The area of the PV inverters shall be surrounded by a completely closed wire mesh fence (wire diameter ≥ 2mm) without any hole up to the corrugated roof sheet. Access shall be through a locked door."

If the inverters are to be installed indoor, the inverter room shall be equipped with redundant air conditioning units, light and plugs.

Logistic restrictions (max. weight and size which could be transported to the island and on the island) and installation location restrictions (size of permissible installations, etc.) must be considered.

Necessary auxiliary power supply shall be provided by Contractor.

Necessary cable connection arrangement for incoming and outgoing cables shall be provided.

Each inverter shall be connected to the grounding system with a cable of adequate diameter. manufacturer requirements shall be followed by the Contractor.

4.2.4.9 *Communication Protocol*

The communication between inverters and PCMS shall be realized with Modbus. The inverter shall be able to be controlled via Modbus communication by PCMS in order to reduce its output power if required to ensure the isolated grid stability.

4.2.4.10 *Operation*

Under normal operation inverters shall be capable of automatically synchronized with isolated grid supply and export power to the isolated grid. All required functions shall be provided in the inverter for safe and reliable auto synchronization.

The Bidder is responsible for the correct installation and operation of the PV inverters. Especially for the installation of the strings in various orientations and directions it must be respected, that only strings with the same orientation and inclination are allowed on the same MPP-Tracker. A combination of strings with different orientation or inclination on the same MPP-Tracker will not be accepted. The Bidder is responsible to design the installation accordingly.

The Contractor shall submit an overall overvoltage and over current protection design for Employer's approval. All inverter incomers and outgoings shall be provided with sufficient overvoltage and over current protection devices / functions.

For the different strings that are connected in parallel to one MPP-Tracker, the amount of modules in that strings must be the same.

Inverter Total Harmonics Distortion (THD) shall be below 3%.

The inverter shall be tested for electromagnetic compatibility in accordance with standards IEC 61000-6-2 (interference immunity) and IEC 61000-6-4 (interference emission).

4.2.4.11 *Tests*

- Workshop Tests

The Inverters shall be completely tested in manufacturer's workshop in accordance with applicable codes and standards.

- Type Tests

Copy of type tests certificates shall be provided for similar rating, if not type tests shall be performed without any extra costs to Employer.

- Site Tests

The Inverters shall be tested at site to ensure proper functionality during e.g.

- Pre-commissioning (including "loop testing")
- Commissioning and test on completion

The site tests shall be witnessed by Employer. The commissioning test program shall be submitted at least two (2) weeks prior to start of the tests.

4.2.4.12 *Documentation*

Complete documentation shall be provided for the design, manufacturing, testing, commissioning, start-up, operation, maintenance and repair of the Inverters and their components.

The Contractor shall provide as minimum the following documentation:

- Technical data sheets
- Inverter installation manual
- Layout drawings for all devices
- Single line diagrams
- Wiring diagrams
- Operation and maintenance manual
- Reports of tests and commissioning with protocols

4.2.5 DC String Combiner Box / AC Distribution Box

4.2.5.1 *General*

This section describes the requirements for design, manufacturing, installation, testing and commissioning of the DC junction boxes or/and AC junction boxes to be provided for the PV power plant. For minimum technical requirements reference shall be made to the data sheet "DC/AC Junction Box" in Section 4, "Data Sheets". The Bidder shall complete the data sheet with all missing information for the proper planning, execution of construction work, commissioning, operation and maintenance.

4.2.5.2 *Components and Equipment*

All components and equipment of the DC/AC junction boxes shall be selected considering easy and long maintenance intervals as well as quick fault diagnosis.

All components and equipment shall be designed for continuous duty at rated load and under the given climatic conditions. The Contractor shall ensure the interchangeability of components and equipment considering the same kind and type are selected for equivalent functions. Terminal blocks used in the DC/AC junction box shall have sufficient voltage and current ratings.

All additional equipment such as fuses, monitoring devices, current transformers, circuit breakers and overvoltage protection shall be of superior quality and from reputable manufacturers. Any additional components, if required, shall be provided and installed by the Contractor.

4.2.5.3 *Construction Requirements*

DC/AC junction boxes shall be made of industrial type fiberglass enclosure, factory assembled, self-standing or structure mounted. The DC/AC junction boxes with IP 65 shall be equipped with

hinged doors and fixed mounted internal components. The access to the junction boxes shall be from the front side door only that shall have possibility to swing out at least 180°.

The cable terminal blocks shall be located in the lower part of the DC/AC junction box and shall be sized in a manner such that an easy cable termination is possible. All cables shall be neatly and securely fixed within the DC/AC junction box. Cable entry to the DC/AC junction box shall be from the bottom side only using appropriate cable glands. No more than one cable per cable gland shall be allowed, the cable entries shall be watertight. The DC junction boxes must be accessibly, securely and squarely installed, and in the shade.

All the DC/AC junction boxes shall have key locking facilities (e.g. padlock).

All terminal connections in the DC/AC junction box shall have proper identification number on the terminal block and wire. All screws, nuts and washers shall be galvanized or cadmium-plated and properly fixed.

4.2.5.4 *Electrical Requirements and DC/AC Junction Box Concept*

A specific number of strings shall be connected to one DC/AC junction box as well as connection to plant control and monitoring system.

The Contractor shall optimize and define location and number of junction boxes in order to minimize the power cable losses.

The contractor shall provide kWh meter with visual display as a totalizer of kWh from all inverters at each PV sites

Each junction box shall be equipped at least with:

- Overcurrent protections and reverse current protection:
  - For DC boxes: DC fuses for at least one polarity of each string connection according to the inverter and PV module manufacturers' recommendations. Each fuse shall be sized/rated by considering the fuse characteristic, module requirements, the minimum and maximum short circuit currents, the selectivity as well as requirements of the connected cable. Only PV string fuses of type gPV according to IEC 60269-6 shall be used. Blocking diodes may not be used in place of string fuses.
  - For AC boxes: MCCB circuit breakers (fixed type) are mandatory (no fuse)
- One (1) overvoltage protection per box. For DC boxes, PV specific surge arrester type 2 shall be provided. The overvoltage and short circuit protection devices shall be provided and shall be selected in line with the feeding network data and the connected equipment requirements:
  - To guarantee personnel and plant safety.

- To ensure a sufficient protection against damages of the equipment, that might arise from the internal and external short circuits as well as from possible atmospheric discharges.
- To ensure as far as possible the continuity of operation for those parts not affected by the fault i.e. by appropriate setting selection to achieve selective tripping where only the faulty device shall trip.

- Earthing bars shall be connected to the PV power plant earthing system
- Monitoring devices for DC junction boxes:
  - Monitoring device in order to allow the detection of fault. The monitoring device shall be easily accessible and replaceable
  - String monitoring device interface with PCMS (measurement of string currents) to allow the detection of faults
  - One main ON/OFF disconnector per box

The selectivity and short current calculation shall be submitted to Employer for approval.

If any auxiliary power supply is required, i.e. for monitoring systems, the supply shall be provided by the Contractor.

The selection and sizing of the DC and AC protections (fuses, isolating switches, circuit breakers, surge arresters etc.) shall be compliant with the voltage level and with the relevant IEC standards.

4.2.5.5 *Tests*

- Workshop Tests:

The DC/AC junction box shall be completely tested in manufacturers' workshop in accordance with applicable codes and standards.

- Type Tests:

Type tests and verifications according to applicable codes and standards shall not be repeated, if a copy of the type test certificate is provided for same model.

- Site Tests:

The DC/AC junction box shall be also tested at site to ensure proper functionality during e.g.

- Pre-commissioning
- Commissioning and test on completion

The site tests shall be witnessed by the Employer. The commissioning test program shall be submitted at least two (2) weeks prior to start of the tests.

4.2.5.6 *Documentation*

Complete documentation shall be provided for the design, manufacturing, testing, commissioning, start-up, operation, maintenance and repair of the DC/AC junction boxes and their components.

- The Contractor shall provide as minimum the following documentation:
- Technical data sheets
- Internal layout drawings showing all installed components
- Wiring diagrams
- Cable lists
- Spare parts list
- Operation and maintenance manual including component list with manufacturer information e.g. catalogue, etc.
- Reports of tests and commissioning with protocols

4.2.6 Meteorological Station

4.2.6.1 *General*

The PV power plant shall be provided with the meteorological measurement station to monitor ambient and weather conditions with respect to below mentioned meteorological parameters.

The Bidder is responsible for the installation of meteorological measurement station minimum four (4) weeks before commissioning (to ensure correct calibration of the system) of the PV power plant.

The power supply for meteorological measurement station shall be from UPS.

The meteorological measurement station shall be compatible with the SCADA system. The provided data to the SCADA system shall be stored locally and be available via internet connection.

The meteorological station shall be installed by the Bidder on a location where no shading from any building, light pole or any other obstacle is expected on the pyranometers or reference cells, nor from the meteorological station on the modules of the PV field.

4.2.6.2 *Technical Requirements for Type 1 meteorological stations*

The following specifications are for **Type 1 meteorological station** which shall be installed on the islands as specified in Chapter 2.6.

1. Global solar irradiation on horizontal plane:

- Two (2) pyranometers (ISO 9060 Secondary Standard): one for horizontal installation and one at the same orientation and inclination as the roof with the largest PV power plant installed on the island
- Metering range: 0 to 2000 W/m²
- Overall accuracy: ± 2 % of metered value (daily average)
- Spectral range 310 to 2800 nm

2. Air temperature
   - Overall accuracy: ± 0.5 °C
   - Metering range :- 40 to + 70 °C
   - Response time : 20 s (T90)
3. Module temperature
   - PT1000 or PT 100 adhesive foil resistor in 4 wire measuring technology
   - At least two (2) independent sensors shall measure the module temperature of the modules
   - State of the art technology to mount the temperature sensor to the module shall be used
4. An anemometer mounted on a mast to measure the wind speed at the site
   - Sensor type: Solid state magnetic sensor for wind speed
   - Wind vane and potentiometer for wind direction
   - Min. measurement range shall be 1…70m/s
   - Wind direction range 0…360°
   - The location of the mast shall be the same as the pyranometers.
   - The mast shall be high enough, that there is no horizontal wind shadow from any other obstacles. Manufacturers recommendations shall be respected
5. Data Logger
   - The data logger shall be time synchronized
   - Analogue inputs with a resolution of at least 16 bits
   - Input voltage range: ± 10 mV to ± 10 V, full-scale
   - Memory extension by using a SD card
   - Interface Base: RS 485 / RS 232 / Ethernet / Modbus(Must be compatible with SCADA system)

- Standard protocol: ASCII / PROFIBUS / Modbus
- Linearity: ± 0.01% Absolute Accuracy: 0.05%
- All analogue inputs shall be fault-protected against short-circuit, over-voltage, transients and ESD
- Data Storage Space: At least 1 GB
- Internal Memory: 4MB
- Keyword protected web application for Employer/Engineer
- Ambient temperature: 0 – 55 °C
- Humidity: up to 100% non-condensing
- Watch Dog Timer: Yes
- Data logger shall be compatible with the climatic conditions on site

4.2.6.3 *Technical Requirements for Type 2 meteorological station*

The following specifications are for **Type 2 meteorological station** which shall be installed on the islands as specified in Chapter 2.6.

1. Global solar irradiation on horizontal plane (Reference cell):
   - Reference cell (same technology as used in PV power plant, suitable to be installed horizontally)
2. Air temperature sensor:
   - Same requirements as Type 1 meteorological station
3. Module temperature:
   - Same requirements as Type 1 meteorological station
4. Data Logger:
   - Same requirements as Type 1 meteorological station

No anemometer is required for Type 2 meteorological station.

4.2.6.4 *Enclosure and environmental conditions*

The PCMS shall be installed in a cabinet in the control room, including all necessary communication modules.

All additional equipment like servers for process data and archive server, etc. shall be located in the same area. Field devices to gather all PV, meteorological data, diesel engine data, BESS data, electrical feeder data, etc. should be installed close to the related areas.

The PCMS and associated accessories shall be accommodated in dedicated equipment cabinets for indoor application. The cabinets shall be constructed as follows:

- Standard sized steel cabinets with external painting colour as per Employers approval
- Certified for minimum IP31 protection class
- Front-patches for LAN cabling
- Cable organisers, cable trays, suspensions and termination components with strain relief for all internal and external cabling
- 20 % housing space for future equipment
- Bottom cable access
- Grounding bus bar for earthing connection
- Power socket for maintenance
- Provision of easy access for maintenance and repair

4.3 Battery Energy Storage System (BESS)

The BESS mainly consists of the following parts:

- Batteries
- Battery Inverters/Chargers
- Housing

The system shall operate fully automated, be remotely monitored and be delivered as a turn-key system.

The BESS is manly designed to support the Diesel Generator system with active and reactive power following the command of the Main Hybrid Controller. The type of battery shall be a power battery that can deliver a high power for a short period of time.

The function of the BESS is to store and supply energy as required, in accordance to the hybrid power system's energy demand.

The battery energy storage system shall perform but not be restricted to the following functionalities:

- Power balancing: The BESS shall ensure an instantaneous active and reactive balance between load and generation. The system shall stabilize the frequency of the grid independently of the changes on load or renewable generation systems.
- Contribution to voltage regulation: The power electronics part of the system shall contribute to the voltage regulation of the grid, performing a proper management of the reactive power circulating in the grid.

A detailed concept of the battery monitoring system needs to be provided by the Bidder

General additional requirements to the system operation:

- The battery system shall be maintenance free, meaning that no regular works or software updates shall be required for a continuous operation.
- The Bidder will inform about the requirement of some kind of preventive maintenance scheduling and the impact of these labours on the warranty terms and conditions of the system.
- The Bidder will also inform about the indicated personnel to perform the above mentioned maintenance tasks (manufacturer, certified sub bidder, etc.)
- The battery system shall have low environmental impact. A life-cycle assessment in the product design and all the environmental considerations will be supplied by the Bidder.
- The Bidder shall provide all the safety considerations of the battery manufacturer about the system and shall supply all the ancillary systems that may be needed to avoid.
- The Bidder shall have a program for battery dismantling and return to factory after its operation life.

4.3.1 Batteries

The selected battery energy storage shall be able to deliver the minimum required power as precised in the Table 2-2 in Chapter 2.5 (column "Battery and battery inverter required minimum power") and meet the requirements of minimum battery capacity at nominal discharge rate (column "Minimum required battery capacity", example given for a 1C battery).

Technical requirements of the battery:

- Battery technology: **Lithium-ion**
- The Battery must be able to supply the required power as stated in the table in Chapter 2.5 (column "Battery and battery inverter required minimum power") for at least **30 minutes for Type B** and for at least **60 minutes for Type C** systems.

  Acceptable nominal discharge-rate : **0.5C to 2C** as long as the required functionalities and specifications are fulfilled: depending on the nominal discharge rate (C-Rate) of the battery offered by the Bidder, the minimum required battery capacity specified in the Table 2-2 Chapter 2.5 for 1C (nominal discharge rate) batteries must be adapted by the bidder if battery with different C-rates is provided.

  EXAMPLE: for an island with a 150kWh 1C battery specified in Table 2-2, if the bidder wishes to offer batteries with a nominal discharge rate of 2C, a minimum capacity of 75kWh instead of 150kWh would be required. On the contrary, for a battery with 0.5C nominal discharge rate, 300kWh would be required.
- The battery itself shall then be composed of modular racks, which consist of several battery trays which are put together from modules which consist of Lithium-ion cells.

The modules, trays and racks shall easily be exchangeable on site to improve reliability in case of fault and to facilitate the maintenance works.

- Communication protocol with the Main Hybrid Controller: Modbus
- Battery roundtrip efficiency ≥ 95%
- **Recycling certificate**: when the battery has achieved its end of life it must enter in a recycling program from the Manufacturer. The transport and shipment costs will be carried by the Employer. The Bidder shall provide a certificate proving that the Manufacturer agrees to receive and recycle the lithium-ion batteries according to international applicable standards.

The cycle life and durability of the batteries is a major requirement in the system. The Bidder shall provide components that full fill the following points:

- The cycle DoD (Depth of Discharge) graph from the battery manufacturer shall be provided by the Bidder (official statement signed from Manufacturer required)
- The battery must be able to provide a minimum of 5.000 cycles at 80% of DoD at 25°C. End of Life shall be 80% of initial capacity. The guaranteed cycle life shall be depending on the energy throughput. The Bidder shall provide a lifetime graph from the manufacturer, showing number of cycles vs. DoD.
- A calendar life of at least 20 years is required (End of Life: 80% of initial capacity), if the guaranteed cycles are not used before.

4.3.2 Battery Inverters/Chargers

- The battery inverters shall be bidirectional and act as inverter and charger to batteries.
- The battery inverters shall have capability to operate parallel in voltage source mode while DG's are running as grid-forming element
- For each island, the battery inverters must be able to deliver the required power as stated in Chapter 2.5 in both directions (nominal power).
- The overload capability of the inverter must be at least 150% of its nominal power for at least 30 seconds.
- Minimum conversion efficiency: ≥94% (one way)
- It is preferred to have max. 3 different sizes of battery inverters for all islands to be able to have a fast change from the spare part storehouse.
- All selected battery inverters shall have the capability to be operated as grid building battery inverters, also for type B to allow the potential future expansion of the system by FENAKA. For Type C islands, they will be configured for a *grid building operation*. For all other (Type B) islands, they will be configured for a *grid support operation*.

- Inverters must always be able to operate in parallel with a Diesel Generator and communicate with the Main Hybrid Controller via Modbus.
- The inverters shall be able to operate in power-frequency-droop control. Adjusting of droop curves shall be possible during operation without a system shutdown.
- The inverter must be able to provide sufficient short circuit power to the system. The required currents must be in accordance with the grid protection concept and the grid study.
- The inverter supplier shall have a proven track record (minimum 5MW over the last 5 years) in island system applications.
- The Bidder shall be available on site for the repair or exchange of parts within 72hours.
- The inverters shall be equipped with suitable DC-breakers and fuses for the battery strings, they shall both be easy accessible and exchangeable.
- The inverters DC voltage range needs to fit the battery voltage range, to ensure a full utilisation of the installed battery capacity.
- On the AC side, the inverter shall be equipped with circuit breakers and disconnectors.
- The inverters shall have isolation supervision.
- The batteries shall be connected to a dedicated feeder on the main LV distribution board of the powerhouse.

4.3.3 BESS Housing

The battery shall preferably be installed in a room/additional building next to the power house where the genset power system is located. It is also allowed to extend the powerhouse for this purpose or provide the system in a pre-wired ISO-Container that shall be installed next to the powerhouse. It is mandatory to use proper concrete foundations for the container. In case of power house re-allocation a pre-wired ISO-Container for battery housing is mandatory. The following specifications for the battery room have to be fullfilled:

- It shall be equipped with a redundant inverter air conditioning system, where a failure of one system will not lead to a complete failure of the battery system. A failure in the air conditioning system must be communicated to the operator via a control system. This can be done with a temperature sensor inside the battery inverter room.
- The ambient battery temperature and surrounding air humidity shall always be kept within the manufacturers specifications.
- For a maximum cooling efficiency the container/building/room of the BESS must have a thermal insulation on walls, ceiling and floor.
- If containers are used they shall be painted white and coating must be according to corrosion protection class 5 for maritime environments.

- The containers shall be installed in a shaded area, where a white roof structure provides shading to the installation area.
- IP54 standard shall be used for the ISO-Containers.
- The housing shall have a closed concept, where no permanent air flow is allowed from outside the housing into the housing.
- A fire & smoke detection system shall be installed in all rooms/containers of the system. In case of fire, a visual and audible alarm has to be activated. The fire protection system shall be equipped with a UPS system to ensure functionality even in case of grid failures.

For additional specifications that have to be full filled, please also see Chapter 4.7.

4.3.4 Protections

4.3.4.1 *AC protections*

- AC overvoltage protection
- EMI filter
- Grid voltage variations
- Frequency failures
- Asymmetric currents
- Voltage sag compensation

4.3.4.2 *DC protections*

- DC overvoltage protection
- Inverter shutting down overload error
- Inverter system isolation detector

4.3.4.3 *Others*

- Output coil and IGBT over-temperature
- Breaker protections of auxiliary systems

Standards

The power storage system to be implemented must comply with international standards in the applicable fields, e.g.:

IEC 61960	Secondary cells and batteries containing alkaline or other non-acid electrolytes - Secondary lithium cells and batteries for portable applications

IEC 61427	Secondary cells and batteries for photovoltaic energy systems
IEEE 1375	Guide for the Protection of Stationary Battery Systems.
EN 50272-2	Safety requirements for secondary batteries and battery installations.
IEC 62619	Secondary cells and batteries containing alkaline or other non-acid electrolytes- Safety requirements for large format secondary lithium cells and batteries for use in industrial applications
UL 1642	Safety Standard for Lithium Batteries
EN 50178 / IEC 60950	Electronic equipment for use in power installations
IEC 62 040-2	Uninterruptible power systems (UPS) - Part 2: Electromagnetic compatibility (EMC) requirements (IEC 62040-2:2005)
IEC 62093	Balance-of-system components for photovoltaic systems - Design qualification natural environments

4.4 Diesel power plant

4.4.1 General

The diesel engines shall be four-stroke machine of modern design operated on commercial grade diesel fuel locally available.

