Section 6: Schedule of Supply

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| 1. List of Goods and Related Services |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Item No. | Name of Goods or Related Services | Description | Unit of Measurement | Quantity |
| 01 | Design, supply, installation, testing and commissioning of Power Plant Control and Monitoring Systems (PCMS) including two (2) years of operation and maintenance support and training. | The minimum overall requirements for the design, delivery, installation, testing and tuning of the overall Plant Control and Monitoring System (PCMS) have been described at sl. (3) of this section | Nos. | twenty (20) |

1. Delivery and Completion Schedule

The delivery period shall start from contract effective date.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Item No. | Description  of Goods  or  Related Services | Delivery Schedule  (Duration) | Location | Required  Completion Date for Related Services |
| 01 | Design, documentation, certification, supply, installation, testing and commissioning of Power Plant Control and Monitoring Systems (PCMS) with all associated balance of plant, and including two (2) years of operation and maintenance support and training.. | See Delivery acceptance conditions below | Name of the islands  Ha. Thuraakunu  Ha. Uligam  Ha.Molhadhoo  Ha.Hoarafushi  Ha.Ihavandhoo  Ha.Kelaa  Ha.Vashafaru  Ha.Dhidhdhoo  Ha.Filladhoo  Ha.Maarandhoo  Ha.Thakandhoo  Ha.Utheemu  Ha.Muraidhoo  Ha. Baarah  Lh.Olhuvelifushi  Lh.Kurendhoo  Ga.Villingili  Sh.Bilehfa  HDh.Finey  HDh.Kumundhoo | 4 months from contract effective date. |

1. Type of System Configurations

The PCMS shall be configured to operate either as Type A, Type B or Type C. These types are described in detail in the following sections. The PCMS should be easily adjustable by the operator to operate either in Type A, Type B or Type C without the need of extra specialist.

1. **Configuration and operation principle of Type A Islands**

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

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

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

At least one diesel genset will be always synchronized. Additionally, a data communication cable between the inverters and the Hybrid System Controller (also called PCMS) shall be installed for command and SCADA purposes.

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

Whenever PV starts to produce energy (Region 2, Figure 1) the load is fed by a combination of diesel gensets and RES. Contingencies and sudden variation of RES can be handled by droop controls at the diesel gensets.

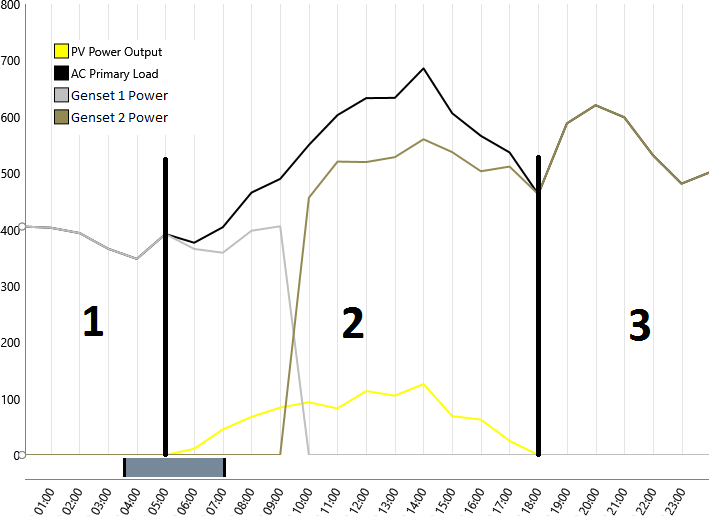


Figure 1: Type A System operation with different energy scenarios

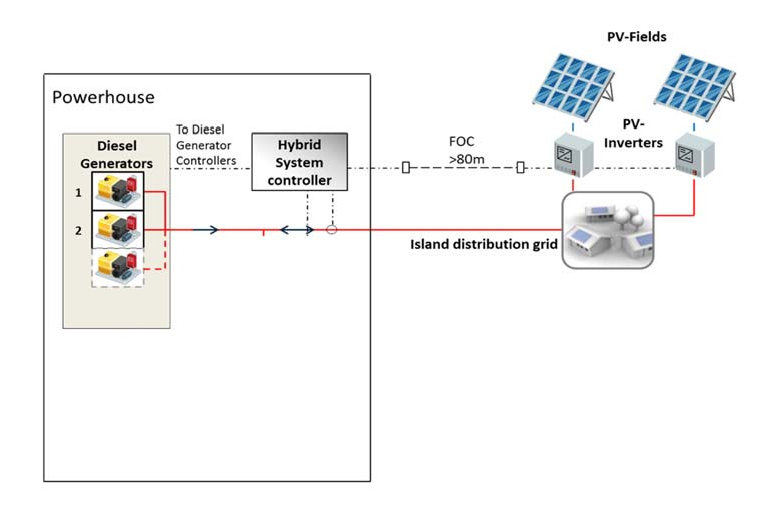


Figure 2: Schematic Block Diagram of BESS integration in the Type A Hybrid System

