**Section 6.1 - Employer’s Requirements**

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**ABBREVIATIONS**

|  |  |  |
| --- | --- | --- |
| **AC** | – | Alternate Current |
| **ADB** | – | Asian Development Bank |
| **CAPEX** | – | Capital Expenditure. |
| **DC** | – | Direct Current |
| **BESS** | – | Battery Energy Storage System. |
| **BPCS** | – | Battery Power Conditioning System |
| **FENAKA** | \_ | Utility for electricity, water and sanitation |
| **GUI** | – | Graphical User Interface |
| **RE** | – | Renewable Energy. |
| **PCMS** | – | Powe Plant Control and Monitoring System |
| **PV** | \_ | Photovoltaic |
| **SCADA** | \_ | Supervisory control and data acquisition |
| **SWA** | – | Steel wire armoured |

**WEIGHTS AND MEASURES**

|  |  |  |
| --- | --- | --- |
| **kW** | – | Kilowatt |
| **kWh** | – | kilowatt-hour |
| **MW** | – | megawatt (1,000 kilowatts) |

# Haa Alif Atoll Technical specifications

## General

The following sections describe the techncial specification for design, manufacturing, installation, testing and commissioning of all components related to the hybrid genset-PV solar system and grid improvement on 14 islands located in the Ha Alif Atoll, Maldives.

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 and grid improvement including positioning of PV modules on each location separate with mounting structure, positioning of inverters, conrollers, transformer, meteorological measurement station and grid connection of PV solar system. A two-dimensional drawing in PDF format is required.
* A general Singel Line Diagramm (SLD)
* Main distribution network diagram
* MV distribution network layout, if applicable
* Sizing calculations
* Cable schedules
* Modification design
* Simulation with PVsyst

# Photovoltaic Modules

## General

### The PV Plant shall be deployed by implementing crystalline silicon. PV modules shall be selected according to the following minimum requirements.

## 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:

* IEC 61215 Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval
* IEC 61730 PV module safety qualification
* IEC 61701 Salt mist corrosion testing of photovoltaic (PV) modules

### The Manufacturer shall be certified according to international Quality and environment Management System Standards ISO9001, ISO14001.

### The manufacturer shall demonstrate the previous supply of modules for large PV power plants (20MW as minimum DC power rate) plants in three continents Europe, America and Asia.

### Proposed module manufacturer shall have a minimum production capacity of 50 MWp for offered or higher capacity model in the year 2015

## Size and rating

### Individual modules shall be at least 250Wp in power output. Minimum module efficiency of mono-crystalline modules:16%; Minimum module efficiency of multi-crystalline modules:15%

### The tolerance of rated output of the PV modules offered may not be larger than 5%, and all tolerance shall be greater than rated. No negative tolerances are allowed

### Modules shall not require any positive or negative grounding

### Temperature coefficient rated power of -0.45%/°C or lower (e.g. -0.44%/°C is defined as lower)

### Module must resist ambient conditions of Section 6.0 paragraph 2.3

### All PV modules within an array shall be of the same type and hence interchangeable. Only one size and model should be used for all sites

### Efficiency / weight on the roof is a consideration for these installations, and therefore module rating of less than 110kg/kWp is desirable. Module efficiency should be more than 145Wp per m2, or less than 6.8m2 per 1kWp. The modules will have high performance under low light conditions, cloudy days, mornings and evenings

### The modules can bear wind loads of at least 2400Pa

## Product and Power Warranty

### Product and workmanship warranty of at least 10 years

### Power output warranty for 25 years of operation based on the nominal module output power (nameplate) with a maximum initial degradation of 2.5% after the first year and a linear degradation during the following 24 years with a minimum output power of 80%

## Module framing

#### The module framing 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.

#### Frames shall be compatible with both the roof mount structure, and compatible with the earthing requirements of section 12.

## Terminal connections

### Modules shall be provided with 14-12 AWG (2- 4mm2) flyleads length approximately 800mm with weather-proof connectors for interconnection of modules into strings without any additional wiring.

## Bypass diodes

### Bypass diodes should be installed in each module to prevent hot-spots in modules, which occur often as a result of partial shading of modules. The bidder shall ensure that every module in a series string of more than 24V nominal voltage, shall include bypass diodes in the module terminal-connection box. The diodes shall be replaceable without replacing the module or module junction-box.

## Labelling and data

### Each module must be labelled indicating at a minimum:

* Manufacturer, Model Number, Serial Number,
* Maximum Power Point Watt Rating (Wp ± tolerance),
* Maximum Power Point Current,
* Maximum Power Point Voltage,
* Open Circuit Voltage and Short Circuit Current of each module.

### The supplier is required to provide for each PV Module type offered the following data:

* Equipment Origin, Type of Certification, and the following data
* I-V Curves at AMx.x, NOCT,
* Temperature coefficients dV/dT, dI/dT, etc
* Dimensions,
* Warranty.

Factory flash test information for each individual module shall be provided on request.

## DC Cabling

### Modules Interconnectors and cabling: Modules shall be provided with 14 to 12 AWG (2.0 to 4mm2) flyleads length approximately 800mm with weather-proof connectors for interconnection of modules into strings without any additional wiring. Only one type of quick connect plug (male and female) may be used for the installation as a whole. Any additional connectors plus the necessary crimping tools shall be provided.

### There are a multitude of professional PV array quick connectors available for array flyleads cables in the 2-4mm2 range, for example Multi-Contact™, Tyco™, SunClix™.

### The connectors shall have the following features:

* Class II rating for flyleads and connectors
* System voltage 1,000V maximum,
* IP65 protection rating
* temperature up to 90oC
* 20A current rating
* 2.5-4mm2 cables
* Snapping locking system

### PV Modules Interconnection: Wiring shall be permanently shaded from UV radiation. Wiring shall be ‘Flexible multi-strand copper conductor cables in flexible UV resistant (e.g. Neoprene) sheath compatible with gland seals’, with any array junction boxes as may be required. The arrangement of modules on the structure, and their interconnection is designed to enhance servicing and inspection.

### Series strings and strings fuses or blocking diodes: Series string fuses are required where four or more parallel sub-array strings are combined within an Array JB into a single array. In this case series string fuses are required in the Array JB on both the positive and negative cables of each string). The string fuse ratings shall be less than Isc x 2 (Amperes).

### When 3 sub-array strings are paralled then the modules must withstand Isc x 2 x 1.15 reverse current if fuses are not used.

### Blocking diodes may not be used in place of string fuses.

## Array junction box

### Each series string of modules shall be connected to its inverter via an array junction box with an isolation switch (and lightning protection if required). The junction boxes or enclosure shall be capable of dissipating the heat generated by internal components (i.e string fuses if used). The array junction box shall be to IP65 rating, and only corrosion resistant PVC boxes shall be accepted for external usage. The junction box shall be provided with internal DIN-rail type electrical connectors. The type of wiring and arrangement of wiring within the junction box should facilitate maintenance and inspection of connections, and meet Class II electrical separation between positive and negative polarities. It shall be clearly labeled internally.

### In any array junction boxes, no more than one cable per gland shall be allowed, and the cable entries shall be watertight. Junction boxes must be accessibly, securely and squarely mounted on the array structure, out of easy access range of tampering and whenever possible in the shade of the PV array.

### Array cabling: Any array cabling for strings, sub-arrays and the complete array shall be firmly attached to the array frame out of direct sunlight and away from easy access by vandals.

### To avoid inductive surges the DC cables shall be bundled together as to minimize the electric field. The positive and the negative string conductors shall be routed with a maximum gap of 100mm. Long DC cable runs to be in earthed metallic cable trays to attenuate surge suppression.

## Mounting Structure

### The PV systems shall be installed on modular array structures, mounted onto the roofs of the sites, on the buildings and roof areas specified.

### The roofs are in all cases corrugated sheets of standing-seam type or trapezoidal/box type profile (typically MSP Seadeck roof sheets profile 26.5mm high, 26,0mm top edge, and 60mm at base, but dimensions and profiles of sheets to be confirmed by Supplier prior to order).

## Structure Assembly

### General Requirements: The array support structures shall be non-tracking (fixed), after installation. The tilt angle to the horizontal shall be in the plane of the roof sheets. The complete structure shall withstand wind speeds of 100km/hr. The height of the lowest part of any module from the roof shall be 100mm and maximum 200mm to provide for sufficient ventilation of the modules.

### The array structure shall comprise of two main components supplied by the bidder:

* Array roof attachment: the means of attachment shall be multiple mountings onto the corrugated roof sheet profiles for better weight distribution, and not attached to the rafters themselves. A clamp type system or specialised system compatible with the trapezoidal roof sheet profiles shall be used with inbuilt waterproofing mechanisms, and are subject to approval of the Purchaser. Any attachments requiring drilling into the roof sheets, purlins or trusses shall require special prior approval. The array mounting superstructure shall be bolted to these roof attachments.
* Array mounting superstructure: a standard approved anodised aluminium array mounting structure or profile for clamp-mounting of modules (refer for example, to Gracesolar™, Schletter™ systems or any other approved substantially functionally equivalent methods).

### All aluminium shall be anodised. Any damage shall be treated. Any contact between unlike materials shall be avoided by using insulation between any aluminium and galvanise roof sections. Stainless steel nuts and bolts shall be used for holding the components together.

### The array support frames and mounting superstructure shall be provided in several identical sections (or sub-arrays) to allow for any thermal expansions and contractions.

