Section 6 - Employer's Requirements

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FIGURE CAPTIONS

TABLE CAPTIONS

ABBREVIATIONS

AC	-	Alternate Current
ADB	–	Asian Development Bank
CAPEX	–	Capital Expenditure.
DC	-	Direct Current
BESS	–	Battery Energy Storage System.
FENAKA	–	the Utility responsible for electricity, water and sanitation
GUI	–	Graphical User Interface
RE	–	Renewable Energy.
PV	-	Photovoltaic
SCADA	_	Supervisory control and data acquisition
SWA	_	Steel wire armoured
SS	_	Substation
PCMS	_	PV/Diesel Hybrid Plant Control and Monitoring System
	_	

WEIGHTS AND MEASURES

kW	–	Kilowatt
kWh	–	Kilowatt-hour
MW	–	Megawatt

1 Scope of Supply of Plant and Services

1.1 General

The aim of the present tender is to hybridize the existing diesel power plants of 13 inhabited islands located in the Haa Dhaalu atoll, Maldives, by installing photovoltaic solar (PV) roof-top systems together with Lithium-ion battery systems. The project also includes the upgrade of the existing diesel power plants into fully automated diesel power system and the improvement of the power distribution grid. The systems shall provide a cost efficient, environment friendly and uninterruptible power supply.

The specific islands are listed in Table 1.

Island Code	Atoll	Island Name
B03	HDh	Hanimaadhoo
B04	HDh	Finey
B05	HDh	Naivaadhoo
B06	HDh	Hirimaradhoo
B07	HDh	Nolhivaranfaru
B08	HDh	Nellaidhoo
B09	HDh	Nolhivaram
B10	HDh	Kurinbee
B12	HDh	Kulhudhuffushi
B13	HDh	Kumundhoo
B14	HDh	Neykurendhoo
B15	HDh	Vaikaradhoo
B17	HDh	Makunudhoo

Table 1: List of islands with island code and atoll

Figure 1: Map of the islands of Haa Dhaalu atoll – Source: Google Earth

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 Bidder 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, implementation into the centralised SCADA system

- Battery system (if applicable, compare with Chapter 2, Site Specifications) 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, implementation into 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, implementation into the centralised SCADA system.
- Upgrade the existing grid infrastructure as per the tender requirements which include but not limited to replacement of cables in the existing LV distribution network in line with the expected future increase in load, replacement of distribution boxes identified based on the conditional assessment, modification/replacement of existing distribution boxes to replace terminations as per the revised cable sizes or due to 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 or for a new DG 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 Bidder 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 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 build.
- survey related to the grid upgrade works which include but not limited to cable routes of the complete distribution network 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 Bidder is responsible for import, transport, storage and handling of any equipment and material needed for installation and implementation of services.

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

The Bidder 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 (if applicable, compare with Chapter 2, Site Specifications)
- Diesel generator system including automated generator synchronisation panel
- Integration of system 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 investigated by the Bidder.

2 Site Specifications

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 Bidder 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 Haa Dhaalu 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 generated with the software METEONORM 7.

	Global Horizontal Irradiation (GHI)	Diffuse Horizontal Irradiation (DHI)	Ambient temperature
	kWh/m²/month	kWh/m²/month	°C
Jan	162	72	27.7
Feb	161	72	27.9
Mar	191	86	29.1
Apr	176	82	29.7
May	146	82	29.6
Jun	137	84	28.7
Jul	146	80	28.3
Aug	155	84	28.3
Sep	162	77	28.1
Oct	158	76	28
Nov	150	72	27.8
Dec	149	69	27.8
Year	**1,893**	**937**	**28.4**

Table 2: Solar resource and meteorological data

The following graphic representation confirms the very constant temperature and solar irradiation over the year, which is due to location of the Maldives close to the equator. March and April are the warmest and sunniest months. The rainy season from May to July explains the slightly lower GHI.

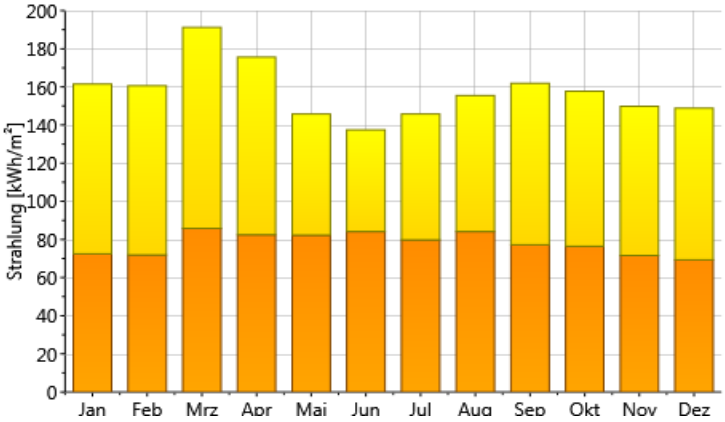


Figure 2: Global and Diffuse horizontal irradiation at the project location (Meteonorm 7)

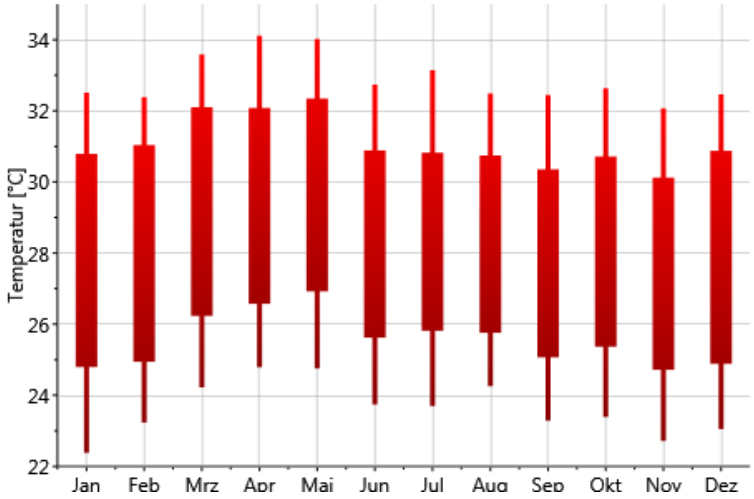


Figure 3: Ambient temperature at the project location (Meteonorm 7)

2.4 Types of hybrid systems and general behaviour

The Tender differentiate between 2 different kinds of systems. The 2 systems to be used are:

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

2.4.1 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 (30min to 2 hours energy reserve). It 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 required.

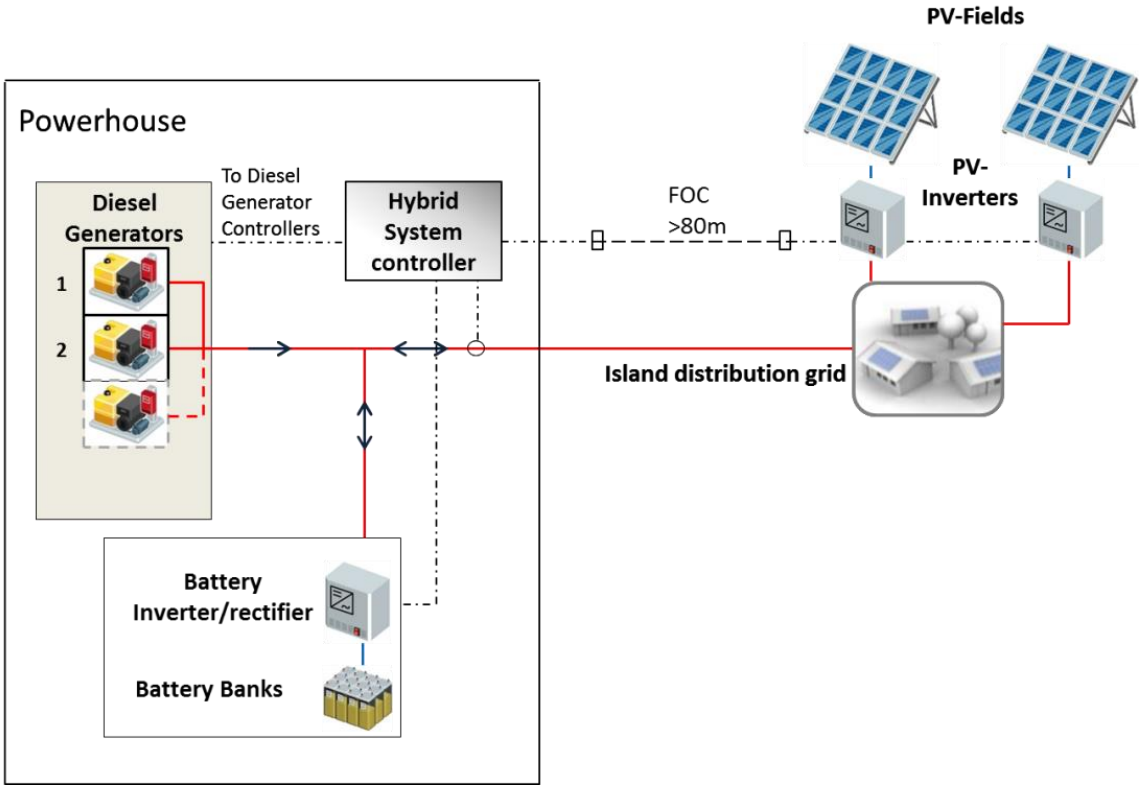


Figure 4: Schematic Block Diagram of Type B System

2.4.2 Type C Hybrid system: PV/Diesel/Grid forming battery

During the day, the PV/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.

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 SCADA purposes.

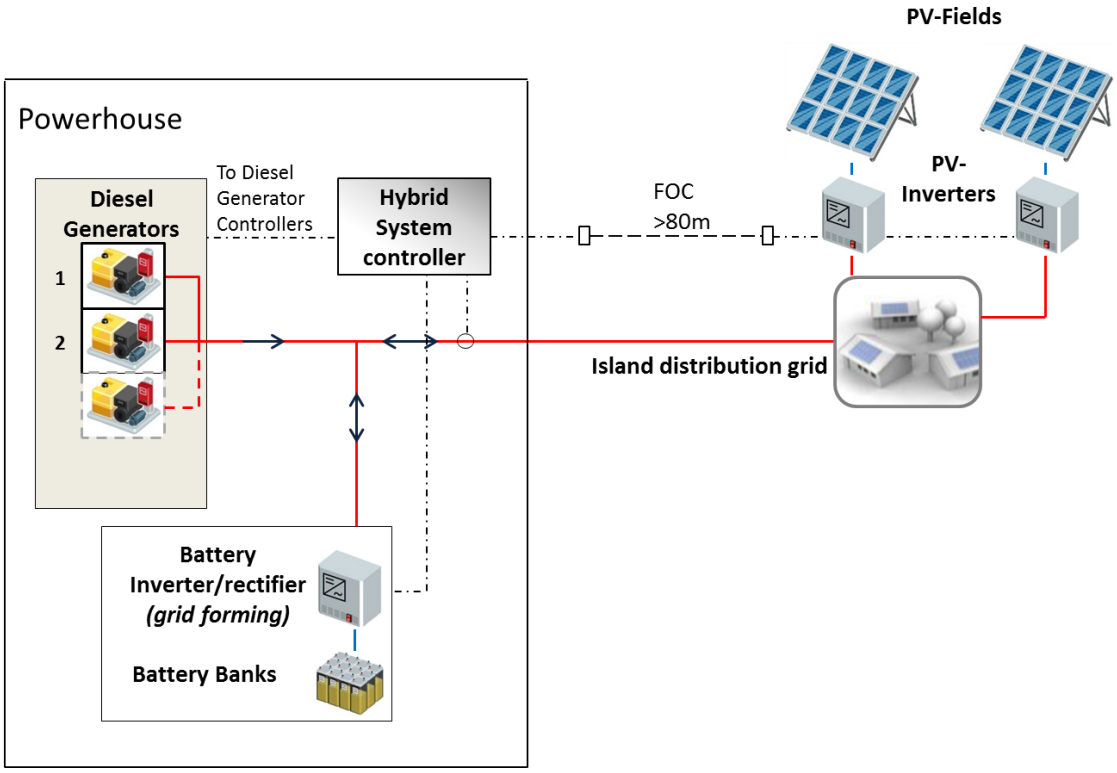


Figure 5: Schematic Block Diagram of Type C System

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

The Contractor shall implement the described systems on the 13 islands as summarized in the table below.

Island	System Type	Size PV (STC)	Battery size @ 1C	New Diesel capacity to be installed (PRP @25°C)
B03 - Hanimaadhoo	Type B	330 kWp	210kWh	350 kW
B04 - Finey	Type C	80 kWp	60kWh	2 gensets: 100 kW, 60 kW
B05 - Naivaadhoo	Type B	70 kWp	45 kWh	100 kW
B06 - Hirimaradhoo	Type C	50 kWp	40 kWh	-
B07 - Nolhivaranfaru	Type B	190 kWp	130 kWh	125 kW
B08 - Nellaidhoo	Type B	130 kWp	85 kWh	125 kW
B09 - Nolhivaram	Type B	180 kWp	120 kWh	125 kW
B10 - Kurinbee	Type B	80 kWp	50 kWh	50 kW
B12 - Kulhudhuffushi	Type B	800 kWp	520 kWh	1000 kW
B13 - Kumundhoo	Type B	100 kWp	70 kWh	2 gensets: 125 kW, 80kW
B14 - Neykurendhoo	Type B	80 kWp	50 kWh	2 gensets: 125 kW, 80kW
B15 - Vaikaradhoo	Type B	70 kWp	45 kWh	100 kW
B17 - Makunudhoo	Type B	110 kWp	70 kWh	125 kW
TOTAL	**-**	**2,270 kWp**	**1,495 kWh**	**2,670kW**

Table 3: Summary of the hybrid system

2.6 B03 Hanimaadhoo Island

The island of Hanimaadhoo is located in the Haa Dhaalu Atoll. It stretches over 6.800 meters in length at a width of 680m. The urbanized area is in the northern end of the island. Mayor facilities are the small harbour in the north-western side of the island and the domestic airport located in the south of the island.

Island code, name, atoll	B03 - Hanimaadhoo
Atoll name	Haa Dhaalu (HDh)
Utility	FENAKA
GPS coordinates	6°45'53 N ; 73°10'43 E
Inhabitants (approx.)	2056
Harbour type	Harbor
Airport	Domestic airport

Table 4: B03 – Island identification and general data

Figure 6: B03 - Location of the buildings with available roofs and the powerhouse

2.6.1 Load profile

The island has a fluctuating energy consumption, which is shown in the Figure 7 below. Based on the collected data the maximum average power consumption at 11:30 AM accounts for 490 kW, while minimum load reaches 280 kW at 06:00 AM. The utility expect a steadily increase of the load by 10%/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 2022 shall be considered for sizing.

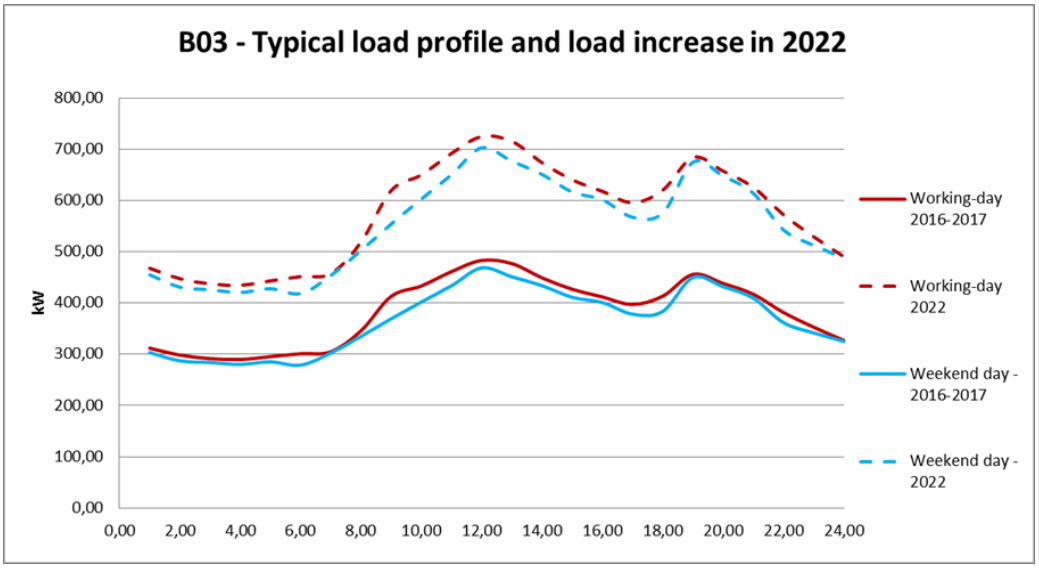


Figure 7: B03 - Typical daily load profile and evolution until 2022

	Average daily consumption [MWh/day]	Yearly consumption [MWh/yr]	Peak power [kW]
2017	9.07	3,310	598
2022	13.60	4,965	897

Table 5: B03 - Consumption and peak power

2.6.2 Diesel generators

4 Diesel generators of different sizes are installed on the island. Diesel generators 2 & 3 shall be integrated in the hybrid PV system.

A new 350kW (440kVA) diesel generator shall additionally be installed and implemented in the PV hybrid system in order to have a diesel generator which match with the demand during daytime. The existing Deep Sea controllers could be reused depending on the solution of the EPC.

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 / NT-855 G6	Cummins / QSK23 G3	Cummins / KTA38 G2	Cummins / NT-855 G6
Engine power rating (continuous)	200 kW	648 kW	648 kW	250 kW
Alternator power rating	250 kVA	810 kVA	810 kVA	312.5 kVA
Hours of operation / date of installation	51,300 hrs 22/05/2005	10,650 hrs 03/07/2014	844 hrs 12/08/2015	36,600 hrs 16/12/2009
General maintenance performed	Yes /03/03/2015 23,000hrs after top overhaul	No	No	Yes, 16,500hrs after top overhaul
Required upgrade / replacement	Yes	-	-	Yes

Table 6: B03 - Diesel generators currently installed

2.6.3 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).

Roof number	Building and name	Roof size X [mm]	Roof size Y [mm]	Slope [°]	Slope Direction	Distance to Powerhouse [m]	Maximum PV power [kWp]	Useable roofs	Maximum PV Capacity on selected roofs [kWp]
B03-1	Agricultural center Roof A 1	2,750	19,000	12	N	150	5.2	x	5.2
B03-2	Agricultural center Roof A 2	2,750	19,000	12	S	150	5.2	x	5.2
B03-3	Agricultural center Roof B 1	14,000	5,250	12	N	150	4.68	X	4.68
B03-4	Agricultural center Roof B 2	14,000	5,250	12	S	150	6.24	X	6.24
B03-7	Agricultural center Roof D 1	18,500	4,500	16	N	150	5.2	X	5.2
B03-8	Agricultural center Roof D 2	18,500	4,500	18	S	150	5.2	X	5.2
B03-11	Youth Center A1	12,000	5,000	22	NE	500	5.2	X	5.2
B03-12	Youth Center A2	12,000	5,000	22	SW	500	5.2	X	5.2
B03-13	Youth Center B1	40,000	7,500	9	N	530	8.32	X	8.32
B03-14	Youth Center B2	40,000	7,500	9	S	530	8.32	X	8.32
B03-15	Youth Center B1.1	16,500	5,000	9	N		7.28	X	7.28
B03-16	Youth Center B2.1	16,500	5,000	9	S		7.28	X	7.28
B03-21	Old School A1	47,100	6,030	26	N	450	28.08	X	28.08
B03-22	Old School A2	47,100	6,030	26	S	450	28.08	X	28.08
B03-23	Old School B1	37,500	5,500	28	N	450	14.56	X	14.56
B03-24	Old School B2	37,500	5,500	28	S	450	5.46	X	5.46
B03-25	Old School C1	16,510	6,075	23	E	450	9.36	X	9.36
B03-26	Old School C2	16,510	6,075	23	W	450	9.36	X	9.36

Roof number	Building and name	Roof size X [mm]	Roof size Y [mm]	Slope [°]	Slope Direction	Distance to Powerhouse [m]	Maximum PV power [kWp]	Useable roofs	Maximum PV Capacity on selected roofs [kWp]
B03-27	New School A1	78,000	4,800	29	N	400-500	35.88	X	35.88
B03-28	New School A2	78,000	4,800	29	S	400-500	35.88	X	35.88
B03-29	New School B1	47,000	4,800	29	E	400-501	21.06	X	21.06
B03-30	New School B2	47,000	4,800	29	W	400-502	21.06	X	21.06
B03-31	New School B3	23,000	4,800	29	E	400-503	9.36	X	9.36
B03-32	New School B4	23,000	4,800	29	W	400-504	9.36	X	9.36
B03-33	New School C1	33,000	4,800	29	N	400-505	14.04	X	14.04
B03-34	New School C2	33,000	4,800	29	S	400-506	14.04	X	14.04
Summary									**334.1**

Table 7: B03 - Analysis of the available roofs and maximum PV power installable

2.6.4 Grid Infrastructure

2.6.4.1 *Electrical system*

a) Generation: 400/230V Frequency: 50 Hz

Phase and type: three phase Wye, earthed neutral, four wire system

b) Distribution Network (LV)

The power house in Hanimadhoo Island has four diesel generators that supply the load requirements of the island. The requirement related to existing and new diesel generators and associated systems are described in the above sections.

The main distribution network in Hanimadhoo, involves two voltage levels, MV (11kV) and LV (400V).

The island is mainly fed through the low voltage distribution network connected to the main low voltage distribution board of the power house.

Outgoing supplies from the power station are at LV (400V) and are connected to distribution boxes in loop in loop out configuration.

Loads located at a significant distance from the power house have been fed through an 11kV network in order to reduce the associated voltage drop and losses in the distribution.

The low voltage in the power house is stepped up to 11kV through transformer. This 11kV network is connected through loop-in loop-out configuration with three substations SS1, SS2 and SS3 built at various locations across the island. The 11kV is then stepped down to low voltage network in these substations to feed the nearby loads.

LV distribution boards at the LV side of the distribution transformers in these substations supply to downstream lower voltage DBs in loop in loop out configuration.

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.

2.6.4.2 *Grid infrastructure upgrade*

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

S No.	Drawing Number	Title
1	J431-GOPA-029-GR-E-D-0001	NETWORK DIAGRAM FOR B03-HANIMAADHOO POWER HOUSE
2	J431-GOPA-029-GR-E-D-0002	NETWORK DIAGRAM FOR B03-HANIMAADHOO SUBSTATION

- This includes but not limited to the following works.

a) Upgrade existing cable network for expected future load of 5kW for each distribution box

b) Modification or replacement of distribution boxes to accommodate the proposed higher size cables connection.

c) Modification or replacement of distribution boxes to accommodate new connection of proposed PV.

d) Modification of existing spare feeder(s) in main distribution board of the power house for direct connection of the proposed PV.

e) Extension of one incomer panel for new diesel generator connection in main distribution board of the power house.

The modification / replacement of distribution boxes, modification of existing spare feeders in the main distribution board of the power house shall be designed to meet the final design kWp of the PV that will be approved by the Employer.