1. **Configuration and operation principle of Type B Islands**

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

The PV plant is seen as a negative load by the Diesel Generators and injects its produced energy into the grid. When RE is scarce, the diesel genset1 operates and supplies all power demand (Region1, Figure 3). Whenever RE generation starts to pick up load (Region 2, Figure 3), the genset1 began the process of ramping down the output power to meet demand. At this stage, the load is shared by genset 1 and RE maintains the power balance. Depending on the RE penetration level in each island, this process continues usually until genset1 power output reaches the pre-set minimum. A hybrid system controller is installed to ensure grid stability and maintain the operation of Diesel Generators above a defined minimum load (usually 25-30%) by curtailing the output power of the PV inverters when needed. The controller will constantly calculate the spinning reserve needed from the Diesel Generators and communicate with the genset system.

The **BESS have a regulatory role in this type of hybrid system**; BESS shall, not only absorb drops in generation (injecting energy), but also must be able to react quickly to potential reductions in demand and hence, must have a safety margin with respect to a percentage of the load. Fast changes in solar radiation are mirrored by battery load changes. To ensure maximum calendar life, batteries must be kept between 20% to 80% of SOC.

If the RE 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 so they do not inject all available energy, in order to maintain energy balance.

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

An additional short-term power battery is included in the system (30 minutes to 2 hours energy reserve).

The **BESS is used to stabilize the grid when required (f/U) against sudden power fluctuation** (from the load and/or the PV plant) and to have enough spinning reserve to start an additional Diesel Generator if needed. The PCMS should be able to control BESS instantly to provide frequency support, exporting active power to compensate any sudden power fluctuation. At the same time, the PCMS would register this event, monitor BESS SoC, adjust curtailment limits on solar PV, and ensure another diesel genset is started if required.