### The structure assembly shall accommodate such cable trunking and any array junction boxes as may be required to meet the specification requirements for module interconnection stipulated in section 2.9.1 of this document.

### The structure shall include attachment places for removable safety barriers, which would be used on a temporary basis while installing and servicing the arrays, and then removed again for future reuse.

### Module clamp mounting: Each panel shall be attached to the array mounting super-structure in four places using the clamp- mount method on the module frames, and the panel shall not itself form part of the support structure, to prevent torsional forces on the panel. The mounting structure and clamping arrangement shall be sufficiently versatile to accommodate the panels.

### The structure and clamp mounting arrangements shall be compatible with the earthing requirements stipulated in section 12 of this document. Earthing clamps may additionally be required.

### The bidder shall supply all necessary fasteners and accessories for mounting the array to the super-structure, and for mounting the super-structure to the roofs may be applicable.

* All nuts, bolts and washers shall be stainless steel, and any other mounting material shall be of corrosion resistant material.
* The clamps for fixing the modules onto the structure should be anodised aluminium with stainless steel bolts, and should be tamper-proof and require a unique allen key or similar device for loosening.

### Finalization of design: A provisional design of the structure is to be submitted with this tender showing strength and size of metal structures, cross-connectors and module brackets. The successful bidder is obliged to provide a final design of the PV array structure and the module layout to the Purchaser for approval prior to finalization.

## Installation of Array Structure

### Orientation and Tilt of the PV Array Site:The structure should be orientated in the orientation of the roof slope for maximum aesthetic appeal, and in the plane of the roof. The optimal solar tilt angle is 5%, but a tilt in the plane of the roof should be used, with minimal solar losses.

### The array shall be installed with sufficient space from edges, so that the after installation the array does not interfere with the roof horizon and there is space for access around sub-array edges.

### Selection of the PV Array Site: The PV arrays shall be installed as per the site layout diagrams to be provided. The structure and location shall allow for unobstructed solar view, there should be no shading on any part of the array at any time of the day, in any season. Consideration should be given to possible future shading by vegetation growth (e.g. the position of young trees) over the system lifetime.

## Quality of Installation

### Roof mount structure: Aluminium clamps onto galvanised roof sheets usually require rubber insulating compound to prevent direct galvanic contact between the sheets and the clamps.

### Repairing damage made: Any required welding, holes drilled or surface damage to the structure after galvanising shall berepaired with Galvadip™, Adensotape™ or Petrotape™ systems, or other approved substantially equivalent cold-galvanising treatments. Any holes made in the material shall be sealed and made waterproof with approved UV resistant material.

### Array junction box and wiring: Any array junction boxes must be mounted squarely and accessibly on the array mounting structure. Wiring shall be UV resistant and should be shaded where possible.

### Array structure earthing: PV module frames and array structures shall be properly earthed in accordance with specifications (Section 12.1.7: PV Array Structure Earthing). Each array and module must be earthed.

### For ease of installation and testing, the best practice approach for earthing modules together is to use separate earth frame flange grounding using stainless bolts, onto earth conductors providing earth continuity.

### Note that the following methods are NOT considered acceptable in the corrosive salt environment.

* Lugged cable between each module and array frame, with array frames providing earth continuity: Combination of copper crimp lug, aluminium and zinc plated "tek" screws are not acceptable.
* Rely on metallic contact between module clamps and frames to provide earth contact, with array structure providing earth continuity: Contact may be lost over time due to corrosion.

### Special earth clamps “bite” in to each module providing earth contact onto array structure, with array structure providing earth continuity: Contact may be lost over time due to corrosion.

### Safety during Installation: Safety harnesses shall be utilized during installation of the structure and modules.

# PV Inverters

## General

### The inverter shall be designed specifically for utility grid interconnection of photovoltaic arrays and be capable of automatic, continuous and stable operation over the range of voltages, currents, and power levels for the size and type of array used. The inverters shall be designed to be able to transmit the maximum output of the PV Plant at all possible ambient temperatures and local conditions, for example soil and dust atmosphere.

### The inverters shall be selected to be for grid tied applications, string type, three phase configuration (separate PE and N conductors) and operate at 50 Hz grid frequency.

### The inverters shall include the following features:

* total harmonic distortion less than 3%
* European efficiency higher than 97.5%
* Maximum input voltage of 1000 V DC
* reactive and active power control with power factor of 0.8 leading and lagging
* Frequency-dependent active power limitation and grid management service
* Minimum frequency operation range 45 Hz - 55Hz
* Nominal AC power between 10 and 30 kWAC for string inverter
* protections shall follow the grid operation set points and conditions
* corrosion prevention due to marine, salty and tropical environment
* Degree of Protection: IP 65, outdoor type
* Inverter must be able to communicate via hard wire (at least 100 Mbit/s) with a controller and reduce the output active and reactive power according to grid load and signals from the power plant controller on a MODbus protocol.
* Access for parameter settings via internet remote control

## Certificates

### The inverters should be TÜV-tested or equivalent for the required Certificates, CE-marked or equivalent and in compliance with the applicable standards also must comply with the IEC 61000-6-2:2005; IEC 61000-6-4:2006; IEC 61727, IEC 62116, UL 1741.

## Warranty

### Product warranty for inverters should be at least 5 years. In addition it should be possible to purchase an extended warranty up to 10 years.

## Rating Requirements

### The inverter DC rating shall be equal or higher than the installed module power (kWp). If the rating is lower, a certificate of the manufacturer is to be provided, certifying full inverter output under STC, local altitude and temperature conditions.

### The inverter shall make use of maximum power point tracking, and will have a wide MPPT range.

### Active Power Management Requirements

* DC power regulation:
  + Inverter Temperature Derating: In order to avoid the grid disconnection, the inverters shall implement a temperature derating, reducing the power output with the temperature.
  + Overload: The inverter shall not switch off under overload-conditions arising from high DC power inputs
* Dynamic 3 phase balancing of power output is required
* Remote Power reduction or power limiting capability via software from centralized plant control is required.
* Frequency–dependent active power reduction mode for over frequency conditions is required. This feature must be configurable in the inverter, allowing a local or remote mode, in order to integrate the PV field converter with the Battery converter.

### Reactive Power Management Requirements

* The PV inverters shall be able to follow reactive power references coming from the power plant controller within their power capability curve and/or to dynamically adjust their power factor setpoint.
* The PV inverters shall implement a Voltage Regulation mechanism to be able to control the grid voltage generating or consuming reactive power if necessary.
* Maximum response time for voltage regulation shall be 1 second.

## Protection Features Requirements

### Programmable settings: All the standard protection features in-built (anti-islanding etc) . The inverter shall be

* AC short-circuit protected,
* Protected from DC-side polarity reversal
* The following features may be integrated into the inverter.
  + DC disconnection switch for each inverter
  + DC ground fault current protection by an integrated Ground Fault Detection and Interruption Device (GFDI) or RCB type B.
  + DC surge arrestors
  + Residual current device.
  + AC disconnection switch.

## 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

## AC combiner boxes

### AC Combiner boxes shall be implemented as required by the design to join in parallel the inverter AC output in the field. They shall fulfill the following minimum requirements:

* Protection of cables and inverters: Industrial standard circuit breakers (MCB) on each pole.
* A main circuit breaker with sufficient capacity for protection and disconnection of all connected inverter circuits.
* Overvoltage protection: 4 kA 8/20µs Type 2 and, if applicable, according to lightning risk assessment (IEC 62305-2), also protection type 1 with 5kA 10/350 µs.
* The enclosures shall be suitable for outdoor use, UV protected and with a minimum protection grade of IP 65.
* The enclosures shall provide Class II double insulation
* The AC combiner boxes shall be protected additionally from direct sunlight and rain.
* All warning and safety labels shall be in English language.

# Meteorological Station

## 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 meteorological station shall contain as a minimum:

* Calibrated pyranometer secondary standard according to ISO 9060 classification to measure the global horizontal irradiance (GHI)
* Calibrated pyranometer secondary standard according to ISO 9060 classification to measure the global inclined irradiance on the plane of the array (POA)
* Shielded ventilated thermocouple to measure ambient temperature with a measurement accuracy of ± 1 °C
* Resistance thermometer (e.g. Pt100, Pt1000) or equivalent to measure the temperature of modules (on the back of the PV modules) with a measurement accuracy of ± 1 °C
* An anemometer mounted on a mast to measure the wind speed at the site. The exact location and height of the mast will follow the recommendations from the supplier of the mounting system
* Dust fall verification for determination of soiling losses by means of two inclined reference cells on the plane of array (POA). The first reference cell shall be cleaned on a weekly
* Data Logger time synchronized with analogue inputs with a resolution of at least 16 bits; Interface Base: RS 485 / RS 232 / Ethernet / Modbus (Must be compatible with SCADA system); All analogue inputs shall be fault-protected against short-circuit, over-voltage, transients and ESD; Data Storage Space: At least 1 GB with Internal Memory: 4MB

# Battery Storage System

## General specifications

### The batteries will set the capacity of the system to provide management support to the diesel gensets and to regulate variation ramps of RES and will be large enough to be used for primary control system.