The diesel engines shall be of the general purpose, stationary, solid injection, internal combustion, compression ignition and exhaust gas super charged type.

The Diesel Generator unit's continuous rating shall be stated in accordance with the data sheets (PRP - Prime power under variable load according to ISO 8258-1). The Diesel Generators shall deliver the rated output at the rated speed at specified site condition no negative tolerance.

The engines shall be capable of providing power to a varying load for an unlimited number of hours per year. The engines shall have sufficient power output to operate the generator at 10% overload for one hour within any twelve hour operation.

4.4.2 Codes and Standards

The Diesel Generator shall be compliant with the following standards:

- ISO 8528-1 (continuous power) Reciprocating internal combustion engine driven alternating current generating sets - Part 1: Application, ratings and performance
- BS 4999 General requirements for rotating electrical machines
- BS 5000 Specification for rotating electrical machines of particular types or for particular applications

- IEC 60034 Rotating electrical machines
- BSEN 61000 Electromagnetic compatibility
- UTE NFC51.111 Rotating electrical machines
- VDE 0530 Rotating electrical machines
- NEMA MG 1-33 Performance standards applying to all machines part 33 – definite purpose synchronous generators for generating set applications

4.4.3 Diesel engine operation

The generators continuous power rating as per the manufacturers commissioning protocol shall be within the tolerance of +20% / -5% of the required power stated in Chapter 2.x.2 of each island specification (or in the overview in Chapter 2.5).

Proven ability to function at low loads: The Diesel Engine shall be capable of functioning continuously at low loads of approximately 25% - 35% and it shall be able to run underneath 25% of its rated power according to the manufacturers specifications, without taking any damage regarding maintenance and lifetime of the generator, and without causing cylinder glazing nor harmful sediments on vales, pistons, combustion chamber or any other parts of the engine. This has to be in line with the manufacturer's warranty.

There shall be digital interface for reading of all the Diesel Generator sensors installed and the operational data of each Diesel Generator that will be exchanged with the PCMS.

4.4.4 Exhaust system specifications

The exhaust system shall accommodate expansion movements and shall be arranged so that vibration from the engine is not transmitted to the building or support structure.

The system shall be designed and surface prepared to avoid corrosion from condensate of the flue gas when the engine is operated under any load under the given ambient conditions. The influence of rain, sea spray and salt on parts external to the powerhouse building shall be mitigated by the design.

Exhaust piping, residential grade exhaust gas silencer and flexible bellows shall be of mild steel and painted with 600degree heat resistant paint. Where the piping penetrates a wall, a through the wall thimble shall be installed.

Thermal insulation shall be installed for the portion of the exhaust gas pipes within the powerhouse.

The thickness of insulation shall be calculated using the economic thickness method in BS 5422, or other equivalent recognized reputable international standards. A separation layer of Aluminium foil shall be applied first to the stainless steel pipe surface to avoid stress corrosion cracking from chlorides in the insulation material.

Pre-formed sections shall be used where possible. Shaped rock wool mattress may be used for removable sections like flexible bellows. All insulation materials used shall be asbestos free.

Insulation applied to exhaust pipes shall be clad with Aluminium. Thickness shall conform to BS5970, or other equivalent recognized reputable international standards.

As per the MEA guide line, the exhaust outlet shall be 1.2m higher than the highest point of the powerhouse roof.

For detailed specifications please also see attached drawing J431-ILF-AD-00025_Diesel Exhaust System_Rev0.

4.4.5 Controllers and generator synchronization

Existing Diesel Generator controllers shall be removed and generators shall be connected to the generator synchronizing panel boards supplied under this project in order to fit the requirements of the hybrid system. The gensets shall be automatically synchronised, as well as started and stopped automatically according to the load demand and the PCMS's commands.

The parameters to be exchanged shall at least be the following, but not be limited to:

- Output voltage
- Output current (single and total)
- Output power (single and total)
- cosphi (single and total)
- Frequency/RPM's
- Rated power of running gensets (single and total)
- Generator Status/Alarms & Errors

The communication between Diesel Generator controllers and PCMS shall be realized via Modbus.

The communication between generator controllers and corresponding actors, sensors, governors, etc. on the genset may be done with different communication protocols, such as CAN-Bus for example.

4.4.6 Technical specifications

- All elements of the Diesel Generators shall be of marine grade quality and designed to withstand the environmental conditions on site.
- The radiator cores shall be solder coated. The solder coated cores shall be type tested by a third party according to ASTM-B117. Certificates shall be provided to the employer on demand.

- The generator shall be painted with high quality marine grade paint.
- The main alternator windings shall be insulated to marine grade level. All rotor and stator windings shall be coated with high-bond epoxy varnish.
- Frequency: 50Hz
- Rated rpm: 1500
- Insulation class: H-class
- Voltage regulation: A.V.R. (electronic)
- Exciting system: self-excited, brushless
- "Common-Rail" fuel injection system with electronically controlled injection desired, if it is available for the size of the engine
- Fuel filter including moisture separator
- Forced-feed lubrication system with piston cooling
- Lube oil heat exchanger
- Exhaust turbochargers with intercooler, integrated in radiator
- Exhaust Emissions shall be within the following limits:

	@ 100% load
NOx (mg/Nm³)	3,682.44
CO (mg/Nm³)	702.03
HC (mg/Nm³)	70.20

Existing fuel flow meter shall be integrated to the system to read and display the volume of fuel transferred to service tanks.

4.4.7 Performance requirements

The following minimum requirements regarding the specific fuel consumption of the Diesel Generator must be met by the offered Diesel Generators:

Output power (in % of PRP@25°C)	25%	50%	75%	100%	
>800kW	280	225	220	220	g/kWh
200-800kW	305	255	235	235	g/kWh
50-200kW	315	265	245	245	g/kWh

<50kW	370	295	270	260	g/kWh

Table 4-1: Specific fuel consumption requirements of Diesel Generators

Prime Power (PRP) according to ISO 8528, 10% overload capability according to ISO 3046.

The consumption of all Diesel Generators will be measured on site during commissioning and will meet the following requirements:

- Measurement equipment will be provided by the Contractor. Method statement is subjected to the approval of the Employer. Preferred measurement system: using a separate small fuel tank and a high precision balance.
- Measurement will be performed by the Contractor at his own costs and in presence of representative of the Employer.
- Measurement with cosφ=0,8 LHV=42700 kJ/kg, 3% measurement tolerance.
- Duration of the test for each Diesel Generator: at least 10 minutes.
- Correction related to site local conditions (temperature, air pressure etc.) according to ISO 3046 standard

4.5 Ice Making Plant

4.5.1 General conditions

Sea water flake ice machine shall produce ice from sea-water

4.5.2 Technical specifications

- It should have continuous ice flake output
- Heavy duty stainless steel construction SS 304 for all the contact surfaces including storage bin
- Noiseless operation
- Water connection (British standard pipe thread)•Flake ice thickness- 1.8 to 2.5mm
- Over loading protection / water shortage auto detection
- Alarm for over loading and water shortage
- Automatic power off during water shortage
- Ice Storage Room Capacity Up to 8 Tonnes (1 unit) and 23 Tonnes (3 units) with stainless steel or polyethylene interior for easy cleaning and should resist scratches and scuffs from ice scoops

- Storage bin base drain tub should rotates at 360º radius to allow ease-of-connection with any floor water drain position•Should have PUF insulation
- Power Supply three phase 400-230 Volts, 50 Hz
- It should meet ENERGY STAR requirements and provide proof of certification
- The compressor shall be open type or hermetic type, mechanically or thermally sealed. The assembled refrigeration system shall be completely dehydrated and charged with the amount of refrigerant and oil necessary for operation.
- Ice machines using chlorofluorocarbons (CFCs) ozone depleting refrigerant gases are not acceptable. Preferably R22A / R 404A-Refrigerant should be used
- Supplied and installed at specified location in Maldives.

4.6 Distribution Grid

4.6.1 General

This section outlines the project requirements and technical specifications for upgrading the grid infrastructure of the islands covered in this project. The Contractor shall fully comply with the requirements given in the subsequent sections during design, manufacture, factory testing, delivery to site, installation, site testing, and commissioning, warranty of the complete system in each island and training of nominated Employer's staff.

The Contractor is required to include all materials, labour, equipment and any additional charges that the Contractor may possibly incur to meet the terms of this contract. The Contractor shall envisage such requirements whether specified in detail or not in this contract document or other relevant documents and drawings enclosed with this contract

It is not the intent of these specifications to specify completely herein all the details of design and manufacturing of the equipment or works involved in the project. It may be noted that norms, standards specified in the sections below are minimum requirements. The equipment and works involved shall conform in all respects to high standards of engineering design and workmanship and should be capable of performing continuous commercial operation within the parameters guaranteed by the supplier in a manner acceptable to the Employer.

4.6.2 Applicable International Standards

Equipment related to upgrade of the distribution network in this project shall be designed, manufactured and tested in full compliance with the latest edition of the standards, codes, rules and regulations which include but not limited to the following.

- LV Switchgear

IEC	60144	Degree of protection of enclosures for LV switchgear and control gear

IEC	60157	LV switchgear and control gear
IEC	61439	LV switchgear and control gear assemblies
IEC	60664	Insulation co-ordination for equipment within LV systems
IEC	60947	LV switchgear and control gear
IEC	61180	HV test techniques for LV equipment
IEC	61641	Enclosed LV switchgear and control gear assemblies
IEC	61643	LV surge protective devices

- LV XLPE-Insulated Underground Cables

IEC	60028	International standard of resistance for copper
IEC	60071	Insulation co-ordination
IEC	60228	Conductors of insulated cables
IEC	60287	Calculation of the continuous current rating of cables (100 % load factor)
IEC	60330	Methods of test for PVC insulation and sheath of electric cables
IEC	60331	Tests for electric cables under fire conditions
IEC	60529	Classification of degrees of protection provided by enclosures
IEC	60885	Electrical test methods for electric cables
IEC	61000	Electromagnetic Compatibility (EMC)
IEC	61034	Measurement of smoke density of cables burning under defined conditions
IEC	62095	Electric Cables – Calculation of current rating – Cable current rating calculations using the finite element method
IEC	60502	Extruded solid dielectric insulated power cables for rated voltages
IEC	60949	Calculation of thermally permissible short circuit currents, taking into account non-adiabatic heating effects

- LV XLPE-Insulated Underground Cables Accessories

IEC	61238	Compression and mechanical connector for power cables
IEC	60230	Impulse Tests on Cable and Their Accessories
IEC	60793	Generic specification and measuring methods
IEC	61238	Compression and mechanical connector for power cables
BS	7888	LV and MV accessories for power cables

4.6.3 Alternative Codes and Standards

The Bidder may propose alternative Codes and Standards provided it is proven that it gives an equivalent degree of quality as the referenced Codes and Standards. Acceptability of any alternative Codes or Standards is at the discretion of the Employer.

4.6.4 Project Requirements

Detailed site survey, data collection including condition assessment of distribution boxes, LV distribution boards and other related equipment (from PV injection point to Powerhouse).

Based on the results of the site survey, the contractor shall produce detailed design in full compliance with the technical specifications and latest revisions of relevant International standards to complete all works required to the satisfaction of the Employer.

Detailed design /study from the Contractor shall be subject to review and approval by the Employer.

Supply, Installation, testing and commissioning of all works related to the upgrade of the segments of existing main distribution network from PV injection point to Powerhouse including, cabling, replacement of distribution boxes, Main LV distribution board in power house with generator control and synchronizing system and associated works including earthing arrangements etc. in line with approved design.

Supply, Installation, testing and commissioning of all works related to the cabling for the upgrade of existing grid in line with approved design.

Supply, Installation, testing and commissioning of all works related to the interconnection of the proposed PV plant to the existing grid in line with approved design.

Supply, Installation, testing and commissioning of all works related to replacement of existing Main LV Distribution board in the Power House in line with approved design.

Supply, Installation, testing and commissioning of all works related to modification and replacement of existing distribution boxes in line with approved design.

Supply, Installation, testing and commissioning of all works related to extension of main LV distribution board in the Power House for new DG connection in line with approved design.

Supply, Installation, testing and commissioning of all works related to modification of existing low voltage distribution boards in 11/0.4kV substations for connection of proposed PV plant in line with approved design.

Testing and commissioning of the entire system including relevant functional tests as per all relevant international standards and local regulations to the satisfaction of the Employer.

Supply of Spare parts, tools and consumable items for each island

Operation and maintenance manuals, spare parts catalogues and "As built" drawings as per the requirement of the Employer shall be provided for each island.

Training the nominated operation and maintenance staff in each island to operate and maintain the equipment supplied under the contract.

Warranty for all equipment and work completed.

All Electrical works under this contract shall be carried out by qualified electrical technicians. Similarly mechanical and civil works shall be carried out by qualified personnel. All detail design shall be approved by relevant government autority.The Contractor shall provide educational or vocational certificates of engineers, designers, technicians and mechanics before commencing any work. Work carried out by unqualified workforce shall not be accepted.

All electrical installations shall be carried out using proper tools. Where tests are required, adequate and appropriate testing instruments with valid calibration certificates shall be utilized to demonstrate compliance of the installations with the specifications and regulations set out in the standards.

Similarly all civil and mechanical work shall be carried out using proper tools and if requested the Contractor shall satisfy the Employer's Representative that appropriate equipment have been utilised in carrying out any of the work in this Contract.

4.6.5 Components and Material Requirements

4.6.5.1 *General*

All equipment/systems shall comply with the latest requirements of IEC / BS recommendation (as a minimum requirement). All components shall be of approved and reliable design and shall be suitable for site service condition prevailing in the islands.

4.6.5.2 *Markings and Labelling*

All devices shall have labels fitted to non-detachable parts of equipment subject to the approval of the Employer's Representative and conforming to the following general requirements. Self-adhesive labels are not acceptable. All labels shall be in the English language unless otherwise stated.

All apparatus shall be clearly labelled indicating where necessary its purpose and the "on" and "off" positions. Labels shall indicate the purpose of all ancillary apparatus such as relays, fuses, etc. Each phase of switchgear and connections shall be coloured as approved to distinguish phases. Fuse labels shall show the type and rating of each fuse.

In addition to the above, warning labels shall be provided as per the MEA regulation on all relevant locations in line with Employer's requirements. Further, all DB installations should carry an interpretation of the warning label given below in Dhivehi and English.

"Danger High Voltage -400 Volts"

Equipment	Type of Label	Remarks/Function
Switches	White traffolyte black lettering	Circuit and equipment

Equipment	Type of Label	Remarks/Function
Wire numbering	White bands black lettering	Clip on type shall not be used
Switchgear	White traffolyte black lettering	Equipment identification
Fuses	White traffolyte black lettering	Type, rating and circuit identification
Instruments	White traffolyte black lettering	Function
DBs and DFPSs	PVC acceptable	Identification number securely riveted
Service pillar fuses	White traffolyte black lettering	Type, rating and circuit identification
Underground cable entry and exit from ground	PVC acceptable	"Danger Underground Cable" with red flash on white background

4.6.6 Distribution Boxes (DBs)

4.6.6.1 *General*

Distribution Boxes shall include the following as a minimum:

- Weatherproof enclosure
- One 200A three pole, moulded case main circuit breaker (MCCB)
- Twelve 40A single pole, miniature circuit breakers (MCB)
- One 63A three pole, miniature circuit breaker (MCB)
- One 16A three pole, residual current circuit breaker with over-current protection (RCBO)
- One electromechanical time switch, 1 channel, 24 hour operating cycle, 15 minute minimum switching
- One insulated common busbar (for outgoing breakers)
- One brass neutral link mounted on to an insulated support
- One insulated terminal block

4.6.6.2 *Specification Drawings*

S No.	Drawing Number	Title
1	J431-GOPA-GEN-GR-E-D-0001	SINGLE LINE DIAGRAM OF DISTRIBUTION BOX: INDICATIVE (COMMON)
2	J431-GOPA-GEN-GR-E-D-0002	DISTRIBUTION BOX LAYOUT: INDICATIVE (COMMON)
3	J431-GOPA-GEN-GR-E-D-0003	DISTRIBUTION BOX MOUNTING DETAILS: INDICATIVE (COMMON)

4.6.6.3 *Enclosure*

Outdoor weatherproof GRP sealed enclosures shall be protected to IP 67, according to IEC 529, and insulation class II according to IEC 232, or other equivalent recognised reputable international standards.

The Contractor shall size the enclosure to a minimum practical limit, without compromising other important features like sequenced and neat component layout, safe minimum clearances, electrical segregation of components from each other, ease of operating control and protective gears etc. The maximum depth of the enclosure shall be 250 mm where practical.

The entire body shall be made out of one piece, with top and bottom canopy. A protective guard from bottom of box to ground line shall match distribution box in material and dimensions. A plain door equipped with at least two locks (8 mm triangular locks with keys) shall be fixed on to the enclosure with at least two removable stainless steel hinges.

Electrical accessories shall be fixed onto a removable rigid base plate fixed to the back of the enclosure. The base shall be solidly earthed to the earth bar.

4.6.6.4 *Manual MCCB*

Appropriately rated three poles manual MCCB, conforming to relevant British Standards shall be used after each incoming cable. The contacts shall be fully rated with anti-welding tips fixed on high conductivity copper backings and shall withstand the prospective short circuit current rating of the intended circuit. The contacts shall be insulated or shrouded to prevent the hazardous accidental contact while working on other parts of the distribution boxes.

The colour of the enclosure shall be RAL 7032.

4.6.6.5 *Busbars and Connection*

Busbars shall be made of hard drawn high conductivity electrolytic copper conductors, rigidly supported on suitable insulators.

Busbars shall be shrouded and preferably segregated from other components and access to busbars shall be possible only by removing bolted covers.

4.6.6.6 *Moulded Case Circuit Breakers*

All moulded case circuit breakers shall be of the thermal magnetic type rated for continuous operation under the stated ambient condition. All the circuit breakers shall be complete with shunt trip coil. Tripping of the CB shall be effected by means of an AC solenoid shunt trip coil and by means of mechanical push-in button. Their symmetrical interrupting capacity shall be 16kA.

The mechanism shall provide positive closing, trip free action with follow through on opening. The contacts shall be of anti-welding silver tungsten tips fixed on high conductivity copper backings.

4.6.6.7 *Miniature Circuit Breakers*

Miniature circuit breakers shall have a short circuit current breaking capacity of 10 kA, and be DIN-rail mounted types. They shall be provided with thermal over current and electromagnetic short circuit release and comply with BS 3871, or other equivalent recognised reputable international standards. The mechanism shall provide positive closing, trip free action with follow through on opening. The contacts shall be of anti- welding silver tungsten tips fixed on high conductivity copper backings.

4.6.6.8 *Factory Assembly*

The distribution boxes shall be factory assembled and tested.

4.6.7 Low Voltage Armoured Cables

4.6.7.1 *General*

These specifications define the requirements for multi-core copper conductor, cross linked polyethylene (XLPE) insulated, steel wire armoured (SWA), and PVC sheathed, 600/1000 Volts, power cables as per the latest IEC / BS standards, or other equivalent recognised reputable international standards.

De-rating factors due to temperature, grouping (or bunching), method of installation, nature of usage, prospective short-circuit etc. shall be taken into consideration. After de-rating, the current carrying capacity of the cable shall be at least 5% greater than the upstream protection of the switchgear.

Auxiliary multi-core control cables shall be PVC or XLPE insulated and PVC sheathed.

4.6.7.2 *Conductor*

Conductors shall be annealed copper stranded conductors complying with IEC 228 or BS 6360, or other equivalent recognised reputable international standards. Multi-core cables with cross-sectional area greater than 16 Sq. mm shall be shaped stranded conductors. Unless otherwise specified XLPE insulated cable mains and sub-mains shall have full-sized neutral conductors.

4.6.7.3 *Insulation*

The insulation shall be XLPE compound complying with the requirements of BS 7655 Type GP8 (general purpose) or other equivalent recognised reputable international standards. The maximum allowable conductor temperature at normal operation shall be 90°C.

4.6.7.4 *Identification*

The cores of cables shall be identified by colour of XLPE compound. For four core cables the colours shall be red, yellow, blue and black. The portions where the insulation colour is visible should be sleeved with red, yellow, blue and black sleeves respectively during installation.

4.6.7.5 *Laying Up*

The cores of cable shall be laid with right hand direction of lay. Where necessary, non-hygroscopic fillers shall be applied

4.6.7.6 *Bedding*

An extruded layer of PVC bedding shall be applied over the assembly to form a circular cable and armour bedding. Where fillers are necessary they shall be of PVC.

4.6.7.7 *Armour*

Armour shall consist of single layer of galvanised round steel wire. The armour shall be applied over the PVC bedding.

4.6.7.8 *Sheath*

The outer sheath covering shall be orange or black, PVC compound complying with the requirements of BS 7655, Type 9, or other equivalent recognised reputable international standards. The thickness shall be in accordance with IEC 227, or other equivalent recognised reputable international standards.