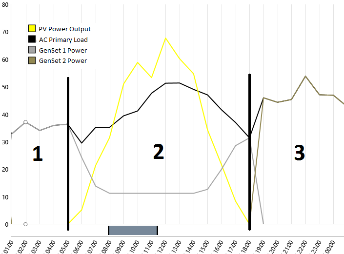


Figure 3: Type B System operation with different energy scenarios

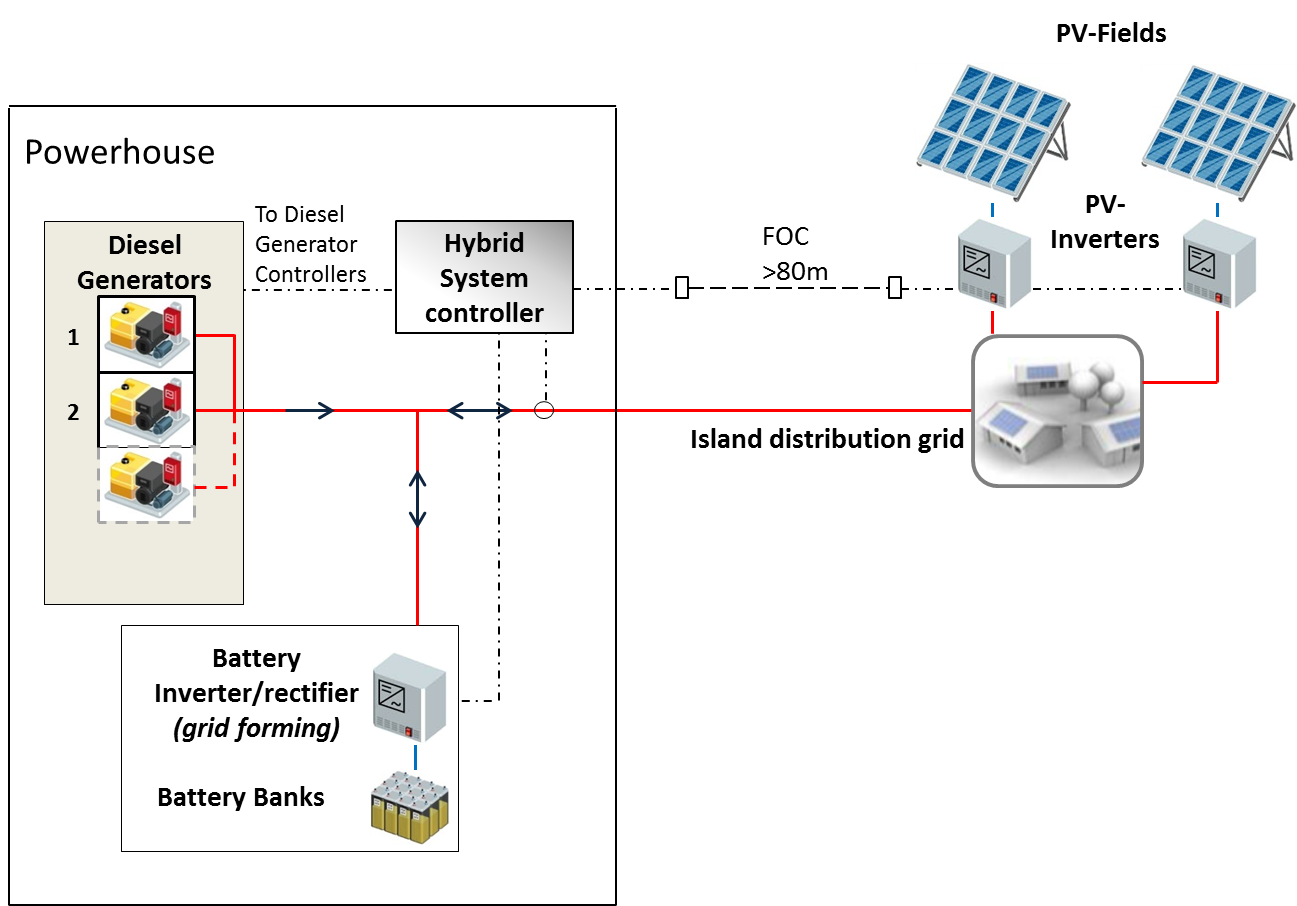


Figure 4: Schematic Block Diagram of BESS integration in the Type B Hybrid System

1. **Configuration and operation principle of Type C Islands**

In this type, grid forming task is always under BESS. Supplier can propose an alternative solution with agreement with employer. The bi-directional grid-forming inverter of the battery needs to function in all four quadrants (absorb/generate active/reactive power) and seamlessly transition among them.

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

A droop-based approach is implemented in which the grid-forming inverter increases the mini-grid frequency and the PV inverters detect it and curtail their output if necessary to maintain the power balance

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

The secondary control is usually programmed 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.

Diesel Generators are used as backup and started to provide energy to the load when the SOCmin of the battery is reached.

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

In the absence of RE (Region 1, Figure 5 ), the Diesels gensets are responsible for forming the grid and serve the load. When the RE generation starts to pick up (Region 2, Figure 5 ), 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 RE maintaining the grid stability. Depending on the RES penetration 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 5) 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 RE output is low enough the load can be served (Region 4, Figure 5) by a combination of gensets, RE and battery.

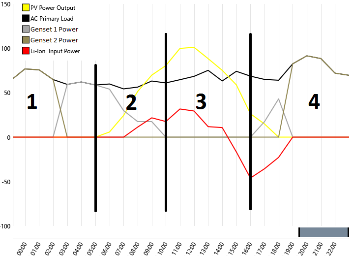


Figure 5: Type C System operation with different energy scenarios

Timeline

Description automatically generated

Figure 4: Schematic Block Diagram of BESS integration in the Type C Hybrid System

1. Technical Specifications

|  |  |  |
| --- | --- | --- |
| Item No. | Name of Goods  or  Related Services | Technical Description,  Specifications, and  Standards |
| 01 | Power Plant Control and Monitoring system (PCMS) | The minimum overall requirements for the design, delivery, installation, testing and tuning of the overall Plant Control and Monitoring System (PCMS) have been described below. |

#### **General requirements**

The PCMS shall provide interactive control and monitoring for specific parts of the PV power plants, the Battery Energy Storage Systems (BESS), diesel power station and auxiliaries, as defined in this specification. Furthermore, all alarms and indications shall be available on Operator workstations. The workstations shall be located close to the Diesel Generator station or in the control room of the already existing Diesel Generator station. The PCMS should be fully compatible and integrated with existing central SCADA located in Male’ through existing Cisco routers.

Special functions and / or exceptions and add-ons dedicated to the individual PV plants are listed in a separate specification dedicated to each plant.

#### General approach

* The system shall be a state-of-the-art, field-proven system based on microprocessor technology. The architecture shall foresee distributed intelligence comparable to an automated real-time control system for data acquisition, processing, transmission, storage and archival, graphical presentation and display.
* All components shall be of approved and reliable design with the highest attainable attributes for uniformity, interoperability and interchangeability. The design shall be modular to facilitate easy maintenance, fault diagnosis and repair of the components, and to support installation and expansion in increments.
* The Bidder shall provide a common PCMS with a central operator station and data handling facilities.
* The minimum data logging interval for all relevant parameters that will be defined by the Employer during detailed design. The systems should have enough data storage capacity to store data up to 2 years. The storage process has to be managed automatically.
* The PCMS System provided by the Contractor should be easily adjustable to operate either Type A, B or Type C without the need of extra specialist.

#### Scope of work

The Bidder is responsible for delivery of the operational PCMS. This includes the design, documentation, certification, supply, delivery, installation, testing and commissioning of PCMS, including all associated balance of plant, meeting the functional requirements of this specification.