### 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 and it will be optimized in the simulation process.

### The following are the minimum techncal specification required:

* Rated Energy Capacity (C) – as specified for individual islands in Section 6.0
* Rated discharge power rate – as specified for individual islands in Section 6.0
* Technology – Li-ion
* DC Voltage range – 600 VDC – 820 CDC approximate
* Rated DC Voltage – 700 VDC Approximate

### The most important parameters of the battery system are the discharge power and the durability of the system. The bidder shall propose the most suitable solutions based on li-ion batteries to achieve at least the specified kW discharge power as specified for individual islands in Section 6.0 paragraph 2.5.1. Bidder shall select the most suitable product to meet the rated and peak discharge power with the lowest kWh installed.

### The battery should be tested under IEC 61427 standard *Secondary cells and batteries for Renewable Energy Storage - General Requirements and methods of test* or equivalent

### The battery will be composed of modular blocks (at least 2) to improve reliability in case of fault and to facilitate the blocks maintenance labors, if necessary.

### The function of the power storage system will be desigened in response to the hybrid power system’s Type (B or C).

## Cycle life and durability

### The cycle life and durability of the batteries is a major issue in the project. The bidder will take into account the following points.

* The cycle vs DoD (Depth of Discharge) graph will be provided by the bidder.
* A minimum of 4000 cycles at 80% of DoD is mandatory.
* A calendar life of at least 10 years is required.

## Functional requirements

### The battery energy storage system shall perform at least the following functionalities according to the island type (B or C):

* Power balancing: The BESS shall ensure an instantaneous 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.

#### Load Following (not for type C islands): The BESS shall provide energy to the load during certain periods of the day allowing the shut-down of the diesel gensets. 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.

## 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.

# Battery Power Conditioning System (BPCS)

## General specifications

### For islands with type C, as specified for individual islands in Section 6.0 the battery inverter must be grid forming. For all other islands inverters can be either grid forming or grid support.

### The power converter shall be bidirectional to charge and discharge the batteries to the grid and will have a rated power to accomodarte the required storage battery capacity and dischage power as specified for individual islands in Section 6.0 paragraph 2.5.1.

### The BPCS shall have galvanic isolation and shall be able to manage active and reactive power following the command from the PCMS. The BPCS shall be composed of two units BPCS system, one unit per rack of batteries in order to have a modular system that will enhance the whole availability of the system.

### Inverters must always be able to operate in parallel with a diesel generator and communicate with the Power Plant 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 overload capability of the inverter must be at least 150% of their nominal power for at least 5 min.

### The inverter supplier shall have a proven track record (minimum 5MW over the last 5 years) in island system applications.

## Protections

### AC protections

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

### DC protections

* DC overvoltage protection
* Inverter shutting down overload error
* Batteries system isolation detector

### Others

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

## Interfaces

* Modbus RTU communication protocol
* Field bus connection with RS485.
* Luminous indicators
* Remote monitoring system (with GSM/GPRS modem), optional.

## Efficiency

### Efficiency: at least 95% at full power.

## Location and Battery System Layout

### The proposed place to install the battery system shall be inside the power house. The conceptual design and positioning of the BESS system in the powerhouse including a work desk with a PC for the SCADA is as below:



Figure 1: Proposed distribution for the battery and control room

### Additionally, the new room should include some ancillary systems to operate the battery on a correct and safe way:

* HVAC: In order to provide optimal performance and maximize life, the battery modules should be maintained at a temperature between 20-30 ºC. To accomplish this, an air conditioning system should be installed to start operation if the temperature exceeds certain limits. The rated power of the HVAC will be stated by the manufacturer, after the study of the environmental conditions.
* Fire suppression: In the unlikely case of an abusive event, a fire suppression system (FSS) should be installed. The FSS is sized for the volume protected and should include a battery for 24 hours of back-up if power is lost.
* Ventilation fans: These fans will help to cool the system and to refresh the air and would operate prior to the air conditioning system starting.

## Maintenance

* The battery system shall be as free of maintenance as possible.
* The bidder shall 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 shall also inform about the indicated personnel to perform the above mentioned maintenance tasks (manufacturer, certified subbidder, etc.)

## Safety and Environmental Considerations

* 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 manufacturer.
* The battery manufacturer shall provide all the safety considerations about the system and supply all the ancillary systems that may be needed to avoid.
* The manufacturer shall have a program for battery dismantling and return to factory after its operation life. Bidder shall submit a manufacturer confirmation of such back to factory return policy.

## Standards

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

|  |  |
| --- | --- |
| IEC 61960  61427 | Secondary cells and batteries containing alkaline or other non-acid electrolytes - Secondary lithium cells and batteries for portable applications  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. |

# Diesel power plant

## General

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

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

### The DG unit’s continuous rating and the diesel engines output shall be stated in accordance with the data sheets and relevant IEC Standards. The diesel Generator shall deliver the rated output at the rated speed at specified site condition with no negative tolerance. The DG unit heat rate shall not exceed the guaranteed heat rate by more than 4%.

### The engines shall be suitable for continuous operation with rated generator output. The DG 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 engines shall have sufficient power output to operate the generator at 10% overload for one hour within any twelve hour operation.

## Previous Experience

### The Contractor shall provide a track record of previously installed Diesel systems of a rated power upper than 1 MW. This previous experience shall also be required for main subcontractors and/or suppliers, and it shall be especially relevant for Power Plant Controller and Power Electronics systems manufacturers or suppliers.

### In order to minimize the risks and to avoid the dilution of responsibilities the Contractor shall select the lowest number of suppliers.

## 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
* Expected life-time of the Diesel Generator shall least 10 years.

### The Diesel Generators shall run in parallel to the PV Plant and the load is controlled by the demand and the production from the PV Plant. In order to control the whole system (PV Inverter, BPCS & Diesel Generator), the Diesel Generator shall implement a Modbus RTU communications protocol, with the following parameters, but no tlimited to:

* Output Voltage
* Output Current
* Frequency
* Output Power
* Diesel level
* Diesel consumption
* RPMs
* Generator Status / Alarms & Errors

## 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 1: Specific fuel consumption requirements of diesel generators

Prime Power (PRP) according to ISO 8528, 10% overload capability according to ISO 3046.

### The consumption of all diesel generators will be measured on site during commissioning and will meet the following requirements:

* Measurement equipment will be provided by the Contractor. Method statement is subjected to the approval of the Employer/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.

## Governor

### The governor shall be capable of maintaining operating conditions specified herein. The frequency shall not vary more than 1% under any condition at generator loads from 0% to 100%. Speed droop shall be adjustable during operation from zero to 5%. For regular engine load test runs the governor shall maintain stable parallel operation without power oscillations.

## Noise

### The DG set shall be efficiently silenced with exhaust silencers complete with interconnecting pipe and fittings. The design of the silencers shall be such that the noise shall not exceed 100dBA within 1 meter distance from Diesel Generator without enclosure. Anti-vibration supports shall be used for the complete exhaust system and shall be arranged to allow for expansion of the exhaust system by the inclusion of expansion bellows.

## Exhaust gases

### The Diesel Generator exhaust gases shall be within the specified limit as below:

|  |  |
| --- | --- |
|  | 100% loading |
| NOx (mg/Nm3) | 3682,44 |
| CO (mg/Nm3) | 702,03 |
| HC (mg/Nm3) | 70,20 |

## Fuel Filter

### Each diesel engine shall have a fine fuel filter and water separator filter. The cartridge of the fine fuel filter shall be installed in the engine in an easily accessible place for maintenance. The filters shall be changed during stoppages of the engine. The Contractor shall take the necessary precautions to ensure that all of the fuel spilled (in the filter change) is captured by a crankcase for spills installed in the generator set and with an adequate connection for drainage.

## Fuel Level and Consumption Meter

### There shall be fuel day tank with level sensor with enough capacity to run the generator for at least 12 hours at rated output. Fuel flow meter shall be implemented to provide actual fuel consumption (subtract fuel supply path and return path) and digital pulse output which can be interfaced with SCADA system for storing in the database.

### The level display meter shall be installed in the metering control and protection panel and shall be connected to the specific SCADA system developed for this project.

## Standards

### The Diesel Generator shall be compliant with the following standards:

* ISO 8258-1
* BS 4999
* BS 5000
* IEC60034
* BSEN 61000
* IEC60034
* UTE NFC51.111
* VDE 0530
* BS4999/5000
* NEMA MG 1-33

## Diesel engine operation

### Only diesel engines with high-pressure direct injection design shall be accepted.

### Proven ability to function at low loads: The minimum load factor possible for the diesel engine is a very important number for the diesel-PV hybrid system, because the diesel generator shall be functioning partially at low loads when the photovoltaic field is at high production. The minimum load factor, on the one hand, defines among other things the degree of penetration of the photovoltaic field in the production of the hybrid system, and on the other, prevents accelerated deterioration and wear of the engines.

### The Diesel Generator offered shall be capable of functioning continuously at low loads (of approximately 25% to 35%), without causing excessive sediments in valves, pistons, etc. of the diesel engines.

### There shall be digital interface for reading of all the diesel generator sensors installed and the operational data of each diesel generator, and for direct connection to the PCMS, local SCADA and the Internet.

## 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

## Lubricant oil system

### The lubricant oil system shall provide an adequate lubricant oil filter, as well as pressurized circulation through all of the lubricated pieces in motion, to ensure safe and reliable functioning of the diesel engine. The pressure of the lubricant shall be monitored to protect each diesel engine. In the event of low pressure, the engine shall be immediately stopped by the control system. All of the alarms shall be transmitted to the control room. The Contractor shall ensure that the lubricating oil system capacity shall be sufficient to enable the engine to run continuously for 12 hours at any load without replenishment.