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 distribution boxes and subsequent transportation of the same to a location identified by FENEKA.

2.6.4.3 *Schedule of Grid Infrastructure Modifications*

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

i. *Schedule of Cables- Powerhouse:*

From	To	Existing Cable (Sq.mm)	Proposed Cable (Sq.mm)	No. of Runs	Length (M)
Feeder-A	DB-A1	4C x 120	4C x 300	1	285
DB-A1	DB-A2	4C x 70	4C x 300	1	107
DB-A2	DB-A3	4C x 70	4C x 300	1	90
DB-A3	DB-A3X1	4C x 35	4C x 240	1	91
DB-A3X1	DB-A3X2	4C x 35	4C x 120	1	78
DB-A3X2	DB-A2X1	4C x 35	4C x 120	1	58
DB-A2X1	DB-A2X2	4C x 35	4C x 120	1	97
DB-A3	DB-A3XX1	4C x 35	4C x 240	1	154
DB-A3XX1	DB-A3XXX1	4C x 35	4C x 120	1	120
DB-A3XXX1	DB-A3XXX2	4C x 35	4C x 120	1	78
DB-A3XXX2	DB-A3XXX3	4C x 35	4C x 70	1	61

From	To	Existing Cable (Sq.mm)	Proposed Cable (Sq.mm)	No. of Runs	Length (M)
DB-A3XXX3	DB-A3XXX4	4C x 16	4C x 50	1	92
Feeder-B	DB-B1	4C x 95	4C x 240	1	160
DB-B1	DB-B2	4C x 95	4C x 150	1	120
DB-B2	DB-B3	4C x 95	4C x 150	1	132
DB-B3	DB-B2X1	4C x 35	4C x 120	1	143
DB-B2X1	DB-C2X1	4C x 35	4C x 120	1	60
Feeder-C	DB-C1	4C x 95	4C x 240	1	269
Feeder-D	DB-D1	4C x 95	4C x 300	1	250
DB-D1	DB-D2	4C x 95	4C x 240	1	224
DB-D2	DB-D3	4C x 95	4C x 240	1	152
DB-D3	DB-D4	4C x 70	4C x 240	1	96
DB-D4	DB-D5	4C x 70	4C x 240	1	76
DB-D5	DB-D6	4C x 70	4C x 150	1	106
DB-D6	DB-D7	4C x 50	4C x 120	1	101
DB-D7	DB-D8	4C x 50	4C x 70	1	106

ii. *Schedule of cables- Substation:*

From	To	Existing Cable (Sq.mm)	Propose Cable (Sq.mm)	No. of Runs	Length (M)
DB_SS2-A2	DB_SS2-A3	4C x 35	4C x 70	1	89
DB_SS2-A3	DB_SS2-A4	4C x 35	4C x 70	1	82
Substation-3_Feeder1	DB_SS3-C1	4C x 120	4C x 240	2	100
DB_SS3-C1	DB_SS3-C2	4C x 95	4C x 240	1	150
DB_SS3-C2	DB_SS3-C3	4C x 95	4C x 240	1	96
DB_SS3-C3	DB_SS3-C4	4C x 70	4C x 240	1	81
DB_SS3-C4	DB_SS3-C5	4C x 70	4C x 240	1	117
DB_SS3-C5	DB_SS3-C6	4C x 70	4C x 240	1	81
DB_SS3-C6	DB_SS3-C7	4C x 50	4C x 150	1	117
DB_SS3-C7	DB_SS3-C8	4C x 50	4C x 150	1	81
DB_SS3-C8	DB_SS3-C9	4C x 50	4C x 150	1	96

From	To	Existing Cable (Sq.mm)	Propose Cable (Sq.mm)	No. of Runs	Length (M)
DB_SS3-C9	DB_SS3-C10	4C x 50	4C x 120	1	98
DB_SS3-C10	DB_SS3-C11	4C x 50	4C x 120	1	88
DB_SS3-C11	DB_SS3-C12	4C x 50	4C x 120	1	112

The following table lists the cables proposed for PV connection to the existing LV distribution network.

iii. *PV Connection to the Powerhouse:*

From	To	No. of runs	Cable Size (sq.mm)	Length (M)
DB-A1	AGRICULTURAL CENTER-PV	1	4C x 70	150
DB-A2X2	OLD SCHOOL-PV	1	4C x 120	75
POWER HOUSE-MAIN LVDB	NEW SCHOOL-PV	1	4C x 300	500

iv. *PV Connection to the Substation*

From	To	No. of runs	Cable Size (sq.mm)	Length (M)
DB_SS2-A4	YOUTH CENTER-PV	1	4C x 120	70

v. *Modification/Replacement of LV distribution equipment*

- Power House

Item Description	Quantity (Nos.)
Replacement of Existing Distribution Box (DB)	23
Modification of existing of Distribution Box (DB)	3
Modification of LV outgoing feeder in Power House for RE Incomer	1
Extension of existing LV Distribution board in Power for new Generator incomer	1

- Substation

Item Description	Quantity (Nos.)
Replacement of Existing Distribution Box (DB)	13

Modification of existing of Distribution Box (DB)	1

2.7 B04 Finey Island

The island of Finey is located in the Haa Dhaalu Atoll. It stretches over 1.680 meters in length at a width of 1000m. The urbanized area is in the central western part of the island. Mayor facility is the small harbour on the east side of the island.

Island code, name, atoll	B04 - Finey
Atoll name	Haa Dhaalu (HDh)
Utility	FENAKA
GPS coordinates	6°44'50.21"N ; 73° 3'4.52"E
Inhabitants (approx.)	554
Harbor type	Harbor

Table 8: B04 – Island identification and general data

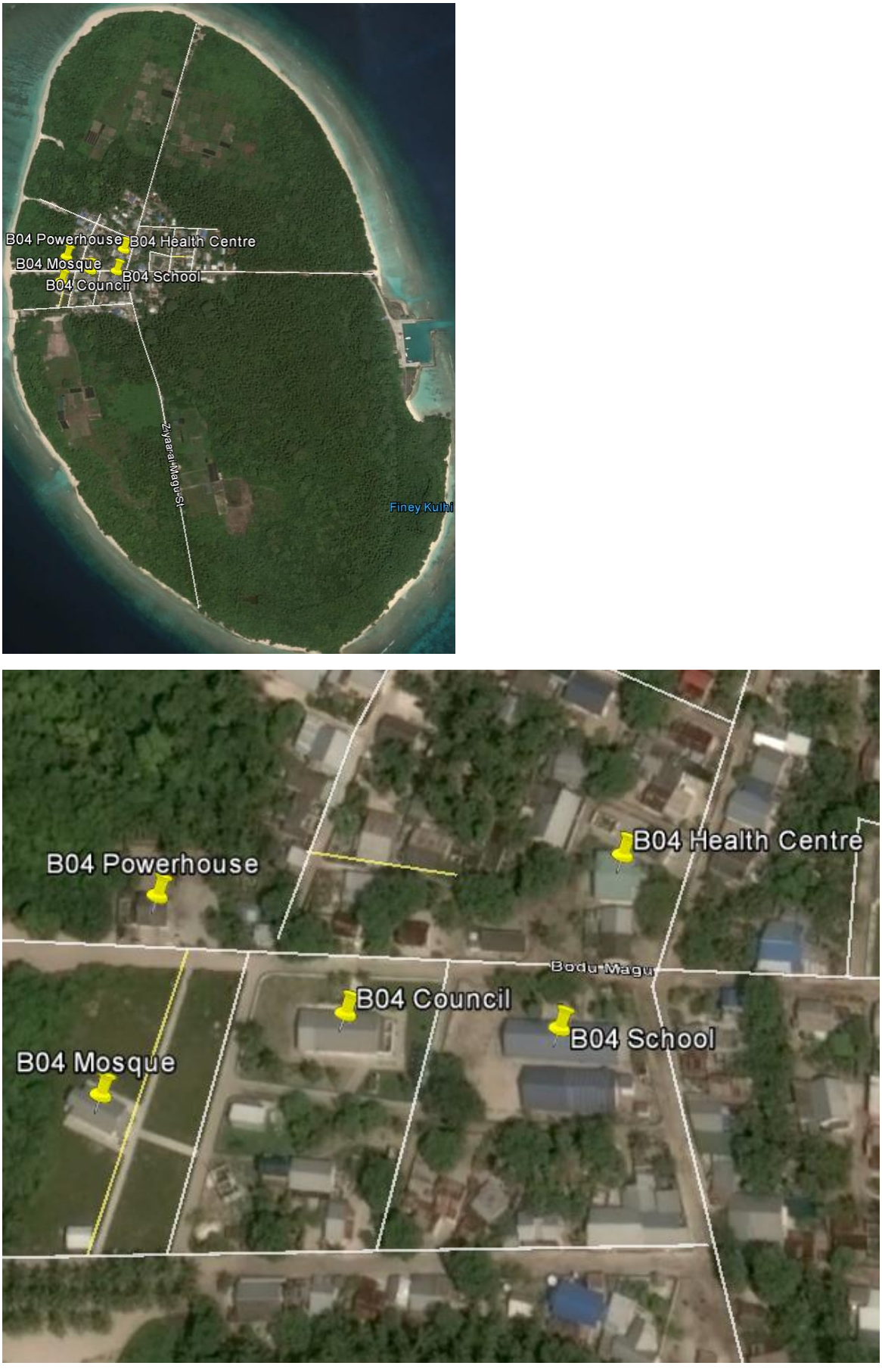


Figure 8: B04 - Location of the buildings with available roofs and the powerhouse

2.7.1 Load profile

The island has a fluctuating energy consumption, which is shown in the Figure 9 below. Based on the collected data the maximum average power consumption at 08:00 – 10:00 PM accounts for 45 kW, while minimum load reaches 30 kW at 06:00 PM. The utility expect a steadily increase of the load by 3%/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.

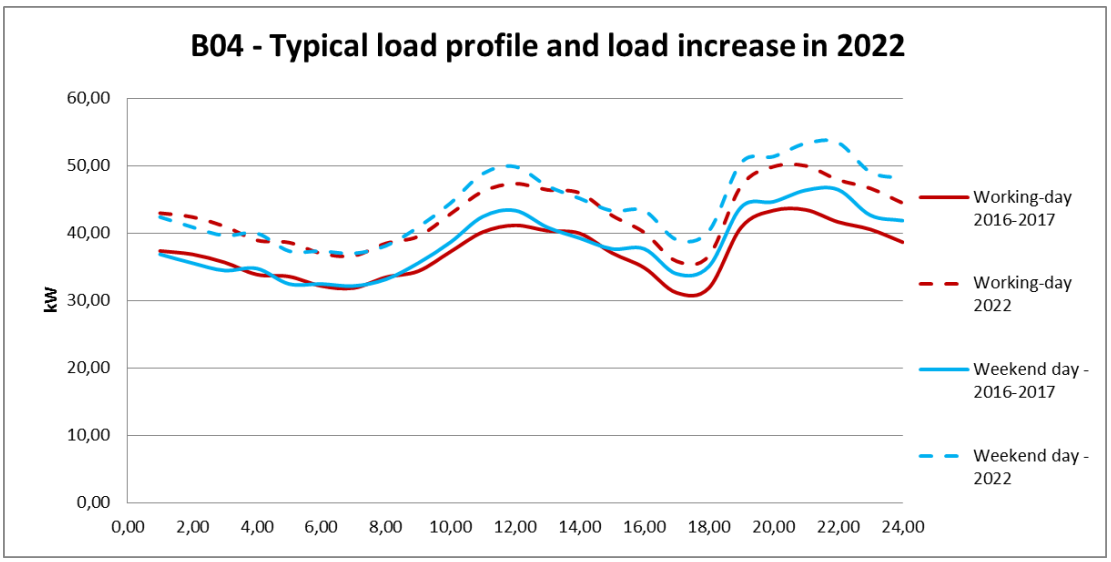


Figure 9: B04 - Typical daily load profile and evolution until 2022

	Average daily consumption [MWh/day]	Yearly consumption [MWh/yr]	Peak power [kW]
2017	0.90	329	57.10
2022	1.04	378	65.68

Table 9: B04 – Consumption and peak power

2.7.2 Diesel generators

3 Diesel generators of different sizes are installed on the island. Diesel generator 2 shall be integrated in the hybrid PV system.

A new 100kW (125kVA) and a new 60 kW (75kVA) diesel generator shall additionally be installed and implemented in the PV hybrid system. The following table shows the existing diesel generators with specifications.

Item	Diesel Generator 1	Diesel Generator 2	Diesel Generator 3
Engine manufacturer & motor references	Cummins 6CTAA8.3G2	Cummins 6CTA8.3G2	Volvo TD 720GE
Engine power rating (continuous)	160kW	112kW	100kW

Item	Diesel Generator 1	Diesel Generator 2	Diesel Generator 3
Alternator power rating	200kVA	140kVA	128kVA
Hours of operation / date of installation	4,600hrs / 2015	7,514hrs 13/03/2014	Brought from Another Island 23/02/2014)
General maintenance done	No	No	History not available
Required upgrade / replacement	If space is needed for the new genset, to be removed / relocated on other island (too large for the load profile)		yes

Table 10: B04 - Diesel generators currently installed

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)

Roof number	Building and name	Roof size X [mm]	Roof size Y [mm]	Slope [°]	Slope Direction	Distance to Powerhouse [m]	Maximum PV power [kWp]	Useable roofs	Maximum PV Capacity on selected roofs [kWp]
B04-1	Council Roof A1	22,498	5,750	15	N	NEW Powerhouse	12.48	X	12.48
B04-2	Council Roof A2	22,498	5,750	15	S	NEW Powerhouse	12.48	X	12.48
B04-3	Health Center A1	7,000	10,000	12	2°N	NEW Powerhouse	6.5	X	6.5
B04-4	Health Center A2	7,000	10,000	12	182°S	NEW Powerhouse	6.5	X	6.5
B04-5	School A1	32,000	4,500	31	N	NEW Powerhouse	9.36	X	9.36
B04-6	School A2	32,000	4,500	31	S	NEW Powerhouse	9.36	X	9.36
B04-7	School B1	5,750	27,000	27	N		15.6	X	15.6
B04-8	School B2	5,750	27,000	27	S		13	X	13
Summary									**85.3**

Table 11: B04 - Analysis of the available roofs and maximum PV power installable

2.7.4 Grid Infrastructure

2.7.4.1 *Electrical system*

a) Generation system

Generation: 400/230V Frequency: 50 Hz

Phase and type: three phase Wye, earthed neutral, four wire system

b) Distribution Network (LV)

The power house in Finey Island has 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.

2.7.4.2 *Grid infrastructure upgrade*

Since the power house will be relocated, modifications related to grid upgrade are not envisaged in FINEY islands.

Existing LV distribution board in the power house will be replaced with the new LV distribution board in line with the conceptual schematic diagram given below.

S No.	Drawing Number	Title
1	J431-GOPA-008-GR-E-S-0001	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (B04-FINEY)

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 subsequent transportation of the same to a location identified by FENEKA.

The PV connection is proposed to be connected directly to the main LV distribution board of the power house.

2.7.4.3 *Schedule of Grid Infrastructure Modifications*

The following table lists the cable proposed for the PV connections directly to the main LV distribution board of the power house.

i. *PV Connections-Power House*

From	To	No.of runs	Cable Size (sq.mm)	Length (m)
COUNCIL-PV	Main LV Distribution Board Power House	1	4C x 35	80
SCHOOL	Main LV Distribution Board in Power House	1	4C x 70	150
HEALTH CENTRE-PV	Main LV Distribution Board Power House	1	4C x 25	160

ii. *Modification/Replacement of LV distribution equipment*

- Power House

Item Description	Quantity (Nos.)
Replacement of existing main LV Distribution board in Power House	1

Since the power house will be relocated, further modifications related to grid upgrade are not envisaged in FINEY islands.

2.8 B05 Naivaadhoo Island

The island of Naivaadhoo is located in the Haa Dhaalu Atoll. It stretches over 1.000 meters in length at a width of 450m. The urbanized area is in the central western part of the island and stretches across the whole island. Mayor facility is the small harbour on the north-east side of the island.

Island code, name, atoll	B05 - Naivaadhoo
Atoll name	Haa Dhaalu (HDh)
Utility	FENAKA
GPS coordinates	6°44'53.00"N ; 72°56'7.00"E
Inhabitants (approx.)	804
Harbor type	Harbor

Table 12: B05 – Island identification and general data

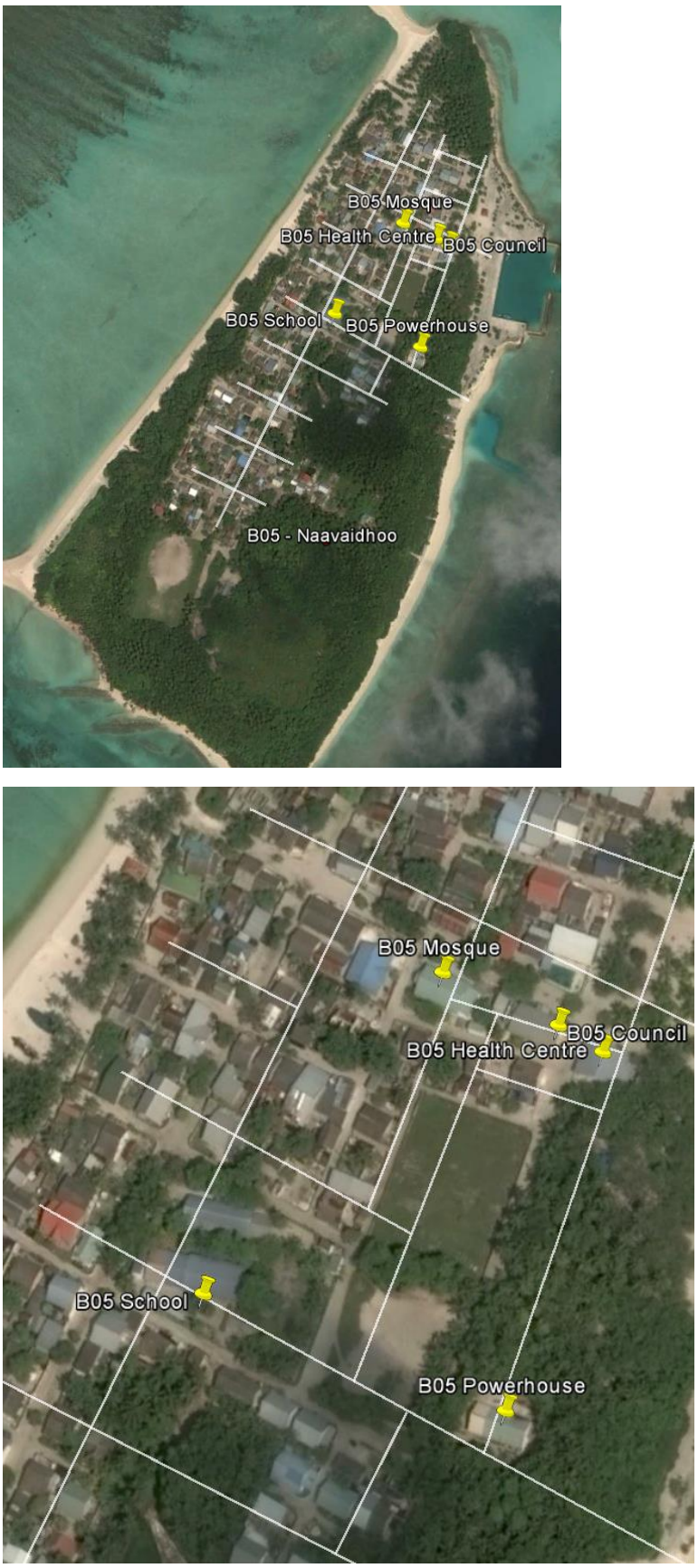


Figure 10: B05 - Location of the buildings with available roofs and of the powerhouse

2.8.1 Load profile

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

Figure 11 below. Based on the collected data the maximum average power consumption at 12:00 AM accounts for 50 -70 kW, while minimum load reaches 30 kW at 06:00 AM. The utility expect a steadily increase of the load by 3%/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.

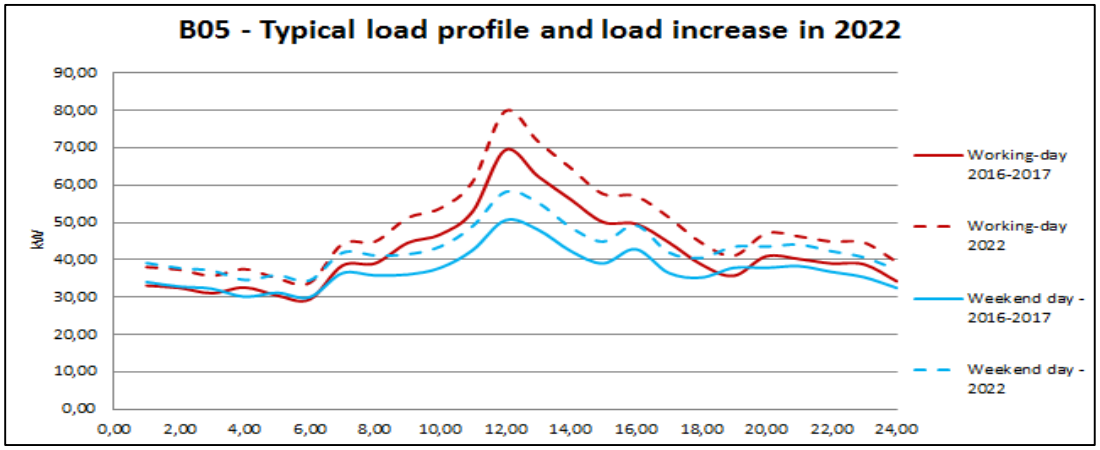


Figure 11: B05 - Typical daily load profile and evolution until 2022

	Average daily consumption [MWh/day]	Yearly consumption [MWh/yr]	Peak power [kW]
2017	0.977	364	86
2022	1.123	410	99

Table 13: B05 – Power consumption and peak power

2.8.2 Diesel generators

3 diesel generators of different sizes are installed on the island. Diesel generator 1 & 2 shall be integrated in the hybrid PV system.

A new 100kW (125kVA) diesel generator shall additionally be installed and implemented in the PV hybrid system.

The following diesel generators are currently used.

Item	Diesel Generator 1	Diesel Generator 2	Diesel Generator 3
Engine manufacturer & motor references	Deutz	Cummins	Cummins
Engine power rating (continuous)	72kW	34kW	160kW

Item	Diesel Generator 1	Diesel Generator 2	Diesel Generator 3
Alternator power rating	90kVA	42.5kVA	200kVA
Hours of operation / date of installation	N/A	N/A	4,525hrs
General maintenance performed	Yes, 2013	No	No
Required upgrade / replacement	-	-	Not necessary as too big for the actual loads. Could be relocated to another island, if necessary.