The scope shall also include training and capacity building of local staff to operate and maintain the system as well as provide warranties for equipment and workmanship and performance guarantees and defects liability for the complete system as a whole.

The works shall include but not be limited to the following:

* Design of the PCMS
* Supply and installation of PCMS including:
  + Programmable logic controllers (PLCs)
  + Software packages to allow plant operators to interrogate (and troubleshoot) the system
  + Racking and cabinets
  + Power supply converters
  + Cables and communications and media converters as required
    - All local communications at the power station, including any supporting infrastructure such as power supplies, cabinets, etc. are the responsibility of the Bidder
    - Communications to remote solar PV plants will be via fibre optic cables will be provided by others. Bidder is responsible for interfacing to this communications infrastructure.
  + Configuration settings and application backup (in native file format)
* Supply and installation of any required structures, footings, cable management
* All system lightning and surge protection as required.
* All system earthing and equipotential bonding as required, including interface to existing earth grids as relevant.
* Co-ordination with the site owner for access and coordination of activities.
* Submission of documentation as per the documentation deliverables list.
* Provide training and capacity building of local staff in the operation, maintenance and safety of the system.
* Supply of all required spares as per the contract, including storage cabinet or equivalent.
* Supply of a full set of tools required for the maintenance and operation of the system.
* Ensuring compatibility with existing equipment and other plant supplied by the Bidder – especially ensuring that the existing controllers, meters and subsystems are also compatible with the procured equipment.
* Assess data available from existing plant (diesel generator controller), BESS and solar PV inverters and ensure that all information required for the effective operation of the PCMS is available on the PCMS.
* All required interfaces and switches shall be included and provided by the Bidder.

#### Bid proposals

The bid proposals shall describe:

* the full system functionality;
* the main system components;
* performance and parameters (data sheets);
* redundancy and/or failure measure concept;
* communication interfaces;
* a backup and recovery concept for the PCMS; and
* anti-virus and malware protection.

#### Spares parts and spare capacity

Spare capacity

* Provide expansion capability to add or reconfigure BESS, solar PV, or thermal generators over the PCMS life (up to 20% of initial connections as spare)
* All Input/Output modules shall include minimum 20% spare capacity.
* Spare capacity in data network and signal transmission and processing:
* Signal transmission and processing have to be prepared with sufficient capacity and spare in bandwidth, bitrate, reliable termination etc. to guarantee the reliable function of the plant.

Spare parts

* All key parts (that cannot be readily repaired or replaced within 5 days) of the PCMS must have spares provided. Where applicable, spares must be pre-programmed with the same program and parameters as the operational equivalent.
* All supplied spare parts shall be of same material / workmanship and interchangeable with the corresponding parts of the executed work, protected against corrosion, have identification labels.

#### Special Tools

* All special tools required for the operation and maintenance of the system shall be provided by Bidder.
* The Bidder must provide sufficient information so that the Employer can order replacement parts for the PCMS as required. Supplied spare parts and tools shall be listed in detail, including, manufacturer, model, part number, stockist, present cost and typical lead time during the design review stage.

#### **Main functional requirements**

#### High Diesel efficiency

Respecting the limits of grid stability and energy spinning reserve, the system shall always be running on the generator point where the highest efficiency of the diesel system can be achieved and at the same time the maximum available PV energy to be fed in the system. Therefore, the PCMS will chose the smallest possible Diesel Generator and have it running on a high percentage of its rated power. If sufficient PV energy is available and the system is already running with the smallest generator, the PCMS will allow the genset to go down to its minimum load and even underneath this minimum load for a certain time, depending on the manufacturers specifications. In any case the PCMS always has to take care that there is no reverse current in any of the three phases.

#### Maximum PV energy to be used

In order to have the highest benefit of the solar power, the PCMS should not cut the PV power until a certain minimum level of power production of the genset is reached and the batteries are charged up to a predefined maximum level. The minimum and maximum limits of the Battery shall be variable and are set at the commissioning of the system.

The system shall be designed in order to allow a genset with maximum rated capacity smaller than the actual load in the system running in parallel to the PV system and the BESS (in type B and C), if there is enough energy from the PV system available.

#### Emergency Mode

It is mandatory that an emergency mode for the PV inverters is implemented. This mode will automatically be activated in the PV inverters, once the communication to the PCMS is lost due to component failure, communication cable break or any other reason.

Once the communication is lost, the PV inverter shall automatically change into emergency mode. The PV inverter shall then work as a normal grid-connected inverter that is limited in its output power to a certain value that is to be set during commissioning and shall be easily adjustable by the operator at a later stage if necessary.

All other parameters on the inverter shall also be easily changeable for this specific mode and may be different to the normal operation.

#### System stability

In some stages of types B and C, diesel Generator will act as frequency and voltage regulator but shall be supported by the BESS and the PV system with reactive and active power to serve the demanded energy. In such a scenario, the BESS shall always be able to support the system, until a new genset is started to take over the load in case of sudden PV drops and load variations. The PCMS must always react quickly enough to control the BESS to avoid a blackout in the system due to sudden PV drops or load increases.