### The necessary lubricants shall be those available in the local market.

## Cooling system

### The Diesel Engine cooling shall provide efficient cooling under all specified ambient conditions.

### The Diesel Engine shall be either water or air cooled. Where water cooling is employed, a sectional radiator shall be mounted on the base frame and shall be arranged to cool the engine jacket water, lubricating oil, and change air as appropriate. Thermostatic control of the jacket water and lubricating oil shall be provided. Circulation of cooling water through the engine and radiator shall be by means of an engine-driven pump. Hose connections shall be provided on all water circuits to enable the systems to be drained for maintenance.

### The cooling fans shall be directly driven by the engine and the hot air shall be ducted to suitable openings in the generator room wall. The duct shall incorporate a flexible section to prevent the transmission of vibration from the engine.

## Powerhouse Ventilation

### The ventilation system for the powerhouse shall consist of two or three air intakes in the upper part of the powerhouse. The air shall cool the Diesel Generator, shall pass through the engine’s radiator and shall be discharged outside of the powerhouse.

### The design of the noise mitigation elements shall take into account the loss of admissible pressure at the air intake and outlet. The fans in the radiators of the diesel engines shall form part of the powerhouse ventilation system. If the pressure of these fans is not sufficient to ventilate the necessary flow volume of air, electrical fans shall be installed at the air intake of the powerhouse.

### The maximum increase in temperature within the powerhouse shall be limited to 10° C in comparison with the outside temperature. The temperature within the powerhouse shall be measured at the height of the air filters of the Diesel Engines.

## Service and spare parts

### For service and maintenance works to be performed in the systems and equipment of the new Generator, the Contractor shall recommend service and maintenance spare parts. The Contractor shall quote these parts as an option. The volume of necessary parts shall be chosen during the contracts negotiations.

## Consumables

### The Contractor shall supply consumables for one years of operation of all the Diesel Generator’s excluding fuel and lubricating oil.

### The Contractor shall supply the first filling of lubricating oil, except fuel.

# Grid Infrastructure

## 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.

## 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 |

## Scope of Work

### The work covered under this Contract shall comprise the detail 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.

### In line with the approved design, the bidder shall be responsible for the 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.

### The bidder shall be responsible for the supply, installation, testing and commissioning of all works related to the cabling for the upgrade of existing grid, interconnection of the proposed PV plant to the existing grid, replacement of existing Main LV Distribution board in the Power House, modification and replacement of existing distribution boxes, extension of main LV distribution board in the Power House for new DG connection in line with approved design.

### In Addition, for the islands with MV transmission line, the bidder shall provide the 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.

### The bidder shall conduct 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.

### The bidder shall supply mandatory spare parts, tools and consumable items for each island. The bidder shall prepare operation and maintenance manuals, spare parts catalogues and “As built” drawings as per the requirement of the Employer for each island.

### The training program shall be included for the nominated operation and maintenance staff in each island to operate and maintain the equipment supplied under the contract.

### 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.

## Workmanship

### Engineers and Technicians: Electrical work 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.

### The Contractor shall provide educational or vocational certificates of engineer, designers, technicians and mechanics before commencing.

### Equipment: All electrical installations shall be carried out using proper tools. Where tests are required, adequate and appropriate testing instruments 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 that appropriate equipment have been utilised in carrying out any of the work in this Contract.

## Components and Material Requirements

### 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.

### 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 |
| Underground cable entry and exit from ground | PVC acceptable | “Danger Underground Cable” with red flash on white background |

Table 2: Labeling

#### In addition to the above, warning labels shall be provided as per MEA regulation on all DF locations. Further, all DB installations should carry an interpretation of the following warning label in Dhivehi and English.

“Danger High Voltage -400 Volts”

## Generator Synchronzing/Disribution Panel

### Cubicles shall be made from high quality steel frame and plates and shall be assembled keep in mind to easy maintenance. Paints applied on the cubicles shall be durable and suitable for harsh environment.

### Components such as isolators, bus bars, relays, switches and instruments shall be from reputable manufactures.

### Synchronizing Panels and Distribution Panels shall fully comply with relevant international standards.

### The Panel shall be manufactured using powder coated mild steel sheets of 1.6 mm thickness. The thickness of the front door panel shall be 2 mm. A strong base frame of 100mm tall shall be provided with the panel Board. The panel board shall be a free standing, bottom cable entry type panel.

### Bus bar

#### TP and N (same size neutral) hard drain high copper conductivity air insulated tinned bus bars will be provided at the back of the enclosure, suitably braced for 30kA -80kA 1 - second fault ratings. The current rating of bus bars shall be 5000A.

### Circuit Breakers

#### A 3 - pole Merlin Gerin ACB, rated at 2000 Amp @ 660/1000V with 220 Volt under Voltage Trip Coil and 5 Ampere rated auxiliary switches will be used main circuit breakers.

### Analogue Metering

* Generator Voltage (R-Y, Y-B, R-B, R-N, Y-N, B-N)
* Generator Current (R, Y, B)
* Generator Frequency
* Generator Active Power (KW)
* Generator Reactive Power (KVAr)
* Battery charging Ampere
* Battery charging Voltage

### Digital Measurements

* Generator Volts: L1-N, L2-N, L3-N, L1-L2, L2-L3, L3-L1
* Generator Amps: L1, L2, L3
* Generator KW: L1, L2, L3, total
* Generator KVA: L1, L2, L3, total
* Generator KVAr: L1, L2, L3, total
* Generator pf: L1, L2, L3, average
* Generator Frequency,
* Busbar Volts: L1-N, L2-N, L3-N, L1-L2, L2-L3, L3-L1
* Busbar Frequency,
* Synchroscope Phase Angle
* Voltage Match Generator-Busbar
* Frequency match Generator-Busbar
* Percent Load
* Governor and AVR output positions
* Battery Voltage
* Engine RPM
* Engine Coolant Temperature
* Engine Oil Pressure
* Engine Oil Temperature
* Engine Fuel Level

### Control Equipment

* Generator Controller
* PLC Controller for Auto Start / Stop / Loading / Unloading/Fixed kW Export
* Emergency Push Button

### General Indications and Warnings

* Generator Under/Over Voltage
* Generator Under/Over Frequency.
* Generator Over Current
* Generator Reverse Power
* DC System High/Low Battery Voltage
* Fuel Level, High/Low
* High Oil Temperature
* High Water Temperature
* Low Lubricating Oil Pressure
* Charge Fail
* Fail to Start
* Fail to Stop

### Auto Manual Load Sharing

* Generator KW sharing
* Generator KVAR sharing
* Auto / Manual Loading
* Auto / Manual Unloading

### Protections

* Over current protection
* Earth fault protection
* Reverse power protection

### DC Systems

Automatic engine battery charger of charging current 5 amps and voltage 12/24V DC for offline charging.

### Power Distribution

* 8 x Distribution Feeder Panels
* Each feeder with Ground Fault protection
* 4 Feeders x 63A MCCB and 4 Feeders x 100A MCCB with ELR Protection and Ampere meters on each feeder

### Warranty

Supply of equipment and work carried out under the supply shall cover by one year warranty. Any defect component or malfunction shall be rectified and replaced.

### Specification Drawings

| **S No.** | **Drawing Number** | | **Title** | |
| --- | --- | --- | --- | --- |
| 1 | | G409-HA ALIF-GEN-GRID-004 | | SINGLE LINE DIAGRAM OF CONTROL & PROTECTION: INDICATIVE (COMMON) |

## 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 of fixed thermal magnetic type with quick break toggle action,
* be able to withstand the specified kA RMS symmetrical interrupting current,
* be of constant characteristics irrespective of physical plan of mounting,
* be inclusive of arc interrupting device of the de-ion type,
* be of high conductivity non-welding alloys for the fixed and moving contacts,
* be suitably treated to resist corrosion throughout the breaker life, including all metallic components,
* be firmly mounted by fixing independent of terminal studs,
* incorporate a common trip device so that all the three phases shall open, should any of the phases overload,
* have anti-welding contacts with silver tungsten tips fixed on high conductivity copper backings,
* be provided with 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,
* have the 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.

## Current Transformers

### Current Transformers (CT) for the operation of instruments and metering equipment shall comply with requirements of latest relevant BSI 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 and shall have secondary winding rated at 5 amps unless otherwise specified. All CTs shall be according to BS 3980, 15 VA class 1 for measuring types 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.

## Instruments and Meters

### All electrical instruments and meters shall comply with BS 89, IEC 51 and IEC 521, 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.

### 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 a later 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.

## 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.

## Indicating Lamps and Fittings

### Indicating lamps shall comprise filament lamps behind removable lenses. Alternatively, low voltage lamps with transformer type fittings may be used.

### Lamps shall be easily removable and replaceable 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.

## 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 “B” 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 of the capacity. 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

### 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 colour shall be as indicated in the following table.

Table 3: Panel wiring colour

|  |  |
| --- | --- |
| **Colour** | **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 |
| Grey | Connections in D.C. circuits |
| Any other colours | 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.

## 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.

### All power cables from generator to control panel shall be 4 core copper conductor cables with Cross-linked polyethylene (XLPE) insulation and polyvinyl chloride (PVC) over-sheath for 600/1000 volts to IEC 502, or other equivalent recognised reputable international standards. All cables shall be rated according to the recommendations of the latest edition of IEEE regulations. 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.