Table 14: B05 - Diesel generators currently installed

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)

Roof number	Building and name	Roof size X [mm]	Roof size Y [mm]	Slope [°]	Slope Direction	Distance to Powerhouse [m]	Maximum PV power [kWp]	Useable roofs	Maximum PV Capacity on selected roofs [kWp]
B05-1	Council Roof A1	5,250	17,000	17	34°N	180	7.8	X	7.8
B05-2	Council Roof A2	5,250	17,000	17	210°SW	180	7.8	X	7.8
B05-3	Health Center A1	10,273	7,750	20	W	180	7.8	X	7.8
B05-4	Health Center A2	10,273	7,750	20	E	180	4.68	X	4.68
B05-5	School A1	32,500	5,500	13	13°N	165	6.76	X	6.76
B05-6	School A 2	32,500	5,500	13	192°S	165	6.76	X	6.76
B05-9	School C1	4,250	22,500	28	17°N	165	6.24	X	6.24
B05-11	Powerhouse A1	19,000	4,500	?	N	0	5.2	X	5.2
B05-12	Powerhouse A2	19,000	4,500	?	S	0	5.2	X	5.2
B05-13	Mosque A1	15,500	4,800	?	N	170	6.24	X	6.24
B05-14	Mosque A2	15,500	4,800	?	S	170	6.24	X	6.24
Summary									**70.7**

Table 15: B05 - Analysis of the available roofs and maximum PV power installable

2.8.4 Grid Infrastructure

2.8.4.1 *The Electrical system*

a) Generation System

Generation: 400/230V Frequency: 50 Hz

Phase and type: Three Phase Wye, Earthed Neutral, Four wire system

b) Distribution Network (LV)

The power house in Naivaadhoo Island has 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 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 Naivaadhoo Island in line with drawings listed in the table below.

S No.	Drawing Number	Title
1	J431-GOPA-014-GR-E-D-0001	NETWORK DIAGRAM FOR B05-NAIVAADHOO
2	J431-GOPA-014-GR-E-S-0001	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (B05-NAIVAADHOO)

- This includes but not limited to the following works.

a) Upgrade of the existing cable network for expected future load of 5kW for each distribution box

b) Modification or replacement of Distribution boxes to accommodate the proposed higher size cables connection.

c) Modification or replacement of Distribution boxes to accommodate new connection of proposed PV.

d) 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 Naivaadhoo Island.

i. *Schedule of Cables- Power House:*

From	To	Existing Cable (Sq.mm)	Proposed Cable (Sq.mm)	No of runs	Length (M)
Naivaadhoo Feeder-2	DB 2B-1	4C x 35	4C x 70	1	210
DB 2B-1	DB 2B-2	4C x 35	4C x 70	1	130
DB 2B-2	DB 2B-3	4C x 35	4C x 70	1	64
DB 2B-3	DB 2B-4	4C x 35	4C x 70	1	98
Naivaadhoo Feeder-5	DB 5E-1	4C x 35	4C x 70	1	134

The following table lists the cables proposed for PV connection to the existing LV distribution network.

ii. *PV Connection- Power House*

From	To	No. of Runs	Cable Size (sq.mm)	Length (M)
DB 1A-1	SCHOOL-PV	1	4C x 35	65
DB 4D-1	POWER HOUSE-PV	1	4C x 35	125
DB 5E-1	COUNCIL-PV	1	4C x 35	65
DB 5E-1	HEALTH CENTRE-PV	1	4C x 35	65
DB 5E-1	MOSQUE-PV	1	4C X35	65

iii. Modification/Replacement of LV distribution equipment

Item Description	Quantity (Nos.)
Replacement of Existing Distribution Box (DB)	3
Modification of existing of Distribution Box (DB)	4
Replacement of Existing Main LV Distribution board in Power House	1

2.9 B06 Hirimaradhoo Island

The island of Hirimaradhoo is located in the Haa Dhaalu Atoll. It stretches over 1.000 meters in length at a width of 570m. The urbanized area is in the south west part of the island. Mayor facility is the small harbour on the east side of the island.

Island code, name, atoll	B06 - Hirimaradhoo
Atoll name	Haa Dhaalu (HDh)
Utility	FENAKA
GPS coordinates	6°43'25.00"N ; 73°1'25.00"E
Inhabitants (approx.)	531
Harbor type	Harbor

Table 16: B06 – Island identification and general data

Figure 12: B06 - Location of the buildings with available roofs and of the powerhouse

2.9.1 Load profile

The island has a fluctuating energy consumption, which is shown in the Figure 13 below. Based on the collected data the maximum average power consumption at 08:00 PM accounts for 30 kW, while minimum load reaches 20 kW at 06:00 AM and 04:00 PM. The utility expect a steadily increase of the load by 3%/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.

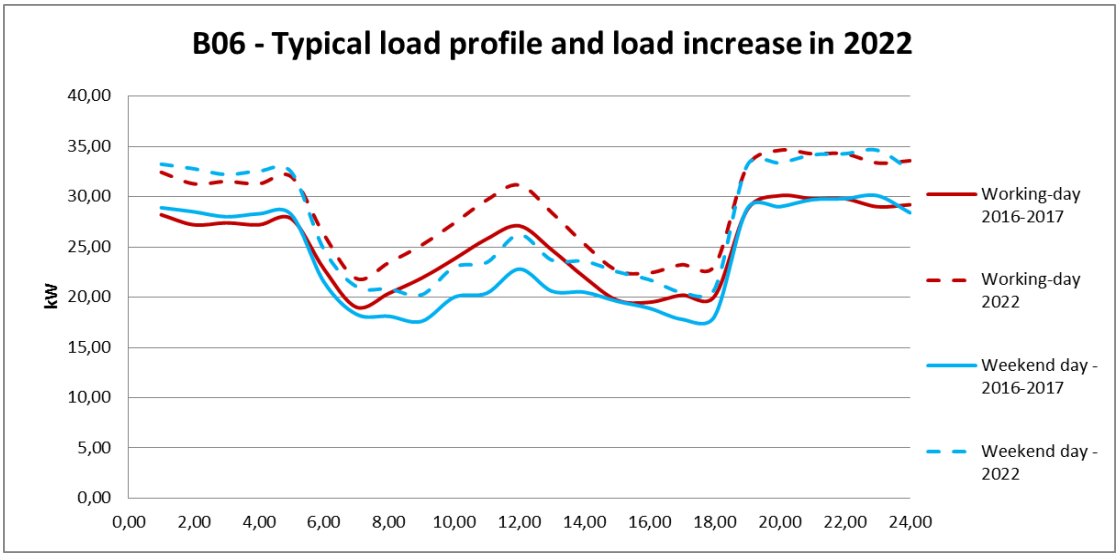


Figure 13: B06 - Typical daily load profile and evolution until 2022

	Average daily consumption [MWh/day]	Yearly consumption [MWh/yr]	Peak power [kW]
2017	0.59	216	38
2022	0.68	249	44

Table 17: B06 – Power consumption and peak power

2.9.2 Diesel generators

4 diesel generators of different sizes are installed on the island. Diesel generators 1, 3 & 4 shall be integrated in the hybrid PV system.

The following diesel generators are currently used.

Item	Diesel Gen. 1	Diesel Gen. 2	Diesel Gen. 3	Diesel Gen. 4
Engine manufacturer & motor references	Deutz BFM1012E	Cummins 6CTA8.3G2	Cummins 6BT5.9G2	Cummins 4BT3.9G1
Engine power rating (continuous)	45kW	150kW	80kW	40kW
Alternator power rating	50kVA	187.5kVA	100kVA	50kVA
Hours of operation / date of installation	18,500 hrs	-	4,642 hrs	8,543 hrs
General maintenance performed	No	No	-	No
Required upgrade / replacement	-	Not used (too large for load profile), could be relocated to another island-	-	-

Table 18: B06 - Diesel generators currently installed

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).

Roof number	Building and name	Roof size X [mm]	Roof size Y [mm]	Slope [°]	Slope Direction	Distance to Powerhouse [m]	Maximum PV power [kWp]	Useable roofs	Maximum PV Capacity on selected roofs [kWp]
B06-7	School A1	5,250	20,000	27	347°N	370	9.36	X	9.36
B06-8	School A2	5,250	20,000	27	167°S	370	9.36	X	9.36
B06-9	School B1	13,820	4,366	28	347°N	370	3.64	X	3.64
B06-10	School B2	17,000	6,134	28	167°S	370	9.36	X	9.36
B06-11	School C1	5,487	22,500	29	7°N	370	10.4	X	10.4
B06-12	School C2	5,487	22,500	29	187°S	370	10.4	X	10.4
Summary									**52.5**

Table 19: B06 - Analysis of the available roofs and maximum PV power installable

2.9.4 Grid Infrastructure

2.9.4.1 *Electrical system*

a) Generation System

Generation: 400/230V Frequency: 50 Hz

Phase and type: three phase Wye, earthed neutral, four wire system

b) Distribution Network (LV)

The power house in Hirimaradhoo Island has 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 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 Hirimaradhoo Island in line with drawings listed in the table below.

S No.	Drawing Number	Title
1	J431-GOPA-007-GR-E-D-0001	NETWORK DIAGRAM FOR B06-HIRIMARADHOO
2	J431-GOPA-007-GR-E-S-0001	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (B06- HIRIMARADHOO)

- This includes but not limited to the following works.

a) Upgrade the existing cable network for expected future load of 5kW for each distribution box

b) Modification or replacement of distribution boxes to accommodate the proposed higher size cables connection.

c) Modification or replacement of distribution boxes to accommodate new connection of proposed PV.

d) 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 Hirimaradhoo Island.

i. *Schedule of Cables- Powerhouse:*

From	To	Existing Cable (Sq.mm)	Proposed Cable (Sq.mm)	No of runs	Length (M)
Main LVDB – Power House_ Feeder 1	DB-A1	4C x 70	4C x 120	1	259
Main LVDB – Power House_ Feeder 2	DB-B1	4C x 70	4C x 120	1	336
DB-B1	DB-B2	4C x 50	4C x 120	1	103
DB-B2	DB-B3	4C x 35	4C x 70	1	57
DB-B3	DB-B4	4C x 35	4C x 70	1	104
DB-B7	DB-B6	4C x 16	4C x 35	1	82
DB-B1	DB-B8	4C x 16	4C x 120	1	206

The following table lists the cables proposed for PV connection to the existing LV distribution network.

ii. *PV Connection*

From	To	No. of Runs	Cable Size (sq.mm)	Length (M)
DB-B8	SCHOOL-PV	1	4C x 120	20

iii. Modification/Replacement of LV distribution equipment

Item Description	Quantity (Nos.)
Replacement of Existing Distribution Box (DB)	4
Modification of existing of Distribution Box (DB)	4
Replacement of Existing Main LV Distribution board in Power House	1

2.10 B07 Nolhivaranfaru Island

The island of Nolhivaranfaru is located in the Haa Dhaalu Atoll. It stretches over 3.760 meters in length at a width of 1.000m. The urbanized area is in the central northern part of the island, the southern part is not populated. There is no harbour but only a jetty on the island.

Island code, name, atoll	B07 – Nolhivaranfaru
Atoll name	Haa Dhaalu (HDh)
Utility	FENAKA
GPS coordinates	6°42'05 N ; 73°07'11'' E
Inhabitants (approx.)	1788
Harbor type	Jetty

Table 20: B07 – Island identification and general data

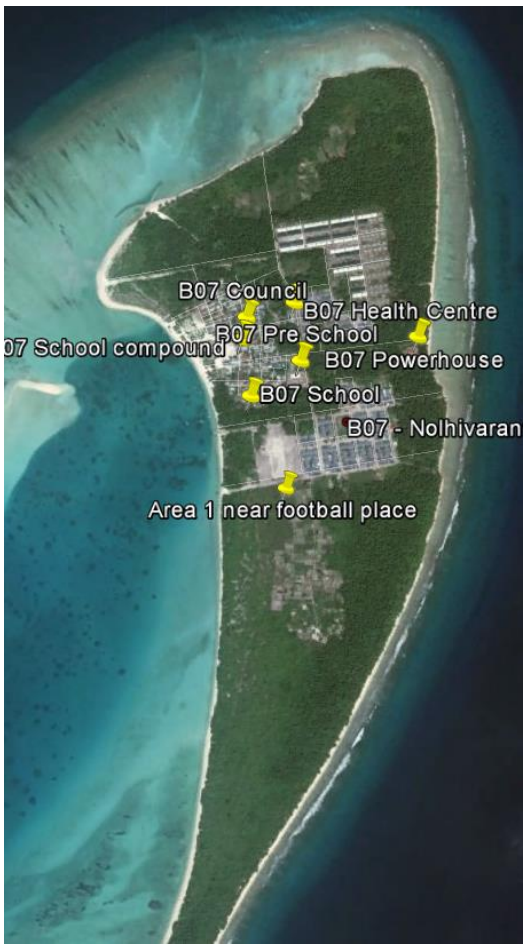


Figure 14: B07 - Location of the buildings with available roofs and of the power house

2.10.1 Load profile

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

Figure 15 below. Based on the collected data the maximum average power consumption at 12:00 AM accounts for 130 kW, while minimum load reaches 90 kW at 06:00 AM and 06:00 PM. The utility expect a steadily increase of the load by 5%/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.

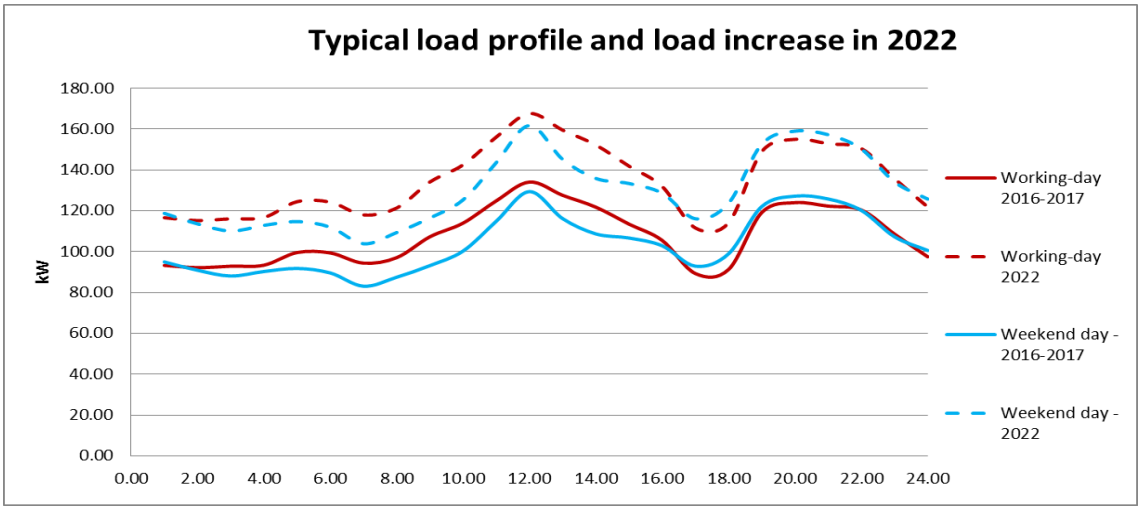


Figure 15: B07 - Typical daily load profile and evolution until 2022

	Average daily consumption [MWh/day]	Yearly consumption [MWh/yr]	Peak power [kW]
2017	2.56	933	160
2022	3.19	1166	204

Table 21: B07 –Power consumption and peak power

2.10.2 Diesel generators

3 diesel generators of different sizes are installed on the island. Diesel generators 1 & 3 shall be integrated in the hybrid PV system.

A new 125kW (156kVA) diesel generator shall additionally be installed and implemented in the PV hybrid system.

The following diesel generators are currently used.

Item	Diesel Generator 1	Diesel Generator 2	Diesel Generator 3
Engine manufacturer & motor references	Cummins NT855-GA	Cummins 6CTA8.3-G2	Cummins 6CTA8.3-G2
Engine power rating (continuous)	200kW	125kW	125kW
Alternator power rating	250kVA	156kVA	156kVA
Hours of operation / date of installation	22/12/2015	1/8/2011	6/2/2011
General maintenance performed			Overhaul Sep 14, 2015
Required upgrade / replacement	-	Yes	-

Table 22: B07 - Diesel generators currently installed

2.10.3 Overview of possible installation locations for PV roof top systems

The table below present the available roofs for PV power plant installation (according to site visit reports from PMU and related DWG), the useable roofs and the maximum installed PV power on the selected roofs allowing reaching the optimum PV sizing simulated.

Roof number	Building and name	Roof size X [mm]	Roof size Y [mm]	Slope [°]	Slope Direction	Distance to Powerhouse [m]	Maximum PV power [kWp] 1	Useable roofs	Maximum PV Capacity on selected roofs [kWp]
B07-7	Health Center A1	24,500	7,750	22	E	500	20.28	X	20.28
B07-8	Health Center A2	24,500	7,750	22	W	500	20.28	X	20.28
B07-9	Preschool A1	5,834	28,500	13	N	520	16.64	X	16.64
B07-10	Preschool A2	5,834	28,500	13	S	520	16.64	X	16.64
B07-11	School A1	5,800	34,000	27	N	640	19.76	X	19.76
B07-12	School A2	5,800	34,000	27	S	640	19.76	X	19.76
B07-13	School B1	5,781	28,000	28	N	640	15.6	X	15.6
B07-14	School B2	5,781	28,000	28	S	640	15.6	X	15.6
B07-15	School C1	6,198	19,500	17	N	640	10.4	X	10.4
B07-16	School C2	6,198	19,500	17	S	640	10.4	X	10.4
B07-17	School D1	6,198	27,000	28	N	640	15.6	X	15.6
B07-18	School D2	6,198	27,000	28	S	640	15.6	X	15.6
Summary									**196.6**

Table 23: B07 - Analysis of the available roofs and maximum PV power installable

[1] Assumption: PV modules crystalline technology / 260Wp / 1000mm x 1650mm.

2.10.4 Grid Infrastructure

2.10.4.1 *Electrical system*

a) Generation System

Generation: 400/230V Frequency: 50 Hz

Phase and type: three phase Wye, earthed neutral, four wire system

b) Distribution Network (LV)

The power house in Nolhivaranfaru Island has 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 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 Nolhivaranfaru Island in line with drawings listed in the table below.

S No.	Drawing Number	Title
1	J431-GOPA-023-GR-E-D-0001	NETWORK DIAGRAM FOR B07-NOLHIVARAMFARU
2	J431-GOPA-023-GR-E-S-0001	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (B07- NOLHIVARAMFARU)

- This includes but not limited to the following works.

a) Upgrade existing cable network for expected future load of 5kW for each distribution box

b) Modification or replacement of distribution boxes to accommodate the proposed higher size cables connection.

c) Modification or replacement of distribution boxes to accommodate new connection of proposed PV.

d) 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 plant 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 Nolhivaranfaru Island.

i. *Schedule of Cables- Powerhouse:*

From	To	Existing Cable (Sq.mm)	Proposed Cable (Sq.mm)	No. of Runs	Length (M)
Nolhivaramfaru Feeder-1	Distribution Board	4C x 70	4C x 240	2	540
Distribution Board	DB-A1	4C x 25	4C x 70	1	173
DB-A1	DB-A2	4C x 25	4C x 50	1	76
DB-A2	DB-A3	4C x 16	4C x 50	1	116
DB-A3	DB-A4	4C x 16	4C x 35	1	75
Distribution Board	DB-B1	4C x 25	4C x 70	1	121
DB-B1	DB-B2	4C x 25	4C x 50	1	68
DB-B2	DB-B3	4C x 16	4C x 35	1	82
Distribution Board	DB-C1	4C x 25	4C x 70	1	187
DB-C1	DB-C2	4C x 16	4C x 70	1	109
Distribution Board	DB-D1	4C x 25	4C x 150	1	87
DB-D1	DB-D2	4C x 25	4C x 150	1	120
Nolhivaramfaru Feeder-2	DB-E1	4C x 95	4C x 120	1	118
DB-E1	DB-E2	4C x 95	4C x 120	1	260
DB-E2	DB-E3	4C x 50	4C x 120	1	88
DB-E3	DB-E4	4C x 50	4C x 120	1	113

From	To	Existing Cable (Sq.mm)	Proposed Cable (Sq.mm)	No. of Runs	Length (M)
DB-E4	DB-E5	4C x 35	4C x 120	1	112
Nolhivaramfaru Feeder-4	DB-G1	4C x 95	4C x 120	1	359
DB-G1	DB-G2	4C x 70	4C x 95	1	132
DB-G2	DB-G3	4C x 50	4C x 70	1	140

The following table lists the cables proposed for PV connection to the existing LV distribution network.

ii. PV Connection

From	To	No. of Runs	Cable Size (sq.mm)	Length (M)
DB-C3	PRE SCHOOL-PV	1	4C x 120	115
DB-D2	SCHOOL-PV	1	4C x 150	50
DB-E5	HEALTH CENTRE-PV	1	4C x 120	55

iii. Modification/Replacement of LV distribution equipment

Item Description	Quantity (Nos.)
Replacement of Existing Distribution Box (DB)	10
Modification of existing of Distribution Box (DB)	11
Replacement of Existing Main LV Distribution board in Power House	1

2.11 B08 Nellaidhoo Island

The island of Nellaidhoo is located in the Haa Dhaalu Atoll. It stretches over 800 meters in length at a width of 500m. The urbanized area is spread over the whole island. Mayor facility is the small harbour on the east side of the island.

Island code, name, atoll	B08 - Nellaidhoo
Atoll name	Haa Dhaalu (HDh)
Utility	FENAKA
GPS coordinates	6°42'57.00"N ; 72°56'47.00"E
Inhabitants (approx.)	1230
Harbor type	Harbor

Table 24: B08 – Island identification and general data

Figure 16: B08 - Location of the buildings with available roofs and of the power house

2.11.1 Load profile

The island has a fluctuating energy consumption, which is shown in the Figure 17 below. Based on the collected data the maximum average power consumption at 12:00 AM and 08:00 PM accounts for 160 kW, while minimum load reaches 100 kW at 06:00 PM. The utility expect a steadily increase of the load by 3%/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.

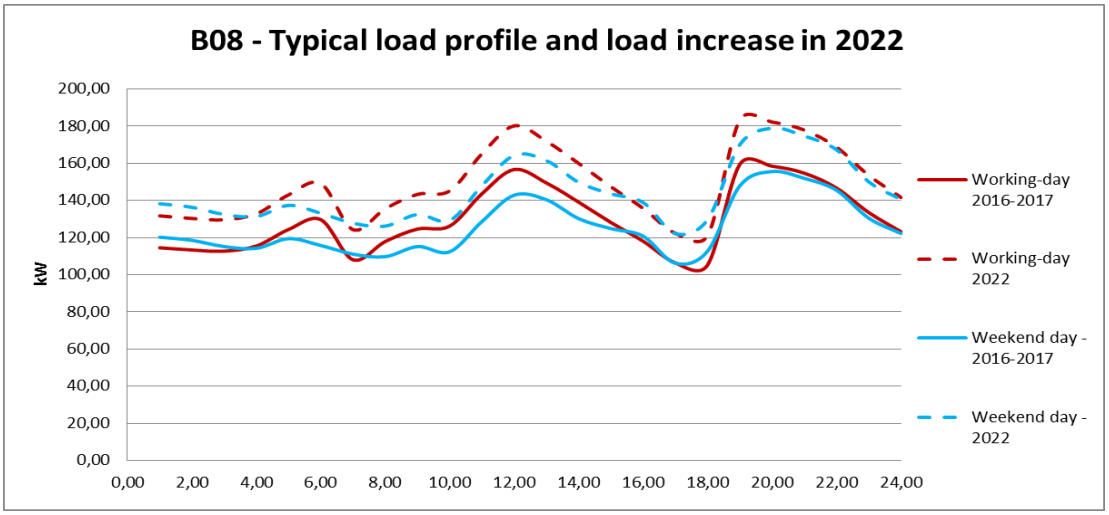


Figure 17: B08 - Typical daily load profile and evolution until 2022

	Average daily consumption [MWh/day]	Yearly consumption [MWh/yr]	Peak power [kW]
2017	3.08	1,125	207
2022	3.55	1,294	238

Table 25: B08 –Power consumption and peak power

2.11.2 Diesel generators

3 diesel generators of different sizes are installed on the island. Diesel generators 1 & 3 shall be integrated in the hybrid PV system.