The outer sheath of cable shall be embossed or labelled, throughout the cable length, indicating the cable size and length printed at interval not greater than one metre as shown in the example below:

- E.g. 4 x 95 mm2 0.6/1 kV Electric Cable CU/XLPE/PVC/SWA/PVC
- E.g. 25m 26m 27m ---- ----

4.6.7.9 *Cable Joints*

All cable joints shall either be Scotch Cast Splicing Kit or Heat Shrinkable Joint Kits conforming to BS 6346, or other equivalent recognised reputable international standards. Only matching size joints to that of the cable shall be used. All joints shall be complete with accessories required to perform joints to satisfy all electrical and mechanical characteristics or requirements stipulated in relevant British Standards.

The generator main circuit breakers and outgoing distribution feeders shall be connected to a common busbar and breaker of suitable rating for the RE Power shall be connected to the main busbar where applicable. Protection shall be provided against overload and earth fault. Instruments shall be provided to measure energy, volts and current (per phase).

4.6.8 LV Distribution board

4.6.8.1 *General*

The equipment provided shall include all control, alarm, metering, indications and communication devices required for Diesel Generator incomers, outgoing feeders and complete integration of the proposed PV connection.

4.6.8.2 *General Arrangement*

All wiring shall be internal. Either upright or desk type panels are permitted.

4.6.8.3 *Manufacture*

The cubicle shall be manufactured in accordance with the recommendations of IEC 60439-1, BS 5486, Class 1 or other equivalent recognized reputable international standards. Equipment shall be designed for indoor installation and metal enclosed to IP 55. Switchboards shall be suitable for operating at 415/240, 50 Hz, 3-phase, 4-wire and earthed.

All components such as MCCBs, ACBs, bus bars, relays, switches and instruments shall be from reputable manufactures and shall meet relevant international standards.

The cubicles, panels shall be completely enclosed metal clad type. The panel shall be floor-mounted, self-supporting and arranged for bottom entry of cables. The control panel shall present a flush appearance with no permanent projecting handles etc.

The cubicles shall be complete with all locks, cable end boxes, colour coded busbars, internal wiring, terminal boards or blocks and accessories. All equipment shall be protected against dust and dampness and tropic proofed in accordance with the relevant codes.

Clearance between live parts and phases shall be in accordance with the relevant BS or IEC standard specifications, or other equivalent recognised reputable international standards.

All secondary or control wirings or cables shall be arranged and protected to prevent damage.

Where ventilation is required all opening shall be covered with fine mesh bronze gauze and provided with hoods to prevent dust falling directly into the enclosure.

Equipment of the same type and rating shall be mechanically and electrically interchangeable, but it shall be impossible to interchange equipment of different current ratings.

4.6.8.4 *Construction*

The panel shall be constructed of braced rolled steel sections of minimum 2 mm thick, with recessed panels, and substantial mounting frames for power and control cables. All bolts, screws, washers etc. shall be corrosion protected. Cubicles shall be assembled taking easy maintenance into consideration. Paints applied on the cubicles shall be durable and suitable for harsh environment.

Doors shall be constructed of material of the same type and thickness as that used in the manufacture of the cabinets, pressed or rolled to give a neat rounded finish. Doors shall be lipped all around and corners shall be neatly mitred and welded.

The rims of the door shall have a flexible seal to dustproof the panel when the doors are in closed position.

Hinges shall be fully concealed or plain barrel and pin type with square chrome plated barrels. In either case hinges shall be arranged to allow the door to be lifted off. Door handles shall be non-rusting material, and shall be of robust construction.

After degreasing and thorough cleaning all steel work shall be rust proofed by immersion in an iron phosphate solution followed by at least two coats of synthetic primer and two coats of air drying paint for the exterior and interior surfaces.

All outside surfaces shall be finished with a final topcoat finish in a stove enamel textured paint colour RAL 7032 light grey. This painting shall be scratch proof and resistant to perspiration from the operators' hands. All inside surfaces shall be painted in gloss white. The painting shall be of such quality that any damage of the paint during transport or erection can be easily repaired at site, by the Contractor. Sufficient additional matching paint shall be supplied for side touch-up.

4.6.8.5 *Busbars*

Busbars shall be made of sleeved high conductivity completely tinned copper conductors, rigidly supported on non-hygroscopic insulators and shall comply with the requirements of the latest relevant BSI standards or other equivalent recognised reputable international standards.

Busbars shall be mounted in segregated compartments and access to Busbars shall be possible only by removing bolted covers. All joints and tap-offs between and from Busbars shall be done using non-rusting bolts and nuts with spring washers.

Barriers shall be provided internally to completely segregate the Busbars and equipment for each circuit from those of all other circuits. Cabling to any circuit shall be possible in complete safety with all other circuits alive.

Busbars shall be fully rated throughout and shall be able to withstand the stresses imposed by vibration, short circuit, thermal expansion, or other causes. Provision shall be made for expansion and contraction of busbars resulting from temperature variations.

The continuous current and short circuit ratings for each panel shall be as indicated in the respective drawings.

4.6.8.6 *Generator Control Circuit Breakers*

All generator incoming circuits shall have a suitably rated triple pole Moulded Case Circuit Breaker (MCCB) (where applicable) along with a neutral link.

All breakers shall have over current protection, closing release and under voltage release suitable for manual closing onto a common busbar.

Circuit Breakers (CB) shall be provided with a suitable electric spring loaded driving motor. Manual spring loading and control shall also be possible.

Tripping of the CB shall be effected by means of an AC solenoid shunt trip coil and by means of a push button. The CB shall have an adjustable thermal overload protection device and an instantaneous magnetic trip device.

Means shall be provided to prevent pumping while closing circuit remains energized should the breaker either fail to latch or be tripped during closing due to the operation of a protective device.

Barriers of heat resisting, non-tracking insulating material shall separate the CB phases. Circuit breakers shall conform to the short circuit category P2 as defined in IEC 152-1, or other equivalent recognised reputable international standards.

4.6.8.7 *Moulded Case Circuit Breakers*

All Moulded Case Circuit Breakers shall be provided with thermal over-current and electromagnetic short circuit release and comply with BS 3871, or other equivalent recognised reputable international standards, and be rated for continuous operation under the specified ambient conditions.

Moulded Case Circuit Breakers shall be provided with the following.

- Fixed thermal magnetic type with quick break toggle action
- Withstand capacity for the specified kA RMS symmetrical interrupting current
- Constant characteristics irrespective of physical plan of mounting
- Inclusive of arc interrupting device of the de-ion type
- High conductivity non-welding alloys for the fixed and moving contacts
- Suitably treated to resist corrosion throughout the breaker life, including all metallic components
- firmly mounted by fixing independent of terminal studs
- Common trip device so that all the three phases shall open, should any of the phases overload
- Anti-welding contacts with silver tungsten tips fixed on high conductivity copper backings
- Trip free mechanisms preventing breaker being maintained in the closed position during overload or short-circuit fault condition, even if the handle is held in the "ON" position,
- Position of the operating level indicate either ON, OFF or TRIPPED in the centre position,
- Where remote or special tripping is required, be fitted with shunt trip.

4.6.8.8 *Air Circuit Breakers*

The Air break circuit breakers shall be four poles, horizontal draw out type and shall have inherent fault current breaking and making capacity as specified.

Circuit breakers shall be mounted along with its operating mechanism on telescopic rails. The cradle should be so designed and constructed as to permit the smooth withdrawal and insertion of the breaker into it. The movement should be free of jerks and shall preferably be on rollers

and not on the flat surface. Suitable guides shall be provided to minimize misalignment of the breaker.

There shall be preferable 'Isolated' and 'Maintenance' positions for the breakers.

Main poles of the circuit breakers shall operate simultaneously in such a way that the maximum difference between the instants of contacts touching during closing shall not exceed half cycle of rated frequency.

Auxiliary switches, position indicators and necessary controls wiring, all mounted on a substantial steel framework, This framework and all metal parts of the moving portion apart from current carrying parts shall, when inserting the circuit breaker into the cubicle, be solidly earthed before the circuit breaker reaches test position, the circuit breaker shall then remain effectively earthed when it is in the cubicle.

The trip functions shall be solid state electronic type and consists of following with LED indication of type of trip.

- Setting of base current
- Adjustable overcurrent protection with adjustable time delay
- Adjustable overload protection with adjustable time delay
- Adjustable instantaneous trip
- Adjustable ground fault trip

Test functions to be provided as a standard on the breaker. The ACB should have following flag indicator.

- On/Off indicator
- Spring charged/uncharged
- Position indicator for connected, test, isolated position.

The ACB should have padlock for locking in the service, test or isolated position. Also the ACB shall be lockable in off position.

The busbar shall be covered by automatic shutters when the ACB is in withdrawn position.

All mechanical interlocks shall be of preventative type and shall be arranged to prevent malfunction as close as possible to the point at which mechanical force is applied, in order to prevent defeat of the interlocks by distortion of linkages. Electrical interlocks shall also function so as to prevent the closing of the circuit breaker before the interlocking demands are fulfilled.

4.6.8.9 *Current Transformers*

Current Transformers (CT) for the operation of instruments and metering equipment shall comply with requirements of latest relevant IEC Standards or other equivalent recognised

reputable international standards. Current transformers shall be constructed safely to withstand, the mechanical and thermal stress imposed by short circuit rating of the associated switchgear.

Current transformers shall have the ratios specified/determined as per detailed design. The secondary winding shall be rated 5A unless otherwise specified. All CTs shall be according to BS 3980, 15 VA, class 1 for metering and class 5P5 for protection.

The secondary windings of each set of current transformers shall be earthed at one point only. Each such connection to the earth bar shall be through a removable link placed in an accessible position.

Current transformers shall be capable of withstanding for one minute, without damage, the effect of an accidental open circuit in the secondary circuit while fully loaded in the primary. Current transformers shall be capable of withstanding a short circuit current of not less than 16 kA for 0.5 seconds.

The method of securing current transformers in position shall be such that no undue pressure is exerted on the windings.

Each current transformer shall carry a name plate with the rating, ratio and other details permanently marked.

4.6.8.10 *Instruments and Meters*

All electrical instruments and meters shall comply with IEC 51, IEC 521 and BS 89 or other equivalent recognised reputable international standards, and unless otherwise specified, shall be of accuracy class 1.

All indicating and recording instruments shall be flush mounted in dust proof cases complying with IEC 68, or other equivalent recognised reputable international standards.

All indicating instruments and apparatus shall be capable of carrying the designed full load currents without undue heating, damages, and changes to the accuracy. They shall not be damaged due to passage of short circuit or fault currents up to the maximum fault current of associated switchgears. All instruments and apparatus shall be back connected.

The size of all indicating instruments, except DC meters shall be 96 mm square with long scale. Instruments supplied from transducers shall have 0-10 mA movements. Running hour meters and kWh shall have 6 digit cyclometer type indicators.

All indicating instruments scales shall be clearly divided and indelibly marked and the points shall be of clean outline. Kilowatt meters and ammeters shall be provided with re-settable maximum demand indicators. Maximum demand indicator shall be of red colour and shall remain at maximum, until reset.

Instrument dials shall be white with black markings. Bezels shall have uniform semi-gloss black high grade finish. The movements of all electrically actuated instruments shall be of the dead beat type. Instruments shall be provided with a readily accessible zero adjustment wherever possible.

In addition a microprocessor-based unit for measurement of electrical parameters may be used. All measured values shall be shown on a suitable built-in LCD display and the measurements shall be transferable as digital output by means of serial communication plug socket RS232 or with the latest technology. The microprocessor unit shall be suitable for 4 wire (Three Phase with earthed Neutral) system with unbalanced load. The unit shall have an easy adaptation to different current transformer ratios. The set-up parameters, with an accuracy of 1%, and the reset of counters and peak values shall be protected by passwords.

The microprocessor unit shall register, as a minimum the following:-

1. Phase voltages U1, U2, U3
2. Line voltages U12, U23, U31
3. Current I1, I2, I3, It
4. Neutral current In
5. Active power P1, P2, P3, Pt
6. Power factor cos.1, cos.2, cos.3, cos.t
7. Frequency f
8. Integrated / maximum demands
9. Maximum demand It, Pt, Qt, St
10. Energy kWh

4.6.8.11 *Control Switches and Push Buttons*

All control switches shall be provided with labels to give clear indication as to the direction of each operation.

Push buttons shall be the non-retaining type made of non-hygroscopic materials, non-swelling and fitted to avoid any possibility of sticking. Push buttons shall be provided with shrouds to prevent accidental operation.

Emergency push buttons shall incorporate "stay-put" features and may be provided with independent reset facilities

4.6.8.12 *Indicating Lamps and Fittings*

Indicating lamps shall comprise of filament lamps behind removable lenses. Alternatively, LED lamps may be provided

Lamps shall be easily removable and replaced from the front of the panel by manual means not requiring the use of extractors.

Lenses shall be made of plastic and of standard colours i.e. red, yellow, blue, green, white and amber, in accordance with IEC 73, or other equivalent recognised reputable international standards.

4.6.8.13 *Internal Wiring*

General

Panel wiring shall be in accordance with BS 6231, or other equivalent recognised reputable international standards. Type "A" conductors shall in general be flexible and not smaller than 32/0.2 mm (1.0 sq.mm). Type "B" conductors shall be stranded and not smaller than 1.5 sq.mm for current transformer secondary circuits. Type "C" conductors shall not be smaller than 2.5 sq.mm.

All cubicle wiring shall be neatly run in wiring looms or in rigid PVC ducting with covers, in such a manner wherever practicable wiring can be readily checked against diagrams. Wire ways shall not be more than 50% full. Wiring and supports shall be of fire resistant materials.

Where wiring is connected to equipment mounted on a hinged door or panel it shall be enclosed in spiral plastic tube to prevent any abrasion of wiring insulations. The length of connection between the fixed and movable portion shall be such that no tension is experienced on any terminal and/or wiring support.

All conductors shall be terminated with acceptable crimping lugs, separate lugs being used for each conductor.

Wiring passing out of the cubicles shall be run in flexible conduits.

Wiring shall only be joined or teed at terminals. Terminals of the clamp type shall not have more than two wires connected.

A systematic numbering system shall be adopted, and shall ensure that the same number is not used on wires forming connections in the same panel. All wires directly in series or parallel shall have the same ferrule number. Wires and terminals associated with tripping and other safety circuits shall be distinctly marked.

Working Temperature shall normally be 40 ºC.

Numbering sleeves shall be fitted to all wires on all panels. Sleeves shall be of white insulating material with black numbers and shall have a gloss finish to prevent adhesion of dirt. They shall not be affected by damp or oil and shall be clearly and permanently marked; temporary marking shall not be acceptable.

Panel Wiring Colour: Wiring colours shall be as indicated in the following table.

Color	Description
Red	Phase A connections in current and voltage transformer circuits only
Yellow	Phase B connections in current and voltage transformer circuits only
Blue	Phase C connections in current and voltage transformer circuits only

Color	Description
Black	A.C. neutral connections, earthed or unearthed, connected to the secondary circuits of current and voltage transformers
Green wit	Connections to earth
Grey	Connections in D.C. circuits
Any ot	A.C. connections other than those above and connections in A.C/D.C

Alternatively, where equipment is wired in accordance with a manufacturer's standard diagram, wiring may be carried out in a single colour except that all connections to earth shall be green with yellow stripes.

Electrical Insulation: Insulating materials shall be finished to prevent deterioration of their qualities under the specified working conditions.

Plastics and inorganic materials shall be of suitable quality, selected from the grades or types in the appropriate IEC Standard, or other equivalent recognised reputable international standards.

4.6.8.14 *Terminals*

All terminals shall be mounted in accessible positions. Adjacent terminals shall be adequately spaced with respect to each other and to the incoming cable gland plate. Terminal leads, terminals, terminal boards and associated equipment if any shall be suitable for terminating the respective type of cables.

The terminal boards shall be amply sized to enable connections to be made in a satisfactory manner. Cable supports shall be provided with terminal boards, if required. Insulating barriers shall be provided between adjacent terminals.

All connections shall be made to the front of the terminal boards. Terminal boards shall have a pair of terminals for incoming and outgoing wires, and not more than two wires shall be connected to any one terminal.

Terminals shall incorporate captive pressure screws that do not bear directly on the wire, but on a serrated clamping plate. The pressure screws shall have an inherent locking feature.

Terminations for circuits operating at voltages greater than 60V shall be protected by insulating covers marked with the working voltages.

DC circuit terminals shall be segregated from AC terminals.

4.6.8.15 *Cable Terminations*

All power and control cabling required for the satisfactory operation of the plant shall be provided. Cables shall be supplied complete with all necessary junction boxes, cables racking and supports, cable accessories and the like.

4.6.8.16 *Factory Assembly*

The control cubicles shall be factory assembled and tested. The Contractor shall provide test certificates to the Employer's Representative prior to shipping.

4.6.9 Installation

4.6.9.1 *General*

The Contractor shall reduce erection and assembly at site to a minimum to keep the installation period as short as possible. To achieve this, equipment shall be prefabricated and assembled at the workshops as much as possible.

All installation work shall be carried out by qualified and experienced electricians.

The Employer's Representative may ask the Contractor to submit proof of the qualification and experience of any person proposed to carry out, or carrying out any installation work. Upon receiving such a request the Contractor shall supply the particulars without delay.

4.6.9.2 *Protection of the Environment*

The Contractor shall ensure that all his employees, representatives and sub- Contractors are aware and follow safe and environmentally friendly practices at the construction site during the Contract period.

Spillage of oil, cleaning fluids and any chemical shall be avoided. The Contractor shall collect, remove and dispose of the soil or water from any area that is deemed to be contaminated by his action or the action of his employees, representatives or sub- contractors. The requirements set forth by the regulators in their regulations shall be observed.

The Contractor shall keep the noise due to construction to a minimum during prayer times and other times when important activities are taking place and shall respect local customs and culture of the communities already living on the island.

All rubbish collected from the site shall be disposed only in areas designated for dumping. The Employer's Representative shall be consulted on the type of material, method, and place of disposal.

4.6.9.3 *LV Switchgear Cubicle*

The switchboard shall be arranged for securing to the floor by a rust proofed base plate, securely fastened, onto the floor. Cable shall be bottom entry.

The floor opening under cubicles, panels shall be sealed by the Contractor after lying of cables etc. to fire proof and vermin proof the installation.

4.6.9.4 *Power Cables*

General

All power and control cabling required for the satisfactory operation of the plant shall be provided. Cables shall be supplied complete with all necessary junction boxes, cable warning tape, cables racking and supports, cable accessories etc.

Unless otherwise specified, all works, materials, equipment, services, safety measures, tests required for the completion of the work shall be performed by the Contractor. The works shall include, but not be limited to the following:

- Excavation of trenches
- Diversion of water, including any pumping if required, associated caused by water
- Refilling, sorting of excavated material
- Backfills, where required
- Cable pulling and cable laying including cable jacks etc.
- Backfilling and compacting the trench
- Multiple handling of material and transporting about the site
- Difficulties in transport due to existing access conditions
- Removal of trees, plants, hard standings (tree roots etc.)
- Clearing, cleaning and dumping the waste and left-over, to authorized sites
- Marking tape, warning tapes, flashing lights, safety warning etc.

Trench Excavation

The Contractor shall lay power cables as generally indicated in the tender drawing.

S No.	Drawing Number	Title
1	J431-GOPA-GEN-GR-E-D-0004	CROSS SECTIONAL VIEW OF INDICATIVE CABLE TRENCH (COMMON)

Before trenching, the Contractor shall obtain approval from the concerned authority or inform the Employer's Representative. Information on already existing power cables, communication cables, cable TV cables and sewerage and water mains shall be gathered and the route of such cables and pipes identified on the land use plan. The Secretariat of the island and FENAKA should be notified in writing.

It is the responsibility of the Contractor to safeguard the existing infrastructure of various service providers, during trenching. Claims and liabilities arising from such damages shall be the responsibility of the Contractor. The Contractor shall also be responsible for making good any damage caused by him to public property. Work shall be carried out in a manner which shall ensure the safety of both the public and the workers.

Both sides of the trench shall be either sloped or protected by other means in accordance with the soil conditions encountered and the safety regulations to be observed.

The following conditions shall apply for the use of cable trenches:

- Cable laid in open trench for more than two weeks shall be protected against the radiation of the sun.
- Open trenches shall be properly secured by red warning tapes on both sides along the trench. Flashing orange colour lights clearly visible from a reasonable distance shall be placed around the open trench, at night.
- Cable trench shall be cleaned from dirt etc. before closing.
- Trenches shall be closed as soon as possible to avoid excessive ingress of dirt, damage and inconvenience to the pedestrians and traffic.

Cable Installation

Cables buried in the ground shall be laid according to the following procedure:

- The trench shall be excavated to a depth of 900 mm.
- Then the trench shall be filled with 100mm thick layer of clean or screened sand. The power cables shall be laid on this layer.
- The trench shall then be filled with 150mm thick layer of clean or screened sand covering the power cables. The consumer mains and street lighting cables should then be laid on this layer.
- The trench shall then be filled with another 150mm thick layer of clean or screened sand covering the consumer mains and street lighting cables.
- The trench shall then be filled further with another 200mm thick layer of clean or screened sand. A yellow plastic warning tape shall then be laid on this layer for the entire length of the cable route, followed by a soft layer of sand carefully rammed.
- The yellow plastic warning tape shall have printed in black the following message

"CAUTION CAUTION CAUTION"

"ELECTRIC CABLE BELOW"

- The printing shall be repeated at intervals not exceeding 500mm and shall be of adequate font size as per relevant standards. The tape shall be made up of polyethylene for durability and shall have a width of at least 150mm.
- The filtered sand shall be free from roots, debris, trash and other organic matter.
- Cables shall pass below all obstructions or anticipated future obstructions as advised by the Employer's Representative except for sewerage and drainage pipes where their depth is considered by the Employer's Representative to be excessive.
- Manufacturer's minimum bending radius for the size of cable shall be observed.