## Distribution Boxes (DBs)

### Drawings

The following drawing shall be referenced:

G409-HA ALIF-GEN-GRID-001: SINGLE LINE DIAGRAM OF DISTRIBUTION BOX, INDICATIVE (COMMON)

G409-HA ALIF-GEN-GRID-002: DISTRIBUTION BOX INSTALLATION, INDICATIVE (COMMON)

### General

#### Distribution Boxes shall include the following as a minimum:

* Weatherproof enclosure
* One 63 Amp three pole, moulded case main circuit breaker (MCCB)
* Twelve 32 Amp single pole, miniature circuit breakers (MCB)
* One 40 Amp triple pole, miniature circuit breaker (MCB)
* One 16 Amp two 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

### Enclosure

#### Outdoor weatherproof GRP sealed enclosures shall be protected to IP 65, 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, 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), 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.

### Manual Isolator

#### Appropriately rated four pole manual load break switch, 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 feeder pillar.

#### The colour of the enclosure shall be RAL 7032.

## 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.

## 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 a mechanical push-in button. Their symmetrical interrupting capacity shall be 16kA.

## Miniature Circuit Breakers

### Miniature Circuit Breakers shall have a short circuit current breaking capacity of 6 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.

## Factory Assembly

### The Distribution Boxes are to be factory assembled.

## Underground Low Voltage Armoured Cables

### 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 to BS 5467, IEC 502, or other equivalent recognised reputable international standards.

### Conductor

#### Conductors shall be annealed copper stranded conductors complying with BS 6360 or IEC 228, 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.

### 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.

### Identification

#### The cores of cables shall be identified by colour of XLPE compound. For four core cables the colours shall be brown, black, grey and blue. The portions where the insulation colour is visible should be sleeved with red, yellow, blue and black sleeves respectively during installation.

### Laying Up

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

### Bedding

#### An extruded layer of PVC bedding shall be applied over the assembly to form a circular cable and armour bedding. Any fillers that are deem necessary shall be of PVC type.

### Armour

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

### Oversheath

#### 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 ---- ----

### 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.

### Service Main and Streetlight Cables

#### Service main and streetlight cables shall be PVC insulated PVC sheathed multi-stranded annealed copper conductor with 600/1000 Volt rating.

#### All active conductors in single phase circuits are to be coloured red.

#### Cables shall be supplied on steel reels. A metallic plate with a reel number shall be firmly fixed to the reel. All the information shall be written, with indelible ink on metallic tags firmly fixed to the reel flange. The following information shall be printed on the reel:

* Size of the cable;
* Type of the cable;
* Length and weight of cable per drum;
* Gross weight;
* Manufacture’s name; and
* Customer’s name and location.

### Factory Test Requirements

#### The Contractor shall submit standard tests performed by the Manufacturer. This includes but is not limited to:

* Conductor resistance;
* Insulation resistance and voltage withstand;
* Load and no load losses; and
* Any other tests carried out as per the manufacturer’s standard.

# Installation

## 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 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 and upon receiving such a request the Contractor shall supply the particulars without delay.

## 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 shall be consulted on the type of material, method, and place of disposal.

## Power Cables

### Drawings

#### The following drawings shall be referenced:

#### G409-HA ALIF-GEN-GRID-003: CROSS SECTIONAL VIEW OF INDICATIVE CABLE TRENCH (COMMON)

#### Size, approximate location and lengths of cables, depth of cable laying and material of bedding, use of a warning tape and backfill, are given in the drawings.

### General

#### 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, difficult work 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 relevant drawing.

G409-HA ALIF-GEN-GRID-003: CROSS SECTIONAL VIEW OF INDICATIVE CABLE TRENCH (COMMON)

#### Before trenching, the Contractor must obtain approval from the any concerned authority or inform the Employer’s Representative. Information on already existing power cables, communication cables, cable TV cables and sewerage and water mains must 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 lying 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.

### Laying Cables

#### Cables buried in the ground shall be laid according to the following procedure:

#### First, 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 except for sewerage and drainage pipes where their depth is considered by the Employer to be excessive.

#### The Manufacturer’s minimum bending radius for the size of cable shall be observed.

#### 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 110dia sanitary sewer and 110dia sanitary force main which shall be located along the centre line of all roads except the 6m roads where they shall be located 4m away from the western or northern boundaries of these 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 that all joints are carried out carefully and systematically as per the technical information and recommendations or guidelines stipulated by the cable and jointing kit Manufacturer, and shall conform to the relevant BSI/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 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 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.

### Distribution Boxes

### Drawings

The following drawings shall be referenced:

G409-HA ALIF-GEN-GRID-001: SINGLE LINE DIAGRAM OF DISTRIBUTION BOX, INDICATIVE (COMMON)

G409-HA ALIF-GEN-GRID-002: DISTRIBUTION BOX LAYOUT, INDICATIVE (COMMON)

### 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 is to locate the distribution boxes generally as shown on 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. The cost associated to fullfill these changes, including short lengths of service mains and joints, will be included in the Contractor’s Scope of Works for this 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 | | G409-HA ALIF-GEN-GRID-002 | | DISTRIBUTION BOX MOUNTING DETAILS, INDICATIVE (COMMON) |

### Termination

#### 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.

### 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.

## LV network Earthing

### The LV neutral earthing shall be achieved via the star point of the generator Neutral earthing shall be done at the busbar of the 400 V Generator control and feeder panel board. The neutral of the busbar shall be solidly earthed. The neutral (start point) of each Generator shall be connected to the main earth bar of the panel board which is solidly earthed.

### The generator body shall be connected to the base frame and the frame of each Generator shall be bonded to the above LV system earthing. The bonding shall be separate and shall be easily disconnected from the LV earthing for measurements. All metal structures of the building not forming part of the lightning protection shall be bonded to this earth connection.

### If the generator Manufacturer prefers an alternative requirement for earthing then a document shall be provided with technical details and justification for the Manufacturer’s preference.

# Control System

## Overview

### This chapter describes the minimum requirements for design, delivery, installation, testing and tuning of the overall Plant Control and Monitoring System (PCMS) which shall be established in the island powerhouses which will integrate renewable systems in their power generation matrix.

### The Control System 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.

### 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.

## General requiremets

### The system shall be a state of the art, field proven system based on microprocessor technology. The architecture shall be built with distributed intelligence as an automated real-time control system for data acquisition, processing, transmission, storage and archival, graphical presentation and display.

### The proposed hybrid system solution aims at a high rate of penetration of renewable energies, in some islands up to 48% of the energy consumed on the island shall be provided by solar energy. Thus, it is necessary to develop a control strategy to make use of as much PV energy available as possible, and maintain system stability.

### 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 PCMS shall be designed with components of proven technology, including all equipment of safe, undisturbed and reliable operation, cabling, patch panels, accessories, tools, software even if not mentioned explicitly in this document.

### All required Interfaces and switches shall be included and provided by the Bidder. Especially the interfaces to and at the diesel engines to be investigated in detail, improved and upgraded, cabled, terminated, commissioned, as well as properly documented in the final documentation.

### All equipment shall be of high quality and reliability. The overall system availability of the PPC shall be 99% or better.

## 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.

## Bid 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.

## Spare capacity, parts and special tool

### A minimum spare capacity at hardware level of 20 % shall be considered in the design. There shall be spare capacity in data network and signal transmission and processing to have sufficient capacity and spare in bandwidth, bitrate, reliable termination etc. to guarantee the reliable function of the plant.

### The Bidder shall 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.

### All special tools required for the operation and maintenance of the system shall be provided by Bidder.

## Performance and Reliability

### All equipment shall be of high quality and reliability. The overall system availability of the PCMS shall be 99% or better.

## Functional Requirement of PCMS

### 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 PPC will allow the Genset to go down to it’s minimum load and even underneath this minimum load for a certain time, depending on the manufacturers specifications. In any case the PPC allways has to take care that there is no reverse current in any of the three phases.

### In order to have the highest benefit of the solar power, the PPC should not cut the PV power until a certain minimum level of the Genset is reached and the batteries are charged up to a predefined max. level.

### The system shall be designed in order to allow a Genset with max. rated capacity smaller than the actuall load in the system running in parallel to the BESS and the PV system, if there is enough energy from the PV system available. 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 keep the system stability. 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 PPC must always react quickly enough to avoid a blackout in the system due to sudden PV drops or load increases.

### Communication

#### The PPC will therefore allways have the communication via Modbus TCP to all energy producers, respectively Diesel Gensets, PV inverters and BESS units. It will recive all necesarry measurement data from those sources, such as Voltage, Current, Cosphi, Battery SOC, Frequency and Warnings/Alarms at the connection points of the sources. According to the actuall state of the system he will then decide and send the controll 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 min. CAT 6 and Fibre optic cables for longer distances. The system shall communicate with and provide data to the SCADA system.

#### All alarms including system alarms and important events shall be taken into account and sent to the SCADA

### Load ramp

### If the PV system is already providing it’s 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 it’s 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.

### 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 conection. The access has to be Password and Username protected.

### Grid Building Systems

##### For systems with Grid Building Battery Inverters (GRIDB), the Main Controll 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.

### Electrical Connections and UPS

#### Redundant power supply for PPC shall be provided from UPS. A minimum of 30 min. of independent power supply shall be guaranted 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 13.

#### Grounding: The PPC 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 PPC and accordingly provide the earthing system that shall be approved by Employer/Engineer.

#### Labelling and Marking: All terminals, plugs, internal and external connecting cables shall be labelled durable and readable with a code approved by the Employer Engineer. Code list shall be included in Documentation.