A new 125kW (156kVA) diesel generator shall be additionally installed and implemented in the PV hybrid system.

The following diesel generators are currently used.

Item	Diesel Generator 1	Diesel Generator 2	Diesel Generator 3
Engine manufacturer & motor references	Cummins 6CTAA8.3-G2	Cummins 6BT5.9G2	Cummins 6CTAA8.3G2
Engine power rating (continuous)	160 kW	80 kW	160 kW
Alternator power rating	200 kVA	100 kVA	200 kVA
Hours of operation / date of installation	3,118hrs	23,101hrs	5,212hrs
General maintenance performed	No	No	No
Required upgrade / replacement	-	Yes (close to overhaul / end of life)	-

Table 26: B08 - Diesel generators currently installed

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).

Roof number	Building and name	Roof size X [mm]	Roof size Y [mm]	Slope [°]	Slope Direction	Distance to Powerhouse [m]	Maximum PV power [kWp]	Useable roofs	Maximum PV Capacity on selected roofs [kWp]
B08-1	Council A1	5,793	22,500		E		10.4	X	10.4
B08-2	Council A2	5,793	22,500		W		10.4	X	10.4
B08-3	Health Centre A1	7,163	17,983		E		12.5	X	12.5
B08-4	Health Centre A2	7,163	17,983		W		12.5	X	12.5
B08-7	School A1	5,500	32,535		N		15.6	X	15.6
B08-8	School A2	5,500	32,535		S		10.4	X	10.4
B08-9	School B1	5,750	52,246		N		18.7	X	18.7
B08-10	School B2	5,750	52,246		S		31.2	X	31.2
B08-11	School C1	5,500	13,000				5.7	X	5.7
B08-12	School C2	5,500	13,000				5.7	X	5.7
Summary									**133.1**

Table 27: B08 - Analysis of the available roofs and maximum PV power installable

2.11.4 Grid Infrastructure

2.11.4.1 *Electrical system*

a) Generation System

Generation: 400/230V Frequency: 50 Hz

Phase and type: three phase Wye, earthed neutral, Four wire system

b) Distribution Network (LV)

The power house in Nellaidhoo Island has 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 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*

i. *The Contractor shall implement the grid upgrade works in Nellaidhoo Island in line with drawings listed in the table below.*

S No.	Drawing Number	Title
1	J431-GOPA-021-GR-E-D-0001	NETWORK DIAGRAM FOR B08-NELLAIDHOO
2	J431-GOPA-021-GR-E-S-0001	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (B08- NELLAIDHOO)

ii. *This includes but not limited to the following works.*

a) Upgrade existing cable network for expected future load of 5kW for each distribution box

b) Modification or replacement of distribution boxes to accommodate the proposed higher size cables connection.

c) Modification or replacement of distribution boxes to accommodate new connection of proposed PV.

d) 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 Nellaidhoo Island.

i. *Schedule of Cables- Power House:*

From	To	Existing Cable (Sq.mm)	Proposed Cable (Sq.mm)	No. of Runs	Length (M)
Nellaidhoo Feeder-1	DB-A1	4C x 50	4C x 70	1	154
DB-A1	DB-A2	4C x 25	4C x 50	1	110
DB-A2	DB-A3	4C x 25	4C x 50	1	84
DB-A3	DB-A4	4C x 25	4C x 50	1	98
DB-A4	DB-A5	4C x 25	4C x 50	1	97
DB-A5	DB-A6	4C x 25	4C x 50	1	95
Nellaidhoo Feeder-2	DB-B1	4C x 50	4C x 150	1	225
DB-B1	DB-B2	4C x 50	4C x 120	1	91
DB-B2	DB-B3	4C x 50	4C x 120	1	150
DB-B3	DB-B4	4C x 35	4C x 95	1	119
DB-B4	DB-B5	4C x 35	4C x 95	1	119
DB-B5	DB-B6	4C x 35	4C x 95	1	143
Nellaidhoo Feeder-3	DB-C1	4C x 50	4C x 120	1	167
DB-C1	DB-C2	4C x 50	4C x 70	1	190
DB-C2	DB-C3	4C x 35	4C x 70	1	172

ii. PV connection

The following table lists the cables proposed for PV connection to the existing LV distribution network.

From	To	No. of Runs	Cable size (Sq mm)	Length (M)
DB-A6	HEALTH CENTRE-PV	1	4C x 70	140
DB-B1	SCHOOL-PV	1	4C x 120	50
DB-B2	COUNCIL-PV	1	4C x 70	70

iii. Modification/Replacement of LV distribution equipment

Item Description	Quantity (Nos.)
Replacement of Existing Distribution Box (DB)	5
Modification of existing of Distribution Box (DB)	10
Replacement of existing main LV Distribution board in Power House	1

2.12 B09 Nolhivaram Island

The island of Nolhivaram is located in the Haa Dhaalu Atoll. It stretches over 2.160 meters in length at a width of 1.150m. The urbanized area is in the central part of the island. Mayor facility is the small harbour on the east side of the island.

Island code, name, atoll	B09 - Nolhivaram
Atoll name	Haa Dhaalu (HDh)
Utility	FENAKA
GPS coordinates	6°42'58.00"N ; 72°56'49.00"E
Inhabitants (approx.)	2397
Harbor type	Harbor

Table 28: B09 – Island identification and general data

Figure 18: B09 - Location of the buildings with available roofs and of the power house

2.12.1 Load profile

The island has a fluctuating energy consumption, which is shown in the Figure 19 below. Based on the collected data the maximum average power consumption at 12:00 AM accounts for 170 kW, while minimum load reaches 115 kW at 06:00 PM. The utility expect a steadily increase of the load by 5%/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.

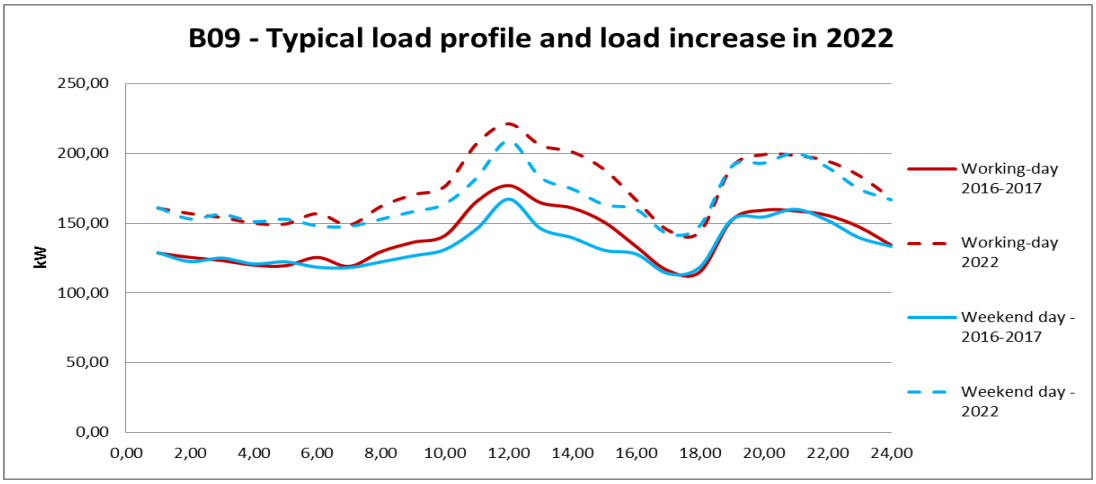


Figure 19: B09 - Typical daily load profile and evolution until 2022

	Average daily consumption [MWh/day]	Yearly consumption [MWh/yr]	Peak power [kW]
2017	3.32	1,212	219
2022	4.15	1,515	274

Table 29: B09 –Power consumption and peak power

2.12.2 Diesel generators

3 diesel generators of different sizes are installed on the island. Diesel generators 1 & 2 shall be integrated in the hybrid PV system.

A new 125kW (156kVA) diesel generator shall additionally be installed and implemented in the PV hybrid system.

The following diesel generators are currently used.

Item	Diesel Generator 1	Diesel Generator 2	Diesel Generator 3
Engine manufacturer & motor references	Cummins	Cummins	Cummins
Engine power rating (continuous)	180 kW	250 kW	160 kW
Alternator power rating	225kVA	312.5kVA	200kVA
Hours of operation / date of installation	Used generator April 19th 2014 6,197hr	(New genset) January 4th 2015 3,964hr	March 27th 2014 4,356hr
General maintenance done	No	No	Yes Oct,2015
Required upgrade / replacement		-	If space is needed for the new genset either this one or the 180kW genset may be removed -

Table 30: B09 - Diesel generators currently installed

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).

Roof number	Building and name	Roof size X [mm]	Roof size Y [mm]	Slope [°]	Slope Direction	Distance to Powerhouse [m]	Maximum PV power [kWp]	Useable roofs	Maximum PV Capacity on selected roofs [kWp]
B09-3	Council A1	5,942	23,941	15	19N	210	13.52	X	13.52
B09-4	Council A2	5,942	23,941	15	199S	210	11.44	X	11.44
B09-5	Health Centre A1	6,000	12,000	17	17°N	120	6.24	X	6.24
B09-6	Health Centre A2	6,285	20,000	17	196°S	120	11.44	X	11.44
B09-7	Health Centre A3	4,697	20,503		either 17°N or 196S	120	8.58	X	8.58
B09-10	School A1	5,522	33,000	26	19°N	160	14.04	X	14.04
B09-11	School A2	5,522	33,000	26	199°S	160	14.04	X	14.04
B09-12	School B1	7,136	22,590	26	19°N	160	15.6	X	15.6
B09-13	School B2	7,135	22,590	26	199°S	160	15.6	X	15.6
B09-14	School C1	5,959	26,500	26	19°N	160	15.6	X	15.6
B09-15	School C2	5,959	26,500	26	199°S	160	15.6	X	15.6
B09-16	School D1	5,949	22,400	15	19°N	160	12.48	X	12.48
B09-17	School D2	5,949	22,400	15	199°S	160	12.48	X	12.48
B09-18	School E1	5,554	18,460		19°N	160	7.28	X	7.28
B09-19	School E2	5,554	18,460		199°S	160	7.28	X	7.28
Summary									**181.2**

Table 31: B09 - Analysis of the available roofs and maximum PV power installable

2.12.4 Grid Infrastructure

2.12.4.1 *Electrical system*

a) Generation System

Generation: 400/230V Frequency: 50 Hz

Phase and type: three phase Wye, earthed neutral, four wire system

b) Distribution Network (LV)

The power house in Nolhivaram Island has 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 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*

i. *The Contractor shall implement the grid upgrade works in Nolhivaram Island in line with drawings listed in the table below.*

S No.	Drawing Number	Title
1	J431-GOPA-024-GR-E-D-0001	NETWORK DIAGRAM FOR B09-NOLHIVARAM
2	J431-GOPA-024-GR-E-S-0001	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (B09- NOLHIVARAM)

ii. *This includes but not limited to the following works.*

a) Upgrade existing cable network for expected future load of 5kW for each distribution box

b) Modification or replacement of distribution boxes to accommodate the proposed higher size cables connection.

c) Modification or replacement of distribution boxes to accommodate new connection of proposed PV.

d) 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 Nolhivaram Island.

Schedule of Cables- Power House

From	To	Existing Cable (Sq.mm)	Proposed Cable (Sq.mm)	No. of Runs	Length (M)
Power House Feeder-1	Substation-1	4C x 95	4C x 300	2	486
Substation-1	DB-111	4C x 35	4C x 120	1	201
DB-111	DB-112	4C x 35	4C x 120	1	88
DB-112	DB-113	4C x 35	4C x 70	1	131
DB-113	DB-114	4C x35	4C x 70	1	93
Substation-1	DB-121	4C x 35	4C x 120	1	170
DB-121	DB-122	4C x 35	4C x 120	1	112
Power House Feeder-2	Substation-2	4C x 95	4C x 240	1	243
Power House Feeder-3	Substation-3	4C x 95	4C x 240	1	357
Substation-3	DB-331	4C x 35	4C x 70	1	116
Power House Feeder-4	DB-411	4C x 35	4C x 150	1	137

iii. *PV Connection*

The following table lists the cables proposed for PV connection to the existing LV distribution network.

From	To	No. of Runs	Cable Size (sq.mm)	Length (M)
DB-411	COUNCIL-PV	1	4C x 50	60
DB-411	HEALTH CENTRE-PV	1	4C x 50	80
DB-411	SCHOOL-PV	1	4C x 120	40

Modification/Replacement of LV distribution equipment

Item Description	Quantity (Nos.)
Replacement of Existing Distribution Box (DB)	8
Modification of Existing of Distribution Box (DB)	3
Replacement of Existing main LV Distribution Board in Power House	1

2.13 B10 Kurinbee Island

The island of Kurinbee is located in the Haa Dhaalu Atoll. It stretches over 830 meters in length at a width of 600m. The urbanized area is in the central north part of the island. Mayor facility is the small harbour on the north-east side of the island.

Island code, name, atoll	B10 - Kurinbee
Atoll name	Haa Dhaalu (HDh)
Utility	FENAKA
GPS coordinates	6°39'58.00"N ; 72°59'50.00"E
Inhabitants (approx.)	709
Harbor type	Harbour

Table 32: B10 – Island identification and general data

Figure 20: B10 - Location of the buildings with available roofs and of the powerhouse

2.13.1 Load profile

The island has a fluctuating energy consumption, which is shown in the Figure 21 below. Based on the collected data the maximum average power consumption at 12:00 AM accounts for 60 kW, while minimum load reaches 35 kW at 06:00 AM. The utility expect a steadily increase of the load by 3%/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.

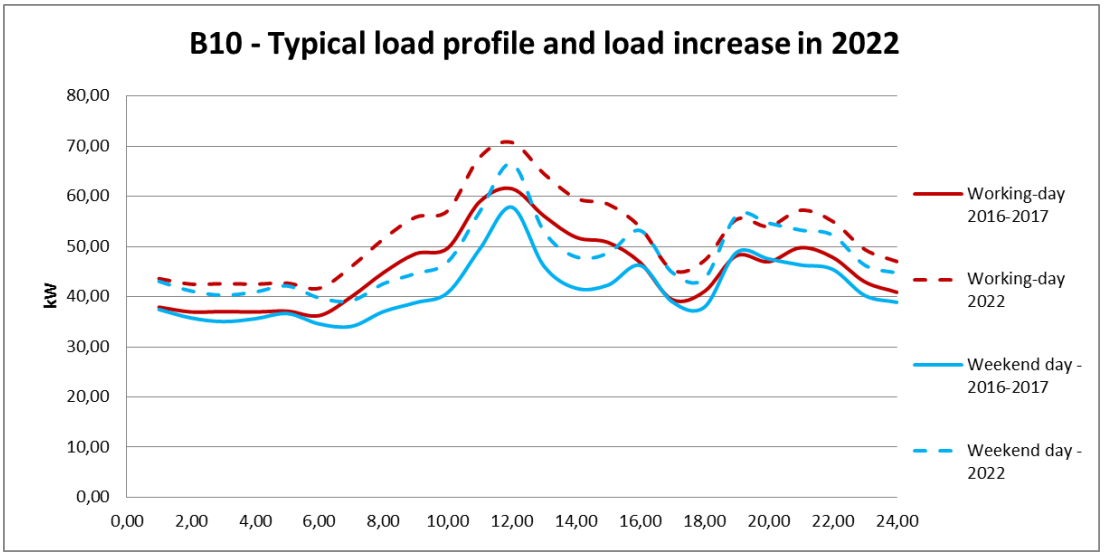


Figure 21: B10 - Typical daily load profile and evolution until 2022

	Average daily consumption [MWh/day]	Yearly consumption [MWh/yr]	Peak power [kW]
2017	1.06	387	76
2022	1.22	445	88

Table 33: B10 –Power consumption and peak power

2.13.2 Diesel generators

3 diesel generators of different sizes are installed on the island. Diesel generators 1 & 3 shall be integrated in the hybrid PV system.

A new 50kW (62.5kVA) diesel generator shall be installed and implemented in the PV hybrid system.

The following diesel generators are currently used.

Item	Diesel Generator 1	Diesel Generator 2	Diesel Generator 3
Engine manufacturer & motor references	Volvo Penta TD720GE	Cummins 6CTAA8.3-G2	Cummins 6BT5.9-G6
Engine power rating (continuous)	100kW	160kW	80kW
Alternator power rating	125kVA	200kVA	100kVA

Item	Diesel Generator 1	Diesel Generator 2	Diesel Generator 3
Hours of operation / date of installation	868 hrs 8 Sep 2015	5,218 hrs 30 Dec 2014	6,217 hrs 16 Jun 2014
General maintenance performed	No	No	No
Required upgrade / replacement		Not necessarily needed in the system, could be removed, if space is needed for new genset	

Table 34: B10 - Diesel generators currently installed

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).

Roof number	Building and name	Roof size X [mm]	Roof size Y [mm]	Slope [°]	Slope Direction	Distance to Powerhouse [m]	Maximum PV power [kWp]	Useable roofs	Maximum PV Capacity on selected roofs [kWp]
B10-3	Health Centre A1	7,000	11,000		19N	250	6.24	X	6.24
B10-4	Health Centre A2	7,000	11,000		199S	250	6.24	X	6.24
B10-5	School A1	6,706	20,269	26	23 NE	275	14.3	X	14.3
B10-6	School A2	6,706	20,269	26	202 Sw	275	14.3	X	14.3
B10-7	School B1	6,706	33,071	30	21N	275	18.2	X	18.2
B10-8	School B2	6,706	33,071	30	200 S	275	24.7	X	24.7
Summary									**83.98**

Table 35: B10 - Analysis of the available roofs and maximum PV power installable

2.13.4 Grid Infrastructure

2.13.4.1 *Electrical system*

a) Generation System

Generation: 400/230V Frequency: 50 Hz

Phase and type: three phase Wye, earthed neutral, four wire system

b) Distribution Network (LV)

The power house in Kurinbee Island has 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 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*

i. *The Contractor shall implement the grid upgrade works in Kurinbee Island in line with drawings listed in the table below.*

S No.	Drawing Number	Title
1	J431-GOPA-017-GR-E-D-0001	NETWORK DIAGRAM FOR B10-KURINBI
2	J431-GOPA-017-GR-E-S-0001	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (B10-KURINBI)

ii. *This includes but not limited to the following works.*

a) Establish new distribution network for the entire island in line with the tender drawings and with an expected future load of 5kW for each distribution box.

b) Replacement of distribution boxes to accommodate the proposed higher size cables connection.

c) Replacement of distribution boxes to accommodate new connection of proposed PV.

d) 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 Kurinbee Island.

i. *Schedule of Cables- Powerhouse*

From	To	Proposed Cable (Sq.mm)	No. of Runs	Length (M)
Feeder-A	DB-A1	4C x 70	1	100
DB-A1	DB-A2	4C x 70	1	111
DB-A2	DB-A3	4C x 50	1	132
DB-A3	DB-A4	4C x 35	1	123
DB-A4	DB-A5	4C x 35	1	126
Feeder-B	DB-B1	4C x 185	1	185
DB-B1	DB-B2	4C x 95	1	105
DB-B2	DB-B2x1	4C x 100	1	100
DB-B2x1	DB-B2x2	4C x 35	1	72
DB-B2x2	DB-B2x3	4C x 35	1	94
DB-B2	DB-B3	4C x 35	1	107
DB-B3	DB-B4	4C x 35	1	87
Feeder-C	DB-C1	4C x 120	1	240
DB-C1	DB-C2	4C x 95	1	117
DB-C2	DB-C2x1	4C x 35	1	101
DB-C2	DB-C3	4C x 50	1	75
DB-C3	DB-C4	4C x 50	1	91
DB-C4	DB-C5	4C x 35	1	150
DB-C6	DB-C7	4C x 35	1	104
Feeder-D	DB-D1	4C x 50	1	377

From	To		Proposed Cable (Sq.mm)	No. of Runs	Length (M)
DB-D1	DB-D1 x1	4C x 35		1	108
DB-D1	DB-D2	4C x 50		1	100
DB-D2	DB-D3	4C x 50		1	165
DB-D3	DB-D3 x1	4C x 35		1	78
DB-D3	DB-D4	4C x 35		1	145
DB-D4	DB-D5	4C x 35		1	104
Feeder – E	DB-E1	4C x 120		1	105
DB-E1	DB-E1x1	4C x 35		1	122
DB-E1x1	DB-E4	4C x 35		1	116
DB-E1	DB-E2	4C x 120		1	98
DB-E2	DB-E3	4C x 120		1	101
DB-E3	DB-E4	4C x 120		1	95
DB-E4	DB-E5	4C x 35		1	163
DB-E5	DB-E6	4C x 35		1	94

ii. *PV Connection*

The following table lists the cables proposed for PV connection to the existing LV distribution network.

From	To	No. of runs	Cable Size (sq.mm)	Length (M)
DB-E3	HEALTH CENTER-PV	1	4C x 50	30
DB-E4	SCHOOL-PV	1	4C x 120	10

iii. *Modification/Replacement of LV distribution equipment*

Item Description	Quantity (Nos.)
Replacement of Existing Distribution Box (DB)	35
Replacement of Existing Main LV Distribution Board in Power House	1

2.14 B12 Kulhudhuffushi Island

The island of Kulhudhuffushi is located in the Haa Dhaalu Atoll. It stretches over 2.500 meters in length at a width of 1.300m. The urbanized area is covering most of the island. It is the biggest island in the Haa Dhaalu Atoll and has the highest population and energy demand in the Haa Dhaalu Atoll. In the north of the island a big lagoon can be found. The local harbour is on the north west side of the island. An international harbour for bigger ships can be found in the south west of the island.

Island code, name, atoll	B12 - Kulhudhuffushi
Atoll name	Haa Dhaalu (HDh)
Utility	FENAKA
GPS coordinates	6°37'19.00"N; 73° 4'13.00"E
Inhabitants (approx.)	9106
Harbor type	Large harbor

Table 36: B12 – Island identification and general data

Figure 22: B12 - Location of the buildings with available roofs and of the power house

2.14.1 Load profile

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

Figure 23 below. Based on the collected data the maximum average power consumption at 02:00 PM accounts for 1.780 kW, while minimum load reaches 1.000 kW at 06:00 AM. The utility expect a steadily increase of the load by 15%/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.