- In places where LV and MV cables share the same trench, the depth of the trench shall be increased to 1100mm. Then after making a bed of 100mm thick layer of clean or screened sand (similar to LV cables), the MV cables shall be laid first. The trench shall then be filled with 200mm thick layer of clean or screened sand covering the MV power cables. The LV cables shall be laid on this layer and continued as described above.
- All LV cables shall be laid above the MV cables in the same trench.
- The warning tapes shall be placed in all trenches with an electric supply cable irrespective of number, type or size of the supply cable.
- The Contractor shall locate or position distribution and consumer service cables under the sidewalks of the roads.

Cable Jointing

The Contractor shall supply and carry out joints where practical. However, no joints shall be performed on power cable segments or runs shorter than 500 metres.

The Contractor shall allow for all works and material including joint kits, copper ferrules, scotch tapes, insulation tapes, jointing, cable preparation, trench and site preparation, tools, equipment, tests etc. for performance of splices and terminations made.

The contactor shall ensure all joints are carried out carefully and systematically as per the technical information and recommendations or guidelines stipulated by the cable and jointing kit manufacturers, and shall conform to the relevant BS/IEC/ISO. Sufficient time shall be allowed to cure the joint if required.

Before backfilling the trench, the Contractor shall perform all relevant tests, on the joint, and test results shall be made available to the Employer's Representative on request.

Consumer mains and streetlight cables shall be "joint free" throughout.

The Contractor shall also provide yellow colour warning or making tape to cover the excavated length within the consumer premises.

Trench Backfilling

Trench shall not be backfilled until all the cables laid are successfully tested by the Contractor for continuity and insulation resistance.

Trench shall be carefully backfilled with excavated material approved for backfilling. The fill materials shall consist of sand or gravel, free from larger stones or rocks, roots, trash, debris and other organic material and thoroughly and carefully consolidated.

The compaction process shall be carried out in stages as necessary. The surface of the refilled trench shall be temporarily reinstated and maintained in a safe condition until completely consolidated.

Cable Records

In order to permit their future location, the position of the cables shall be clearly and accurately recorded on the route plan on a scaled map. The Contractor shall record on an approved cross-section the depth of the cables, the arrangement of the cables, the position of obstructions and other particulars as may be required.

The Contractor shall carefully mark the location and depth of all joints. Cable location plans shall be submitted with "As Built" drawings, except that the original field draft of the cable locations shall be the Employer's property and shall be delivered to the Employer's Representative within one month of the cables referred to being covered.

The Contractor shall update the record of the cable locations on a Land Use Plan (LUP) as soon as the cables are laid. The Contractor shall then provide a draft of "as built record" of cable locations for coordination purposes within 32 days of backfilling the trenches.

The Contractor shall clearly mark, on the map of the island, which shall be handed over to the Employer at the end of the work, as part of "as built drawings", the exact location of the joint.

4.6.9.5 *Distribution Boxes*

General

The works includes, but are not limited to the following:

- Mounting distribution boxes on free standing walls
- Construction and plastering of free standing walls to support the distribution boxes where necessary
- Power cable terminations
- Consumer cable terminations
- Streetlight mains terminations
- Labelling all terminations
- Fixing protective covers or guards etc.
- Insulation and continuity tests

Positioning of Distribution Boxes

The Contractor shall locate the distribution boxes as shown in the drawings, or at the location of an existing distribution box on the site.

The Contractor shall however, make minor adjustments to suit the site. Such minor repositioning may include locating the distribution box on or close to the boundaries between properties, or the avoidance of access ways, or otherwise avoiding inconvenience to the residents of the property.

These changes shall not be accepted as a variation to the Contract.

Wall Mounting

Where the wall is not plastered, the Contractor shall plaster at least the area covered by the DB, using acceptable quality cement and local white sand mix, before fixing the DB on to the wall.

Where there is no household boundary wall, at location indicted, the Contractor shall erect a freestanding wall of at least 700 mm (W) x 1800 mm (H) dimension, plastered on both sides. It is estimated that not many location shall require walls erected in this manner.

The DBs and cable guards shall be fixed to the wall section using approved corrosion protected mechanical or chemical anchors.

S No.	Drawing Number	Title
1	J431-GOPA-GEN-GR-E-D-0003	DISTRIBUTION BOX MOUNTING DETAILS: INDICATIVE (COMMON)

Cable Terminations

All power, consumer service mains, and streetlight cables shall enter the DB from the bottom. All termination of wires and cables shall be neatly stripped without nicking the strands of conductors. Cable lugs for power cables shall be of adequate size and carefully crimped for enhanced electrical and mechanical performance. Lugs shall be made from high purity copper tube, and shall be annealed. All terminations shall be complete with lug sleeves of the colour same as that of the core. Sleeves used in termination shall be selected to suit the service temperature conditions under which the cable is to operate. PVC cable glands shall be fitted in all cases to prevent any stress being borne by the conductors or terminals and to prevent entry of vermin. Cable glands shall match cable sizes.

Provision shall be made for earthing the wire armouring at termination by means of a metallic bond of adequate conductance, and the bonding connection should be as short and as straight as possible. The wire armouring shall be maintained electrically continuous and careful attention shall be paid to the design of bonding clamps to ensure the resistance across a clamp is not higher than the equivalent length of the complete wire armour of the cable.

No termination shall be accepted, if the insulation reading after 24 hours of completion is less than 100 mega ohms using a standard 1000V insulation tester.

Cable Protection Guard

Incoming and outgoing cable (cable from trench to distribution box and distribution box to cable trench) to distribution boxes shall be covered using a fibreglass cover box. A label indicating working voltage and identification number of the distribution box shall be attached. The cover box shall be fixed such that it is easily removable for maintenance and extension works.

Panel boards

Panel boards supplied and installed under this contract, shall be properly earthed. A hard drawn high conductivity bare copper earth bar rigidly mounted on non-hygroscopic insulators shall be

provided on each cubicle, coupled together to form continuous bar running the full length of the switchboard.

This bar shall be connected to the main earthing system. The Contractor shall connect all the metallic parts not forming part of the live circuits and all the instrument transformers, to this bar.

All necessary studs, connectors, and earth bars shall be provided to permit the connection of each switchboard. The provisions for earthing shall be such that no reliance is placed on the conductivity of metal to metal joints without the use of special conductors.

4.6.10 Commissioning and Acceptance Tests

4.6.10.1 *Grid Infrastructure*

The electrical acceptance testing and commissioning of any part of the power system should meet the relevant standards to ensure that the equipment under test conditions functions as intended and required.

The Contractor shall record and update measurements and adjustments made to complete the power system including the distribution network. The Contractor is required to submit such records together with all commissioning records and test sheets to the Employer's Representative upon completion of the project as one single bound volume.

4.6.10.2 *Specific Tests*

Any equipment installed (mechanically, electrically and electronically operated) in the power system should be tested according to the relevant standards. Such testing of the equipment shall be carried out in various stages of the project. Some of the tests shall be carried out on the manufacturer's site while others are to be carried out on the site upon completion of the project.

Testing of the connection cubicles, distribution boxes, isolators, cables, and associated equipment normally includes that done by the manufacturer as their standard practice. Reports of such tests should be submitted to the Employer's Representative prior to the installation of the equipment.

The electrical wiring of any equipment forming a complete system or part of a subsystem shall be type tested and test reports submitted to the Employer's Representative. The wiring, layout and overall equipment design should be inspected for conformity with the relevant specifications and drawings approved. The wiring and installations for LV systems shall comply with IEC 60364.

Often a system encompasses of items of equipment integrated together to form a complete electrical installation. In such installations, the performance and characteristic behaviour of the integrated equipment shall be matched by the Contractor to provide adequate, efficient and economical operation for the system as a whole.

All the protective devices like relays and contactors shall be checked to verify if they are set to the approved settings.

4.6.11 Factory Test Requirements

The Contractor shall submit standard tests performed by the manufacturer. This includes but is not limited to:

- Cables
- Distribution boxes
- LV distribution board

4.6.12 Tests upon Completion

The Contractor shall be asked to provide a commissioning plan for approval prior to carrying out the tests required by the Employer's Representative. The plan should be submitted in advance at least a month ahead before the commissioning is expected to start. All the tests should be carried out as set out in the commissioning plan.

After completion of erection of a sub system or the whole system, the Contractor shall be asked to carry out its functional testing. Where performance lacks, the Contractor shall be asked to recalibrate and adjust the sub system or the whole system for optimum performance and to the expectation of the Employer's Representative. It is noted that all necessary testing instruments shall be provided by the Contractor.

The tests shall be conducted by the Contractor in the presence of an Employer's Representative(s) appointed by the Employer's Representative. All the test sheets should be signed by both parties.

4.7 Civil and Mechanical requirements

4.7.1 General

The design, execution and performance of civil and mechanical works shall follow the requirements laid down in the Maldives National Building Code 2008 and subsequently released compliance documents (e.g. Approved Document for Maldives Building Code Structure Clause B1 and Durability Clause B2), which shall be state of the art, functional and complete in all parts. Acceptable solution or verification method described in a compliance document is automatically deemed to comply with the Code.

Other alternative ways of design can be used, provided these can be demonstrated to the satisfaction of the regulating agency as meeting the required performance standards stipulated in the Building Code. These other methods are alternative solutions and need to be approved by the regulating agencies before a building consent can be issued based on the alternative solution.

4.7.2 Applicable Standards

The latest editions of the British Standards as per Approved Document for Maldives Building Code Structure Clause B1 and Durability Clause B2 are valid for the construction of structures. The list does not claim to be complete but serves as a minimum framework for all works.

4.7.3 Earthworks

4.7.3.1 *General*

The design and execution of the earth works shall be state of the art, functional and complete in all parts. The site investigation shall be carried out in accordance with BS 5930-2015; Code of Practice for Ground Investigations and BS 1377; Method of Test for Soil for Civil Employing Purposes.

This specification applies to all earth and rockwork required for the construction of buildings, any types of structure and burying service lines in the ground as well as to excavation works in connection with pavement, roadwork and landscaping as far as earthwork is concerned and deals with the handling and disposal of the materials to be re-used or taken to soil dumps on or off site.

The Bidder shall satisfy himself as to the on-site conditions on the site including the nature of the strata to be excavated, obstructions, etc.

Generally, shelter, foundations, slabs and other structures shall be founded on form bearing strata by means that all excavation work for foundations shall meet the requirements of structural analysis based on the results obtained from the soil investigation and of the available information.

Excavation shall be done to the required dimensions including required working spaces and shall be finished according to the specified lines and slopes. All necessary precautions shall be taken to cause the minimum possible alteration or disturbance to the material lying under and adjacent to the excavation final lines.

Excavations below ground-water level must be approved by the Employer and kept water-free. Contractor solely shall assume the full responsibility for both shoring and strutting of excavations and for dewatering operations.

The fill materials used are to be examined and approved. Excavated materials can be used if they can be compacted to the specified / required densities in a reasonable length of time. It shall be free of highly plastic clays, of all materials subject to decay, decomposition or dissolution, and of cinders or other materials which will corrode installed materials.

Compaction below foundations is to be performed with approved equipment, properly adjusted for the type of excavation to be compacted and the fill material to be used. After placement, even distribution, and correct adjustment of the moisture content of the fill material, it is to be compacted to at least 95 % Proctor compaction density. If the specified density cannot be achieved the material shall be excavated and disposed of as unsuitable material.

If applicable the backfilled or reinstated areas shall be protected against washouts or erosion by a layer of rip rap and the Contractor is also responsible to provide adequate flood prevention measures in and around the area of all installed facilities. The used materials must be weather- and water-proof and must not suffer any ill effects through the action of seawater.

The earthworks shall also include all landscaping works as required.

4.7.3.2 *Execution (Assembling, Installation)*

All execution works shall be in accordance with the specification.

The works shall be excavated either by hand or by use of excavating plant and tools accepted by the Employer.

Excavation by hand is required mandatory close to existing installations (if any) and/or underground services.

The Bidder shall carry out all kind of earth and rockwork for the following works as defined hereafter (where applicable):

- Clearing and grubbing
- Excavation of top soil
- Open cut excavation including shoring and dewatering as required
- Backfilling
- Safety precaution during earthwork
- Grading
- Replacement of material
- Trench excavation for service lines
- Embankments and erosion protection
- Landscaping

4.7.3.3 *Safety Precaution*

The Bidder shall be responsible for all necessary safety measures.

Proper strutting, sheeting and bracing, including re-arrangement of the installations when necessary, stabilization and protection of slopes, methods of excavation to reduce risks of slides shall be Bidders responsibility. The additional moving of soil resulting from such damages shall not be considered as additional work.

4.7.3.4 *Protection of Existing Utilities and Services*

During construction, the Contractor shall provide all protection for existing utilities and services as required for construction operations.

In addition to the requirements specified herein, the Bidder shall comply with the following requirements.

Use all necessary precautionary and protective measures required to maintain existing utilities, services and appurtenances that shall be kept in operation. In particular, the Bidder shall take adequate measures to prevent undermining of utilities and services presently in services.

Protect existing or new utilities and services where required by the Bidders operations and/or as required by the Employer. The Bidder shall be responsible for bracing and supporting utilities and services to prevent settlement, displacement or damage.

4.7.3.5 *Dust Control*

The Contractor shall use all means necessary to control dust on the construction site.

Surfaces shall be regularly watered to prevent dust becoming a nuisance for the public and interfering with the proper execution of the works. Waste oil is not permitted for the use as dust control.

4.7.4 Foundations

4.7.4.1 *General*

Foundation works shall be performed so as to ensure the bearing of all loads without detriment for and damage to the structures. The Bidder shall choose up to date methods and equipment in accordance with relevant internationally recognized standards.

4.7.4.2 *Civil Design*

The design and engineering shall be state of the art in accordance with all relevant codes and standards, functional and complete in all aspects.

4.7.4.3 *Design Criteria for Layout, Arrangement, Drawings, Execution*

4.7.4.4 *Foundations*

Foundations for structures, equipment, transformers (with oil containment) or PV panels are described where the foundations rest on the natural bearing soil. Design of such foundations shall meet with the safe loading requirements and in line with the relevant international standards. Depth of foundations shall be according to design criteria of sub-structures.

Contractor shall bear all costs for any soil improvement.

4.7.4.5 *Shop Drawings*

The Bidder shall prepare and submit for the Employer for approval, shop drawings showing in detail, profiles, sections, jointing, cast-in items, reinforcing, anchorage and fastenings to be employed in this work. The Bidder shall be fully responsible for the design of any supplementary steel reinforcement required to withstand handling and erection stresses. This reinforcement shall be clearly indicated on the shop drawings.

Approval of shop drawings shall not relieve the Bidder of responsibility or liability for structural failures of fastening devices supplied by him or for damage of any kind during handling and erection.

4.7.5 Specifications for concrete structures

All buildings, equipment and material used must withstand environment with high humidity, salinity and temperature over the power plant life time.

This specification refers to exposure class 'Aggressive, with Chlorides and Sulphates' which is applicable to any structure exposed to occasional spray or splash from seawater or discharge water and any structure in the ground or in contact with the ground up to 0.5 m above ground elevation.

Materials (cement, aggregates, water, admixtures etc.) and mix design shall be selected in order to withstand the exposure class for the lifetime of the plant.

4.7.5.1 *Materials*

Concrete constituent materials shall mean the materials which are used in the concrete mix, as specified in this chapter or as otherwise agreed in writing. The materials shall be obtained from approved sources known to produce the required quality and with no adverse effect on the durability of the concrete.

The Contractor shall obtain the approval of Employer in writing for all materials before they are brought to site. To obtain the approval of a proposed material, the Contractor shall submit a fully documented request stating:

- type of material;
- for which mix it is intended to be used;
- to which part of the specification it refers;
- name and address of source, manufacturer, and supplier;
- representative samples;
- reference list for similar application;
- relevant test results;

The samples will be kept for reference for the duration of the project. The test results shall include the outcome of the tests specified in this chapter. Where more than one test has been performed, the results shall be presented as average, minimum and maximum values.

Employer has the right at any time to withdraw approvals and/or to reject any material if the subsequent production test values deviate from the approved pre-test values, or if in their opinion the material does not meet the objective of the works. Employer shall have access to all sources of supply and to transport and storage facilities for the purpose of inspection and sampling.

4.7.5.2 *Design and Pretesting of Mix*

The Contractor shall select constituent materials and design his concrete mix in compliance with the environmental conditions. He shall through the specified sampling and testing, including the specified documentation from trial mixing and production trials, demonstrate that he has fulfilled these requirements.

The documentation shall be submitted to the Employer for approval in adequate time before the planned start of concrete production for permanent works. No concrete shall be placed in the permanent works until the pretesting has been completed, documented, submitted, and accepted in writing by the Employer. However, for blinding layers pretesting shall be limited to documentation of materials and compressive strength.

The pre-tested and approved mix design shall not be changed without prior written approval from the Employer. However, the approved admixture dosage may be changed +-25% as required to ensure consistent concrete properties, without prior approval, but always subject to the condition that the total amount of admixture shall be within the limits recommended by the manufacturer and within limits documented by pre-testing to give an acceptable quality.

The Contractor shall keep written records for all materials used in the works, to show that they have been tested and found in conformity. This applies also to any ready-mix supply. The Contractor shall furthermore keep records of the production quality control.

4.7.5.3 *Concreting Workmanship*

4.7.5.3.1 Planning and Documentation

Before any concreting is allowed to proceed, the following shall have been fully documented by the Contractor, found compliant, and accepted by the Employer, all in accordance with relevant chapters of this specification:

- concrete materials and pretesting of concrete production;
- a specific method statement with a comprehensive planning documentation for each casting;
- inspection of excavations, construction joints, water stops, forms, reinforcement and embedded items;
- Contractor's notice confirming that the above has been completed and that he intends to cast the concrete.

4.7.5.3.2 Placing and Compaction

Concrete shall be delivered as close to its final place of deposit as practically possible, as quickly as possible, and always within the time limits and the temperature limits specified.

All handling of the fresh concrete into its final place of deposit shall be completed as quickly as possible and always before the initial set, by methods which will prevent segregation and loss of ingredients and in a manner which will assure that the required quality of concrete is

maintained. ACI 304R cl 5.1 (General Considerations) shall apply unless otherwise stated or implied in this specification.

Concrete shall not be allowed to drop into place from a height of more than 1 meter, and dropping concrete shall not be disturbed in its vertical fall by hitting reinforcement, etc, which may cause segregation. Where necessary to limit drop heights or to avoid segregation, placing shall be by means of trunks, chutes, buckets, hoppers, etc. ACI 304R cl 5.4 (Placing) shall apply unless otherwise stated or implied in this specification.

Pumping, if used, shall be controlled so that segregation does not occur in the discharged concrete, and the loss of slump shall be within pre-determined limits.

At no time shall the fresh concrete be in contact with aluminium or aluminium alloys.

All equipment which is used in handling fresh concrete shall be kept clean and free of hardened concrete. Under no circumstances shall spilled concrete or hardened concrete be allowed to enter into the permanent works.

Compaction shall be performed to ensure that the concrete becomes a dense, homogeneous mass, completely filling the form and surrounding the reinforcement, thus achieving the desired strength, appearance, and durability.

Concreting shall not take place during rain or during storms, or until rainwater and dust has been removed from the form after such events.

4.7.5.3.3 Making good of Defects

While certain casting defects may occur in spite of all precautions, the Contractor shall do his best to minimize such defects, and he shall adjust his methods if the number, size or type of defects in the opinion of the Employer gives reasonable cause for concern.

All defects after casting shall be recorded by the Contractor and brought to the attention of the Employer before any making good is carried out.

The making good shall comply with the following minimum requirements which are intended for normally occurring defects of limited and acceptable extent.

Any defect which in the opinion of the Employer is frequent or large or unusual, including any defect which is not covered by this specification shall be subject to a specific procedure to be proposed by the Contractor for the Employer's acceptance.

Repairs will be accepted only if they can bring the structure to the quality level of a well build new structure. If this cannot be achieved and documented, the faulty work shall be replaced.

If it is found that a significant amount of voids, cavities, honeycombs, etc, is concealed behind a surface skin of laitance or mortar, then the Contractor shall expose the full extent of the defects by sweep-blasting or by a similar method to the approval of the Employer.

4.7.5.3.4 Temperature during hardening

The maximum temperature in the concrete during hardening shall not exceed 55°, unless the contractor can document to the satisfaction of the Employer that a higher temperature will have

no detrimental effects on the strength and durability (crack-width due restraint forces) of the structure. The documentation shall take into account that higher temperatures may cause larger pores and lower durability in the concrete.