### Enclosure and environmental conditions

#### 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 PPC 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.

## System functionality for hybrid system

### System functionality for type A hybrid system.

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

#### When a single genset is providing primary regulation for the whole minigrid (slack unit), this genset can function in sychronous (fixed speed) mode. This means that changes in the net load (demand – uncontrolled generation) initially translate on a speed (frequency) deviation until the governor control (usually based on a PI controller) restores the torque for the new power level at reference frequency.

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

#### At least one Diesel will be always syncronized.

#### Type A islands are characterized by low RES penetration, therefore stability issues due to RES variability will have a limited impact and batteries will not be installed.

#### When there is no RES (Region 1 and 3, Figure 2) diesels provide all the energy. The power plant controller selects the most efficient diesel gensert for each given load.

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

### 

Figure 2: Type A System Operation with different energy scenarios

### System functionality for Type B hybrid system : From the energy balance perspective, the system should operate in the following way:

#### The higher the penetration of renewable power, the more difficult it becomes for diesel gensets to maintain stability without help from storage systems, as sharp changes in renewable generation (passing clouds, wind gusts etc.) represent a higher change in the output of gensets.

#### At least one Diesel will be always connected .The generators have to manage the generation load to maintain the voltage and frequency..

#### When RES is scarce, the diesel genset1 operates and supplies all power demand (Region 1, Figure 2)

#### When the RES generation starts to pick up (Region 2, Figure 2), the genset1 began the process of ramping down the output power to maintain the demand load. At this stage load is shared by genset1 and RES maintaining the grid stability. Depending on the RES peneration level in each island, this process continues usually until the ramping down the genset power reaches the preset minimum output power of the generator1. Note that the batteries have a regulatory role in this scenario: they not only must absorb drops in generation (injecting energy), but also must be able to react quickly to possible reductions in demand. For this reason they must have a safety margin with respect to a percentage of the load percentage. The excess energy has to be managed by the PV inverter at the time of maximum penetration of renewable. Fast changes in solar radiation are mirrored to battery load changes. To ensure maximum calendar life, batteries must not be kept over 85% of SOC, depending on the battery specification. This is other important reason to keep the SOC relatively low, apart from mandatory operational reasons. If the RES generation is higher than demand, and the batteries are fully charged, then the PV energy production must be adjusted to the operating point of the PV inverters for them not to inject all available energy, in order to maintain energy balance.

#### At some point RES generation decreases and generator2 starts to pick up the load (Region 3, Figure 2). The generator1 shuts down and load is now shared by the genset2 and RES to maintain the grid stability. The shutdown and start-up of Diesels is governed by the power plant controller which should be fine tuned for each island.

#### From the point of view of electrical stability of the system, to guarantee power quality of electricity supply, at least two types of operations for primary control have to be arranged.

#### The batteries should immediately manage the large and fast variations that occur in PV production due to phenomena such as passing clouds, providing or absorbing the energy required to maintain the frequency of the AC grid. The storage system must be able to provide all the demanded energy for at least for 10 minutes.

#### The small and slow fluctuations in demand and PV generation should be managed by the diesel gensets. The battery life is directly dependent on the number of charge and discharge cycles, so that, if small (unless fast) variations are covered by the battery, its useful life will be drastically reduced.

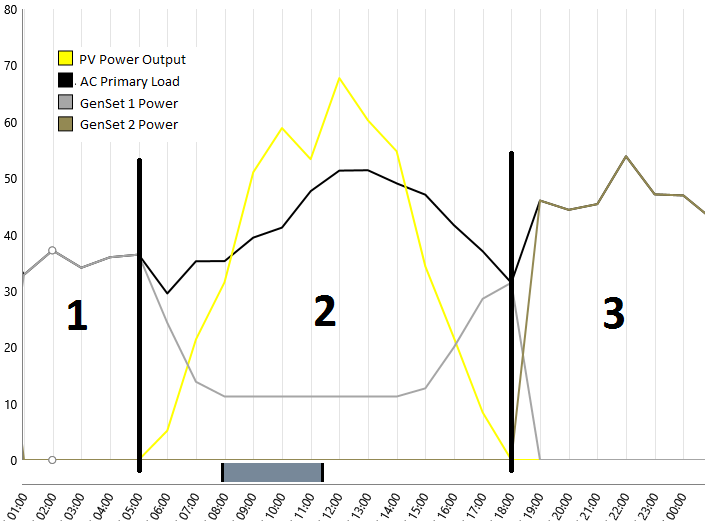


Figure 2: Type B System Operation with different energy scenarios

### System functionality for Type C hybrid system

#### In this architecture, the grid forming task is switched between the genset and the grid forming inverter, allowing the minigrid to operate at times without running a diesel generator to save fuel achieving high energy renewable penetrations. In this configuration,

#### The bi-directional grid forming inverter of the battery needs to function in all four quadrants (absorb/generate active/reactive power) and seamlessly transition between them. A droop-based approach in which the grid-forming inverter increases the minigrid frequency and the PV inverters detect it and curtail their output if necessary to maintain power balance. This method presents a clear advantage when the inverters are far apart from each other.

#### The secondary control is usually programed in the grid-forming of the battery and it has the task of synchronizing and bringing online diesel generators following an algorithm that depends on the state of charge of the batteries and the current load. Some more advanced systems will have external algorithms for secondary control that factor load and renewable generation forecast to save fuel, optimizing the use of batteries.

#### In the abssence of RES (Region 1, Figure 4), the Diesels gensets are responsible for forming the grid and serve the load

#### When the RES generation starts to pick up (Region 2, Figure 4), the genset began the process of ramping down the output power to maintain the demand load. At this stage load is shared by genset1 and RES maintaining the grid stability. Depending on the RES peneration level in each island, the PV excess can be used to charge the battery.

#### If the available solar energy and the SOC of the battery allow it (Region 3, Figure 4) solar energy shall always be the prioritized energy to be used in the system, and diesel generators shall only be turned on if necessary.

#### Whenever the RES output is low enough the load can be served (Region 4, Figure 4) by a combination of gensets, RES and battery .

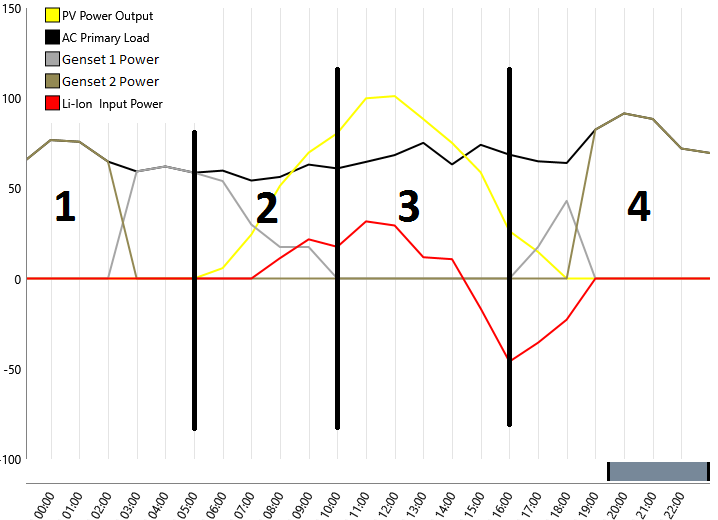


Figure 4: Type C System Operation with different energy scenarios

### These detailed operations are closely conditioned by the statism curves implemented in the equipment control devices, so that determining these statism curves is considered a critical aspect for the correct operation of the grid.

### Excess Electricity

#### Given the variability in the energy demand curve (on daily and yearly bases), the high level of RES penetration in the minigrid proposed for some islands (island Type B and C), and the limited battery energy storage capacity, there will be moments when excess electricity will be produced by the photovoltaic system. A curtailment policy would have to be implemented to cut production from the photovoltaic system when supply exceeds demand.

### Reactive Power Control and Voltage Stabilization

#### The control system shall operate the plant in order to achieve the optimal reactive power management. The control system shall provide the voltage stabilization of the grid by means of sending the appropriate reactive power commands to the distributed generators.

### Active Power Control

#### Adequate reaction time of the control of diesel generators and output power of PV inverters and BESS in case of sudden load change, loss of PV power (cloud event), etc.

### Frequency Regulation

#### The abrupt change in the loads connected to the grid or a malfunctioning generator are examples of events that can cause the frequency of the AC supply goes out of acceptable limits, causing disconnections generation systems and / or loads. To prevent these events, the control system will also work with the aim of contributing to frequency regulation. Active power shall be increased when the lower frequency threshold given is exceeded, after which it shall followed a droop frequency / power previously established. Similarly, when the grid frequency increases above an upper threshold value the certain amount of reactive power shall be decreased from the grid according to the specified power droop / pre-set frequency. The maximum allowed time to offer the required response due to frequency regulation purposes shall be 1 second.

### Monitoring

#### The proposed PCMS system shall be capable of monitoring all the main parameters of hybrid power plant. The following shall be the minimum data exchanges for all the nodes:

* Grid voltage
* Frequency
* PV generation
* Diesel generation
* Diesel consumption
* Lub-oil consumption
* Meter information
* Battery state
* Meteorological data
* Operator messages
* Event /alarm lists

#### Monitoring of auxiliaries such as fire detection signals and HVAC, status of the PV power plants, BESS and diesels.

#### Analysis and evaluation of energy production and plant status of the PV & diesel generators along with the battery system. Analysis of the performance of the PV plant (performance ratio).