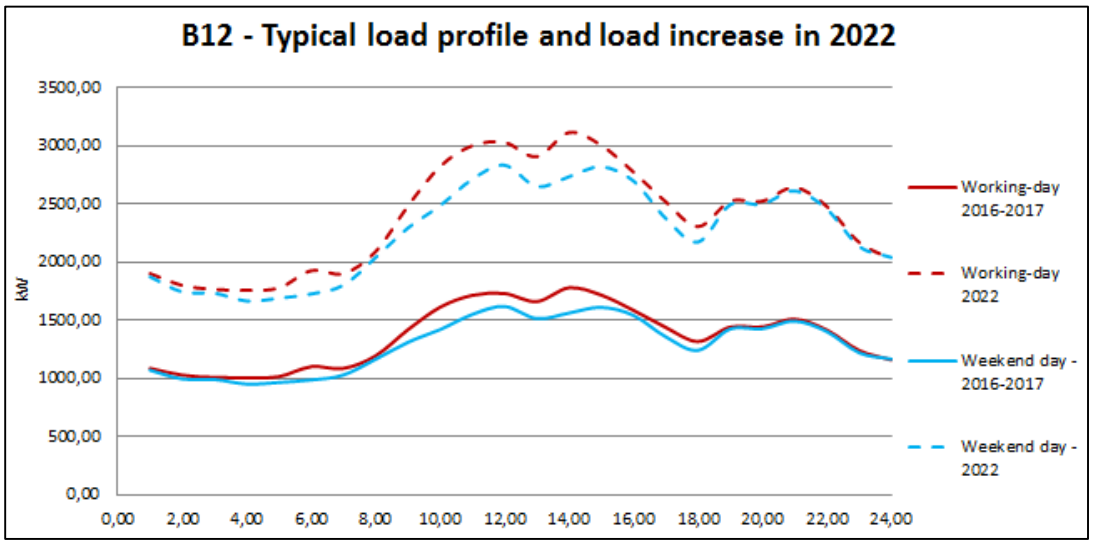


Figure 23: B12 - Typical daily load profile and evolution until 2022

	Average daily consumption [MWh/day]	Yearly consumption [MWh/yr]	Peak power [kW]
2017	32.2	11,753	2,168
2022	56.4	20,586	3,794

Table 37: B12 –Power consumption and peak power

2.14.2 Diesel generators

4 diesel generators of different sizes are installed on the island. Diesel generators 1, 2 & 3 shall be integrated in the hybrid PV system.

A new 1000kW (1250kVA) diesel generator shall additionally be installed and implemented in the PV hybrid system

The following diesel generators are currently used.

Item	Diesel Gen. 1	Diesel Gen. 2	Diesel Gen. 3	Diesel Gen. 4
Engine manufacturer & motor references	Cummins KTA50-G3	Cummins KTA50-G3	Cummins KTA50-G3	Cummins KTA50-G1
Engine power rating (continuous)	1,000kW	1,000kW	1,000kW	800kW
Alternator power rating	1,250kVA	1,250kVA	1,250kVA	1,000kVA
Hours of operation / date of installation	5,389hrs Year 2015	5,612hrs Year 2015	23,804hrs Year 2011	37,648hrs Year 2006
General maintenance performed	No	No	No	1 overhaul
Required upgrade / replacement	-	-	-	To be replaced

Table 38: B12 - Diesel generators currently installed

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).

Roof number	Building and name	Roof size X [mm]	Roof size Y [mm]	Slope [°]	Slope Direction	Distance to Powerhouse [m]	Maximum PV power [kWp] [2]	Useable roofs	Maximum PV Capacity on selected roofs [kWp]
B12-5	University B1	5,500	66,935	12		180	33.28	X	33.28
B12-6	University B2	5,500	66,938	12		180	33.28	X	33.28
B12-7	University C1	7,000	36,000	8		180	26.52	X	26.52
B12-8	University C2	7,600	36,000	8		180	10.4	X	10.4
B12-9	University D1	5,000	25,877	12		180	12.48	X	12.48
B12-10	University D2	5,000	25,877	12		180	12.48	X	12.48
B12-11	University E1	5,000	23,434	12		180	10.92	X	10.92
B12-12	University E2	5,000	23,434	12		180	10.92	X	10.92
B12-13	Jalaaluddin School A1	5,703	66,000	10	356 N	100	39.52	X	39.52
B12-14	Jalaaluddin School A2	5,703	60,707	10	176 S	100	36.4	X	36.4
B12-15	Jalaaluddin School B1	6,301	60,746	10	358 N	100	36.4	X	36.4
B12-16	Jalaaluddin School B2	6,301	76,000	10	178 S	100	45.76	X	45.76
B12-17	Jalaaluddin School C1	6,324	32,365	10	358 N	100	18.72	X	18.72
B12-18	Jalaaluddin School C2	6,324	32,365	10	178 S	100	18.72	X	18.72
B12-19	Jalaaluddin School D1	6,000	13,000	10	W	101	6.24	X	6.24
B12-20	Jalaaluddin School D2	6,000	9,000	10	E	102	4.16	X	4.16
B12-21	Jalaaluddin School E1	10,000	13,000	10	W	103	14.3	X	14.3
B12-22	Jalaaluddin School E2	10,000	13,000	10	E	104	14.3	X	14.3

[2] Assumption: PV modules crystalline technology / 260Wp / 1000mm x 1650mm.

Roof number	Building and name	Roof size X [mm]	Roof size Y [mm]	Slope [°]	Slope Direction	Distance to Powerhouse [m]	Maximum PV power [kWp] [2]	Useable roofs	Maximum PV Capacity on selected roofs [kWp]
B12-23	Afeefudin school New Building A1	6,250	28,800	12		410	11.44	X	11.44
B12-24	Afeefudin school New Building A2	6,250	28,800	12		410	11.44	X	11.44
B12-25	Afeefudin school New Building B1	7,000	47,000			411	35.1	X	35.1
B12-26	Afeefudin school New Building B2	7,000	47,000			412	35.1	X	35.1
B12-27	Afeefudin school New Building C1	9,000	39,000			413	40.04	X	40.04
B12-28	Afeefudin school New Building C2	9,000	39,000			414	40.04	X	40.04
B12-29	Mosque A1						40	X	40
B12-30	Kulhudhuffushi Port	14,000	44,000	7	NE	Separate Substation	37.44	X	37.44
B12-31	Kulhudhuffushi Port	14,000	44,000	7	SW		37.44	X	37.44
B12-32	Atoll Education Centre A1	7,000	30,000	25	N		22.1	X	22.1
B12-33	Atoll Education Centre A2	7,000	30,000	25	S		22.1	X	22.1
B12-34	Atoll Education Centre G1	7,000	30,000	25	N		22.1	X	22.1
B12-35	Atoll Education Centre G2	7,000	30,000	25	S		22.1	X	22.1
B12-36	Atoll Education Centre E1	7,000	30,000	10	N		22.1	X	22.1
B12-37	Atoll Education Centre E2	7,000	30,000	10	S	Separate Substation	22.1	X	22.1
Summary									**805.44**

Table 39: B12 - Analysis of the available roofs and maximum PV power installable

2.14.4 Grid Infrastructure

2.14.4.1 *Electrical system*

a) Generation System

Generation: 400/230V Frequency: 50 Hz

Phase and type: three phase Wye, earthed neutral, four wire system

b) Distribution Network (LV)

The power house in Kulhudhuffushi Island has four diesel generators that supply the load requirements of the island. The requirements related to existing and new diesel generators and associated systems given in the above sections.

The island is fed through the 11kV Voltage Distribution network which is stepped up through two transformers connected to the Main Low Voltage distribution board of the power house.

This 11kV network is connected through loop-in loop-out configuration with five substations SS1, SS2, SS3, SS4 and SS5 located at various locations across the island. One substation is built for feeding the loads in the port facility of this island. The 11kV is then stepped down to low voltage network in these substations to feed the loads close these substations.

Distribution boards at the LV side of the distribution transformers in these substations supply to downstream DBs in loop in loop out configuration.

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*

i. *The Contractor shall implement the grid upgrade works in Kulhudhuffushi Island in line with drawings listed in the table below.*

S No.	Drawing Number	Title
1	J431-GOPA-032-GR-E-D-0001	NETWORK DIAGRAM FOR B12-KULHUDHUFUSHI - SUBSTATION 01
2	J431-GOPA-032-GR-E-D-0002	NETWORK DIAGRAM FOR B12-KULHUDHUFUSHI - SUBSTATION 02
3	J431-GOPA-032-GR-E-D-0003	NETWORK DIAGRAM FOR B12-KULHUDHUFUSHI- SUBSTATION 03
4	J431-GOPA-032-GR-E-D-0004	NETWORK DIAGRAM FOR B12-KULHUDHUFUSHI - SUBSTATION 04
5	J431-GOPA-032-GR-E-D-0005	NETWORK DIAGRAM FOR B12-KULHUDHUFUSHI - SUBSTATION 05
6	J431-GOPA-032-GR-E-S-0001	CONCEPTUAL SCHEMATICE DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (B12 KULHUDHUFUSHI)

S No.	Drawing Number	Title
7	J431-GOPA-032-GR-E-S-0002	CONCEPTUAL SCHEMATICE DIAGRAM FOR LV DISTRIBUTION BOARD OF SUBSTATION 3 (B12 KULHUDHUFUSHI)
8	J431-GOPA-032-GR-E-S-0003	CONCEPTUAL SCHEMATICE DIAGRAM FOR LV DISTRIBUTION BOARD OF SUBSTATION 4 (B12 KULHUDHUFUSHI)
9	J431-GOPA-032-GR-E-S-0004	CONCEPTUAL SCHEMATICE DIAGRAM FOR LV DISTRIBUTION BOARD OF SUBSTATION 5 (B12 KULHUDHUFUSHI)
10	J431-GOPA-032-GR-E-S-0005	CONCEPTUAL SCHEMATICE DIAGRAM FOR LV DISTRIBUTION BOARD OF PORT SUBSTATION (B12 KULHUDHUFUSHI)

ii. *This includes but not limited to the following works.*

a) Upgrade existing cable network for expected future load of 5kW for each distribution box

b) Modification or replacement of distribution boxes to accommodate the proposed higher size cables connection.

c) Modification or replacement of distribution boxes to accommodate new connection of proposed PV.

d) Modification of existing LV distribution boards in 11/0.4kV substations to connect the proposed PV.

e) Replacement of existing main LV distribution boards with the new LV distribution boards in the power house.

The modification / replacement of distribution boxes, modification of LV distribution boards of the substations shall be designed to meet the final design kWp of the PV power plant that will be approved by the Employer.

The new LV distribution boards 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 boards to the new LV distribution boards 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 Kulhudhuffushi Island.

i. *Schedule of Cables-SUBSTATION-1*

From	To	Existing Cable (Sq.mm)	Proposed Cable (Sq.mm)	No. of Runs	Length (M)
SS1_ Feeder-1	DB-111	4C x 50	4C x 120	1	28
DB-111	DB-112	4C x 50	4C x 120	1	137
DB-112	DB-113	4C x 50	4C x 70	1	80
DB-113	DB-114	4C x 25	4C x 70	1	82
DB-114	DB-115	4C x 25	4C x 50	1	89
SS1_ Feeder-4	DB-141	4C x 50	4C x 120	1	200
DB-141	DB-142	4C x 50	4C x 120	1	200
DB-142	DB-143	4C x 50	4C x 70	1	200
DB-143	DB-144	4C x 50	4C x 70	1	200

ii. *Schedule of Cables-SUBSTATION-2*

From	To	Existing Cable (Sq.mm)	Proposed Cable (Sq.mm)	No. of Runs	Length (M)
SS2_Feeder-1	DB-211	4C x 70	4C x 120	1	121
DB-211	DB-212	4C x 70	4C x 120	1	75
DB-212	DB-213	4C x 70	4C x 120	1	100
DB-213	DB-214	4C x 70	4C x 120	1	75
SS2_Feeder-2	DB-221	4C x 70	4C x 150	1	128
DB-221	DB-222	4C x 70	4C x 150	1	126
DB-222	DB-223	4C x 70	4C x 120	1	111
DB-223	DB-224	4C x 70	4C x 120	1	105
DB-224	DB-225	4C x 70	4C x 120	1	80
DB-225	DB-225x1	4C x 16	4C x 35	1	69
SS2_Feeder-5	DB-251	4C x 120	4C x 300	2	501
DB-251	DB-252	4C x 120	4C x 240	1	124

From	To	Existing Cable (Sq.mm)	Proposed Cable (Sq.mm)	No. of Runs	Length (M)
DB-252	DB-253	4C x 120	4C x 150	1	67
DB-253	DB-254	4C x 70	4C x 150	1	108
DB-254	DB-255	4C x 70	4C x 120	1	65
DB-255	DB-256	4C x 70	4C x 95	1	54
SS2_Feeder-6	DB-261	4C x 120	4C x 300	1	551
DB-261	DB-262	4C x 70	4C x 120	1	75

iii. *Schedule of Cables-SUBSTATION-3*

From	To	Existing Cable (Sq.mm)	Proposed Cable (Sq.mm)	No. of Runs	Length (M)
SS3_Feeder-1	DB-311	4C x 70	4C x 120	1	46
DB-311	DB-312	4C x 70	4C x 120	1	69
DB-312	DB-313	4C x 70	4C x 120	1	60
DB-313	DB-314	4C x 35	4C x 120	1	92
DB-314	DB-315	4C x 35	4C x 70	1	77
SS3_Feeder-2	DB-321	4C x 120	4C x 240	1	403
DB-321	DB-322	4C x 70	4C x 120	1	88
DB-322	DB-323	4C x 70	4C x 120	1	109
DB-323	DB-324	4C x 50	4C x 120	1	65
DB-324	DB-325	4C x 16	4C x 50	1	72
SS3_Feeder-5	DB-351	4C x 70	4C x 300	1	497
DB-351	DB-351x1	4C x 70	4C x 95	1	97
DB-351	DB-352	4C x 70	4C x 120	1	18
DB-352	DB-353	4C x 70	4C x 120	1	76
DB-353	DB-354	4C x 35	4C x 95	1	100

iv. *Schedule of Cables-SUBSTATION-4*

From	To	Existing Cable (Sq.mm)	Proposed Cable (Sq.mm)	No. of Runs	Length (M)
SS4_Feeder-1	DB-411	4C x 50	4C x 70	1	280

From	To	Existing Cable (Sq.mm)	Proposed Cable (Sq.mm)	No. of Runs	Length (M)
SS4_Feeder-6	DB-461	4C x 120	4C x 240	1	738
SS4_Feeder-7	DB-471	4C x 70	4C x 120	1	497

v. PV Connection

The following table lists the cables proposed for PV connection to the existing LV distribution network.

From	To	No. of Runs	Cable Size (sq.mm)	Length (M)
AFEEFUDIN SCHOOL-PV	KULHUDHUFFUSHI-POWERHOUSE	1	4C x 300	410
KULHUDHUFFUSHI-PORT-PV	KULHUDHUFFUSHI-PORT-S/S	1	4C x 120	100
MOSQUE-PV	KULHUDHUFFUSHI- S/S 3-MAIN LVDB	1	4C x 70	220
JALAALUDDIN SCHOOL-PV	KULHUDHUFFUSHI- S/S 4- MAIN LVDB	1	4C x 240	100
ATOLL EDUCATION CENTRE-PV	KULHUDHUFFUSHI- S/S 4- MAIN LVDB	1	4C x 120	100
UNIVERSITY-PV	KULHUDHUFFUSHI- S/S 5- MAIN LVDB	1	4C x 150	180

vi. Modification/Replacement of LV distribution equipment

a) Power House

Item Description	Quantity (Nos.)
Replacement of existing LV distribution boards	1

b) Port Substation

Item Description	Quantity (Nos.)
Modification of LV Outgoing Feeder in substation Main LV DB for RE Incomer	1

c) Substation 1

Item Description	Quantity (Nos.)
Replacement of Existing Distribution Box (DB)	42

d) Substation 2

Item Description	Quantity (Nos.)
Replacement of Existing Distribution Box (DB)	71

e) Substation 3

Item Description	Quantity (Nos.)
Replacement of Existing Distribution Box (DB)	81
Modification of LV Outgoing Feeder in substation Main LV DB for RE Incomer	1

f) Substation 4

Item Description	Quantity (Nos.)
Replacement of Existing Distribution Box (DB)	55
Modification of LV Outgoing Feeder in substation Main LV DB for RE Incomer	1

g) Substation 5

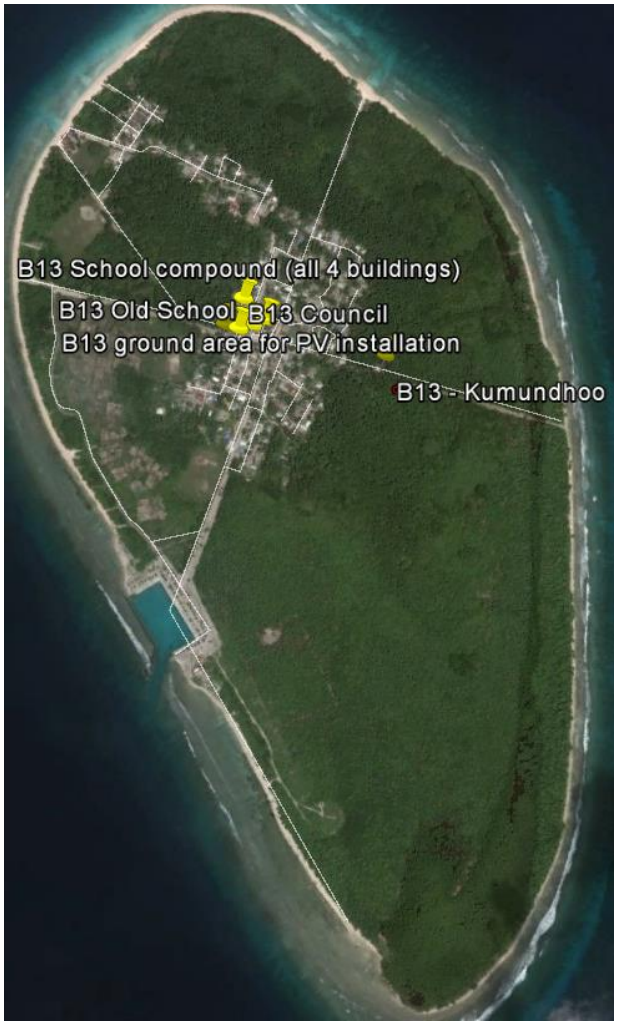
Item Description	Quantity (Nos.)
Replacement of Existing Distribution Box (DB)	7
Modification of LV Outgoing Feeder in substation Main LV DB for RE Incomer	1

2.15 B13 Kumundhoo Island

The island of Kumundhoo is located in the Haa Dhaalu Atoll. It stretches over 2.300 meters in length at a width of 1.100m. The urbanized area is in the central north part of the island. Mayor facility is the small harbour on the south-west side of the island.

Island code, name, atoll	B13 - Kumundhoo
Atoll name	Haa Dhaalu (HDh)
Utility	FENAKA
GPS coordinates	6°34'28.00"N ; 73° 3'4.00"E
Inhabitants (approx.)	1397
Harbor type	Harbor

Table 40: B13 – Island identification and general data



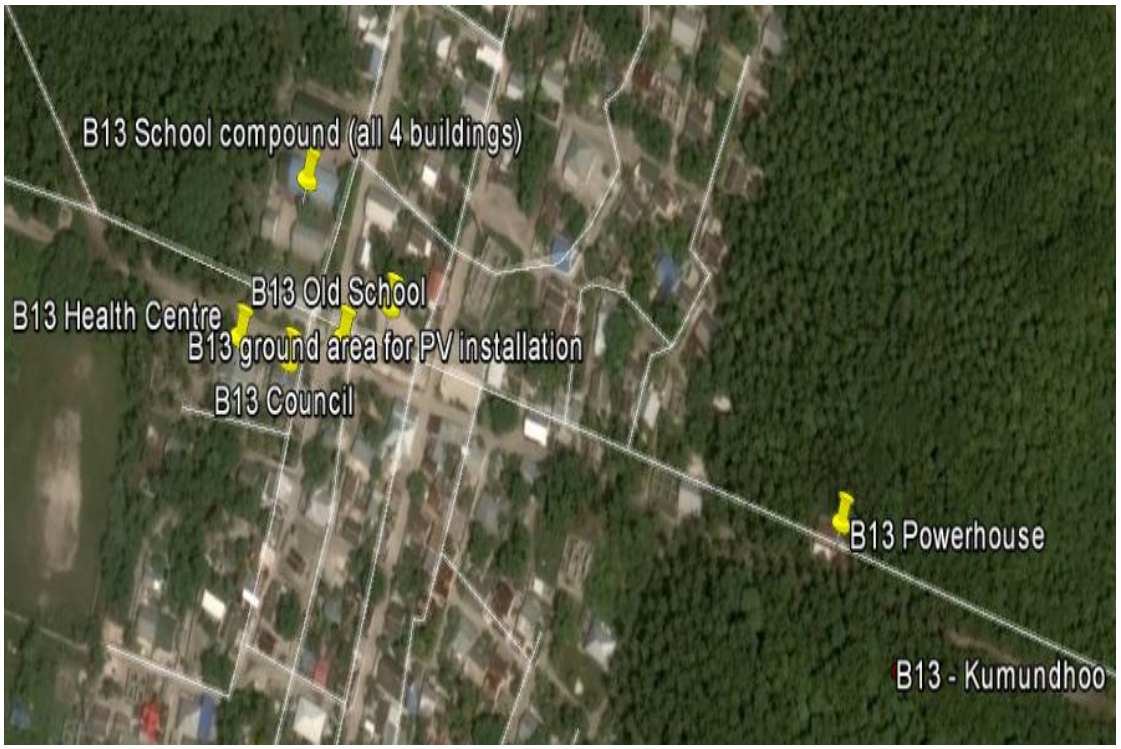


Figure 24: B13- Location of the buildings with available roofs and of the powerhouse

2.15.1 Load profile

The island has a fluctuating energy consumption, which is shown in the Figure 25 below. Based on the collected data the maximum average power consumption at 12:00 AM accounts for 85 kW, while minimum load reaches 52 kW at 06:00 PM. The utility expect a steadily increase of the load by 5%/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.