The Contractor shall always minimize thermal cracking by proper planning of the work and by taking precautions to minimize temperature differences. Thermal cracks are likely to develop in massive structures (smallest dimension more than 0.5 m) and structures with restrained movement in the hardening phase (e.g. wall/slab) unless adequate measures are taken.

The particular amendment to the standard specification may state specific limits to the acceptability of cracks in certain structures; the Contractor shall take all necessary precautions to comply with such specified limits, including but not limited to precautions mentioned in the following guidelines.

The Contractor's planning and methods for temperature monitoring and control shall be submitted as a part of the relevant method statement. It shall be revised if experience on site shows that the adopted methods do not lead to the desired results.

Any crack which occurs in spite of the planning shall be injected to the satisfaction of the Employer, or other measures shall be taken if in the opinion of the Employer they are needed to achieve an acceptable and compliant structure.

4.7.5.3.5 Protection against Evaporation

Concrete shall always be protected against evaporation during hardening. Particular care must be exercised to implement the curing at the earliest possible stage during periods of high temperature, low relative humidity, or strong winds which alone or in combination can cause extremely rapid drying-out.

Curing shall be performed for a period of not less than 14 days. The Contractor shall keep a log record with starting and completion dates plus dates of all specified curing operations.

4.7.5.3.6 Construction Joints

Construction joints are the joints between different pours. Such joints shall be pre-planned and kept to the minimum for the execution of the work, and they shall take into account structural requirements as well as requirements to appearance. Keys or other details may be specified in the particular amendments to the specification or in the drawings, and shall always take priority over the requirements specified in this section.

Joints which are not shown on the drawings but which are considered desirable for practical reasons shall be proposed by the Contractor for the Engineer's approval.

If kickers are used at wall or column bases, it must be ensured that the concrete in the kickers are compacted and cured in accordance with this specification. Kickers at walls shall be poured in one go with the base slab.

The alignment of joints shall generally be straight, horizontal or vertical, parallel or perpendicular to adjoining parts of the structure.

Vertical joint faces shall have a formed surface; horizontal joint faces shall be level and flat.

Reinforcement shall continue across joints.

4.7.6 Protection of Concrete

Protection of concrete as specified in this chapter shall mean blinding's, membranes, coating systems, etc., which shall be applied for the purpose of protecting the finished concrete structure against exposure to action or substances which may cause deterioration of concrete and/or corrosion of reinforcement.

4.7.6.1 *Protection on Concrete Structures in Contact with the Ground*

Foundations and concrete structures in contact with the ground shall have a protection on all earth-covered faces of the underground part as follows:

All sides and any earth-covered top of such structures shall be protected by a bituminous coating system consisting of:

- a penetrating bituminous primer applied in one coat;
- a high build bituminous coating with a content of fibres, applied in minimum three coats;

The total dry film thickness of the coating shall be not less than 1.0 mm.

The bottom side of the structure shall be protected by a preformed membrane. Tanking may be provided by a flexible self-adhesive impervious composite sheeting of a total thickness not less than 1.5 mm consisting of a sheet not less than 0.3 mm thick of three layer cross-laminated high density poly-ethylene, and a rubber-bitumen compound.

All preparation, priming, ancillary materials, accessories, details and workmanship for the application shall be in strict accordance with the manufacturer's recommendations.

The overlap between the membrane under the structure and the coating on vertical faces shall be detailed by the Contractor to the satisfaction of the Employer, making sure that all faces remain protected.

The bottom-protection membrane (on the blinding concrete) shall be protected by a concrete overlay and shall be laid on a concrete blinding and protected by a concrete overlay of minimum 50 mm thickness.

4.7.6.2 *Protection on Concrete Structures above Ground*

Sea-walls and similar shore-line structures directly facing the sea shall be considered as being in a splash zone even if they are standing on the shore above the high-water level. Where such structures are exposed to spray from the surf, it may be necessary to treat them as splash zone in their full height.

Splash zones and tidal zones of structures standing in the sea shall be coated from 2 m below lowest low-water level and to the top of the splash zone. The extent of the splash zone shall be defined in the design drawings but shall generally not be less than 4 m above mean sea level.

Higher levels may be relevant where the structure is exposed to surf, large waves and/ or large tidal variations.

The coating shall effectively seal the concrete from ingress of chlorides and sulphates and it shall have adequate flexibility to follow temperature movements on exposed faces without cracking. The coating shall be durable and resistant to warm saline sea-water, wave action, and UV exposure; the coating should be easy to repair and re-apply and must be available in light colours.

The successful performance of the complete coating system shall be documented on basis of similar applications in marine structures under similar climatic conditions. The guaranteed minimum service life shall be at least 15 years.

The system shall at least be equal to an epoxy-polyurethane system (solvent free epoxy base coat followed by polyurethane topping). It shall always be obtained from a well reputed manufacturer with a fully documented record from similar applications, and it must have documented test results to show that it is effective in stopping chloride ingress. The work for an epoxy-polyurethane system shall as a minimum include:

- sweep-blasted of the concrete surface to remove any loosely adhering matter;
- making good of casting defects after the sweep blasting;
- apply levelling layer of approved cementitious material;
- apply primer/sealer if recommended by the manufacturer, followed by minimum three applications of high-build layers to a minimum total dry film thickness of 350 microns, or a thickness as stated in the manufacturer's guarantee;

4.7.7 Structural Steel Work

4.7.7.1 *Material*

The steel qualities for the individual construction elements are to be chosen in accordance with UBC, chapter 22, structural steel. The steel quality is to be verified by the manufacturer's certificate.

Other types of steel may only be used after thorough tests of the technological properties and acceptance by the Employer.

4.7.7.2 *Workmanship*

4.7.7.2.1 Drawings

All necessary drawings for the manufacture and erection must be prepared in accordance to the general time schedule and approved prior to commencement of work.

The shop drawings shall clearly indicate all different items with respect to the erection work.

A separate material recognition list shall be prepared for each building.

The item numbers in these lists must be identical to those shown in the shop drawings.

4.7.7.2.2 Design and Construction

Buildings and structures must be designed for seismic loads. SBC shall be followed.

Compatibility of dimensions and setting-out data of steelwork shall be verified by the Contractor before fabrication of steelwork commences.

All joints and connections are to be made by welding or by means of screws.

The tolerances for the steel structure must be in accordance with those for the other parts of the building.

Attention must be given to the effects of temperature fluctuation on the steel structure.

The Contractor shall make all necessary expansion joints. Movement shall be made possible by providing double columns.

The Contractor shall allow for deformation due to permanent loads and the process and sequence of fabrication, erection and construction such that the completed steelwork is within the specified tolerances.

Braces (wind braces and gable walls) which resist live loads and assure stability of the building are to be used for buildings.

Connection design shall provide adequate access for welding and inspection during fabrication. The profile of the joint shall enable satisfactory non-destructive testing to be carried out.

Special attention is drawn to the deflection limitations of the steel structures.

The maximum deflection of trusses, floor beams and girders may not exceed 1/300 of the span. For trusses the deflection due to dead load may be compensated by super elevation. The maximum deflection of rafters and spars must be less than 1/400 of the span.

The design loads for buildings are to be taken from SBC and AISC standards.

A velocity of 45 m/sec is to be assumed for calculation of wind loads.

Additional to wind loads a vertical live load for roofs is to be calculated with 1 kN/m2. Live loads for flat roofs have to be chosen according to the purpose of use.

4.7.7.2.3 Erection Program

Before starting the execution of the works, the Contractor shall furnish a detailed programme according to the general time schedule. Each month the Contractor shall provide a progress report in duplicate to the Employer, indicating the progress of work.

The Contractor shall be solely responsible for the accuracy of all relevant dimensions of the structure.

4.7.7.2.4 Manufacturer's Instruction

All work at site, i.e. handling, storage and erection shall be carried out strictly in accordance with the manufacturer's instructions and recommendations.

4.7.8 Brickwork

4.7.8.1 *Materials*

Clay bricks and blocks, calcium silicate bricks and concrete bricks and blocks shall comply with the relevant requirements of BS 3921, BS 187, BS EN 772-2, BS EN 772-3 and BS EN 771-3 respectively. The dimensions of special bricks shall comply with BS 4729.

Clay bricks and blocks, calcium silicate bricks and concrete bricks and blocks shall comply with the relevant requirements of BS 3921, BS 187, BS EN 772-2, BS EN 772-3 and BS EN 771-3 respectively. The dimensions of special bricks shall comply with BS 4729.

The Contractor shall supply the brick samples of each type to be used together with the test certificates for crushing strength through the independent laboratory to the Employer for his approval. The crushing test shall be fulfilled according BS EN 772-2. Separate samples of each type of block taken at random from loads delivered shall be deposited for approval by the Employer. The Employer will reject any load or part load which would be determined below the required strength, uncured, under or over the required size, damage or to have any other defect which may consider detrimental to the work concerned.

Bricks and blocks shall where practicable be grooved or keyed where they are to receive plastering or rendering.

4.7.8.2 *Workmanship*

Unless otherwise specified, brick and blockwork walls shall be constructed in accordance with the recommendations of BS EN 1996.

Prior to the laying of any facing brickwork, sample panels 900 mm by 600 mm of each facing brick shall be built using mortars made with different fine aggregates, white or coloured cements, or colouring agents as directed by the Employer. When the required ingredients for the mortar have been determined and approved by the Employer they shall be used for all mortar for facing brickwork and the appropriate test panel shall be retained for reference and shall represent the standard to which all facing brickwork shall conform.

Reinforcement has to be applied in accordance with static requirements, fire rating etc.

Lugs galvanized mild steel butterfly type shall be provided at all junctions between block walls and reinforced concrete columns. These lugs are to be cast into reinforced concrete columns and built into ends of exterior wall panels. They shall be spaced vertically not exceeding 450 mm.

4.7.8.3 *Mortar for brickwork and blockwork*

Cement shall be ordinary Portland cement. Lime shall be hydrated high calcium lime or hydrated semi-hydraulic lime to BS EN 459-1. Sand shall be clean natural sand free from clay or clay film over the grains or shall be crushed natural stone of approved quality.

Both sand and crushed stone shall be to BS EN 13139. Water used for mixing mortar shall be from the same source as water used for concrete.

Lime mortar shall be used for brickwork and blockwork above the ground level damp proof course unless otherwise specified or ordered by the Employer. Such mortar shall consist of cement, lime and sand in the proportions of 1:1:6 unless otherwise specified or ordered by the Employer.

Cement and lime shall be stored at the site in a perfectly dry structure and all consignments shall be used in order of delivery. Cement and lime affected by dampness shall not be used in the works.

Vertical damp proof courses shall be approved at all door and window reveals and shall comply with BS 8215.

Contractor shall also make provision for pocket chases etc. for electrical and other installations.

Mortar shall be mixed and used in accordance with clauses 2.1.2 (3) of BS EN 1996-2 including PD 6697 (recommendation for the design of masonry structures to BS EN 1996-1 and BS EN 1996-2).

Where approved by the Employer, plasticizers or proprietary masonry cements may be used as an alternative to lime in the mortar. In this case the proportions of the mix shall be based upon the manufacturer's instructions but shall be to the Employer's approval.

All engineering brickwork and brickwork below damp proof course level shall be built using cement mortar.

4.7.8.4 *Joints in brickwork and blockwork*

Joints shall be broken accurately and the thickness of bed joints shall be not greater than 12 mm and not less than 9 mm.

Facing brickwork shall be finished with weathered joints 3 mm deep formed before the mortar has set.

Brickwork or blockwork for internal surfaces which are not to be rendered or plastered shall be fair faced with a flush joint made as work proceeds.

Joints in brickwork or blockwork which is to be rendered or plastered shall be raked out to a depth of 5 to 10 mm.

Separation joints shall be formed by inserting approved joint filler 10 mm thick. 4 weeks after the bricks have been laid the filler shall be raked out to a depth of 20 mm and the joints shall be pointed with mortar.

4.7.9 Painting

Subject of this specification are external paints on plaster and concrete as well as internal paints on plaster, concrete, gypsum and metal.

4.7.9.1 *Materials*

All materials are to be delivered to the site in original barrels. At the latest after the drying none of the paints or coats used shall cause any odour nuisance. For control purposes the individual paints are to be different in shade as far as oil-and varnish-paints are concerned.

External paint on plaster areas:

This paint is to be carried out with plastic dispersion. It is to be capable of breathing, shall be rain-tight and completely resistant against exhaust gases of any kind. The paint is to consist of a prime coat and a finish coat. According to the suction capacity of the base, thinning with water of up to 50 % is allowed.

As far as the finish coat is concerned, the thinning is limited to 10 % however.

External paint on concrete:

This paint is to be conducted with concrete scumble glaze. It is to be capable of breathing, shall be lightfast, weather resistant and hardened against exhaust gases of any kind. The surface of this paint is to be glazing. The paint consists of a prime coat with undiluted colour and a finish coat with the same colour. The drying times between the individual paints are to be strictly adhered to.

Internal paint on plaster areas:

This paint is to be conducted with plastic dispersion. It is to be capable of breathing, shall be lightfast and wash-resistant. The paint consists of a prime coat, the so-called impregnation base, thinned up to 30 % according to the suction capacity of the base. This paint is not to rest glossy (bright) on the surface.

The second paint also consists of dispersion, however, thinned up to 10 % only. The third paint is to be thinned up to 5 % only.

Internal paint on concrete:

This paint is to be carried out exactly in the same manner as external paint on concrete. Special attention shall be paid that the finish concrete surface shall be either semi glossy or mat to avoid any reflection caused by the lighting system.

Paint on metal:

The paint on metal consists of three coats, i.e. a prime coat by twofold application of protection against corrosion according to specification. Holes, cracks etc. are to be levelled with suitable sealing material. Onto the prime coat a rubbing varnish paint of impact resisting rubbing varnish is to be applied. After the drying of the rubbing varnish the finish varnish coat is to be applied with silky lustre varnish. Structural steelwork is to be painted according to specification sections above.

4.7.9.2 *Workmanship*

For the respective paints sufficiently big samples with at least three gradations of colour are to be mixed.

The base is to be cleaned of all contaminations, influencing the paint and its adhesion capacity respectively. Loose plaster and damages respectively are to be removed or to be repaired with the same material. For repairs of plaster gypsum is to be used by no means.

The repaired surface is to be in accordance with the original surface; no application points are to show. The surfaces to be painted are to be absolutely dry, formwork lube residues are to be removed from concrete surfaces and to be pre-treated respectively so as to guarantee a perfect adhesion of the paint without spotting. Dispersion paints are to be applied with a lambskin roller, at places of difficult access suitable brushes are to be used. The paints are to be applied in such a manner that the painted surface appears as uniform surface without application points, strips, brush streaks, splashes etc. Separation lines between paints of different colours as well as delimitation lines are to be sharp and clean.

Painting works outside are to be carried out at the most favourable weather-conditions prevailing for the respective kind of paint. No painting works are to take place if the temperature of the base or the surrounding air is above 50°C.

The temperature limits indicated are to be adjusted correspondingly when using special materials. The paints are to be applied in such a manner that they appear as uniform surface without application points, strips, brush streaks, splashes etc.

Separation lines in the paint as well as delimitation lines are to be sharp and clean. In addition to the visual check on the paints pine hole check and dry film thickness shall be required by using appropriate equipment to conform the continuity of the painting and also the thickness of the coating.

After the completion of the paint the ground and body colours used, the method of rust removal, as well as year and time of the paint (from ... to ...) are to be indicated at an easily visible place with varnish paint of corresponding hiding power and durability.

Because of excellent readability the text is to be written in sufficiently big letters and numbers. The examination of the paints is conducted according to the following method:

- Degree of rust removal
- Thickness of the prime and finish coats
- Overall dry layer
- Non-porous state
- Observance of the working conditions
- Observance of intermediate and final drying times

Wings of doors and gates are to be treated in horizontal position. All surfaces, objects, fittings etc. which are subjected to the danger of contamination or damages are to be covered or otherwise protected according to the circumstances. Paints not in compliance with the specification are to be removed; these surfaces are to be coated again with the corresponding paint.

4.7.10 Water Proofing

The waterproofing of the usable areas for the roof shall be guaranteed for 10 years for material, workmanship and other liabilities which may be caused by leaks/failure of the system. The guarantee provided by the Bidder shall be supported by manufacturers guarantee for the same period.

4.7.11 Ladder Access to Roofs

The Bidder shall install ladders for maintenance access to the roofs where PV arrays are installed.

For tall buildings and roofs, permanent access ladders of corrosion resistant aluminium material shall be securely attached and mounted to the walls of the respective buildings. The lowest rung of any permanent ladder shall be 3m above the ground to prevent unauthorised access to the roofs. Further moveable aluminium ladders shall be provided for access to the 3m rung.

For standard single story buildings and low roofs permanent access ladders are not required and simple moveable aluminium ladders of sufficient length shall suffice. All moveable ladders shall be kept locked in the plant rooms.

4.8 Power Plant Control and Monitoring system - PCMS

This chapter describes the minimum overall requirements for design, delivery, installation, testing and tuning of the overall Plant Control and Monitoring System (PCMS) which shall be obligator fulfilled by each certain PCMS located at the individual site locations.

The PCMS shall provide interactive control and monitoring for specific parts of the PV power plants, the Battery Energy Storage Systems (BESS), diesel power station and auxiliaries, as defined in this specification. Furthermore, all alarms and indications shall be available on Operator workstations. The workstations shall be located close to the Diesel Generator station or in the control room of the already existing Diesel Generator station. The PCMS will be fully compatible with existing D-hybrid central SCADA located in Male.

It is within the scope and responsibility of the Contractor to design the details in especially with respect to the technical features and possibilities of the PCMS System family and components finally selected for realization.

Special functions and / or exceptions and add-ons dedicated to the individual PV plants are listed in a separate specification dedicated to each plant.

4.8.1 General Requirements

4.8.1.1 *General Approach*

- The system shall be a state of the art, field proven system based on microprocessor technology. The architecture shall foresee distributed intelligence comparable to an automated real-time control system for data acquisition, processing, transmission, storage and archival, graphical presentation and display.
- All components shall be of approved and reliable design with the highest attainable attributes for uniformity, interoperability and interchangeability. The design shall be modular to facilitate easy maintenance, fault diagnosis and repair of the components, and to support installation and expansion in increments.

The Bidder shall provide a common Plant Control and Monitoring System with central operator station and data handling facilities.

The minimum data logging interval for all relevant parameters that will be defined by the Employer during detailed design and that can be stored shall be ≤ 1 minute.

The PCMS System provided by the Contractor should be easily adjustable to operate either Type A, B or Type C without the need of extra specialist.

4.8.1.2 *Scope and Limits*

All components for the PCMS, interfaces and interconnection at the defined destinations, including all equipment for safe, undisturbed and reliable operation, cabling, patch panels, accessories, tools, software, even if not mentioned explicitly in this document are within the scope of the Contractor.

All required interfaces and switches shall be included and provided by the Bidder.

4.8.1.3 *Bid Documentation*

The bid documentation shall describe

- The full system functionality,
- The main system components,
- Performance and parameters (data sheets),
- redundancy and/or failure measure concept,
- communication interfaces,
- a backup and recovery concept for the PCMS,
- anti-virus and malware protection,

4.8.1.4 *Spares and spare capacity*

Spare capacity on hardware level:

A minimum spare capacity at hardware level of 20 % shall be considered in the design.

Spare capacity in data network and signal transmission and processing:

Signal transmission and processing have to be prepared with sufficient capacity and spare in bandwidth, bitrate, reliable termination etc. to guarantee the reliable function of the plant.

4.8.1.5 *Spare Parts and Special Tools*

All special tools required for the operation and maintenance of the system shall be provided by Bidder.

The Bidder shall also provide a list of spare parts necessary to allow quick repair of the most likely equipment faults including data logger, communication equipment, range extenders/media converters, hard disks and power supplies.

4.8.2 Main functionality

4.8.2.1 *High Diesel efficiency*

Respecting the limits of grid stability and energy spinning reserve, the system shall always be running on the generator point where the highest efficiency of the diesel system can be achieved and at the same time the maximum available PV energy to be fed in the system.

Therefore the PCMS will chose the smallest possible Diesel Generator and have it running on a high percentage of its rated power. If sufficient PV energy is available and the system is already running with the smallest generator, the PCMS will allow the genset to go down to its minimum load and even underneath this minimum load for a certain time, depending on the manufacturers specifications. In any case the PCMS always has to take care that there is no reverse current in any of the three phases.

4.8.2.2 *Maximum PV energy to be used*

In order to have the highest benefit of the solar power, the PCMS should not cut the PV power until a certain minimum level of power production of the genset is reached and the batteries are charged up to a predefined maximum level. The minimum and maximum limits of the Battery shall be variable and are set at the commissioning of the system.

The system shall be designed in order to allow a genset with maximum rated capacity smaller than the actual load in the system running in parallel to the BESS and the PV system, if there is enough energy from the PV system available.

4.8.2.3 *Emergency Mode*

It is mandatory that an emergency mode for the PV inverters is implemented. This mode will automatically be activated in the PV inverters, once the communication to the PCMS is lost due to component failure, communication cable break or any other reason.