#### Logging and archiving of all events such, meteorological data, yield, (false) alarms, system & hardware failure, including analysis and self-monitoring, etc.

#### Alarms, events, diagnostic (hardware and software) and reporting and annunciation management.

#### Authorization levels and definition of user rights (log in/off) including monitoring, engineering and system manager levels with respective multiple password organizations for access control.

#### Safe and stable automatic and manual operation function, high reliability of all components. Appropriate data storage capacity and all equipment shall be suitable for faultless reliable continuous operation

### 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.

### Safety and Protection

#### The control system shall implement a second loop for safety and protection surveillance.

#### In the event that the control system receives an alarm signal or detect any critical failure of any of the subsystems, the control system shall send an emergency STOP command if necessary to mitigate the effect of possible damages to persons or other subsystems.

# Utility compatibility

## 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.

## 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.

## 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.

## 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.

## 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).

## 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** |
| 3rd through 9th | Less than 4,0 % |
| 11th through 15th | Less than 2,0 % |
| 17th through 21st | Less than 1,5 % |
| 23rd through 33rd | Less than 0,6 % |
| **Even harmonics** | **Distortion limit** |
| 2nd through 8th | Less than 1,0 % |
| 10th through 32nd | Less than 0,5 % |

## 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.

## 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°.

## Safety and protection

### General

#### The safe operation of the inverter in conjunction with the utility network shall be ensured at all times.

#### Safety disconnection from utility network: The inverter shall automatically and safely disconnect from the grid in the event of an abnormal condition. Abnormal conditions include

* network voltage or frequency out-of-bounds conditions,
* loss-of-grid conditions and prevention of islanding
* DC current injection threshold exceeded
* PV field earth leakage
* Inverter over temperature

#### Disconnection switching unit: The inverter shall be equipped with a disconnection switching unit which separates the inverter from the grid due to the above abnormal conditions.

* The disconnection switching unit shall be able to operate under all operating conditions of the utility network.
* A failure within the disconnection switching unit shall lead to disconnection and indication of the failure condition.
* A single failure within the disconnection switching unit shall not lead to failure to disconnect.
* Failures with one common cause shall be taken into account and addressed through adequate redundancy.
* The disconnection switching unit shall disconnect from the network by means of two series switches. Each switch shall be separately rated to the inverter’s nominal power output. At least one of the switches shall be an electromechanical switch while the second switch may be part of the existing solid state switching circuits of a utility-interconnected static power converter. The electromechanical switch shall disconnect the inverter on the neutral and the live wire(s).
* The fault current breaking capacity of the disconnecting switch shall be appropriately sized for the application.

#### Abnormal conditions can arise on the utility system and requires a response from the connected inverter. This response is to ensure the safety of utility maintenance personnel and the general public, and also to avoid damage to connected equipment. The abnormal utility conditions of concern are voltage and frequency excursions above or below the values stated in this clause. The inverter shall disconnect if these conditions occur. The parameters for disconnection shall correspond to those below, but shall be adjustable.

### Over-voltage and under-voltage

#### The inverter shall cease to energize the utility distribution system should the network voltage deviate outside the conditions specified in table below. This applies to any phase of a multiphase system. The system shall sense abnormal voltage and respond. The following conditions shall be met, with voltages in r.m.s. and measured at the POC (Point of Connection). All discussions regarding system voltage refer to the nominal voltage. The parameters for disconnection shall correspond to those below, but shall be adjustable in the field.

|  |  |
| --- | --- |
| **Response to abnormal voltages** | |
| **1** | **2** |
| **Voltage range**  **(at point of utility connection)** | **Maximum trip time**  S |
| V < 50 % | 0,2 s |
| 50 % ≤ V < 85 % | 2 s |
| 85 % ≤ V ≤ 110 % | Continuous operation |
| 110 % < V < 120 % | 2 s |
| 120 % ≤ V | 0,16 s |

### Over-frequency and under-frequency

#### The inverter system shall cease to energize the utility network when the utility frequency deviates outside the specified conditions. When the utility frequency is outside the range of 49,5 Hz and 50,5 Hz, the system shall cease to energize the utility.

### Prevention of islanding

#### An islanding condition shall cause the inverter to cease to energize the utility network within 2 s, irrespective of connected loads or inverters. One active islanding detection method and one passive island detection method shall be used to avoid an unintentional island.

|  |  |
| --- | --- |
| **Active and passive types of anti-islanding protection of inverters** | |
| **Active type** | **Passive type** |
| Frequency shift | Power phase jump detection |
| Active power fluctuation | 3rd harmonic voltage rise |
| Reactive power fluctuation | Frequency change rate detection |
| Load fluctuation |  |

### DC current injection

#### The static power converter of the inverter shall not inject DC current greater than 1 % of the rated AC output current into the utility interface under any operating condition. The inverter shall cease to energize the utility network within 500 ms if this threshold is exceeded.

### Response to utility recovery

#### After a voltage or frequency out-of-range condition that has caused the inverter to cease energizing the utility network, the inverter shall not re-energize the utility network for 60 s after the utility service voltage and frequency have recovered to within the specified ranges.

# Earthing

## 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 12.1.6. 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 13 Lightning Protection), but it is anticipated that for the current system configurations all within one building that no additional protection will be required.

### 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.

### 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.

### 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.

# Lightning Protection

## General requirements

### 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.

# Labelling, safety signs and notices

## General requirements

### 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 |  |
| * 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 |  |

# 

# Noise and Radio Interference

## General requirements

### 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

# Commissioning and Onsite Acceptance Tests

## General considerations

### Prior to delivery of the project, the bidder must perform a series of onsite tests to verify the proper performance of every system. Commissioning tests effectively place responsibility for system or component performance on the Supplier. The commissioning tests are the responsibility of the supplier.

### The tests will avoid as far as possible a negative impact on the daily lives of the habitants of the islands. In that sense it will be studied the use of one or two diesel generators only for testing purposes, keeping the rest of systems connected in normal operating conditions.

### The electrical architecture of the tests will allow the complete disconnection from the main network of elements under test, so that at no time will be jeopardized the safety of the personnel performing the tests neither citizens of the island, and also the rest of the equipment. If any damage occurs, the contracting company will be responsible to restore affected systems under its own cost.

### The bidder shall include a tests plan including electrical drawings, where it will be clearly stated all the tests processes and the assessment of potentials impacts on the regular operation of the power plants at the islands.

### 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 will be properly documented and checked by the Project Management Team prior to the delivery of the project.

## PV Plant Tests

### Commissioning performance tests of the PV plant shall fulfil at least:

* the routine inspection of standard of installation that shall be undertaken according to standards in the specification;
* standard functional tests that may be done on any equipment,
* performance tests, including performance of arrays, strings and sub-strings, inverter efficiencies, line voltage drops etc.
* benchmarking of the performance ratio (PR) for each site, which requires consideration of each array orientation.

### 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 internet based monitoring.

### The procedure for the commissioning and onsite test of the PV plants shall include at leat the items summarized below:

* Gathering and review of information (technical specifications and As-built electrical plans).
* PV modules visual check.
* Array supports visual check.
* Array Junction Boxes inspection (enclosure quality, internal isolators, cable glands and labelling, etc.).
* Array cables to inverter 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).
* Plant performance ratio tests.

## Battery Energy Storage System 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 BPCS.
* Communications wiring between Batteries and BPCS is correctly connected.
* No mechanical damages exist.

### Charge and Discharge at Nominal Power Rate

#### Several full charge and discharge cycles at rated power will be carried out, or at least to the minimum state of charge expected to operate the system on a daily basis.

### Charge and Discharge at Peak Power Rate

#### During charge and discharge testing process the ESS shall achieve the peak power ratings at least once per complete cycle. The duration of the peak power shall be the necessary to achive the optimum control of the hybrid plant and will be within the values provided by the manufacturer.

### Communications BMS-BPCS Test

#### Communications between battery BMS and BPCS 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.

### Communication ESS-PPC Test

#### ESS must communicate with PPC 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 PPC to ESS monitoring parameters from the ESS to the PCC. Tests must be conducted both at zero power and at nominal power.

## Diesel Generator

### Test at the factory

#### In order to verify materials and work quality, the Employer and/or the Employer’s Representative shall be entitled to carry out inspections at the factory during the manufacturing of the project’s equipment.

#### All the equipment, modules, and systems shall be tested in the factory according to the manufacturer’s standards and the procedures set forth in the following sections. Both the test procedures and results shall be documented in a detailed report to be submitted to the Employer.

#### Four weeks before starting the main equipment’s factory tests, the Contractor shall send the Employer the detailed description of the planned tests for their approval. The tests may only be performed upon the Employer written approval:

* Diesel engines
* Alternators Diesel groups

#### All factory tests shall be performed by the Contractor / Manufacturer in the presence of the Employer, if requested.

#### All measuring instruments’ calibration certificates shall be effective for six months at the least.

#### The aforementioned main equipment shall only be transported to the site after complying with the factory tests and the prior authorization of the Employer.

#### All diesel engines tests shall be performed with calibrated and sealed instruments according to ISO 3046.

### Test to be performed at all Islands

#### Every equipment pieces provided under this contract shall be fully tested in situ by the Contractor in nominal operating conditions in order to prove quality compliance, functionality, and the equipment’s guaranteed values (continuous operation with low-load vegetal, power, fuel and lubricating oil consumption, noise level).