#### Generator switching

It shall also be avoided to have frequent start and stop scenarios of the Diesel Generator. If an additional genset is started or the genset was switched for a bigger one, there shall be a minimum time for how long this genset has to stay online, before it is switched off or changed for a smaller one. This parameter shall be easily adjustable by the operator.

#### Load ramp

In types B and C, if the PV system is already providing its maximum available power to the system and the load demand is still rising, the Diesel Generator has to provide this energy. If there are slow load changes, the Diesel Generator will directly serve the loads and rise its power output. For sudden load changes caused by either PV drops or load increase, or both at the same time,

the PCMS should be able to control BESS instantly to provide frequency support, exporting active power to compensate any sudden power fluctuation. 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 easily adjustable by the controller from the controlling room on site as well as from selected users online, anywhere with an internet connection. The access has to be Password and Username protected. Especially parameters like load set-points of Diesel Generators allowed ramp rates of the generator, ramp rates of battery, the timing of battery, all setup parameters of needed current sensors and parameters that are provided by genset controllers.

The PCMS shall support at least 5 DG sets and 5 PV sites without any modification or upgrade to the system

#### Type C grid building systems

For systems with Grid Building Battery Inverters (GRIDB), the main control unit shall turn off the Diesel Generators completely, if the available solar energy and the SOC of the battery allow it. Solar energy shall always be the prioritized energy to be used in the system, and Diesel Generators shall only be turned on if necessary.

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

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

#### **Technical specification requirements**

The Contractor shall provide standard hardware and software configurations to the extent possible as long as it meets or exceeds the requirements of this specification. International standards shall be applied for hardware and software interfaces to allow system expansion in terms of equipment and software functions (if required).

#### System Security

The PCMS or each subsystem shall be designed in accordance with ISO / IEC 27002, ISA 99 or equivalent Standards.

For security reasons all log-in and log-out events shall be logged in the event list. All user changes and modifications to the system as well as parameter and program modifications shall be logged with the exact time and operator’s assignment in the event list too. It shall be possible to print this information.

For software security, at least the following has to be provided:

* Up to date anti-virus program to be delivered and installed
* Up to date firewall to be delivered and installed
* All access ports (USB, CF-cards, etc.) shall be included in the security scenario and protected/secured against infiltration of malware

#### Over-Voltage Protection

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

#### Grounding

The PCMS equipment shall be connected via a common potential equalization bar to the earthing network Station.

The Contractor shall coordinate earthing concept and requirements with the manufacturer of the PCMS and accordingly provide the earthing system that shall be approved by the Employer.

#### Labelling and Marking

All terminals, plugs, and internal and external connecting cables shall be labelled, durable and readable with a code approved by the Employer.

#### Cabinets

The PCMS and associated accessories shall be accommodated in dedicated equipment cabinets.

For indoor application, the cabinets shall be constructed as follows:

* Standard sized steel cabinets with external painting colour as per Employer/Engineers approval
* Certified for minimum IP41 protection class
* Power distribution box with main filter and main switch (separate 2-pole breakers for each device)
* Front-patches for LAN cabling
* Cable organisers, cable trays, suspensions and termination components with strain relief for all internal and external cabling
* Over-voltage protection for all devices (if required)
* 20 % housing space for future equipment
* Ventilation fan to ensure that maximum allowable operating temperature of all equipment inside the cabinets shall not be exceeded
* Bottom cable access
* Document pocket
* Grounding bus bar for earthing connection
* Doors with glass front and locking system
* Inner light and power socket for maintenance
* Provision of easy access for maintenance and repair, all devices with rear plugs shall be draw-able

#### Electrical Interface Units

Electrical Interface Units (EIUs) as data acquisition modules shall be designed and provided to perform the interface between the electrical equipment and the PCMS. The EIU hardware shall be fitted with process interface slot-in modules for digital inputs and outputs, analogue inputs, Ethernet communication modules, etc.

The EIU shall be of same make and type all over the Plant and shall have Ethernet connection with PCMS. The power supply of the EIU shall be powered from the UPS.

#### Performance and Reliability

* All equipment shall be of high quality and reliability. The overall system availability of the PCMS shall be 99% or better.
* All equipment shall be protected against cyber-attacks.
* PCMS lifetime shall be 25 years.

#### Software Requirements

* Open source code for all software shall be utilised wherever this option is available. Open source code shall be provided as a deliverable, including documentation. If proprietary software is utilised, then in the event that an OEM is unable to meet the required commitment to support any proprietary software needed for operations, then this software must be made available to the Employer in a standard, usable, source code form with documentation such software. Provision to meet this requirement through a third party shall be made in advance (prior to Completion) in the event OEM is unavailable to release software.
* The PMCS shall be based on standard proven firmware and software, which shall already been implemented in other systems. The software engineering tool shall be provided to configure, set up and modify the data acquisition, data processing and database system components. The software application shall include facilities to perform programmable logic functions.
* The system shall have monitoring and self-diagnostics features for both, hardware and software.
* Licensed software copy required for the proposed system shall be provided. The latest proven anti-virus software shall be installed in the PCMS.
* All logins to the system shall be password protected. Data transmission via public internet shall be encrypted.