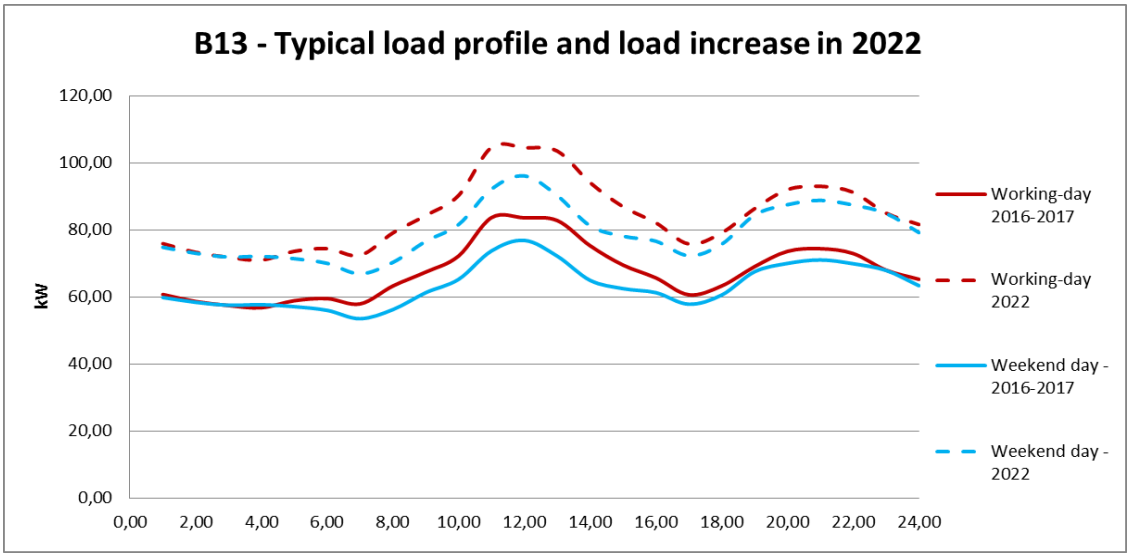


Figure 25: B13- Typical daily load profile and evolution until 2022

	Average daily consumption [MWh/day]	Yearly consumption [MWh/yr]	Peak power [kW]
2017	1.59	582	103.57
2022	1.99	727	129.46

Table 41: B13–Power consumption and peak power

2.15.2 Diesel generators

3 diesel generators of different sizes are installed on the island. Diesel generator 2 shall be integrated in the hybrid PV system.

A new 125kW (156kVA) and a new 80kW (100kVA) diesel generator shall be installed and implemented in the PV hybrid system.

The following diesel generators are currently used.

Item	Diesel Generator 1	Diesel Generator 2	Diesel Generator 3
Engine manufacturer & motor references	DEUTZ Model No: BF6M1013E	CUMMINS Model No: 6CTAA8.3.G2	CUMMINS Model No: 6BTAA5.9G2
Engine power rating (continuous)	112kW	160kW	104kW
Alternator power rating	140kVA	200kVA	130kVA
Hours of operation / date of installation	Actual running hrs not available Running hrs after 2011 Sep: 30,119hrs	2,268hrs / Dec 19th 2014	Actual running hrs not available Running hrs after 2011 Sep: 21,149hrs
General maintenance performed	Running hrs after Top Overhaul : 1,830hrs	No	Running hrs after Top Overhaul : 2,671hrs
Required upgrade / replacement	To be replaced for 125kW	-	To be replaced for 80kW

Table 42: B13- Diesel generators currently installed

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).

Roof number	Building and name	Roof size X [mm]	Roof size Y [mm]	Slope [°]	Slope Direction	Distance to Powerhouse [m]	Maximum PV power [kWp]	Useable roofs	Maximum PV Capacity on selected roofs [kWp]
B13-1	Council A1	5,500	17,000	20	21°N	370	7.8	X	7.8
B13-2	Council A2	5,500	17,000	20	199°S	370	7.8	X	7.8
B13-3	Health Centre A1	8,500	10,800	20	111°E	415	9.36	X	9.36
B13-4	Health Centre A2	8,500	10,800	20	291°SW	415	9.36	X	9.36
B13-11	School C1	5,500	31,000	30-38	NE	420	15.08	X	15.08
B13-12	School C2	5,500	31,000	30-39	SW	420	15.08	X	15.08
B13-11	School D1	5,900	33,000	30-40	NE	420	18.72	X	18.72
B13-12	School D2	5,900	33,000	30-41	SW	420	18.72	X	18.72
Summary									**101.92**

Table 43: B13 - Analysis of the available roofs and maximum PV power installable

2.15.4 Grid Infrastructure

2.15.4.1 *Electrical system*

a) Generation System

Generation: 400/230V Frequency: 50 Hz

Phase and type: three phase Wye, earthed neutral, four wire system

b) Distribution Network (LV)

The power house in Kumundhoo Island has 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 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*

i. *The Contractor shall implement the grid upgrade works in Kumundhoo Island in line with drawings listed in the table below.*

S No.	Drawing Number	Title
1	J431-GOPA-019-GR-E-D-0001	NETWORK DIAGRAM FOR B13-KUMUNDHOO
2	J431-GOPA-019-GR-E-S-0001	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (B13-KUMUNDHOO)

ii. *This includes but not limited to the following works.*

a) Upgrade existing cable network for expected future load of 5kW for each distribution box

b) Modification or replacement of distribution boxes to accommodate the proposed higher size cables connection.

c) Modification or replacement of distribution boxes to accommodate new connection of proposed PV.

d) 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 Kumundhoo Island.

i. *Schedule of Cables- Power House*

From	To	Existing Cable (Sq.mm)	Proposed Cable (Sq.mm)	No. of Runs	Length (M)
Kumundhoo Feeder-B	DB-B1	4C x 25	4C x 70	1	277
Kumundhoo Feeder-C	DB-C1	4C x 35	4C x 150	1	260
DB-C1	DB-C2	4C x 35	4C x 150	1	260
DB-C2	DB-C3	4C x 35	4C x 150	1	260
DB-C3	DB-C3x1	4C x 16	4C x 50	1	83
DB-C3	DB-C3x2	4C x 16	4C x 50	1	71
DB-C3	DB-C4	4C x 25	4C x 150	1	90
DB-C4	DB-C5	4C x 25	4C x 150	1	77
DB-C5	DB-C6	4C x 16	4C x 120	1	70
Kumundhoo Feeder-D	DB-D1	4C x 120	4C x 150	1	260
DB-D1	DB-D2	4C x 95	4C x 120	1	148
DB-D2	DB-D3	4C x 95	4C x 120	1	103
DB-D3	DB-D4	4C x 70	4C x 120	1	65
DB-D4	DB-D5	4C x 70	4C x 120	1	60
DB-D5	DB-D6	4C x 50	4C x 120	1	64
DB-D6	DB-D7	4C x 35	4C x 120	1	85

From	To	Existing Cable (Sq.mm)	Proposed Cable (Sq.mm)	No. of Runs	Length (M)
DB-D7	DB-D8	4C x 25	4C x 50	1	75
DB-D8	DB-D9	4C x16	4C x 35	1	68

ii. *PV Connection*

The following table lists the cables proposed for PV connection to the existing LV distribution network.

From	To	No. of Runs	Cable Size (sq.mm)	Length (M)
DB-C4	COUNCIL-PV	1	4C x 50	60
DB-C4	HEALTH CENTRE-PV	1	4C x 70	130
DB-D7	SCHOOL-PV	1	4C x 240	50

iii. *Modification/Replacement of LV distribution equipment*

Item Description	Quantity (Nos.)
Replacement of Existing Distribution Box (DB)	31
Replacement of Existing main LV distribution board in Power House	1

2.16 B14 Neykurendhoo Island

The island of Neykurendhoo is located in the Haa Dhaalu Atoll. It stretches over 1.350 meters in length at a width of 1.700m. The urbanized area is in the north-west part of the island. Mayor facility is the small harbour on the north side of the island.

Island code, name, atoll	B14 - Neykurendhoo
Atoll name	Haa Dhaalu (HDh)
Utility	FENAKA
GPS coordinates	6°32'42.00" ; 72°58'42.00"E
Inhabitants (approx.)	1370
Harbor type	Harbour

Table 44: B14 – Island identification and general data

Figure 26: B14 - Location of the buildings with available roofs and of the powerhouse

2.16.1 Load profile

The island has a fluctuating energy consumption, which is shown in the Figure 27 below. Based on the collected data the maximum average power consumption at 12:00 AM accounts for 85 kW, while minimum load reaches 50 kW at 05:00 PM. The utility expect a steadily increase of the load by 3%/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.

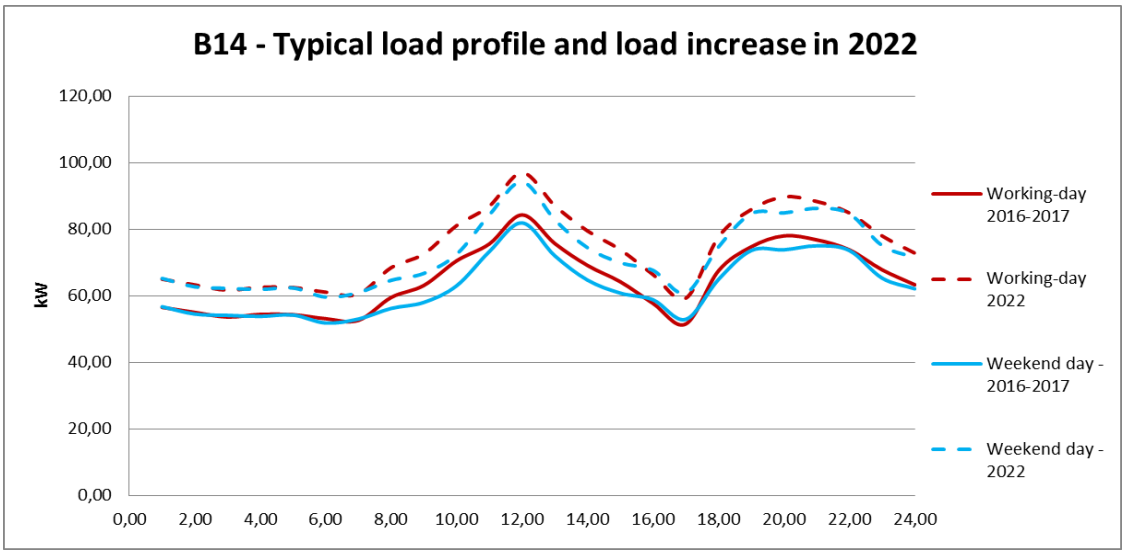


Figure 27: B14 - Typical daily load profile and evolution until 2022

	Average daily consumption [MWh/day]	Yearly consumption [MWh/yr]	Peak power [kW]
2017	1.54	563	104.45
2022	1.77	647	120.12

Table 45: B14 –Power consumption and peak power

2.16.2 Diesel generators

3 diesel generators of different sizes are installed on the island. None of the existing diesel generator shall be used for the hybrid system.

A new 125kW (156kVA) and a new 80kW (100kVA) diesel generator shall be installed and implemented in the PV hybrid system.

The following diesel generators are currently used.

Item	Diesel Generator 1	Diesel Generator 2	Diesel Generator 3
Engine manufacturer & motor references	Cummins NT855GA	Cummins 6CT8.3G2	Cummins 6BT5.9G1
Engine power rating (continuous)	200kW	100kW	68kW
Alternator power rating	250kVA	125kVA	85kVA
Hours of operation / date of installation	5,217hrs 12-01-2015	70,602hrs	40,258hrs
General maintenance performed	No	Yes/Overhaul 735hrs	Yes/Top Overhaul 14,101hrs
Required upgrade / replacement	Too large for load profile: could be relocated to another island and replaced by a smaller genset for more efficient operation	To be replaced for 125kW	To be replaced for 80kW

Table 46: B14 - Diesel generators currently installed

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).

Roof number	Building and name	Roof size X [mm]	Roof size Y [mm]	Slope [°]	Slope Direction	Distance to Powerhouse [m]	Maximum PV power [kWp]	Useable roofs	Maximum PV Capacity on selected roofs [kWp]
B14-1	Council A1	7,194	21,000	25	S	150	14.82	X	14.82
B14-2	Council A2	4,806	21,000	31	N	150	8.58	X	8.58
B14-10	School A1	5,440	32,500	30	357°N	75	15.6	X	15.6
B14-13	School B2	5,170	32,000	30	176.5 S	75	15.6	X	15.6
B14-16	School D1	5,750	27,000	29	12°N	75	15.6	X	15.6
B14-17	School D2	5,750	27,000	31	184S	75	15.6	X	15.6
Summary									**85.8**

Table 47: B14 - Analysis of the available roofs and maximum PV power installable

2.16.4 Grid Infrastructure

2.16.4.1 *Electrical system*

a) Generation System

Generation: 400/230V Frequency: 50 Hz

Phase and type: three phase Wye, earthed neutral, four wire system

b) Distribution Network (LV)

The power house in Neykurendhoo Island has 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 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*

i. *The Contractor shall implement the grid upgrade works in Neykurendhoo Island in line with drawings listed in the table below.*

S No.	Drawing Number	Title
1	J431-GOPA-020-GR-E-D-0001	NETWORK DIAGRAM FOR B14-NEYKURENDHOO
2	J431-GOPA-020-GR-E-S-0001	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (B14-NEYKURENDHOO)

ii. *This includes but not limited to the following works.*

a) Upgrade existing cable network for expected future load of 5kW for each distribution box

b) Modification or replacement of distribution boxes to accommodate the proposed higher size cables connection.

c) Modification or replacement of distribution boxes to accommodate new connection of proposed PV.

d) 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 Neykurendhoo Island.

i. *Schedule of Cables- Power House:*

From	To	Existing Cable (Sq.mm)	Proposed Cable (Sq.mm)	No. of Runs	Length (M)
Neykurendhoo Feeder-1	DB-A1	4C x 25	4C x 70	1	315
DB-A1	DB-A2	4C x 25	4C x 70	1	110
DB-A2	DB-A3	4C x 25	4C x 50	1	100
DB-A3	DB-A4	4C x 25	4C x 50	1	130
Neykurendhoo Feeder-2	DB-B1	4C x 25	4C x 70	1	289
DB-B1	DB-B2	4C x 25	4C x 50	1	112
Neykurendhoo Feeder-3	DB-C1	4C x 50	4C x 120	1	89
DB-C1	DB-C2	4C x 35	4C x 70	1	145
DB-C2	DB-C3	4C x 25	4C x 70	1	137
DB-C3	DB-C4	4C x 25	4C x 50	1	112
DB-C4	DB-C5	4C x 25	4C x 50	1	147
DB-C5	DB-C6	4C x 25	4C x 50	1	127
DB-C6	DB-C7	4C x 25	4C x 50	1	126
Neykurendhoo Feeder-4	DB-D1	4C x 25	4C x 70	1	142
DB-D1	DB-D2	4C x 25	4C x 50	1	99

From	To	Existing Cable (Sq.mm)	Proposed Cable (Sq.mm)	No. of Runs	Length (M)
Neykurendhoo Feeder-5	DB-E1	4C x 35	4C x 120	1	220
DB-E1	DB-E2	4C x 25	4C x 120	1	117
DB-E2	DB-E3	4C x 25	4C x 120	1	84
DB-E3	DB-E4	4C x 25	4C x 120	1	102
DB-E4	DB-E4x1	4C x 25	4C x 70	1	104
DB-E4x1	DB-E4x2	4C x 25	4C x 70	1	227
DB-E4x2	DB-E4x3	4C x 25	4C x 70	1	176

ii. *PV Connection*

The following table lists the cables proposed for PV connection to the existing LV distribution network.

From	To	No. of Runs	Cable size (Sq mm)	Length (M)
DB-C1	SCHOOL-PV	1	4C x 120	150
DB-E1	COUNCIL-PV	1	4C x 50	35

iii. *Modification/Replacement of LV distribution equipment*

Item Description	Quantity (Nos.)
Replacement of Existing Distribution Box (DB)	5
Modification of existing of Distribution Box (DB)	17
Replacement of existing Main LV distribution Board in Power House	1

2.17 B15 Vaikaradhoo Island

The island of Vaikaradhoo is located in the Haa Dhaalu Atoll. It stretches over 830 meters in length at a width of 600m. The urbanized area is in the central north part of the island. Mayor facility is the small harbour on the north-east side of the island.

Island code, name, atoll	B15 - Vaikaradhoo
Atoll name	Haa Dhaalu (HDh)
Utility	FENAKA
GPS coordinates	6°32'57.00"N ; 72°57'10.00"E
Inhabitants (approx.)	1807
Harbor type	Harbour

Table 48: B15 – Island identification and general data

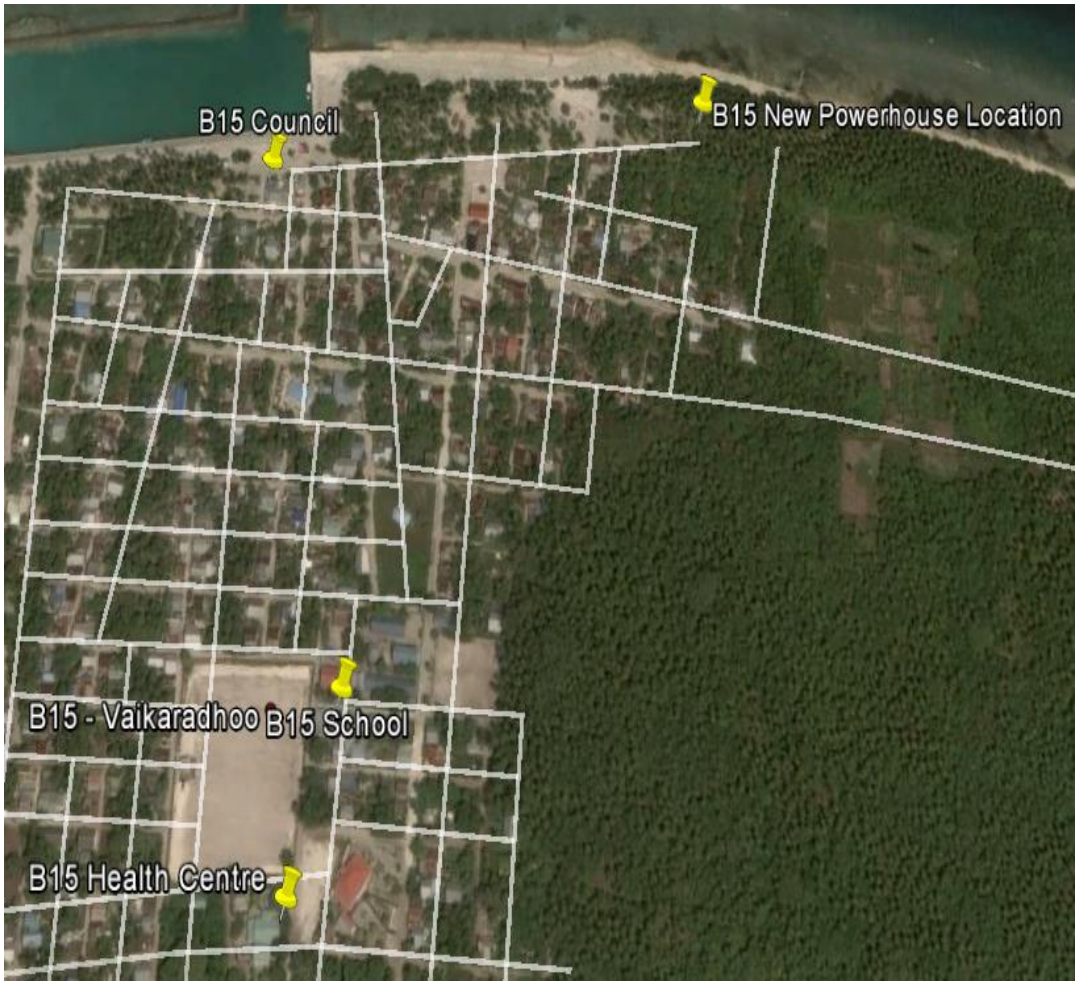


Figure 28: B15 - Location of the buildings with available roofs and of the powerhouse

2.17.1 Load profile

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

Figure 29 below. Based on the collected data the maximum average power consumption at 12:00 AM accounts for 80-90 kW, while minimum load reaches 60 kW at 08:00 AM. The utility expect a steadily increase of the load by 3%/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.

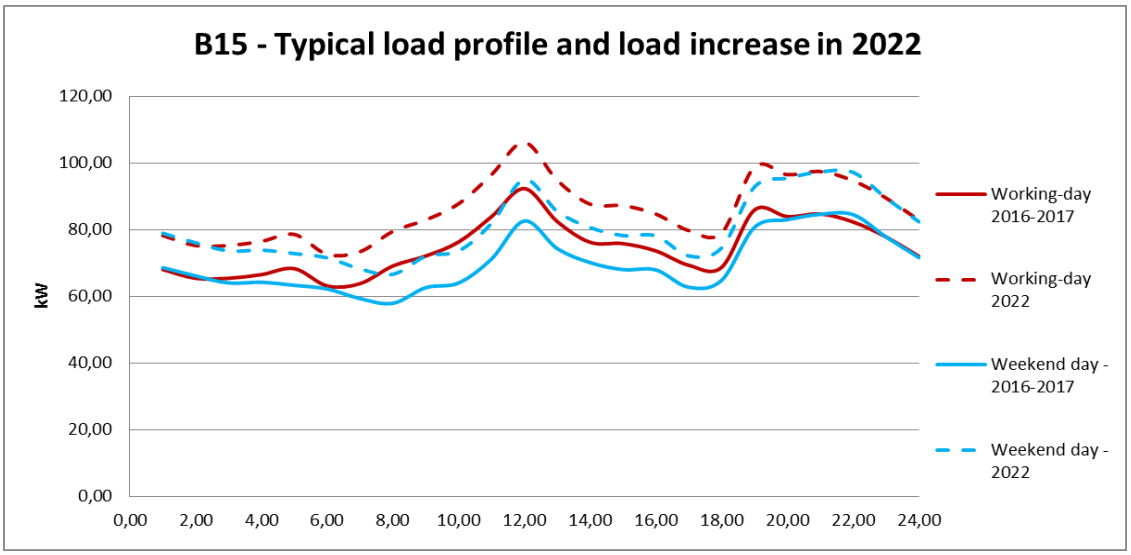


Figure 29: B15 - Typical daily load profile and evolution until 2022

	Average daily consumption [MWh/day]	Yearly consumption [MWh/yr]	Peak power [kW]
2017	1.76	641	114.36
2022	2.02	738	131.51

Table 49: B15 –Power consumption and peak power

2.17.2 Diesel generators

3 diesel generators of different sizes are installed on the island. Diesel generators 2 shall be integrated in the hybrid PV system.

A new 100kW (125kVA) diesel generator shall additionally be installed and implemented in the PV hybrid system.

The following diesel generators are currently used.

Item	Diesel Generator 1	Diesel Generator 2	Diesel Generator 3
Engine manufacturer & motor references	Cummins	Cummins	Cummins
Engine power rating (continuous)	250kW	160kW	120kW
Alternator power rating	312.5kVA	200kVA	150kVA

Item	Diesel Generator 1	Diesel Generator 2	Diesel Generator 3
Hours of operation / date of installation	13 Nov 2014	2008	1999
General maintenance performed	NO	YES / 08 FEB 2015	NO
Required upgrade / replacement	Too large for load profile: could be relocated to another island and replaced by a smaller genset for more efficient operation	-	To be replaced for 100kW

Table 50: B15 - Diesel generators currently installed

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).