Once the communication is lost, the PV inverter shall automatically change into emergency mode. The PV inverter shall then work as a normal grid connected inverter that is limited in it's

output power to a certain value that is to be set during commissioning and shall be easily adjustable by the operator at a later stage if necessary.

All other parameters on the inverter shall also be easily changeable for this specific mode and may be different to the normal operation.

4.8.2.4 *System stability*

In this case most of the energy in the system will be provided by the PV system. The Diesel Generator will still act as frequency and voltage regulator but shall be supported by the BESS and the PV system with reactive and active power to serve the demanded energy.

In such a scenario, the BESS shall always be able to support the system, until a new genset is started to take over the load in case of sudden PV drops and load variations. The PCMS must always react quickly enough to avoid a blackout in the system due to sudden PV drops or load increases.

4.8.2.5 *Generator switching*

It shall also be avoided to have frequent start and stop scenarios of the Diesel Generator. If an additional genset is started or the genset was switched for a bigger one, there shall be a minimum time for how long this genset has to stay online, before it is switched off or changed for a smaller one. This parameter shall be easily adjustable by the operator. Additional parameters have to be respected before a genset can be switched.

4.8.2.6 *Load ramp*

If the PV system is already providing its maximum available power to the system and the load demand is still rising the Diesel Generator has to provide this energy. If there are slow load changes, the Diesel Generator will directly serve the loads and rise its power output. For sudden load changes caused by either PV drops or load increase, or both at the same time, the BESS shall support the system. The parameter of the allowed load ramp on the genset shall be adjustable by the operator.

4.8.2.7 *System Parameters*

All limits as well as minimum and maximum values of all parameters needed to configure the system shall be easy adjustable by the controller from the controlling room on site as well as from selected users online, anywhere with internet connection. The access has to be Password and Username protected. Especially parameters like: load set-points of Diesel Generators, allowed ramp rates of generator, ramp rates of battery, timing of battery, all setup parameters of needed current sensors and parameters that are provided from genset controllers.

The PCMS shall support at least 5 DG sets and 5 PV sites without any modification or upgrade to the system

4.8.2.8 *Type C grid building systems*

For systems with Grid Building Battery Inverters (GRIDB), the main control unit shall turn off the Diesel Generators completely, if the available solar energy and the SOC of the battery allow it. Solar energy shall always be the prioritized energy to be used in the system, and Diesel Generators shall only be turned on if necessary.

The energy magament system software and hardware in Type A islands should be ready for future upgrade to Type B or C concept island.

Type C should also allow operation of multiple masters (grid forming entities such as Battery or Diesel generators) and only use PV as a slave. If one master fails the other master units should able to run the grid giving the system extra redundancy.

The Battery inverter must be synchronized to other voltage sources in both cases: *i)* Battery inverter is online first and the other voltage source (DG, Grid, other Battery Inverter) must be synched to the battery inverter, *ii)* Other voltage sources are first online (DG, other Battery Inverter), the battery inverter must be synchronized to them. Specially when a static (isochronous) voltage source such like an DG without synchronization capability the synchronization must be done with an external synch check and breaker. The measurement of the requirement parameters of voltage, frequency etc. must be done fast and accurate enough to guaranty synchronization.

4.8.3 Main Topics of PCMS

The Contractor shall provide standard hardware and software configurations to the extent possible as long as it meets or exceeds the requirements of this specification. International standards shall be applied for hardware and software interfaces to allow system expansion in terms of equipment and software functions (if required).

4.8.3.1 *System Security*

The PCMS or each subsystem shall be designed in accordance to ISO / IEC 27002, ISA 99 or equivalent Standard.

For security reasons all log-in and log-out events shall be logged in the event list. All user changes and modifications to the system as well as parameter and program modification shall be logged with the exact time and operator's assignment in the event list too. It shall be possible to print this information.

For software security, at least the following has to be provided:

- Up to date anti-virus program to be delivered and installed
- Up to date firewall to be delivered and installed
- All access ports (USB, CF-cards, etc.) shall be included in the security scenario and protected/secured against infiltration of malware

4.8.3.2 *Over-Voltage Protection*

Those parts of the system that are electrically connected to cables leaving a building shall be fitted with over-voltage protection.

4.8.3.3 *Grounding*

The PCMS equipment shall be connected via a common potential equalization bar to the earthing network Station.

The Contractor shall coordinate earthing concept and requirements with the manufacturer of the PCMS and accordingly provide the earthing system that shall be approved by the Employer.

4.8.3.4 *Labelling and Marking*

All terminals, plugs, internal and external connecting cables shall be labelled durable and readable with a code approved by the Employer.

For Ethernet connectivity interfaces, only shielded cables of type CAT 6 or better shall be applied in a structured cabling according to ISO 24702 and to the description within this specification.

Fibre optic cables shall be delivered and installed according to the description within this specification.

4.8.3.5 *Cabinets*

Central Unit Servers and associated accessories shall be accommodated in dedicated equipment cabinets.

For indoor application, the cabinets shall be constructed as follows:

- Standard sized steel cabinets with external painting colour as per Employer/Engineers approval
- Certified for minimum IP41 protection class
- Power distribution box with main filter and main switch (separate 2-pole breakers for each device)
- Front-patches for LAN cabling
- Cable organisers, cable trays, suspensions and termination components with strain relief for all internal and external cabling
- Over-voltage protection for all devices (if required)
- 20 % housing space for future equipment
- Ventilation fan to ensure that maximum allowable operating temperature of all equipment inside the cabinets shall not be exceeded
- Bottom cable access

- Document pocket
- Grounding bus bar for earthing connection
- Doors with glass front and locking system
- Inner light and power socket for maintenance
- Provision of easy access for maintenance and repair, all devices with rear plugs shall be draw-able

4.8.3.6 *Electrical Interface Units*

EIUs as data acquisition modules shall be designed and provided to perform the interface between the electrical equipment and the PCMS. The EIU hardware shall be fitted with process interface slot-in modules for digital inputs and outputs, analogue inputs, Ethernet communication modules, etc.

The EIU shall be of same make and type all over the Plant and shall have Ethernet connection with PCMS. The power supply of the EIU shall be powered from the UPS.

4.8.3.7 *Performance and Reliability*

All equipment shall be of high quality and reliability. The overall system availability of the PCMS shall be 99% or better.

All equipment shall be protected against cyber-attacks. PCMS lifetime shall be 25 years.

4.8.3.8 *Software Requirements*

The PMCS shall be based on standard proven firmware and software, which shall already been implemented in other systems. The software engineering tool shall be provided to configure, set up and modify the data acquisition, data processing and database system components. The software application shall include facilities to perform programmable logic functions.

The system shall have monitoring and self-diagnostics features for both, hardware and software.

Licensed software copy required for the proposed system shall be provided. The latest proven anti-virus software shall be installed in the PCMS.

All logins to the system shall be password protected. Data transmission via public internet shall be encrypted.

4.8.4 Alarm and Event Management

4.8.4.1 *General*

All alarms including system alarms and important events shall be listed up on the display. The lists shall be in chronological sequence showing:

- The precise date and time with the specified resolution in actual sequential of events;

- Plant identification code;
- Clear text/denomination of alarms and events;
- Status message (open, close, off, high, low);
- The actual value in case of high/low alarms derived from analogue values;
- Sorting of alarms per sub group shall be possible.

Alarms and signals that happened in the past can be recalled by the operator at any time. If any new alarm appears while monitoring any other page, flashing signal on the screen shall show the new event/signal to the operator.

Dedicated soft-pushbuttons shall serve the operator for alarm handling such as buzzer signal acknowledgement, alarm acknowledgement, alarm clearing and page flipping. Differentiation between alarms and events shall be done by colour coding (e.g. Alarms: red colour). Further colour for distinction of alarms according to the degree of urgency or type of alarms is also required.

Flashing functions of alarm messages shall be according to standards related to conventional alarm.

The flashing frequency for coming and going alarms shall be different.

First out alarms shall be marked clearly and needs special acknowledgement.

4.8.4.2 *Report Generation*

Automatic and configurable generation of typical reports (total or detailed power generation data, problems, efficiency analysis, weather reporting etc.) shall be supported internally or with the help of formatted data output and provisioning of corresponding templates and input filters for e.g. MS Excel or similar. It shall be possible to print the generated reports. The format of the logs and reports shall be subject to the approval of the Employer.

4.8.5 Data Communication Network

The PCMS shall have the communication via Modbus TCP to all energy producers, respectively Diesel Generators, PV inverters and BESS units. It will receive all necessary measurement data from those sources, such as voltage, ampere, cos phi, battery SOC, frequency and warnings/alarms at the connection points of the sources. According to the actual state of the system it will then decide and send the control to the relevant sources, if and how they should react, be switched on or off or regulate their power output. The communication shall be realized with network cables CAT 6 and fibre optic cables for longer distances. The system shall communicate with and provide data to the SCADA system.

The PCMS shall also be able to include any other sensors necessary for the functioning of the system and provide the data of additionally included sensors in the Modbus protocol. The communication protocol of the sensors to be included may be of a different kind than Modbus.

The supplied system shall include a data communication network to ensure the proper interconnection of all components of the PCMS such as but not limited to: cables, accessories, media converters, repeaters, amplifiers, switching and routing equipment including accessories, their housing as required, as well as the management systems necessary to operate the data communication network.

Ethernet with a minimum data rate of 100 Mbit/s shall be provided.

The network shall be fault tolerant for single failure and shall at least be installed in ring structure.

Switches used in the network and to interface equipment shall be manageable and able to interface to FOC on upper level cabling structure.

All FOC cables shall be terminated to patch panels; no fibres to be loose.

Interface to switches shall be performed via patch cables.

Underground splices shall not be foreseen.

4.8.6 Power Supply & Cabling

4.8.6.1 *General*

Power supply for PCMS shall be provided from UPS. All redundant devices shall have redundant power supply modules.

The Contractor shall perform all cabling and installations works for outdoor and indoor equipment as well as the interface interconnection and termination at existing devices

4.8.6.2 *Additional communication cable*

There shall be an additional fibre optic cable installed between the power house and the council of each island. In the power house the cable shall be routed to the control room where the PCMS will be installed. It shall be connected to the FOC network of the power plant. In the council the cable shall be routed into a room that is selected from the council. On each side a spare cable of 20 meters shall be left.

4.8.6.3 *Electrical connections and UPS*

Redundant power supply for PCMS shall be provided from UPS. A minimum of 30 min. of independent power supply shall be guaranteed for on-site conditions.

Over-Voltage Protection: Those parts of the system that are electrically connected to cables leaving a building shall be fitted with over-voltage protection. For special specifications see Chapter 3.9 Lightning protection.

Grounding: The PCMS equipment shall be connected via a common potential equalization bar to the earthing network of the diesel power station building.

The Bidder shall coordinate earthing concept and requirements with the manufacturer of the PCMS and accordingly provide the earthing system that shall be approved by the Employer.

Labelling and Marking: All terminals, plugs, internal and external connecting cables shall be labelled durable and readable with a code approved by the Employer. Code list shall be included in documentation.

4.8.6.4 *Category 6 cables*

At least shielded Cat 6 cables shall be used for Ethernet communication system with a length less than 100m. The cables shall be according to ISO 24702 suitable to function properly and faultless under the prevailing environmental conditions and rodent-protected for direct buried application. The cables shall have a frequency spectrum up to 250 MHz and be terminated in 8P8C modular connectors.

The cables shall be halogen free.

4.8.6.5 *Fibre Optic Cables (FOC)*

Depending on the requirements by the proposed control system single mode and / or multi-mode FOCs shall be used.

The manufacturing, construction, labelling and testing of the fibre optic cable system shall meet the requirements established in the relevant applicable ITU and IEC codes, standards and recommendations.

Application

The fibre optic cable shall be suitable to function properly and faultlessly under the prevailing environmental conditions and rodent-protected for direct buried application.

The fibre optic cable shall be laid in buried cable conduits. Therefore a fully dielectric fibre optic cable suitable for ducted or direct buried applications, filled with compound to prevent axial and longitudinal ingress of water and / or soluble chemicals throughout the cable shall be provided. The cable shall have loose tubes as secondary coating of fibres.

Main Cable Structure

The cable shall be:

- Halogen free
- Metal free
- Axial and longitudinal tightness against water and / or soluble chemicals
- Rodent-protected
- Traction elements of Kevlar
- Lifetime of cable >30 years
- FOC fibre with primary coating Ø 250 +/- 15µm
- Secondary coating of fibres

- Filled centre fibre with 24 fibres
- Standard coloring

Outer cladding:

- Halogen free
- UV persistent
- Markings containing
- Manufacturer numbering
- Type of cable
- Number of fibres' and type of fibre
- Date; Metering and P/N marking

Cable markings shall be printed on the outer fibre cable jacket. The markings shall be permanent, insoluble in water and be legible for the duration of cable life. The markings shall be printed at intervals of not more than 2 meters.

Fibres and number of fibres

Diameter fibre:9 µm (+/- 10 %) – Single Mode

Diameter fibre:62,5 µm (+/- 10 %) – Multi Mode

Diameter cladding:125 µm(+/- 3µm)

Diameter coating:250 µm(+/- 15µm)

Damping: Single Mode max:

< 0,4dB/km, typ. 0,36dB/km at 1310 nm wavelength and

< 0,3 dB/km, typ. 0,26 dB/km at 1550 nm wavelength.

Multi Mode max:

< 0,9 dB/km, typ. 0,9 dB/km at 1310 nm wavelength.

Number of fibres: The long distance cable shall contain a minimum number f 12 fibres.

4.8.6.6 *Measurement after Cable Installation*

Measurement of splices

To verify the maximum damping of splices ODTR measurement in both directions shall be performed. The max damping of 0.1 dB per splice shall not exceed.

Measurement of Cable Run from Termination to Termination

The characteristics of the cable run shall be measured and verified and protocolled by:

- Bi-directional Power Loss Measurement at 1310 +30/-15 nm and 1550 +30/-70 nm
- Bi-directional OTDR Measurement at 1310 +30/-15 nm und 1550 +30/-70 nm

The values for maximum damping are:

- max. damping splice: 0,10 dB
- max. damping connectors (pair): 0,50 dB

4.8.6.7 *Fibre Optic Cable Accessories*

A detectable reinforced underground marking and warning tape shall be laid in the ground 300 mm above the protection conduit.

The patch cord consists of a single / multi-phase fibre optic cable with plug connections on both ends. Pigtails are fibre cables pre-assembled with a connector at one end. The fibres of the patch cords and pigtails shall be according the specified fibres and all components shall have a service life of more than 20 years with a minimum of contact durability of 1000.

Type of connectors shall match the requirements of PCMS I/O modules and shall be of same type all over the plant. Contractor shall decide the used type (ST; SC; FC/PC)

The connecter loss shall not exceed 0.5 dB per connector pair.

OTDR (Optical Time Domain Reflectometer) test report shall be submitted to Employer/Engineer.

The termination of each fibre in transmit and receive direction shall be provided on an optical distribution frame (ODF) for access to the transmission equipment. The ODF for receive and transmit direction shall be configured in accordance to the specified number of fibres (24). The ODF are to be installed in termination cabinets, which may be combined with the communication system.

4.8.6.8 *Industrial Ethernet Switches (Managed type)*

Industrial Ethernet Switches foreseen for installation shall provide the following:

- Compliance: IEEE 802.3 ISO/IEC 8802/3
- Technology: Store and forward
- Filtering Services / prioritization: IEEE 802.1 D/p
- Port type: Min 100 Mbps Media as necessary
- Diagnostics: Indication of power status, link status, data, full duplex, link failure (fibre disconnected)
- Management: SNMP, HTTP
- Design: Fan less
- Mechanical design: Stability against shock and vibration

- Min. operating temp. range: 0°C - 55°C
- Rel. humidity: 0% - 100%
- Diagnostics: LEDs for indication of power status, link status, data, full duplex, link failure (fibre disconnected)
- EMC: EN 55022, EN 50082-2
- VLAN support: IEEE 802.1Q, MAC Address / Port Based
- MTBF: >20 years

4.9 Utility compatibility

4.9.1 General

The applicable standard related to interconnecting an inverter to a utility network is IEC 61727: 2004, "Photovoltaic (PV) systems – Characteristics of the utility interface". The inverter's AC voltage, current and frequency shall be compatible with the utility system in accordance with IEC 61727.

4.9.2 Normal voltage operating range

Inverter shall operate at and shall support the network voltage. The inverter shall synchronise with the utility network before a connection is established. The inverter shall not generate the voltage of the grid, but shall inject current into the system.

4.9.3 Flicker

The operation of the inverter, in conjunction with other existing and future loads at the same point of connection, shall not cause flicker levels to increase beyond the levels specified in IEC 61000-3.

4.9.4 DC injection

The static power converter of the inverter shall not inject DC current exceeding 1 % of the rated AC output current into the utility AC. Interface under any operating condition in accordance with EN 50178. This relates specifically to inverters where the static power converter has no simple separation from the utility network.

4.9.5 Electromagnetic Compatibility

EMC to possible electromagnetic emissions from facilities or equipment to be installed, so the installation team is right to safe conditions of use, as well as the equipment to be connected to it. The inverter must be prepared and be electromagnetic compatible in function of electromagnetic immunity (IEC61000-6-2) and Emission (IEC61000-6-4).

4.9.6 Harmonics and waveform distortion

In accordance with IEC 61000-3, only devices that inject low levels of current and voltage harmonics will be accepted; the higher harmonic levels increase the potential for adverse effects on connected equipment.

Acceptable levels of harmonics, voltage and current depend upon distribution system characteristics, type of service, connected loads or apparatus, and established utility practice. The embedded generator output shall have low current-distortion levels to ensure that no adverse effects are caused to other equipment connected to the utility system.

Total harmonic current distortion shall be less than 5% at rated generator output in accordance with IEC 61000-3-. Each individual harmonic shall be limited to the percentages listed below.

Current distortion limit as a function of harmonics	
1	2
Odd harmonics	**Distortion limit**
3^{rd} through 9^{th}	Less than 4,0 %
11^{th} through 15^{th}	Less than 2,0 %
17^{th} through 21^{st}	Less than 1,5 %
23^{rd} through 33^{rd}	Less than 0,6 %
Even harmonics	**Distortion limit**
2^{nd} through 8^{th}	Less than 1,0 %
10^{th} through 32^{nd}	Less than 0,5 %

4.9.7 Power factor

The inverter shall not inject reactive power into the utility network, while the drain of reactive power shall be limited to a power factor of 85%. The inverter shall operate at these power factors in the range 10% to 100% of nominal power.

4.9.8 Synchronization

The inverter shall synchronize with the utility network before the parallel connection is made. Automatic synchronization equipment shall be the only method of synchronization. The limits for the synchronizing parameters for each phase are:

- frequency difference: 0,3 Hz,
- Voltage difference: 5 % = 11,5 V per phase, and phase angle difference: 20°.

4.9.9 Safety and protection

General: The safe operation of the inverter in conjunction with the utility network shall be ensured at all times.

Safety disconnection from utility network: The inverter shall automatically and safely disconnect from the grid in the event of an abnormal condition. Abnormal conditions include

- network voltage or frequency out-of-bounds conditions,
- loss-of-grid conditions and prevention of islanding
- DC current injection threshold exceeded
- PV field earth leakage
- Inverter over temperature

Disconnection switching unit: The inverter shall be equipped with a disconnection switching unit which separates the inverter from the grid due to the above abnormal conditions.

- The disconnection switching unit shall be able to operate under all operating conditions of the utility network.
- A failure within the disconnection switching unit shall lead to disconnection and indication of the failure condition.
- A single failure within the disconnection switching unit shall not lead to failure to disconnect.
- Failures with one common cause shall be taken into account and addressed through adequate redundancy.
- The disconnection switching unit shall disconnect from the network by means of two series switches. Each switch shall be separately rated to the inverter's nominal power output. At least one of the switches shall be an electromechanical switch while the second switch may be part of the existing solid state switching circuits of a utility-interconnected static power converter. The electromechanical switch shall disconnect the inverter on the neutral and the live wire(s).
- The fault current breaking capacity of the disconnecting switch shall be appropriately sized for the application.

Abnormal conditions can arise on the utility system and requires a response from the connected inverter. This response is to ensure the safety of utility maintenance personnel and the general public, and also to avoid damage to connected equipment. The abnormal utility conditions of concern are voltage and frequency excursions above or below the values stated in this clause. The inverter shall disconnect if these conditions occur. The parameters for disconnection shall correspond to those below, but shall be adjustable.

Over-voltage and under-voltage: The inverter shall cease to energize the utility distribution system should the network voltage deviate outside the conditions specified in table below. This applies to any phase of a multiphase system. The system shall sense abnormal voltage and respond. The following conditions shall be met, with voltages in r.m.s. and measured at the POC (Point of Connection). All discussions regarding system voltage refer to the nominal voltage.

The parameters for disconnection shall correspond to those below, but shall be adjustable in the field.

Response to abnormal voltages	
1	**2**
Voltage range **(at point of utility connection)**	**Maximum trip time** S
V < 50 %	0,2 s
50 % ≤ V < 85 %	2 s
85 % ≤ V ≤ 110 %	Continuous operation
110 % < V < 120 %	2 s
120 % ≤ V	0,16 s

Over-frequency and under-frequency: The inverter system shall cease to energize the utility network when the utility frequency deviates outside the specified conditions. When the utility frequency is outside the range of 49,5 Hz and 50,5 Hz, the system shall cease to energize the utility.