#### **Other Functionalities**

#### Settings Operator User level

There will be two configurable DG control mode: Manual and Auto: the gensets are controlled by the EMS depending on the actual requirements by load, the availability of solar power, as well as the SoC of the battery system.

If the system is set to auto mode, the following range of setting options should be available:

* genset start/stop control mode and changeover capability between Manual DG control mode and auto DG control mode
* Status of the start stop control
* Activation time-based Priority Swap
* Deactivation of some gensets so that they are not considered any further for AUTO start/stop operation
* Information on the actual configuration of the DGs: Nominal power, Actual priority for the gensets (considering the presently valid priority set)

#### The following range of setting options should be available in Administrator user Level

* Potential Drop in Actual PV Power
* Potential Increase in Load Power
* Minimum Diesel Genset Operating Point
* Prevent daytime discharge
* State of Charge criteria for charging/discharging
* Diesel genset target operating point for battery discharge
* Charge battery to hold diesel generator set for minimum operation
* Max ramp up /. Ramp down rate for diesel gen set.
* Diesel gen set time of use

#### **Alarm and Event Management**

#### General

All alarms including system alarms and important events shall be listed up on the display. The lists shall be in chronological sequence showing:

* The precise date and time with the specified resolution in actual sequential of events;
* Plant identification code;
* Clear text/denomination of alarms and events;
* Status message (open, close, off, high, low);
* The actual value in case of high/low alarms derived from analogue values;
* Sorting of alarms per sub group shall be possible.
* Alarms and signals that happened in the past can be recalled by the operator at any time. If any new alarm appears while monitoring any other page, flashing signal on the screen shall show the new event/signal to the operator.
* Dedicated soft pushbuttons shall serve the operator for alarm handling such as buzzer signal acknowledgement, alarm acknowledgement, alarm clearing and page flipping. Differentiation between alarms and events shall be done by colour coding (e.g. Alarms: red colour). Further colour for a distinction of alarms according to the degree of urgency or type of alarms is also required.
* Flashing functions of alarm messages shall be according to standards related to conventional alarms.
* The flashing frequency for coming and going alarms shall be different.
* First-out alarms shall be marked clearly and need special acknowledgement.

#### 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.

### 

#### **Data Communication Network**

The PCMS shall have the communication via Modbus TCP to all energy producers, respectively Diesel Generators, PV inverters and BESS units. It will receive all necessary measurement data from those sources, such as voltage, ampere, cos phi, battery SOC, frequency and warnings/alarms at the connection points of the sources. According to the actual state of the system it will then decide and send the control to the relevant sources, if and how they should react, be switched on or off or regulate their power output. The communication shall be realized with network cables CAT 6 and fibre optic cables for longer distances. The system shall communicate with and provide data to the SCADA system.

The PCMS shall also be able to include any other sensors necessary for the functioning of the system and provide the data of additionally included sensors in the Modbus protocol. The communication protocol of the sensors to be included may be of a different kind than Modbus.

The supplied system shall include a data communication network to ensure the proper interconnection of all components of the PCMS such as but not limited to: cables, accessories, media converters, repeaters, amplifiers, switching and routing equipment including accessories, their housing as required, as well as the management systems necessary to operate the data communication network.

Ethernet with a minimum data rate of 100 Mbit/s shall be provided.

The network shall be fault tolerant for single failure and shall at least be installed in ring structure.

Switches used in the network and to interface equipment shall be manageable and able to interface to FOC on upper level cabling structure.

All FOC cables shall be terminated to patch panels; no fibres to be loose.

Interface to switches shall be performed via patch cables.

Underground splices shall not be foreseen.

#### **Power Supply & Cabling**

#### General

Power supply for PCMS shall be provided from UPS.

The Bidder shall perform all cabling and installations works for outdoor and indoor equipment as well as the interface interconnection and termination at existing devices.

#### Additional communication cable

#### Electrical connections and UPS

A redundant power supply for PCMS shall be provided from UPS. A minimum of 30 min. of independent power supply shall be guaranteed for on-site conditions.

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

**Grounding:** The PCMS equipment shall be connected via a common potential equalization bar to the earthing network of the diesel power station building.

The Bidder shall coordinate earthing concept and requirements with the manufacturer of the PCMS and accordingly provide the earthing system that shall be approved by the Employer.

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

#### Category 6 cables

At least shielded Cat 6 cables shall be used for an Ethernet communication system with a length less than 100m. The cables shall be according to ISO 24702 suitable to function properly and faultless under the prevailing environmental conditions and rodent-protected for direct buried application. The cables shall have a frequency spectrum of up to 250 MHz and be terminated in 8P8C modular connectors.