Roof number	Building and name	Roof size X [mm]	Roof size Y [mm]	Slope [°]	Slope Direction	Distance to Powerhouse [m]	Maximum PV power [kWp]	Useable roofs	Maximum PV Capacity on selected roofs [kWp]
B15-1	Health Centre A1	7,146	20,000	20	355°N		6.5	X	6.5
B15-2	Health Centre A2	7,146	20,000	20	175°S		10.4	X	10.4
B15-5	Council A1	5,401	17,000	16	355 °N		7.8	X	7.8
B15-6	Council A2	5,401	13,000	16	175 °S		5.72	X	5.72
B15-7	School A1	3,810	36,577	29	N		10.92	X	10.92
B15-9	School B1	4,572	17,984	28	N		7.02	X	7.02
B15-10	School B2	4,572	17,984	28	S		5.46	X	5.46
B15-12	School C2	3,810	25,601	26	S		7.28	X	7.28
B15-13	School D1	3,810	24,384	25	N		6.76	X	6.76
B15-14	School D2	3,810	24,384	25	S		3.38	X	3.38
Summary									**71.24**

Table 51: B15 - Analysis of the available roofs and maximum PV power installable

2.17.4 Grid Infrastructure

2.17.4.1 *Electrical system*

a) Generation System

Generation: 400/230V Frequency: 50 Hz

Phase and type: three phase Wye, earthed neutral, four wire system

b) Distribution Network (LV)

The power house in Vaikaradhoo Island has 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 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*

Since the power house will be relocated, modifications related to grid upgrade are not envisaged in VIKARADHOO islands.

Existing main LV distribution board in the power house shall be replaced with the new LV distribution board in line with the conceptual schematic diagram given below.

S. No.	Drawing Number	Title
1	J431-GOPA-000-GR-E-D-0001	COCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (B15-VAIKARADHOO)

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 subsequent transportation of the same to a location identified by FENEKA.

The PV connection is proposed to be connected directly to the main LV distribution board of the power house.

2.17.4.3 *Schedule of Grid Infrastructure Modifications*

i. *Schedule of Cable Power House:*

The following table lists the cable proposed for the PV connections directly to the Main LV distribution board of the Power house.

From	To	No. of Runs	Cable size (Sq.mm)	Length (M)
COUNCIL-PV	Main LV Distribution Board in Power House	1	4C x 50	250
SCHOOL	Main LV Distribution Board in Power House	1	4C x 70	140
HEALTH CENTRE-PV	Main LV Distribution Board in Power House	1	4C x 50	340

Since the power house will be relocated, further modifications related to grid upgrade are not envisaged in VIKARADHOO islands.

ii. *Modification/Replacement of LV distribution equipment*

Item Description	Quantity (Nos.)
Replacement of Existing Main LV distribution Board in Power House	1

2.18 B17 Makunudhoo Island

The island of Makunudhoo is located in the Haa Dhaalu Atoll. It stretches over 1.800 meters in length at a width of 600m. The urbanized area is in the north part of the island. Mayor facility is the small harbour on the west side of the island.

Island code, name, atoll	B17 - Makunudhoo
Atoll name	Haa Dhaalu (HDh)
Utility	FENAKA
GPS coordinates	6°24'37.00"N ; 72°42'21.00"E
Inhabitants (approx.)	1608
Harbor type	Harbor

Table 52: B17 – Island identification and general data

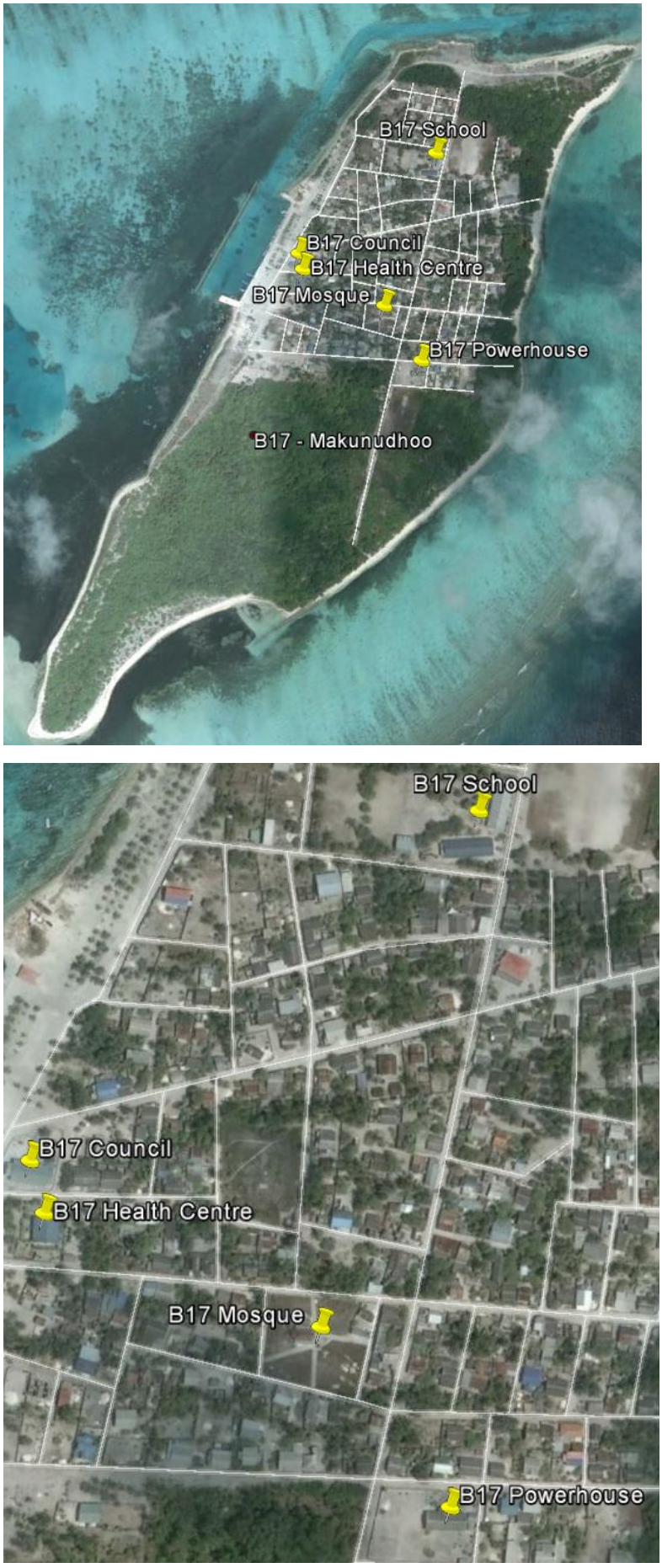


Figure 30: B17 - Location of the buildings with available roofs and of the power house

2.18.1 Load profile

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

Figure 31 below. Based on the collected data the maximum average power consumption at 12:00 AM accounts for 160 kW, while minimum load reaches 100 kW at 06:00 PM. The utility expect a steadily increase of the load by 5%/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.

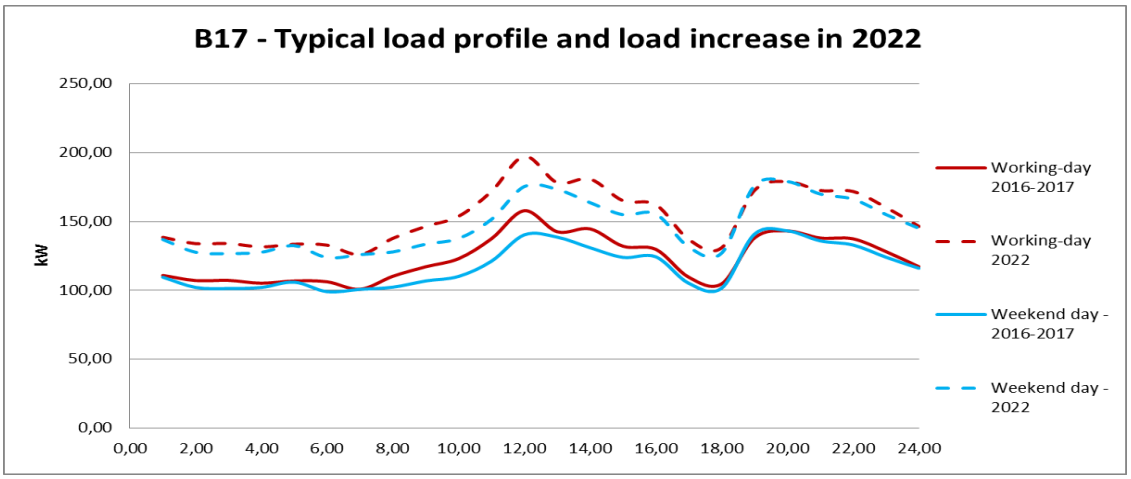


Figure 31: B17 - Typical daily load profile and evolution until 2022

	Average daily consumption [MWh/day]	Yearly consumption [MWh/yr]	Peak power [kW]
2017	2.92	1,065	195.42
2022	3.65	1,331	244.28

Table 53: B17 –Power consumption and peak power

2.18.2 Diesel generators

3 diesel generators of different sizes are installed on the island. Diesel generators 2 & 3 shall be integrated in the hybrid PV system.

A new 125kW (156kVA) diesel generator shall additionally be installed and implemented in the PV hybrid system.

The following diesel generators are currently used.

Item	Diesel Generator 1	Diesel Generator 2	Diesel Generator 3
Engine manufacturer & motor references	Cummins QSL9-G5	Cummins 6LTAA8-9G2	Cummins NTA855-G1B
Engine power rating (continuous)	236kW	200kW	250kW
Alternator power rating	295kVA	250kVA	312.5kVA
Hours of operation / date of installation	17/11/2011 11,200 hrs	5/3/2014 6,800 hrs	2/10/2014 4,600 hrs
General maintenance performed	Yes, 700hrs after Top Overhaul	No	No
Required upgrade / replacement	To be replaced (relocated) for new 125kW	-	-

Table 54: B17 - Diesel generators currently installed

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).

Roof number	Building and name	Roof size X [mm]	Roof size Y [mm]	Slope [°]	Slope Direction	Distance to Powerhouse [m]	Maximum PV power [kWp]	Useable roofs	Maximum PV Capacity on selected roofs [kWp]
B17-1	Health Centre A1	8,250	14,500	18	6°N	560	12.48	X	12.48
B17-2	Health Centre A2	8,250	14,500	18	188°S	560	12.48	X	12.48
B17-3	Council A1	6,000	22,200	16	8°N	590	12.48	X	12.48
B17-4	Council A2	6,000	22,200	16	194°S	590	6.24	X	6.24
B17-5	School A1	5,650	26,000	16	102°E	540	14.56	X	14.56
B17-6	School A2	5,650	26,000	16	281°W	540	14.56	X	14.56
B17-7	School B1	5,000	29,000	30	4°N	540	14.04	X	14.04
B17-8	School B2	5,000	29,000	30	183°S	540	14.04	X	14.04
B17-9	School C1	4,750	17,500	19	7°N	540	7.02	X	7.02
B17-10	School C2	4,750	17,500	19	185°S	540	7.02	X	7.02
Summary									**114.92**

Table 55: B17 - Analysis of the available roofs and maximum PV power installable

2.18.4 Grid Infrastructure

2.18.4.1 *Electrical system*

a) Generation System

Generation: 400/230V Frequency: 50 Hz

Phase and type: three phase Wye, earthed neutral, four wire system

b) Distribution Network (LV)

The power house in Makunudhoo Island has 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 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*

i. *The Contractor shall implement the grid upgrade works in Makunudhoo Island in line with drawings listed in the table below.*

S No.	Drawing Number	Title
1	J431-GOPA-025-GR-E-D-0001	NETWORK DIAGRAM FOR B17-MAKUNUDHOO
2	J431-GOPA-025-GR-E-S-0001	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (B17-MAKUNUDHOO)

ii. *This includes but not limited to the following works.*

a) Upgrade existing cable network for expected future load of 5kW for each distribution box

b) Modification or replacement of distribution boxes to accommodate the proposed higher size cables connection.

c) Modification or replacement of distribution boxes to accommodate new connection of proposed PV power plants.

d) 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 Makunudhoo Island.

i. *Schedule of Cables- Powerhouse:*

From	To	Existing Cable (Sq.mm)	Proposed Cable (Sq.mm)	No. of Runs	Length (M)
MAKUNUDHOO FEEDER-A	DB-A1	4C x 50	4C x 120	1	186
DB-A1	DB-A2	4C x 50	4C x 120	1	88
DB-A2	DB-A3	4C x 35	4C x 120	1	77
DB-A3	DB-A4	4C x 35	4C x 70	1	90
DB-A4	DB-A5	4C x 25	4C x 70	1	86
DB-A5	DB-A6	4C x 25	4C x 70	1	112
DB-A6	DB-A7	4C x 25	4C x 70	1	103
DB-A7	DB-A8	4C x 25	4C x 50	1	120
DB-A8	DB-A9	4C x 25	4C x 50	1	98
MAKUNUDHOO FEEDER-B	DB-B1	4C x 50	4C x 120	1	157
DB-B1	DB-B2	4C x 50	4C x 120	1	78
DB-B2	DB-B3	4C x 50	4C x 120	1	93
DB-B3	DB-B4	4C x 50	4C x 120	1	77
DB-B4	DB-B5	4C x 50	4C x 120	1	89
DB-B5	DB-B6	4C x 50	4C x 120	1	114

From	To	Existing Cable (Sq.mm)	Proposed Cable (Sq.mm)	No. of Runs	Length (M)
DB-B6	DB-B7	4C x 35	4C x 150	1	127
DB-B7	DB-B8	4C x35	4C x 150	1	126
DB-B8	DB-B9	4C x35	4C x 95	1	136
DB-B9	DB-B10	4C x 25	4C x 95	1	81
MAKUNUDHOO FEEDER-3	DB-C1	4C x 50	4C x 150	1	233
DB-C1	DB-C2	4C x 50	4C x 150	1	80
DB-C2	DB-C3	4C x 50	4C x 150	1	80
DB-C3	DB-C4	4C x 50	4C x 150	1	80
DB-C4	DB-C5	4C x 35	4C x 150	1	87
DB-C5	DB-C6	4C x 35	4C x 150	1	123
DB-C6	DB-C7	4C x 35	4C x 120	1	75
DB-C7	DB-C8	4C x 35	4C x 120	1	98
DB-C8	DB-C9	4C x 35	4C x 120	1	100
DB-C9	DB-C10	4C x 35	4C x 120	1	75
DB-C10	DB-C11	4C x 35	4C x 120	1	57
MAKUNUDHOO FEEDER-4	DB-D1	4C x 50	4C x 120	1	206
DB-D1	DB-D2	4C x 50	4C x 120	1	121
DB-D2	DB-D3	4C x 35	4C x 70	1	119
DB-D3	DB-D4	4C x 35	4C x 70	1	173
DB-D4	DB-D5	4C x 35	4C x 70	1	80
DB-D5	DB-D6	4C x 35	4C x 70	1	88
DB-D6	DB-D7	4C x 35	4C x 70	1	85
DB-D7	DB-D8	4C x 35	4C x 70	1	125
MAKUNUDHOO FEEDER-5	DB-E1	4C x 50	4C x 120	1	75
DB-E1	DB-E2	4C x 50	4C x 120	1	99
DB-E2	DB-E3	4C x 35	4C x 70	1	89
DB-E3	DB-E4	4C x 35	4C x 70	1	108
DB-E4	DB-E5	4C x 35	4C x 70	1	80

From	To	Existing Cable (Sq.mm)	Proposed Cable (Sq.mm)	No. of Runs	Length (M)
DB-E5	DB-E6	4C x 35	4C x 70	1	86
DB-E6	DB-E7	4C x 35	4C x 70	1	93
DB-E7	DB-E8	4C x 25	4C x 50	1	78
DB-E8	DB-E9	4C x 25	4C x 50	1	94

ii. PV Connection

The following table lists the cables proposed for PV connection to the existing LV distribution network.

From	To	No. of runs	Cable Size (sq.mm)	Length (M)
DB-B8	SCHOOL-PV	1	4C x 150	65
DB-E7	HEALTH CENTRE-PV	1	4C x 50	55
DB-E7	COUNCIL-PV	1	4C x 50	55

iii. Modification/Replacement of LV distribution equipment

Item Description	Quantity (Nos.)
Replacement of Existing Distribution Box (DB)	27
Modification of existing of Distribution Box (DB)	20
Replacement of Existing Main LV Distribution Board in Power House	1

3 Technical specifications

3.1 General

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

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.
- 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

3.2 Photovoltaic Power plant

3.2.1 Photovoltaic Modules

3.2.1.1 *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 2,23 MWp (+2.5%/-0%), distributed in 13 islands.

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

3.2.1.2 *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
- CE Certification

3.2.1.3 *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.

3.2.1.4 *Quality*

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).

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.

3.2.1.5 *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 allowed.

3.2.1.6 *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 3.8 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.

3.2.1.7 *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.

3.2.1.8 *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 Bidder 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.

3.2.2 DC Cabling

3.2.2.1 *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.

3.2.2.2 *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.

3.2.3 Mounting Structure

3.2.3.1 *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. In a few cases (if the available roof space is not sufficient) a free standing mounting structure, free standing shelter with PV module

mounting structure on top or offshore installation may be considered. This section focuses on roof top installations unless otherwise stated in Chapter 2.

3.2.3.2 *Materials and Installation*

Roof coverings, typically, are made out of corrugated sheets of standing-seam type or trapezoidal/box type profile.

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 20 years without any signs of visible corrosion.

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. In case of free standing PV module mounting structures the soil investigation results shall be considered as well.

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

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.

3.2.3.3 *Azimuth & Inclination*

The mounting structure shall be fixed mounted (no tracking system) and shall be orientated in the orientation of the roof slope as well as in the plane of the roof.

The Bidder shall submit the PV modules installation arrangement for Employer's approval.

3.2.3.4 *Cabling*

The mounting structure shall be provided with the adequate size/number of the 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.

3.2.4 PV Inverters

3.2.4.1 *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.

3.2.4.2 *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

3.2.4.3 *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.

3.2.4.4 *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 e.g. Underwriters Laboratories Inc. (UL) standard conformity.

3.2.4.5 *Euro-Efficiency of Inverter*

The minimum euro-efficiency of the proposed inverter shall be at least 98% (according to DIN EN 50524).

3.2.4.6 *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.

3.2.4.7 *Technical Concept*

Only string inverter concepts are allowed. The Tenderer 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.

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.
- Indoor installation in new building: In case where no existing building / room are available the Contractor shall build a new building for inverter housing.

The inverter room shall be equipped with redundant air conditioning units, light and plug.

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.

3.2.4.8 *Communication Protocol*

A proven communication protocol such as Profibus, Modbus, and Ethernet shall be provided by the Bidder. The selected communication protocol shall be compatible with PCMS according to Chapter 3.7. The inverter shall be able to be controlled by PCMS in order to reduce its output power if required to ensure the isolated grid stability.

3.2.4.9 *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 MPPT-Tracker. A combination of strings with different orientation or inclination on the same MPPT-Tracker will not be accepted. The Bidder is responsible to design the installation accordingly.

The Bidder 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 MPPT-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).

3.2.4.10 *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.

3.2.4.11 *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 Bidder 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

3.2.5 DC String Combiner Box / AC Distribution Box

3.2.5.1 *General*

This section describes the requirements for design, manufacturing, installation, testing and commissioning of the monitored 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 Tenderer shall complete the data sheet with all missing information for the proper planning, execution of construction work, commissioning, operation and maintenance.

3.2.5.2 *Components and Equipment*

The Contractor shall use DC junction boxes and DC distribution boxes as well as AC junction boxes and AC distribution boxes for interconnection of the PV plant.

All components and equipment of the DC/AC junction boxes shall be selected considering easy and long intervals maintenance 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 Contractor.

3.2.5.3 *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.

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

A specific number of strings shall be connected to one DC/AC junction box. Further connection to plant control and monitoring system is described in Volume II, 2.2 "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.

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/Engineer for approval.

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

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.

3.2.5.5 *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 (including "loop testing")
- Commissioning and test on completion

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

3.2.5.6 *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

3.2.6 Meteorological Station

3.2.6.1 *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.

3.2.6.2 *Technical Requirements for every island*

1. The following measurement equipment shall be provided for the meteorological station of the 12 islands of the atoll (all islands except B12 - Kulhudhuffushi) with the minimum requirements:
2. Global solar irradiation on horizontal plane (Reference cell):
    - Reference cell (same technology as used in PV power plant, suitable to be installed horizontally
3. Air temperature sensor
    - Overall accuracy: ± 0.5 °C
    - Metering range :- 40 to + 70 °C
    - Response time : 20 s (T90)
4. 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
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
    - Interface Base: RS 485 / RS 232 / Ethernet / Modbus(Must be compatible with SCADA system)
    - Standard protocol: ASCII / PROFIBUS / Modbus
    - Linearity: ± 0.005% 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 extreme climatic conditions on site

3.2.6.3 *Technical Requirements for island B12 Kulhudhuffushi*

6. The following measurement equipment shall be provided for the meteorological station of B12 - Kulhudhuffushi with the minimum requirements:
   - Two (2) pyranometers (ISO 9060 Secondary Standard), one for horizontal installation and 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
7. Air temperature
   - Overall accuracy: ± 0.5 °C
   - Metering range :- 40 to + 70 °C
   - Response time : 20 s (T90)
8. 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
9. 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

10. 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: ± 0.005% 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 extreme climatic conditions on site

3.2.6.4 *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

3.3 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.
- Round trip efficiency of inverter and battery combined shall be higher than 88%

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.

3.3.1 Batteries

In accordance with the defined system operation, the chosen batteries are of the li-ion type; the number of strings is one of the decision variables that shall be optimized in the simulation process by the Bidder.

The Bidder shall select the most suitable product to meet the rated and peak charge and discharge power with the lowest kWh installed. The maximum discharge rate shall not exceed 2C.

The most important parameters of the battery system are the discharge power and the durability of the system. The bidder will propose the most suitable solutions based on li-ion batteries to achieve at least the discharge power of the appropriate system mentioned in Chapter 2, Site Specification.

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 iithium-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.

The battery management system shall communicate via Modbus with the Main Hybrid Controller.

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

- The cycle DoD (Depth of Discharge) graph of the battery manufacturer shall be provided by the Bidder.
- The guaranteed cycle life (End of Life : 80% of initial capacity) shall be the following:
  - A minimum of 4.000 cycles at 80% of DoD at 25°C

and

- A minimum of 800 cycles at 80% of DoD at 25°C and

  a minimum of 1.500 cycles at 60% of DoD at 25°C and

  a minimum of 2.400 cycles at 40% of DoD at 25°C and

  a minimum of 3.500 cycles at 20% of DoD at 25°C

- 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.

Recycling of the battery: 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 Contractor shall provide a certificate proving that the Manufacturer agrees to receive and recycle the lithium-ion batteries according to international applicable standards.

3.3.2 Battery Inverters/Chargers

- The battery inverters shall be bidirectional and act as inverter and charger to batteries.
- The battery inverters must be able to deliver the required power as stated in Chapter 2 of each island in both directions.
- The overload capability of the inverter must be at least 150% of their nominal power for at least 5 min.
- Minimum conversion efficiency: ≥96%
- 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.
- For island B04 and B06 inverters must be grid building. For all other islands inverters can be grid building or grid supporting.
- 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.