Prevention of islanding: An islanding condition shall cause the inverter to cease to energize the utility network within 2 s, irrespective of connected loads or inverters. One active islanding detection method and one passive island detection method shall be used to avoid an unintentional island.

Active and passive types of anti-islanding protection of inverters	
Active type	**Passive type**
Frequency shift	Power phase jump detection
Active power fluctuation	3rd harmonic voltage rise
Reactive power fluctuation	Frequency change rate detection
Load fluctuation	

DC current injection: The static power converter of the inverter shall not inject DC current greater than 1 % of the rated AC output current into the utility interface under any operating condition. The inverter shall cease to energize the utility network within 500 ms if this threshold is exceeded.

Response to utility recovery: After a voltage or frequency out-of-range condition that has caused the inverter to cease energizing the utility network, the inverter shall not re-energize the utility network for 60 s after the utility service voltage and frequency have recovered to within the specified ranges.

4.10 Earthing

4.10.1 General requirements

The bonding of equipment should prevent dangerous voltage differentials arising between metallic equipment during fault conditions, and provide alternative conduction paths to power cables should ground surges from nearby lightning strikes arise.

The main earth point for the system shall be a systems earth electrode, as specified in Section 4.10.2. It shall be located directly below each array structure.

The earth electrode shall be the common point for the casings of all balance of system components, and the array structure.

The risk of lightning strikes varies according to location. However, for all site locations the following basic guidelines will apply, as the electrical distribution is contained within one building.

For some sites additional lightning protection circuits may be required (see Section 4.11 Lightning Protection), but it is anticipated that for the current system configurations all within one building that no additional protection will be required.

4.10.2 Earth electrode

Two types of earth electrode are suitable:

- Spike earths
- Multiple spike earths (trench earth)

Bare copper or bare galvanised steel, in stranded, strip or rod form are satisfactory earth materials in non-aggressive soils. Because galvanised ferrous materials corrode sacrificially to copper, galvanised iron and steel electrodes should not be buried in close proximity to bare copper. In aggressive soils only galvanised steel earth rods should be used. The down conductors shall be connected to copper or galvanised/stainless earth spikes of minimum length 1200mm.

The spikes shall be driven vertically into the ground till buried to a depth of at least 0.3 m. If necessary, several spikes shall be interconnected as a trench earth to achieve the required resistance.

10mm2 shall be used as earth straps to bind components to the earth electrode, No loops shall be created to avoid inductive voltage. PE cable will be wired jointly with the positive and negative unipolar cable. Under no circumstances shall connection points, bolts, screws, etc. used for bonding or earthing be utilised for any other purpose. It will be responsibility of the Bidder to supply and fit earth terminals or clamps on equipment that must be earthed where these are not provided.

4.10.3 PV mounting structure earthing

PV mounting structure and PV module frame shall be connected to the earthing system.

Earthing of exposed conductive parts of electrical equipment, including structural metalwork is also generally required.

- Each PV roof system structure shall always be bonded directly to its own earth electrode. The bonding material shall be minimum 10mm2.
- For multiple PV arrays, it is recommended that a trench be used to bond the individual earth spikes together underground.

Continuity between the module frames and the mounting structure shall be maintained.

4.10.4 Equipment Earthing and Bonding

All metal equipment and casings shall be bonded together, as they are inter-connected by the power cables. The bonding shall be made using copper conductors of 10mm2 minimum. A separate conductor shall be used specifically for that purpose.

The resistance requiremnt in between enclosures shall be less than 1 ohm. The resistance measured against ground shall be less than 1 ohm.

The design shall base on international standards and codes like IEC or specific Maldivian standards and codes. The specific standards applicable for earthing requirements are:

IEC 60364-7-712 Electrical installations of buildings Part 7-712 Requirements for special installation locations-Solar photovoltaic (PV) power supply systems

IEC 60364-5-54 Electrical installations of buildings Part 5-54 Selection and erection of electrical equipment - Earthing arrangements, protective conductors and protective bonding conductors

4.11 IEC 62548 Photovoltaic (PV) arrays - Design requirementsLightning Protection

Lightning protection shall be designed inherently into the system configurations, earthing, and some level of surge protection shall be built into the inverters themselves.

For mitigation of overcurrent the Bidder shall follow the installation practice below:

- All DC cables should be installed to provide as short runs as possible and positive and negative cables of the same string or main DC supply should be bundled together, avoiding the creation of loops in the system. This requirement for short runs and bundling includes any associated earth/bonding conductors.
- Long cables (eg. PV main DC cables over about 50 m) should be installed in earthed metal conduit or trunking, or be screened cables such as mineral insulated or armoured.

Additional the following overvoltage protection devices shall be provided:

- DC system: surge arrestors, class 2, on the inverter DC inputs or DC distribution box shall be provided.
- AC system: surge arrestors, class 2, at the incoming point of supply shall be provided. The surge arrestors shall be installed in the Main DB.

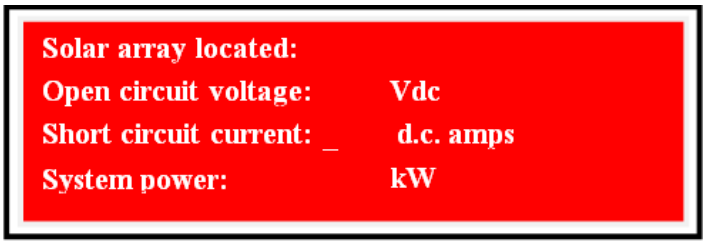
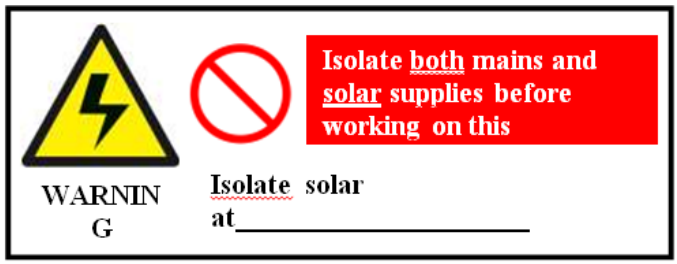
The surge arrestors shall be of class 2 with visual fault indication, 40kA (8/20) according to IEC 61643-1 for sensitive electronics, clamping voltage to less than 1,500V. Units with replaceable LP modules are required.

4.12 Labelling, safety signs and notices

All labelling and signage must be in English. All notices, labels or signs shall be durable and not removable except by determined and deliberate action. The inscriptions shall be legible and indelible. All custom signage to be ABS plastic silk-screened quality, indelible and shall be easily noticeable.

Where possible, standard approved symbolic safety signage is to be used. All DB labels shall be professional quality signage.

In addition to the standard electrical labels required in terms of British DTI standards regarding electrical installations, the following signs are required:

Locations	Sign number	Example design
• Main DB • Main display	1	
• FENAKA • Transformer • Tx breaker cubicle • Main DB • Inverter DB	2	

Locations	Sign number	Example design
• Inverter • Inverter DB	3	Shutdown Procedure: Turn off inverter AC main isolator Turn off PV array isolator Do not open d.c. plug and socket connectors or PV string isolator under load
• Main DB	4	PV system - main a.c isolator
• Tx Breaker cubicle	5	PV system - FENAKA a.c isolator
• PV Array JB	6	PV Array d.c, Junction Box. Danger Contains live parts during daylight
• PV array JB • Inverter DB • Long DC cable runs from array JB to inverter	7	d.c. cables are continuously live High voltage 700V dc!
• Roof top locations • PV Array JB	8	Do not open d.c. plug and socket connectors or PV string isolator under load

4.13 Noise and Radio Interference

The systems offered shall be designed, supplied and installed to minimise audible noise. The maximum allowable residual sound level is 50 dB LAeq for all electronic equipment. This requirement does not apply to the Diesel Generators.

The systems shall be screened from emitting electromagnetic interference.

No equipment may generate any radio interference with other equipment or systems and all equipment shall be suppressed to prevent interference of commercial radio and TV reception. The equipment and methods used in determining the acceptable levels of radio interference shall be as specified in IEC CISPR 22.6

4.14 Commissioning and Onsite Acceptance Tests

Prior to delivery of the project, the Bidder must perform a series of onsite tests to verify the proper performance of every system.

The onsite test will be divided per individual systems: PV plant and control system. After performing the tests per each system, it will be performed the tests for the entire hybrid plant.

Commissioning tests effectively place responsibility for system or component performance on the supplier. The commissioning tests are the responsibility of the supplier.

All the tests shall be properly documented and checked by the Project Management Team prior to the delivery of the project.

Tests shall be made on the functioning of solar panels, and respective electrical components, isolators and circuit breakers, metering, earthing, bonding, and operation of the data-logging system and monitoring.

The procedure for the commissioning and onsite test of the PV plants shall include at least the items summarized below:

- Gathering and review of information (technical specifications and as-built electrical plans).
- PV modules visual check.
- Mounting structure visual check.
- String combiner boxes inspection (enclosure quality, internal isolators, cable glands and labelling, etc.).
- Cable inspection.
- Cabling earthing and earth faults.
- Array tests (measurement and record solar irradiance and string/array IV curves)
- Inverters test (commissioning procedure provided by the supplier).

4.14.1 Cold Commissioning: Testing of the PV Plant

The verification of the Commissioning tests will be based at least on IEC 62446-1, 2016: Grid-connected photovoltaic systems – Minimum requirements for system documentation,

Commissioning tests, and inspection, for all electrical Commissioning. The verifications shall include, but not be limited to, the following equipment to be tested:

- PV modules
- PV modules support structure
- Support structure foundations
- String cabling
- LV DC cabling
- String combiner boxes
- Inverters
- Cable trays, inspection chambers, wiring, etc. both for DC and AC power, data transmission, and all other required transmission lines, including junction boxes, fuses, and all other required electrical equipment
- Meteorological stations and monitoring system
- Low-voltage installation, civil works, and medium-voltage installation (if applicable)
- All measurements as defined and described in IEC 62446

The Cold Commissioning tests shall include the measurement of 100% of the open circuit voltage (Voc) of the PV module strings. The minimum irradiance on the plane of array for the Voc measurements is 600 W/m².

The adequacy of the measurement devices proposed by the Bidder in terms of measurement uncertainty, calibration, etc. will be assessed and must be confirmed by the Employer prior to the start of the tests. A report with the measurement results of all strings will be presented by the Bidder in digital form as an Excel file. Strings which show a deviation from the mean value of the measured strings by more than 10% shall be highlighted in the report. Counter measures will be coordinated with the Employer.

4.14.2 Hot Commissioning: Testing of the PV Plant

Once the PV Plant is energized (this may require a dump load during testing), the Bidder shall demonstrate that the overall system and equipment operates in accordance with the following:

- Equipment manufacturer specifications
- Specifications of the contract
- All relevant national and international norms and standards

For Hot Commissioning testing, the following supplies and equipment will be commissioned / tested:

- DC operating current tests

- Inverter functionality
- Combiner boxes
- Monitoring system functionality (intern/extern)
- Meteorological station(s) if applicable
- Safety devices
- Transformer(s) if applicable
- Security System functionality
- Visual check of grounding and lightning protection system
- Visual check of MV equipment if applicable

4.14.3 Commissioning and Testing of BESS and PCMS

Tests of separate control system allow at least check the correct operation of the control hardware and communications interfaces.

The Bidder will provide a detailed test plan for this system separately, which shall include at least the following items:

- Visual inspection, labelling and technical specifications checking
- Power supply test.
- Test of communication with SCADA.
- Test of command sending and reception to distributed generation systems.
- Test of reception of monitoring parameters of the distributed systems
- Test of communication latency
- Several full charge and discharge cycles at rated and peak power will be carried out, or at least to the minimum state of charge expected to operate the system on a daily basis
- During charge and discharge testing process the BESS shall achieve the peak power ratings at least once per complete cycle. The duration of the peak power shall be the necessary to archive the optimum control of the hybrid plant and will be within the values provided by the manufacturer.
- Communications between battery BMS and PCMS controller will be tested. The tests will be performed at zero, nominal and peak power ratings of the system, in order to ensure that possible electromagnetic noise will not affect the communications.
- BESS must communicate with PCMS so it is considered essential to carry out communications tests of these subsystems separately. Communications tests shall include both the sending of control operating commands from PCMS to BESS and

monitoring parameters from the BESS to the PCMS. Tests must be conducted both at zero power and at nominal power.

- The correct functioning of ancillary systems of the BESS will be tested, including at least:
  - Air conditioning system temperature regulation is working correctly.
  - Lights
  - Electric Outlet

The functional performance onsite tests of the control algorithm will be carried out during the hybrid plant tests.

Tests performed onsite will let the provider to verify the correct operation of the BESS at the final location. The test record shall include at least measurements of battery temperatures, power electronics temperatures, current and power values achieved, possible detected alarms and any other outstanding incidence that may occur. The tests of the BESS will include at least the following features

Mechanical completion: The mechanical completion checking will consist on the following:

- Batteries power output is properly connected to the Battery Inverters.
- Communications wiring between Batteries and Battery Inverter and Main Power Plant Controller is correctly connected.
- No mechanical damages exist.

4.14.4 Hybrid Plant Test

The hybrid plant tests are intended to validate the performance of the entire plant and will involve all the systems operating in a coordinated way to achieve the target of a reliable power supply of the islands, with a significant reduction on the diesel consumption.

The test of the full hybrid plant will be the last to be completed, and will require a good coordination between all suppliers, which shall be available to be present during the tests of the systems together.

The Bidder will provide the details of the test plan for the whole system, which shall include at least the following items:

- Power balance tests. Through these tests the capability of maintaining the power balance in the grid versus sudden reduction in photovoltaic generation and/or increments in the loads will be verified. The tests shall include the manual reduction of the PV generation at different rates at least 25%, 50%, 75% and 90% of PV when a constant PV power of min. 80% of installed kWp is available for the AC PV connected capacity. This shall be repeated with different ramp rates (reduction of kW/sec), that have to be confirmed by the Employer.

- Tests to verify the response to voltage variations will be also performed. It shall be checked that the compensation response of the system to voltage variations to be less than 1 minute.
- Settings and adjustments of diesel protections and their performance versus sudden power unbalances in the grid.
- Power quality tests. Measurements of all the parameter related with the power quality shall be taken during the tests phase: THD (voltage and current), flicker, frequency and voltages. All these measurements shall show the compliance with the national requirements, as well as the technical requirements stated on this bid.
- Measurement of the diesel consumption. Once the functionality of hybrid control system is tested, it shall be carried out a comparison between the previously recorded diesel consumption and the new measured consumption rates. The results shall be given to the Employer in form of a report.

4.15 Documentation

The bid documentation shall describe the full system functionality, main system components, performance and parameters (data sheets), connection of existing equipment, redundancy principle, communication interfaces, the backup and recovery concepts for the PCMS, anti-virus and malware protection, and shall include the software and hardware requirements for the proposed backup concept.

4.15.1 Documentation to be submitted with Bid

The Bidder must complete all forms given in Section 4 - Bidding Forms of the Bidding Document for the Hybrid Power Plant. All of them shall be submitted electronically as PDF, Excel or Word-file. Technical data sheets should be supplemented by additional descriptions, explanations, drawings and all other information necessary for a clear understanding of the bid to enable the Employer to undertake the necessary assessment, evaluation and verification of the technical and performance features of the bid.

In any case major deviations are discouraged and Employer reserves the right to reject any bid as noncompliant in his sole discretion.

The Bidder shall include the interface documents in his bid.

The Bidder shall include a list of his sub-contractors.

The Bidder shall submit a record of the executed projects in the power sector within the last 5 years.

The Bidder shall include the civil design criteria in his bid consisting of but not limited to corrosion protection plan, load bearing capacities of roads and bridges for truck traffic. The Bidder shall prepare a binding description of included furniture, equipment, appliances and the like together with the respective type of quality.

4.15.2 Documentation to be submitted after contract award

The following describes the minimum scope of information, documents, drawings, etc. to be submitted by the successful Bidder to the Employer after award of contract during the design and engineering phase and during site construction of the PV Hybrid plant. The Employer reserves the right to request from the successful Bidder such additional information, drawings, documents, etc. as may be reasonably required for proper understanding and definition of the design and engineering of the project.

The successful Bidder shall provide four (4) copies of all drawings and documentation to be submitted by him. For the as-built documentation a well-organized electronic file including an Excel based table of contents, two (2) copies (plus electronic copy) shall be provided. All information with respect to connection points and interfaces between the Plant and the grid, and any other interface as well as for the entire PV Hybrid plant itself shall be included. The number of copies or the final content may be amended as may otherwise be required by the provisions of the Contract or as may otherwise be reasonably required by the Employer.

Bi-monthly status reports shall be provided by the successful bidder. Any revision of the project implementation schedule shall not be delivered later than seven (7) days after such revision.

4.15.3 Documentation to be submitted during detail design

The following documents shall be submitted as a minimum by the successful Bidder to the Employer within a maximum of two (2) months after the date of contract award:

- Detail design reports of all systems, buildings, and structures.
- The Bidder shall hand-in his method statements for construction methods
- General arrangement and layout drawings
- Project documents (data sheets, specifications, drawings) for major systems and components including system description of the main systems
- Single line diagrams
- Calculations and layouts for grounding, earthing, lightning protection, surge prevention
- Cable list and cable size calculation
- Soil resistivity measurement
- Detailed layout drawings not limited to architectural, structural and electrical drawings.
- Report of the design loads and load bearing capacities buildings and structures
- Underground / aboveground ducts and cable arrangement drawings (civil and electrical)
- Quality assurance philosophy
- Information about corrosion protection for steel structures

- Operation and maintenance philosophy
- Emergency Response Plan
- HSE plan

4.15.4 Final Documentation

Before the final acceptance of the PV Hybrid plant the Contractor shall deliver to the Employer the final documentation, both in digital and hard copies (2x). The final documentation for the PV plant shall be prepared in accordance with the IEC 62446 standard.

For the PV Hybrid plant the final documentation shall comprise at least the following:

- All As-built drawings (civil, mechanical, electrical) but not limited to:
  - SLD's
  - Cable routing plans and calculations
  - Cable list
  - Substructure and module mounting details
  - Roof penetration
  - Generator synchronizing panel and main distribution panel drawings
- Data sheets of installed components
- Warranties of installed components
- O&M manuals
- Site safety procedures
- HSE procedure and plan
- Test protocols
- Performed studies and tests
- Mechanical completion documents (not limited to):
  - Data sheets and manuals of components and equipment
  - Serial number of inverters, transformers, combiner boxes, etc.
  - Flash list of installed modules
  - Acceptance protocols
  - Calibration protocols
- Factory Acceptance Test Reports for all mechanical and electrical equipment
- Acceptance protocols between Contractor and Subcontractor

- Commissioning protocols
- Provisional Acceptance Certificate
- Punch lists (Reserve lists) for the Defects Liability Period
- Password for inverters, internal communication and SCADA system

4.16 Training Program

The Bidder is required to provide training at manufacturer's site for two persons from each power house and two staff from Fenaka head office (total 28 persons). In addition local staff should be given training on operation and maintenance during construction.

The training shall take one week on the manufacturer's premises plus one week on the 12 construction sites for each team separate.

All living, accommodation, food, transport expenses of the trainees during the period of training/study tour including airfares, incidental expenses, medical expenses, medical insurances etc. will be covered by the Contractor including pocket allowance of US$100/day/person for training abroad.

The goal of the training and qualification program is to ensure that the PV Hybrid plant's personnel acquire and maintain the combination of knowledge and demonstrated skills to full fill their responsibilities. Likewise, the Employer will acquire the knowledge required to full fill his responsibilities as plant owner during operation. This will reasonably assure that the plant is operated safely and efficiently, while also ensuring its long-term economic success.

The trained persons must subscribe in a list and sign, how many hours they have attended the training.

Every attendant must receive a training documentation/handbook, where the training subjects are documented in detail.

During implementation the Contractor shall train the Employeers personel. The training shall be split in a practical and a theoretical part.

For the practical part, the staff to be trained shall be involved in the building process of the power plant, in order to understand the overall system.

The practical part shall consist of 14 training days with a 2 hours session each day.

The theoretical part shall be 10 days with a 2 hours session each day.

The Bidder shall be flexible enough to adapt the content of the training to the state of knowledge of the attendees

The training shall comprise but not be limited to the following:

- Technical basics and components of a PV plant (PV modules and inverters), grid storage, and a diesel plant

- General function of a PV plant, battery storage, and a diesel plant
- General function of a battery management system
- General function of power transformer sub-station, middle and low voltage switchgear as applicable
- General function of a PV diesel controller
- Norms and standards
- Health, Safety, and Environmental (HSE), First Aid
- Control room daily work
- Operation of a PV plant and a diesel plant
- Monitoring of the PV plant and the diesel plant
- Access to the monitoring system
- Monitoring of the hybrid controller
- Fault detection
- Action plan after fault detection
- Preventive maintenance
- Supervision and managing of corrective maintenance
- Performance of first level corrective maintenance, such as the replacement of spare parts and / or spare inverters
- Spare parts logistic and usage
- Plant documentation
- Monthly reporting
- Communication with suppliers
- Managing of insurance claims
- Maintenance of green areas, internal paths
- Cleaning of modules
- Maintenance and cleaning of pyranometers and other sensors

4.17 O&M Requirements during the one year Defect Liability period

4.17.1 Plant operation and control

Bidder shall provide O&M support services (no daily operation of the plant is required). The operation and control system of the plant system should not be limited to registration of data, but should comprise functions for assessment and interpretation of operating conditions in particular in order to allow for remote diagnosis of errors.