The cables shall be halogen-free.

#### Fibre Optic Cables (FOC)

Depending on the requirements of the proposed control system single mode and/or multi-mode FOCs shall be used.

The manufacturing, construction, labelling and testing of the fibre optic cable system shall meet the requirements established in the relevant applicable ITU and IEC codes, standards and recommendations.

The fibre optic cable shall be suitable to function properly and faultlessly under the prevailing environmental conditions and rodent-protected for direct buried application.

The fibre optic cable shall be laid in buried cable conduits. Therefore a fully dielectric fibre optic cable suitable for ducted or direct buried applications, filled with compound to prevent axial and longitudinal ingress of water and/or soluble chemicals throughout the cable shall be provided. The cable shall have loose tubes as a secondary coating of fibres.

**Main Cable Structure**

The cable shall be:

* Halogen free
* Metal free
* Axial and longitudinal tightness against water and / or soluble chemicals
* Rodent-protected
* Traction elements of Kevlar
* Lifetime of cable >30 years
* FOC fibre with primary coating Ø 250 +/- 15µm
* Secondary coating of fibres
* Filled centre fibre with 24 fibres
* Standard coloring
* Outer cladding:
* UV persistent
* Markings containing:
  + Manufacturer numbering;
  + Type of cable;
  + Number of fibres’ and type of fibre;
  + Date;
  + Metering; and
  + P/N marking.

Cable markings shall be printed on the outer fibre cable jacket. The markings shall be permanent, insoluble in water and be legible for the duration of cable life. The markings shall be printed at intervals of not more than 2 meters.

**Fibres and number of fibres**

* Diameter fibre:9 µm (+/- 10 %) – Single Mode
* Diameter fibre:62,5 µm (+/- 10 %) – Multi Mode
* Diameter cladding:125 µm(+/- 3µm)
* Diameter coating:250 µm(+/- 15µm)
* Damping: Single Mode max:
* < 0,4dB/km, typ. 0,36dB/km at 1310 nm wavelength and
* < 0,3 dB/km, typ. 0,26 dB/km at 1550 nm wavelength.
* Multi Mode max:< 0,9 dB/km, typ. 0,9 dB/km at 1310 nm wavelength.
* Number of fibres: The long distance cable shall contain a minimum number f 12 fibres.

#### Measurement after Cable Installation

**Measurement of splices**

To verify the maximum damping of splices ODTR measurement in both directions shall be performed. The max damping of 0.1 dB per splice shall not exceed.

Measurement of Cable Run from Termination to Termination

The characteristics of the cable run shall be measured and verified and protocolled by:

* Bi-directional Power Loss Measurement at 1310 +30/-15 nm and 1550 +30/-70 nm
* Bi-directional OTDR Measurement at 1310 +30/-15 nm und 1550 +30/-70 nm
* The values for maximum damping are:
* max. damping splice: 0,10 dB
* max. damping connectors (pair): 0,50 dB

#### Fibre Optic Cable Accessories

A detectable reinforced underground marking and warning tape shall be laid in the ground 300 mm above the protection conduit.

The patch cord consists of a single / multi-phase fibre optic cable with plug connections on both ends. Pigtails are fibre cables pre-assembled with a connector at one end. The fibres of the patch cords and pigtails shall be according the specified fibres and all components shall have a service life of more than 20 years with a minimum of contact durability of 1000.

Type of connectors shall match the requirements of PCMS I/O modules and shall be of same type all over the plant. Contractor shall decide the used type (ST; SC; FC/PC)

The connecter loss shall not exceed 0.5 dB per connector pair.

OTDR (Optical Time Domain Reflectometer) test report shall be submitted to Employer/Engineer.

The termination of each fibre in transmit and receive direction shall be provided on an optical distribution frame (ODF) for access to the transmission equipment. The ODF for receive and transmit direction shall be configured in accordance to the specified number of fibres (24). The ODF are to be installed in termination cabinets, which may be combined with the communication system.

#### Industrial Ethernet Switches (Managed type)

Industrial Ethernet Switches foreseen for installation shall provide the following:

* Compliance: IEEE 802.3 ISO/IEC 8802/3
* Technology: Store and forward
* Filtering Services / prioritization: IEEE 802.1 D/p
* Port type: Min 100 Mbps Media as necessary
* Diagnostics: Indication of power status, link status, data, full duplex, link failure (fibre disconnected)
* Management: SNMP, HTTP
* Design: Fan less
* Mechanical design: Stability against shock and vibration
* Min. operating temp. range: 0°C - 55°C
* Rel. humidity: 0% - 100%
* Diagnostics: LEDs for indication of power status, link status, data, full duplex, link failure (fibre disconnected)
* EMC: EN 55022, EN 50082-2
* VLAN support: IEEE 802.1Q, MAC Address / Port Based
* MTBF: >20 years

For Ethernet connectivity interfaces, only shielded cables of type CAT 6 or better shall be applied in structured cabling according to ISO 24702 and to the description within this specification.