3.3.3 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. In case of power house re-allocation as for islands B04 Finey Island and B15 Vaikaradhoo Island a pre-wired ISO-Container shall be provided for battery housing. The Following specifications have to be full filled:

- 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 system. Any failure in the air conditioning system must be communicated to the operator via a control system.
- 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 3.6.

3.3.4 Protections

3.3.4.1 *AC protections*

- AC overvoltage protection
- EMI filter
- Grid voltage variations

- Frequency failures
- Asymmetric currents
- Voltage sag compensation

3.3.4.2 *DC protections*

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

3.3.4.3 *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

3.4 Diesel power plant

3.4.1 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.

3.4.2 Diesel engine operation

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 specification, 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.

3.4.3 Controllers and generator synchronization

Existing diesel generator controllers shall be exchanged 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.

They shall be able to communicate via Modbus and 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

3.4.4 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% loading
NOx (mg/Nm³)	3,682.44
CO (mg/Nm³)	702.03
HC (mg/Nm³)	70.20

- Flow meters to measure the consumed fuel at each Generator shall be installed with all existing and new gensets. The flow meters shall be digital and integrated in the PCMS.

3.4.5 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 56: 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/Engineer. 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/Engineer.
- 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

3.4.6 Standards

The Diesel Generator shall be compliant with the following standards:

- ISO 8528-1 (continuous power)
- BS 4999
- BS 5000
- IEC60034
- BSEN 61000
- IEC60034
- UTE NFC51.111
- VDE 0530
- BS4999/5000
- NEMA MG 1-33

3.5 Distribution Grid

3.5.1 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.

3.5.2 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

3.5.3 Alternative Codes and Standards

The Bidder/Contractor 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.

3.5.4 Project Requirements

Detailed site survey, data collection including condition assessment of distribution boxes, LV distribution boards and other related equipment.

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 existing main distribution network 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 licensed by MEA or under the direct supervision of an electrical engineer licensed by MEA. Similarly mechanical and civil works shall be carried out by qualified personnel approved by relevant government authority (MEA, MHI etc.) to the satisfaction of the Employer's Representative.

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.

3.5.5 Components and Material Requirements

3.5.5.1 *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.

3.5.5.2 *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
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

Equipment	Type of Label	Remarks/Function
Underground cable entry and exit from ground	PVC acceptable	"Danger Underground Cable" with red flash on white background

3.5.6 Distribution Boxes (DBs)

3.5.6.1 *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

3.5.6.2 *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)

3.5.6.3 *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.

3.5.6.4 *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.

3.5.6.5 *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.

3.5.6.6 *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.

3.5.6.7 *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.

3.5.6.8 *Factory Assembly*

The distribution boxes shall be factory assembled and tested.

3.5.7 Low Voltage Armoured Cables

3.5.7.1 *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.

3.5.7.2 *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.

3.5.7.3 *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.

3.5.7.4 *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.

3.5.7.5 *Laying Up*

The cores of cable shall be laid with right hand direction of lay. Where necessary, non-hygroscopic fillers shall be applied

3.5.7.6 *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.

3.5.7.7 *Armour*

Armour shall consist of single layer of galvanised round steel wire. The armour shall be applied over the PVC bedding.

3.5.7.8 *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 ---- ----

3.5.7.9 *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).

3.5.8 LV Distribution board

3.5.8.1 *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.

3.5.8.2 *General Arrangement*

All wiring shall be internal. Either upright or desk type panels are permitted.

3.5.8.3 *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.

3.5.8.4 *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.

3.5.8.5 *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.

3.5.8.6 *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.

3.5.8.7 *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.

3.5.8.8 *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.

3.5.8.9 *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.

3.5.8.10 *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

3.5.8.11 *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

3.5.8.12 *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.

3.5.8.13 *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
Black	A.C. neutral connections, earthed or unearthed, connected to the secondary circuits of current and voltage transformers
Green with yellow stripes	Connections to earth

Color	Description
Grey	Connections in D.C. circuits
Any other colors	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.

3.5.8.14 *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.

3.5.8.15 *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.

3.5.8.16 *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.

3.5.9 Installation

3.5.9.1 *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.

3.5.9.2 *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.

3.5.9.3 *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.

3.5.9.4 *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, 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.

3.5.9.5 *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.

3.5.10 Commissioning and Acceptance Tests

3.5.10.1 *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.

3.5.10.2 *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.

3.5.11 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

3.5.12 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.

3.6 Civil and Mechanical requirements

3.6.1 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.

3.6.2 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.

3.6.3 Earthworks

3.6.3.1 *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.

3.6.3.2 *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

3.6.3.3 *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.

3.6.3.4 *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.

3.6.3.5 *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.

3.6.4 Foundations

3.6.4.1 *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.

3.6.4.2 *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.

3.6.4.3 *Design Criteria for Layout, Arrangement, Drawings, Execution*

3.6.4.4 *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.

3.6.4.5 *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.

3.6.5 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.

3.6.5.1 *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.

3.6.5.2 *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.

3.6.5.3 *Concreting Workmanship*

3.6.5.3.1 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.

3.6.5.3.2 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.

3.6.5.3.3 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.

3.6.5.3.4 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.

3.6.5.3.5 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.

3.6.5.3.6 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.

3.6.6 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.

3.6.6.1 *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.

3.6.6.2 *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;

3.6.7 Structural Steel Work

3.6.7.1 *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.

3.6.7.2 *Workmanship*

3.6.7.2.1 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.

3.6.7.2.2 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 EPC 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 EPC Contractor shall make all necessary expansion joints. Movement shall be made possible by providing double columns.

The EPC 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.

3.6.7.2.3 Erection Program

Before starting the execution of the works, the EPC Contractor shall furnish a detailed programme according to the general time schedule. Each month the EPC Contractor shall provide a progress report in duplicate to the Employer, indicating the progress of work.

The EPC Contractor shall be solely responsible for the accuracy of all relevant dimensions of the structure.

3.6.7.2.4 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.

3.6.8 Brickwork

3.6.8.1 *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.

3.6.8.2 *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.

3.6.8.3 *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.

3.6.8.4 *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.

3.6.9 Painting

Subject of this specification are external paints on plaster and concrete as well as internal paints on plaster, concrete, gypsum and metal.

3.6.9.1 *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.

3.6.9.2 *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.

3.6.10 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.

3.6.11 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.

3.7 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.

It is within the scope and responsibility of the EPC 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.

3.7.1 General Requirements

3.7.1.1 *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.

3.7.1.2 *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 EPC.

All required interfaces and switches shall be included and provided by the Bidder.

3.7.1.3 *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,

3.7.1.4 *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.

3.7.1.5 *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.

3.7.2 Main functionality

3.7.2.1 *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.

3.7.2.2 *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.

3.7.2.3 *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.

3.7.2.4 *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.

3.7.2.5 *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.

3.7.2.6 *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.

3.7.2.7 *System functionality for type B hybrid system on a sunny weather day scenario (no clouds):*

In the morning when the sun rises, the battery will be at a predefined and from the operator adjustable value SOC_{night}, which allows the system to use the maximum battery inverter capacity for a predefined and adjustable amount of time that is needed to start a new genset.

The PV modules start to produce electricity and the inverters feed it into the grid. Once there is enough PV power that a smaller genset and the available PV power is sufficient to serve the loads, the PCMS shall switch the gensets accordingly. This shall continue until the smallest genset is running at minimum partial load. If there is still more power available from the PV, the battery shall be charged to the maximum SOC allowed. This SOC_{max} shall be variable and adjustable by the operator. If still more PV is available, the PCMS shall regulate the PV in order to keep the grid balanced. If sudden changes occur, where PV regulation is not fast enough, the battery system and as a last option the genset shall provide energy to the system in order to keep system stability.

When PV power starts to slowly decrease after midday, the generator shall increase its power until the generator reaches its maximum power output and an additional or bigger genset is started. This goes on until the PV power is zero.

At the end of the day, the Battery will provide power to the grid until the SOC_{night} is reached. The battery shall not be used during the night. During the night, the PV inverters as well as the battery inverters shall be used to provide reactive power to the grid. The genset shall provide the active and reactive power which is additionally needed.

3.7.2.8 *System functionality for type B hybrid system on a cloudy weather day scenario:*

When a sudden drop of PV due to clouds, a load increase or both at the same time occur, the required energy in the system might be higher than the possible available energy of the genset and the solar together.

In this case the battery shall provide the additionally needed energy for as long as either the solar power rises again or an additional genset is started.

The decision of the PCMS when to start an additional genset shall be dependent on several factors as ongoing energy shortage time, battery SOC, Ramp rate of sudden power demand and available spinning reserve in the genset. If an additional genset is started and after a while PV power rises again, the genset will lower its power again until it reaches its minimum possible load. If there is still more PV power available, then the battery shall be charged up to a variable and from the operator adjustable SOC_{ready}.

Once SOC_{ready} is reached again, and there is enough PV power available to run the system with a smaller genset, the running genset shall be turned off or switched for a smaller one again.

A frequent switching on and off of the gensets shall be avoided. A minimum running time for a once started genset shall be defined.

Apart from the above described functions, the battery system shall only be used if a predefined and adjustable ramp rate (kW/sec) is exceeded. Load changes that are slower shall be compensated by the genset and the PV system.

3.7.2.9 *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.

3.7.3 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).

3.7.3.1 *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

3.7.3.2 *Over-Voltage Protection*

Those parts of the system that are electrically connected to cables leaving a building shall be fitted with over-voltage protection.

3.7.3.3 *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.

3.7.3.4 *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.

3.7.3.5 *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

3.7.3.6 *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.

3.7.3.7 *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.

3.7.3.8 *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.

3.7.4 Alarm and Event Management

3.7.4.1 *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.

Old pages can be recalled by operator at any time. If any new alarm appears while monitoring an old page, flashing signal on the screen shall warn the operator to return to the first page.

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.

3.7.4.2 *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.

3.7.5 Data Communication Network

The PCMS shall have the communication via Modbus TCP to all energy producers, respectively Diesel gensets, 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 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.

3.7.6 Power Supply & Cabling

3.7.6.1 *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

3.7.6.2 *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.

3.7.6.3 *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.

3.7.6.4 *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.

3.7.6.5 *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.

3.7.6.6 *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

3.7.6.7 *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.

3.7.6.8 *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

3.8 Utility compatibility

3.8.1 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.

3.8.2 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.

3.8.3 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.

3.8.4 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.

3.8.5 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).

3.8.6 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 %

3.8.7 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.

3.8.8 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°.

3.8.9 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	3^{rd} 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.

3.9 Earthing

3.9.1 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 3.9.2. 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 (In general, it is advantageous to locate all equipment as close as possible together to minimise voltage drop losses and to simplify earthing issues.)

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 3.10 Lightning Protection), but it is anticipated that for the current system configurations all within one building that no additional protection will be required.

3.9.2 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 300mm. If necessary, several spikes shall be interconnected as a trench earth to achieve the required resistance.

16mm2 bare copper straps shall be used as earth straps to bind components to the earth electrode, No loops should 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.

3.9.3 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 array structure shall always be bonded directly to its own earth electrode. The bonding material shall be minimum 16mm2 XSA bare copper straps.
- For multiple PV arrays, it is recommended that a trench earth be used to bond the individual earth spikes together underground.

Continuity between the module frames and the mounting structure shall be maintained.

3.9.4 Equipment Earthing and Bonding

All metal other equipment and casings (as outlined below) shall be bonded together, as they are inter-connected by the power cables. The bonding shall be made using copper conductors of 10mm2 XSA minimum. A separate conductor shall be used specifically for that purpose.

- The array structure shall be bonded directly to the main earth electrode with a resistance of less than 1.7ohms.
- The inverter casings shall be bonded (directly or indirectly) to the main earth electrode with a resistance of less than 1.7ohms.
- The resistance between any enclosures in any one location, shall be less than 0.2 ohms.
- The earth resistance of the earth electrode shall be less than 10ohms.

3.10 Lightning 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 shall be provided. The surge arrestors shall be installed in the DC distribution box.

- 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.

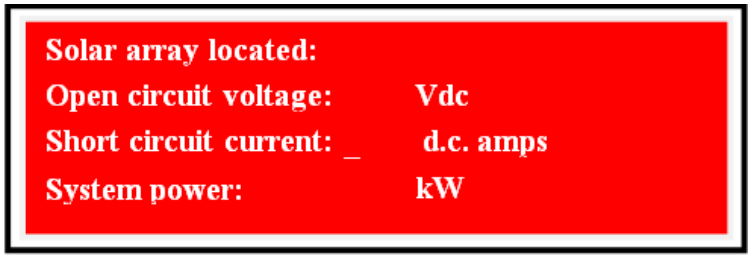
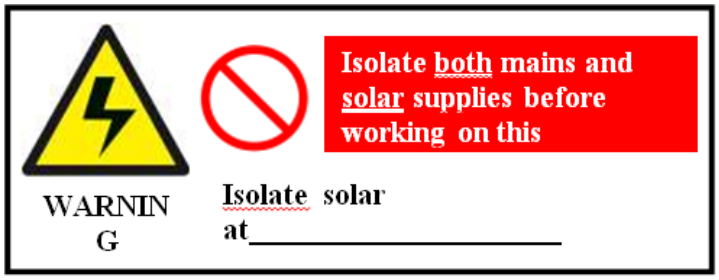
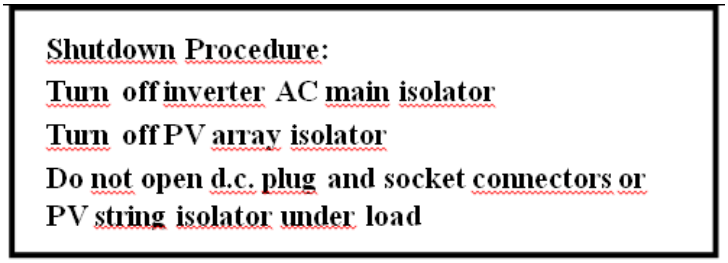
The surge arrestors shall be of class 2 with visual fault indication, 40kA (8/20) according to IEC 61643-1 for sensitive electronics, clamping voltage to less than 1,500V. Units with replaceable LP modules are required.

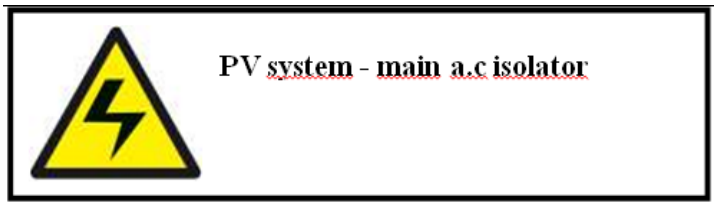
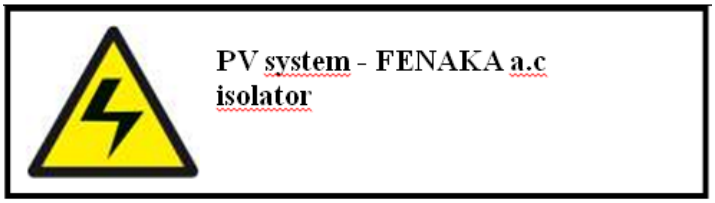
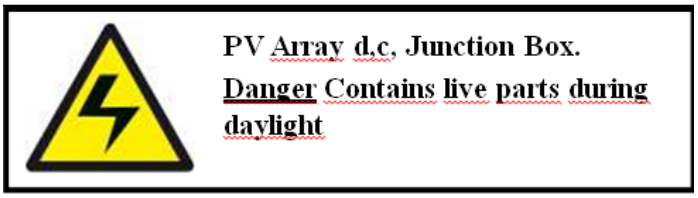
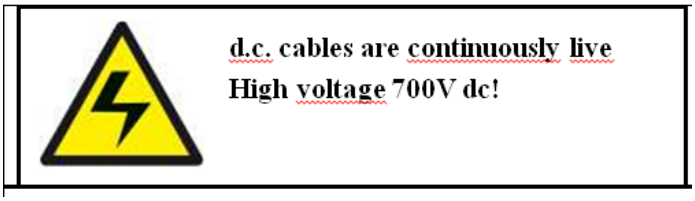
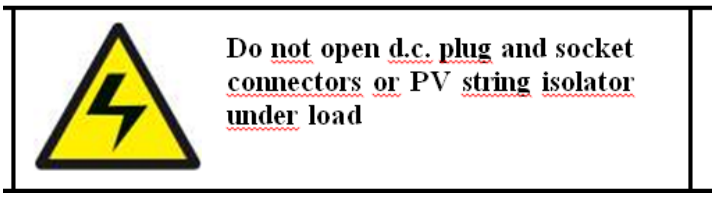
3.11 Labelling, safety signs and notices

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	
• Inverter • Inverter DB	3	

Locations	Sign number	Example design
• Main DB	4	
• Tx Breaker cubicle	5	
• PV Array JB	6	
• PV array JB • Inverter DB • Long DC cable runs from array JB to inverter	7	
• Roof top locations • PV Array JB	8	

3.12 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 must be screened from emitting electromagnetic interference.

No equipment may generate any radio interference with other equipment or systems and all equipment must be suppressed to prevent interference of commercial radio and TV reception. The equipment and methods used in determining the acceptable levels of radio interference must be as specified in IEC CISPR 22.6

3.13 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).

3.13.1 Cold Commissioning: Testing of the PV Plant

The verification of the Commissioning tests will be based at least on the latest published testing procedure IEC 62446: 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.

3.13.2 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

3.13.3 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.

3.13.4 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.

3.14 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.

3.14.1 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.

3.14.2 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 EPC 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.

3.14.3 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

3.14.4 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

3.15 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 13 construction sides 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.

The training must be translated into local language Dhivehi

Every attendant must receive a training documentation/handbook, where the training subjects are documented in detail.

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

3.16 O&M Requirements during the one year Defect Liability period

3.16.1 Plant operation and control

Bidder shall be responsible for the daily operation of the plant to satisfy energy delivery and provide technical and engineering support. 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 regarding the operation of the plant including electricity production, efficiency, fuel consumption, availability, maintenance performed.

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.

Bidder shall carry out and/or manage all planned overhaul maintenance of the plant, including major overhauls and inspections. 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.

3.16.2 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.

3.16.3 PV Plant specific maintenance activities

The PV plant scope of work shall comprise the following activities:

- Inspection and testing according to IEC 62446. 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.

3.16.4 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.

3.17 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.

4 Drawings

The following drawings are provided in attachment to the present Volume 6.

S No.	Drawing Number	Title
General Design		
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	J431-GOPA-GEN-GR-E-D-0004	CROSS SECTIONAL VIEW OF INDICATIVE CABLE TRENCH (COMMON)

S No.	Drawing Number	Title
Tender Design		
1	J431-GOPA-029-GR-E-D-0001	NET WORK DIAGRAM FOR B03-HANIMAADHOO POWER HOUSE
2	J431-GOPA-029-GR-E-D-0002	NET WORK DIAGRAM FOR B03-HANIMAADHOO SUBSTATION
3	J431-GOPA-008-GR-E-S-0001	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (B04-FINEY)
4	J431-GOPA-014-GR-E-D-0001	NET WORK DIAGRAM FOR B05-NAIVAADHOO
5	J431-GOPA-014-GR-E-S-0001	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (B05-NAIVAADHOO)
6	J431-GOPA-007-GR-E-D-0001	NET WORK DIAGRAM FOR B06-HIRIMARADHOO
7	J431-GOPA-007-GR-E-S-0001	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (B06-HIRIMARADHOO)
8	J431-GOPA-023-GR-E-D-0001	NET WORK DIAGRAM FOR B07-NOLHIVARAMFARU
9	J431-GOPA-023-GR-E-S-0001	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (B07-NOLHIVARAMFARU)
10	J431-GOPA-021-GR-E-D-0001	NET WORK DIAGRAM FOR B08-NELLAIDHOO

S No.	Drawing Number	Title
11	J431-GOPA-021-GR-E-S-0001	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (B08-NELLAIDHOO)
12	J431-GOPA-024-GR-E-D-0001	NET WORK DIAGRAM FOR B09-NOLHIVARAM
13	J431-GOPA-024-GR-E-S-0001	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (B09-NOLHIVARAM)
14	J431-GOPA-017-GR-E-D-0001	NET WORK DIAGRAM FOR B10-KURINBI
15	J431-GOPA-017-GR-E-S-0001	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (B10-KURINBI)
16	J431-GOPA-032-GR-E-D-0001	NET WORK DIAGRAM FOR B12-KULHUDHUFFUSHI - SUBSTATION 01
17	J431-GOPA-032-GR-E-D-0002	NET WORK DIAGRAM FOR B12-KULHUDHUFFUSHI - SUBSTATION 02
18	J431-GOPA-032-GR-E-D-0003	NET WORK DIAGRAM FOR B12-KULHUDHUFFUSHI- SUBSTATION 03
19	J431-GOPA-032-GR-E-S-0002	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF SUBSTATION 03 (B12-KULHUDHUFFUSHI)
20	J431-GOPA-032-GR-E-D-0004	NET WORK DIAGRAM FOR B12-KULHUDHUFUSHI - SUBSTATION 04
21	J431-GOPA-032-GR-E-S-0003	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF SUBSTATION 04 (B12-KULHUDHUFFUSHI)
22	J431-GOPA-032-GR-E-D-0005	NET WORK DIAGRAM FOR B12-KULHUDHUFUSHI - SUBSTATION 05
23	J431-GOPA-032-GR-E-S-0004	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF SUBSTATION 05 (B12-KULHUDHUFFUSHI)
24	J431-GOPA-032-GR-E-S-0001	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (B12-KULHUDHUFFUSHI)
25	J431-GOPA-032-GR-E-S-0005	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF PORT SUBSTATION (B12-KULHUDHUFFUSHI)
26	J431-GOPA-019-GR-E-D-0001	NET WORK DIAGRAM FOR B13-KUMUNDHOO
27	J431-GOPA-019-GR-E-S-0001	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (B13-KUMUNDHOO)
28	J431-GOPA-020-GR-E-D-0001	NET WORK DIAGRAM FOR B14-NEYKURENDHOO

S No.	Drawing Number	Title
29	J431-GOPA-020-GR-E-S-0001	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (B14-NEYKURENDHOO)
30	J431-GOPA-000-GR-E-S-0001	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (B-15VAIKARADHOO)
31	J431-GOPA-025-GR-E-D-0001	NET WORK DIAGRAM FOR B17-MAKUNUDHOO
32	J431-GOPA-025-GR-E-S-0001	CONCEPTUAL SCHEMATIC DIAGRAM FOR LV DISTRIBUTION BOARD OF POWER HOUSE (B17-MAKUNUDHOO)

5 Supplementary Information

The following supplementary information's are provided in attachment to the present Volume 6.

S No.	Title
1	KMZ file of roofs for PV installation
2	List of Signals required for centralized SCADA System

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.

11. Description of the Facilities or part thereof: [. . . *description* . . . .]

12. 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.

13. Description of the Facilities or part thereof: [. . . *description* . . .]

14. 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		