Electrical load data, PV generator data and diesel engine data and the battery status (SOC) shall be acquired by the PCMS and handled within data storage, protocol, reporting and monitoring. It is mandatory that the PCMS shall retrieve all necessary data to ensure reliability and performance according to its intended purpose.

Bidder shall prepare monthly reports using the remote PCMS regarding the operation of the plant including electricity production, efficiency, fuel consumption, availability. Any maintenance performed during the month shall also be reported and the action taken described clearly.

Bidder shall performe a minimum quarterly periodic maintenance services and service reports

Bidder may sub-contract the performance of parts or all of the services, subject to the approval of the Employer and on the basis that the Bidder remains fully liable for the performance of the sub- contracted obligations.

4.17.2 Moreover, Bidder shall liaise with the original equipment manufacturer to identify changes in the recommendations for the monitoring and maintenance of the equipment that constitutes the plant.Preventive maintenance requirements

The maintenance of the plant shall be based on the following operation, dispatching, and other requirements:

- Maintenance activities for the plant affecting the power output shall take place outside the peak load periods, i.e. during the period of low power demand and low solar irradiation conditions (morning/ evening/ at night).
- Maintenance of the plant shall be carried out at a minimum in accordance with the equipment manufacturers' suggested maintenance requirements and the scheduling requirements of Employer and follow applicable standards and industry practices.

4.17.3 PV Plant specific maintenance activities

The PV plant scope of work shall comprise the following activities:

- Inspection and testing according to IEC 62446-1, 2016. In particular the inspection shall comprise the control and preventive maintenance of
  - Modules
  - Inverters

- Junctions boxes
- Cabling
- Cable terminations
- Mounting structure

- Annual IV-curve measurement and thermographic (IR) checks of a sample of at least 5% of the installed modules and electrical connections for identification of possible underperformance and/or hot spots
- Maintenance of the site including green areas, paths, cable servitudes etc.
- Cleaning of modules to keep the losses due to soiling low. The cleaning must be performed according to the recommendations from the PV module supplier.
- Regular software updates of the PV inverter must be installed
- Cleaning of battery cabinets

PV plant specific maintenance activities shall be performed during periods with low irradiation, preferably during morning, eventing or night hours.

4.17.4 Corrective maintenance requirements

For the first one year of operation of the hybrid plant, the Bidder is required to provide full corrective maintenance at no extra cost for the Employer. Corrective maintenance means the repair or replacement of defective material and components.

Corrective maintenance activities shall be initiated as soon as a failure is detected. It shall always be ensured that the staff of the Employer is present and trained during each corrective maintenance activities.

If a failure will be detected O&M personal shall initiate corrective maintenance measures within 6 hours after its occurrence.

The Bidder shall be responsible for maintaining and refilling the spare parts stock at no additional cost for the Employer. An overview of the spare parts approach, major inspection, overhauls of equipment, and replacement program of equipment shall be provided, including:

- Spare and wear parts and consumables necessary for the proper and continuing functioning of the plant during the Defect Liability Period (DLP)
- Requirements and storage conditions for the spare and wear parts and consumables
- Replacement strategy, spare parts, and reaction periods for inverters for the first five years after the provisional acceptance of the plant.

Furthermore, the Bidder shall manage all warranty cases including the dismantling, packaging, shipping and / or safe disposal of defective materials.

4.18 Spare parts, consumables and special tools

The Bidder shall provide all spares parts and consumables necessary for the correct functioning during the warranty period and for performing the necessary maintenance activities. All spare parts shall be directly interchangeable with the corresponding parts in the power plants and shall meet the requirements of the present specifications.

Spare parts comprise all disciplines (civil, mechanical, electrical and I&C works) and shall be in compliance with the corresponding Schedules in Section 4.

All the special tools and other equipment that are necessary for the overhaul, maintenance and adjustment of the power plant facilities and equipment shall be included in the Bidder's scope of supply.

5 Drawings

The following drawings are provided in attachment to the present Volume 6.

S No.	Drawing Number	Title
General Design		
1	G409-THAA-GEN-GRID-001	SINGLE LINE DIAGRAM OF DISTRIBUTION BOX: INDICATIVE (COMMON)
2	G409-THAA-GEN-GRID-002	DISTRIBUTION BOX LAYOUT: INDICATIVE (COMMON)
3	G409-THAA-GEN-GRID-003	CROSS SECTIONAL VIEW OF INDICATIVE CABLE TRENCH (COMMON)
4	G409-THAA-GEN-GRID-004	FRONT VIEW CONTROL AND PROTECTION PANEL: INDICATIVE (COMMON)

S No.	Drawing Number	Title
Tender Design		
1	G409-THAA-N02-SLD-1	N-02 VILUFUSHI GRID SLD PROPOSED
2	G409-THAA-N02-SLD-2	N-02 VILUFUSHI CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE
3	G409-THAA-N03-SLD-1	N-03 MADIFUSHI GRID SLD PROPOSED
4	G409-THAA-N03-SLD-2	N-03 MADIFUSHI CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE
5	G409-THAA-N04-SLD-1	N-04 DHIYAMIGILI GRID SLD PROPOSED
6	G409-THAA-N04-SLD-2	N-04 DHIYAMIGILI CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE
7	G409-THAA-N05-SLD-1	N-05 GURAIDHOO GRID SLD PROPOSED
8	G409-THAA-N05-SLD-2	N-05 GURAIDHOO CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE
9	G409-THAA-N06-SLD-1	N-06 KANDOODHOO GRID SLD PROPOSED
10	G409-THAA-N06-SLD-2	N-06 KANDOODHOO CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE
11	G409-THAA-N07-SLD-1	N-07 VANDHOO GRID SLD PROPOSED

S No.	Drawing Number	Title
12	G409-THAA-N07-SLD-2	N-07 VANDHOO CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE
13	G409-THAA-N08-SLD-1	N-08 HIRILANDHOO GRID SLD PROPOSED
14	G409-THAA-N08-SLD-2	N-08 HIRILANDHOO CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE
15	G409-THAA-N9-SLD-1	N-09 GAADHIFFUSHI GRID SLD EXISTING
16	G409-THAA-N9-SLD-2	N-09 GAADHIFFUSHI CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE
17	G409-THAA-N10-SLD-1	N-10 THIMARAFUSHI GRID SLD PROPOSED
18	G409-THAA-N10-SLD-2	N-10 THIMARAFUSHI CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE
19	G409-THAA-N11-SLD-1	N-11 VEYMANDOO GRID SLD PROPOSED
20	G409-THAA-N11-SLD-2	N-11 VEYMANDOO CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE
21	G409-THAA-N12-SLD-1	N-12 KINBIDHOO GRID SLD PROPOSED
22	G409-THAA-N12-SLD-2	N-12 KINBIDHOO CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE
23	G409-THAA-N13-SLD-1	N-13 OMADHOO GRID SLD PROPOSED
24	G409-THAA-N13-SLD-2	N-13 OMADHOO CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE

6 Certificates

6.1 Form of Completion Certificate

Contract: [. . . . .*insert name of contract and contract identification details*. . . . .]

Date:

Certificate No.:

To: [. . . . .*insert name and address of contractor*. . . . .]

Dear Ladies and/or Gentlemen,

Pursuant to GCC Clause 24 (Completion of the Facilities) of the General Conditions of the Contract entered into between yourselves and the Employer dated [. . . . .*insert date*. . . . .], relating to the [. . . .*brief description of the Facilities* . . . .], we hereby notify you that the following part(s) of the Facilities was (were) complete on the date specified below, and that, in accordance with the terms of the Contract, the Employer hereby takes over the said part(s) of the Facilities, together with the responsibility for care and custody and the risk of loss thereof on the date mentioned below.

5. Description of the Facilities or part thereof: [. . . .*description* . . . .]

6. Date of Completion: [. . . .*date* . . . .]

However, you are required to complete the outstanding items listed in the attachment hereto as soon as practicable.

This letter does not relieve you of your obligation to complete the execution of the Facilities in accordance with the Contract nor of your obligations during the Defect Liability Period.

Very truly yours,

[. . . .*Signature* . . . .]

Project Manager

6.2 Form of Operational Acceptance Certificate

Contract: [. . . . *insert name of contract and contract identification details*. . . . .]

Date:

Certificate No.:

To: [. . . . *insert name and address of contractor*. . . . .]

Pursuant to GCC Sub clause 25.3 (Operational Acceptance) of the General Conditions of the Contract entered into between yourselves and the Employer dated [. . . *date*. . .], relating to the [. . . *brief description of the facilities*. . . .], we hereby notify you that the Functional Guarantees of the following part(s) of the Facilities were satisfactorily attained on the date specified below.

7. Description of the Facilities or part thereof: [. . . *description* . . .]

8. Date of Operational Acceptance: [. . . *date* . . .]

This letter does not relieve you of your obligation to complete the execution of the Facilities in accordance with the Contract nor of your obligations during the Defect Liability Period.

Very truly yours,

[. . . . *Signature* . . . .]

Project Manager

7 Change Orders

7.1 Change order procedure

7.1.1 General

This section provides samples of procedures and forms for implementing changes in the Facilities during the performance of the Contract in accordance with GCC Clause 39 (Change in the Facilities) of the General Conditions.

7.1.2 Change Order Log

The Contractor shall keep an up-to-date Change Order Log to show the current status of Requests for Change and Changes authorized or pending. Entries of the Changes in the Change Order Log shall be made to ensure that the log is up-to-date. The Contractor shall attach a copy of the current Change Order Log in the monthly progress report to be submitted to the Employer.

7.1.3 References for Changes

(1) Request for Change as referred to in GCC Clause 39 shall be serially numbered CR-X-nnn.

(2)Estimate for Change Proposal as referred to in GCC Clause 39 shall be serially numbered CN-X-nnn.

(3) Acceptance of Estimate as referred to in GCC Clause 39 shall be serially numbered CA-X-nnn.

(4) Change Proposal as referred to in GCC Clause 39 shall be serially numbered CP-X-nnn.

(5) Change Order as referred to in GCC Clause 39 shall be serially numbered CO-X-nnn.

Note:

(a) Requests for Change issued from the Employer's Home Office and the Site representatives of the Employer shall have the following respective references:

Home Office	CR-H-nnn
Site	CR-S-nnn

(b) The above number "nnn" is the same for Request for Change, Estimate for Change Proposal, Acceptance of Estimate, Change Proposal and Change Order.

7.2 Change Order Forms

7.2.1 Request for Change Proposal Form

[*Employer's letterhead*]

To: [*Contractor's name and address*] Date:

Attention: [*Name and title*]

Contract Name: [*Contract name*]

Contract Number: [*Contract number*]

Dear Ladies and/or Gentlemen:

With reference to the captioned Contract, you are requested to prepare and submit a Change Proposal for the Change noted below in accordance with the following instructions within [*number*] days of the date of this letter [or on or before (*date*)].

1. Title of Change: [*Title*]
2. Change Request No./Rev.: [*Number*]
3. Originator of Change:

   Employer: [Name]

   Contractor (by Application for Change Proposal No. [Number Refer to Annex 6.2.7])
4. Brief Description of Change: [*Description*]
5. Facilities and/or Item No. of equipment related to the requested Change: [*Description*]
6. Reference drawings and/or technical documents for the request of Change:

   Drawing No./Document No. *Description*
7. Detailed conditions or special requirements on the requested Change: [*Description*]
8. General Terms and Conditions:

   (a) Please submit your estimate showing what effect the requested Change will have on the Contract Price.

   (b) Your estimate shall include your claim for the additional time, if any, for completing the requested Change.

   (c) If you have any opinion that is critical to the adoption of the requested Change in connection with the conformability to the other provisions of the Contract or the safety of the Plant or Facilities, please inform us in your proposal of revised provisions.

   (d) Any increase or decrease in the work of the Contractor relating to the services of its personnel shall be calculated.

(e) You shall not proceed with the execution of the work for the requested Change until we have accepted and confirmed the amount and nature in writing.

[*Employer's name*]

[*Signature*]

[*Name of signatory*]

[*Title of signatory*]

7.2.2 Estimate for Change Proposal Form

[*Contractor's letterhead*]

To: [*Employer's name and address*] Date:

Attention: [*Name and title*]

Contract Name: [*Contract name*]

Contract Number: [*Contract number*]

Dear Ladies and/or Gentlemen:

With reference to your Request for Change Proposal, we are pleased to notify you of the approximate cost to prepare the below-referenced Change Proposal in accordance with GCC Sub clause 39.2.1 of the General Conditions. We acknowledge that your agreement to the cost of preparing the Change Proposal, in accordance with GCC Sub clause 39.2.2, is required before estimating the cost for change work.

1. Title of Change: [*Title*]
2. Change Request No./Rev.: [*Number*]
3. Brief Description of Change: [*Description*]
4. Scheduled Impact of Change: [*Description*]
5. Cost for Preparation of Change Proposal: [*insert costs, which shall be in the currencies of the contract*]

(a)	Engineering	(Amount)
(i)	Engineer _____ hours (hrs) x _____	rate/hr = _____
(ii)	Draftsperson _____ hrs x _____	rate/hr = _____
	Sub-total _____ hrs	_____
	Total Engineering Cost	_____
(b)	Other Cost	_____
	Total Cost (a) + (b)	_____

[*Contractor's name*]

[*Signature*]

[*Name of signatory*]

[*Title of signatory*]

7.2.3 Acceptance of Estimate Form

[*Employer's letterhead*]

To: [*Contractor's name and address*] Date:

Attention: *[Name and title]*

Contract Name: *[Contract name]*

Contract Number: *[Contract number]*

Dear Ladies and/or Gentlemen:

We hereby accept your Estimate for Change Proposal and agree that you should proceed with the preparation of the Change Proposal.

1. Title of Change: [*Title*]
2. Change Request No./Rev.: [*Request number/revision*]
3. Estimate for Change Proposal No./Rev.: [*Proposal number/revision*]
4. Acceptance of Estimate No./Rev.: [*Estimate number/revision*]
5. Brief Description of Change: [*Description*]
6. Other Terms and Conditions: In the event that we decide not to order the Change accepted, you shall be entitled to compensation for the cost of preparing the Change Proposal described in your Estimate for Change Proposal mentioned in para. 3 above in accordance with GCC Clause 39 of the General Conditions.

[*Employer's name*]

[*Signature*]

[*Name of signatory*]

[*Title of signatory*]

7.2.4 Change Proposal Form

[*Contractor's letterhead*]

To: [*Employer's name and address*] Date:

Attention: [*Name and title*]

Contract Name: [*Contract name*]

Contract Number: [*Contract number*]

Dear Ladies and/or Gentlemen:

In response to your Request for Change Proposal No. [Number], we hereby submit our proposal as follows:

1. Title of Change: [*Name*]
2. Change Proposal No./Rev.: [*Proposal number / revision*]
3. Originator of Change: Employer: [*Name*] / Contractor: [*Name*]
4. Brief Description of Change: [*Description*]
5. Reasons for Change: [*Reason*]
6. Facilities and/or Item No. of Equipment related to the requested Change: [*Facilities*]
7. Reference drawings and/or technical documents for the requested Change:

   [*Drawing/Document No./Description*]

8. Estimate of increase/decrease to the Contract Price resulting from the Change Proposal:

		Amount
		[*insert amounts in the currencies of the Contract*]
(a)	Direct material	_____
(b)	Major construction equipment	_____
(c)	Direct field labor (Total hrs)	_____
(d)	Subcontracts	_____
(e)	Indirect material and labor	_____
(f)	Site supervision	_____

(g) Head office technical staff salaries

Process engineer _____ hrs @ _____ rate/hr _____

Project engineer _____ hrs @ _____ rate/hr _____

Equipment engineer _____ hrs @ _____ rate/hr _____

Procurement _____ hrs @ _____ rate/hr _____

Draftsperson _____ hrs @ _____ rate/hr _____

Total _____hrs

(h) Extraordinary costs (computer, travel, etc.) _____

(i) Fee for general administration, % of Items _____

(j) Taxes and customs duties _____

Total lump sum cost of Change Proposal [*Sum of items (a) to (j)*]

Cost to prepare Estimate for Change Proposal [*Amount payable if Change is not accepted*]

9. Additional time for Completion required due to Change Proposal

10. Effect on the Functional Guarantees

11. Effect on the other terms and conditions of the Contract

12. Validity of this Proposal: within [Number] days after receipt of this Proposal by the Employer

13. Other terms and conditions of this Change Proposal:

(a) You are requested to notify us of your acceptance, comments or rejection of this detailed Change Proposal within [Number] days from your receipt of this Proposal.

(b) The amount of any increase and/or decrease shall be taken into account in the adjustment of the Contract Price.

(c) Contractor's cost for preparation of this Change Proposal: [*. . . .insert amount. This cost shall be reimbursed by the employer in case of employer's withdrawal or rejection of this Change Proposal without default of the contractor in accordance with GCC Clause 39 of the General Conditions . . . .*]

[*Contractor's name*]

[*Signature*]

[*Name of signatory*]

[*Title of signatory*]

7.2.5 Change Order Form

[*Employer's letterhead*]

To: *[Contractor's name and address]* Date:

Attention: *[Name and title]*

Contract Name: *[Contract name]*

Contract Number: *[Contract number]*

Dear Ladies and/or Gentlemen:

We approve the Change Order for the work specified in the Change Proposal (No. [*number*]), and agree to adjust the Contract Price, Time for Completion, and/or other conditions of the Contract in accordance with GCC Clause 39 of the General Conditions.

1. Title of Change: [*Name*]
2. Change Request No./Rev.: [*Request number / revision*]
3. Change Order No./Rev.: [*Order number / revision*]
4. Originator of Change: Employer: [*Name*] / Contractor: [*Name*]
5. Authorized Price:

   Ref. No.: [*Number*] Date: [*Date*]

   Foreign currency portion [*Amount*] plus Local currency portion [*Amount*]
6. Adjustment of Time for Completion

   None Increase [*Number*] days Decrease [*Number*] days
7. Other effects, if any

Authorized by: _____ Date: _____

Employer

Accepted by: _____ Date: _____

Contractor

7.2.6 Pending Agreement Change Order Form

[*Employer's letterhead*]

To: *[Contractor's name and address]* Date:

Attention: *[Name and title]*

Contract Name: *[Contract name]*

Contract Number: *[Contract number]*

Dear Ladies and/or Gentlemen:

We instruct you to carry out the work in the Change Order detailed below in accordance with GCC Clause 39 of the General Conditions.

1. Title of Change: [*Name*]
2. Employer's Request for Change Proposal No./Rev.: [*number/revision*] dated: [*date*]
3. Contractor's Change Proposal No./Rev.: [*number / revision*] dated: [*date*]
4. Brief Description of Change: [*Description*]
5. Facilities and/or Item No. of equipment related to the requested Change: [*Facilities*]
6. Reference Drawings and/or technical documents for the requested Change:

   [*Drawing / Document No. / Description*]
7. Adjustment of Time for Completion:
8. Other change in the Contract terms:
9. Other terms and conditions:

[*Employer's name*]

[*Signature*]

[*Name of signatory*]

[*Title of signatory*]

7.2.7 Application for Change Proposal Form

[*Contractor's letterhead*]

To: [*Employer's name and address*] Date:

Attention: [*Name and title*]

Contract Name: [*Contract name*]

Contract Number: [*Contract number*]

Dear Ladies and/or Gentlemen:

We hereby propose that the work mentioned below be treated as a Change in the Facilities.

1. Title of Change: [*Name*]
2. Application for Change Proposal No./Rev.: [*Number / revision*] dated: [*Date*]
3. Brief Description of Change: [*Description*]
4. Reasons for Change:
5. Order of Magnitude Estimation (amount in the currencies of the Contract): [*Amount*]
6. Scheduled Impact of Change:
7. Effect on Functional Guarantees, if any:
8. Appendix:

[*Contractor's name*]

[*Signature*]

[*Name of signatory*]

[*Title of signatory*]

8 Personnel Requirements

Using Form PER-1 and PER-2 in Section 4 (Bidding Forms), the Bidder must demonstrate that it has personnel who meet the following requirements:

No.	Position	Total Work Experience [years]	Experience In Similar Work [years]
1	Project Manager (PV/electrical engineer)	12	7
2	PV engineer	10	5
3	Battery specialist	5	3
4	Civil engineer	10	5
5	Electrical engineer	10	5
6	Electro-mechanical engineer (Diesel)	10	5
7	Site supervision manager	7	3

All staff must be fluent in English

9 Equipment Requirements

Using Form EQU in Section 4 (Bidding Forms), the Bidder must demonstrate that it has the key equipment listed below:

No.	Equipment Type and Characteristics	Minimum Number Required
1	Electrical construction elevator to transport PV modules on the roofs	4
2		
3		