#### The Contractor shall supply the necessary additional load on the network for simultaneous tests of all groups at 100% load through load banks (resistances). The Contractor shall also supply all measuring instruments and any other type of equipment required to perform all on site tests according to the technical specifications.

#### At least 4 weeks before starting the tests, the Contractor shall provide the Employer with the tests program for approval.

#### Before the acceptance test, the Contractor shall bring the whole system operational and notify in writing to the Employer for the tests.

#### The Employer shall inspect the system to verify such arrangement and start the tests, and shall answer the Contractor within 5 business days.

#### Firstly, the Generator reliability and efficiency tests shall be performed. Once these are concluded and all requirements are complied with, the Diesel Generator shall be tested together with the hybrid plant, i.e., with the photovoltaic plant, batteries, and the rectifier. In these tests the whole system shall be subject to operation with fluctuating loads and emergency situations.

#### All tests shall be performed according to the following standards:

* Diesel engines: ISO 3046-1 and ISO 3046-3
* Diesel groups: ISO 8528-6 including the measures detailed in chapter 6.5 “Extent of Acceptance Test“

### Final Acceptance Test of the Diesel Generator

#### The Employer shall officially declare the completion of Diesel Generator’s final acceptance test by issuing completion certificate at the end of the guarantee phase when the retention is released and transferred to the Contractor.

## Grid Infrastructure

### General

#### 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 Grid Infrastructure. The Contractor is required to submit such records together with all commissioning records and test sheets to the Employer upon completion of the project as one single bound volume.

### 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 equipments 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 Panel Boards, 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 prior to the installation of the equipment.

#### Typical tests shall include but not limited to:

* Insulation resistance of cables

#### 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. 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.

## Ancillary Systems Tests

### The correct functioning of ancillay systems of the BESS will be tested, including at least:

* Air conditioning system temperature regulation is working correctly.
* Lights
* Electric Outlet

## Hybrid Plant Test

### General

#### 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 comsumption.

#### The test of the full hybrid plant will be the last to be completed, and will require a good coordination between all suppliers, which should be available to be present during the tests of the systems together.

### Specific Tests

#### 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 Employers Engineer.
* 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 esults shall be given to the Emplyers Engineer in fom of a report.

# Documentation

## General

### 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 PPC, anti-virus and malware protection, and shall include the software and hardware requirements for the proposed backup concept.

## Types documents

### Complete documentation shall be provided for the design, procurement and construction. As far as the permits of authorities are required, the documents shall be provided in English.

### The final documentation shall include at least the following:

* Construction drawings for buildings
* Structural calculations
* Material specifications
* Method statements for construction
* Technical reports

### Special attention shall be given to the fact, that documentation shall be submitted with sufficient time allocated for approval prior to manufacturing/assembly.

### Documentation shall be prepared in accordance with the relevant ISO standards or equivalent

## 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 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 3 years.

## 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 11 kV network, 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.

## 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
* Drawings and documents required for permitting, certifying and/or licensing of the Plant
* 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
* interface concept (concept and settings of protection equipment at the interface)
* Detailed layout drawings not limited to architectual, 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

## 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 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
* 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 electrial 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

# Training Program

## Types of training program

### The Bidder is required to provide Training Program for the personnel of the Employer as well as for the Hybrid Plant local staff during construction and operation phase. Employer will assign several employees for the training.

### The training has to be carried out by the Bidder “on the work” during the Defect liability Period/Warranty Period and cover all aspects of O&M and will also include foreign training if necessary in the manufacturer’s factories.

### Foreign training venue(s) will be at Manufacturer's Factory premises. 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 Bidder including pocket allowance of US$100/day/person.

### Employer will assign the following table’s staff for foreign training:

|  |  |
| --- | --- |
| Location | Person |
| Island Power Plant | 1x 14 |
| Fenaka Head Office | 2 |
| PMU | 2 |
|  |  |
|  |  |
|  |  |
| Total | 18 |

### The goal of the training and qualification program is to ensure that the Hybrid Plant’s personnel acquire and maintain the combination of knowledge and demonstrated skills to fulfill their responsibilities. Likewise, the Employer will acquire the knowledge required to fulfill 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 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

# O&M during one year Defect Liability period

## 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.

## 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.

## 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.

## 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.

## 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.

# Drawings

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

## General Design

|  |  |  |
| --- | --- | --- |
| **S No.** | **Drawing Number** | **Title** |
| ***General Design*** | | |
| 1 | G409-HA ALIF-GEN-GRID-001 | SINGLE LINE DIAGRAM OF DISTRIBUTION BOX: INDICATIVE (COMMON) |
| 2 | G409-HA ALIF-GEN-GRID-002 | DISTRIBUTION BOX LAYOUT: INDICATIVE (COMMON) |
| 3 | G409-HA ALIF-GEN-GRID-003 | CROSS SECTIONAL VIEW OF INDICATIVE CABLE TRENCH (COMMON) |
| 4 | G409-HA ALIF-GEN-GRID-004 | Front View Control and protection panel: INDICATIVE (COMMON) |

## Tender Design

| **S No.** | **Drawing Number** | **Title** |
| --- | --- | --- |
| ***Tender Design*** | | |
| 1. 1 | G409-HA ALIF-A01-SLD-1 | A-1 Thuraaku Grid SLD Proposed |
| 1. 2 | G409-HA ALIF-A01-SLD-2 | A1-Thuraaku PH Single LIne Panel |
| 1. 3 | G409-HA ALIF-A02-SLD-1 | A-2 Uligam Grid SLD Proposed |
| 1. 4 | G409-HA ALIF-A02-SLD-2 | A2-Uligam PH Single LIne Panel |
| 1. 5 | G409-HA ALIF-A05-SLD-1 | A-5 Mulhadho Grid SLD Proposed |
| 1. 6 | G409-HA ALIF-A05-SLD-2 | A-5 Mulhadho PH Singel Line Panel |
| 1. 7 | G409-HA ALIF-A06-SLD-1 | A-6 Hoarafushi Grid SLD Proposed |
| 1. 8 | G409-HA ALIF-A06-SLD-2 | A-6 Hoarafushi PH SIngle Line Panel |
| 1. 9 | G409-HA ALIF-A07-SLD-1 | A-7 Ihavandh Grid SLD Proposed |
| 1. 10 | G409-HA ALIF-A07-SLD-2 | A-7 Ihavandh PH Single Line Panel |
| 1. 11 | G409-HA ALIF-A08-SLD-1 | A-8 Kela Grid SLD Proposed |
| 1. 12 | G409-HA ALIF-A08-SLD-2 | A-8 Kelaa PH Single Line Panel |
| 1. 13 | G409-HA ALIF-A09-SLD-1 | A-9 Vashafaru Grid SLD Proposed |
| 1. 14 | G409-HA ALIF-A09-SLD-2 | A-9 Vashafar PH Single Line Panel |
| 1. 15 | G409-HA ALIF-A10-SLD-1 | A-10 DhidhdhOO Grid SLD Existing |
| 1. 16 | G409-HA ALIF-A10-SLD-2 | A-10 Dhidhdh PH Single Line Panel |
|  | G409-HA ALIF-A10-SLD-3 | A-10 Dhidhdh SUB1 Single Line Panel |
|  | G409-HA ALIF-A10-SLD-4 | A-10 Dhidhdh SUB2 Single Line Panel |
| 1. 17 | G409-HA ALIF-A11-SLD-1 | A-11 Filladh Grid SLD Proposed |
| 1. 18 | G409-HA ALIF-A11-SLD-2 | A-11 Filladh PH Single Line Panel |
| 1. 19 | G409-HA ALIF-A12-SLD-1 | A-12 Maarand Grid SLD Proposed |
| 1. 20 | G409-HA ALIF-A12-SLD-2 | A-12 Maarandhoo PH SIngel LIne Panel |
| 1. 21 | G409-HA ALIF-A13-SLD-1 | A-13 Thakand Grid SLD Proposed |
| 1. 22 | G409-HA ALIF-A13-SLD-2 | A-13 Thakanddhoo PH Single Line Panel |
| 1. 23 | G409-HA ALIF-A14-SLD-1 | A-14 Utheem Grid SLD Proposed |
| 1. 24 | G409-HA ALIF-A14-SLD-2 | A-14 Utheem PH Single Line Panel |
| 1. 25 | G409-HA ALIF-A15-SLD-1 | A-15 Muraidh Grid SLD Proposed |
| 1. 26 | G409-HA ALIF-A15-SLD-2 | A-15 Muraidh PH Single Line Panel |
| 1. 27 | G409-HA ALIF-A16-SLD-1 | A-16 Baarah Grid SLD Proposed |
| 1. 28 | G409-HA ALIF-A16-SLD-2 | A-16 Barrah Single Line Panel |

# Supplementary Information

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

|  |  |
| --- | --- |
| **S No.** | **Title** |
| 1 | List of Signals required for centralized SCADA System |
| 2 | Ha Alif Atoll Islands Available Roof size |

# Certificates

## 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.

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

2. 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

## 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 Subclause 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.

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

2. 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

## Change Orders

### Change order procedure

### 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.

### 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.

### 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.

## Change Order Forms

### 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* ]

### 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 Subclause 39.2.1 of the General Conditions. We acknowledge that your agreement to the cost of preparing the Change Proposal, in accordance with GCC Subclause 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* ]

### 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*]

### 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*]

### 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

### 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*]

### 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*]