Fibre optic cables shall be delivered and installed according to the description within this specification.

#### **Defect liability period**

The defect liability period shall be one year. During this period, the Bidder shall provide O&M support services and corrective maintenance/ re-programming of PCMS at no extra cost to the Employer. O&M support includes monitoring the functioning of PCMS and preparing monthly reports by collecting data remotely regarding the operation of the plant including electricity production, efficiency, fuel consumption, and availability. 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, 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.

Corrective maintenance means the repair or replacement of defective material and components and re-programming as required for smooth operations of the hybrid power plants.

#### **Ongoing O&M and troubleshooting support**

Contractor must provide a comprehensive support and maintenance plan for all Hardware and Software provided (including any 3rd party products) including committed KPIs and Service Levels Vendor will adhere to.

For the first two years from the date of commissioning of the projects (including the defect liability period), the Contractor will be responsible for remotely monitoring the functioning and performance of hybrid plants with the help of PCMS and submitting a monthly performance report to the Employer. In case there is any fault, or malfunctioning of the plant or the PCMS the Contractor will immediately report the Employer with possible reasons for such issues. The above-mentioned services for the first two years will be a part of the supply contract. During this period, the Contractor will provide technical support to FENAKA to address any technical, functional and performance issues of any of the units in regards to functioning or re-programming of the PCMS for the smooth functioning of the hybrid plants. The Contractor, as and when required will depute competent technical personnel to jointly work with FENAKA personnel to address such issues to the satisfaction of the employer.

#### **Documentation**

A comprehensive set of Documentation is to be provided as part of any subsequent project and must include as a minimum the following:

* Comprehensive Design Documentation covering the complete design, including:
  + High level design documents
  + Detailed design documents
  + Interface, signaling & interconnect documents
  + Technical and operational manuals
  + Performance and capacity analysis documentation
  + Security documentation
  + Availability and disaster recovery documentation.
* Deployment documentation, including:
  + Pre-installation site survey reports
  + Site deployment documentation. Including drawing
  + Detailed responsibility matrices
  + Detailed equipment lists (BoQ/BoM)

All documentation costs will be included within the offered unit prices.

#### **Training**

The Bidder is required to provide training at the manufacturer’s site for two persons from each powerhouse, two staff from FENAKA head office and two staff from PMU (a total of 10 persons). In addition, local staff should be given training on operation and maintenance during the installation/ integration of PCMS. The training shall take one week on the manufacturer’s premises plus one week on the 15 sites for each team separately.

All living, accommodation, food, and transport expenses of the trainees during the period of training/study tour including airfares, incidental expenses, medical expenses, medical insurance etc. will be covered by the Contractor including a pocket allowance of US$100/day/person for training abroad.

The training shall comprise but not be limited to the following:

* Health, Safety, and Environmental (HSE)
* Overview of Hybrid systems configurations
* Overview of the operational and control system of PCMS
* Hybrid systems configurations specific to the integration of PCMS
* Specific operational and functional features of PCMS
* Programming and priority setting of PCMS to control hybrid power plants
* Monitoring of functional status of different system components through PCMS
* Monitoring of the functioning of PCMS
* Fault detection through PCMS
* Re-programming of PCMS based on plant reconfiguration and/or upgradation
* Preventive and corrective maintenance of PCMS
* Use of PCMS operation manual
* Collection, storage and processing of data remotely and at the plant site regarding the operation of the plant including electricity production, efficiency, fuel consumption, and availability.
* Preparation of report

1. List of Islands

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Sl. No. | Name of island | Geographical coordinates | Type A/B/C | Current DG Capacity (kVA) | Installed BESS capacity (kWh) | PV inverter aggregated AC capacity (kVA) |
|  | Ha. Thuraakunu |  | B | 50, 128, 160 | 85 | 100 |
|  | Ha. Uligam |  | C | 80, 128, 165 | 240 | 120 |
|  | Ha. Molhadhoo |  | C | 48, 60 | 120 | 60 |
|  | Ha. Hoarafushi |  | B | 350, 600, 250 | 150 | 330 |
|  | Ha. Ihavandhoo |  | B | 250, 350, 450 | 150 | 320 |
|  | Ha. Kelaa |  | B | 120, 200, 236 | 100 | 200 |
|  | Ha. Vashafaru |  | C | 50, 80, 80 | 240 | 120 |
|  | Ha. Dhidhdhoo |  | B | 500, 800, 500 | 250 | 250 |
|  | Ha. Filladhoo |  | C | 160, 80, 70 | 280 | 140 |
|  | Ha. Maarandhoo |  | C | 160, 90, 60 | 280 | 140 |
|  | Ha. Thakandhoo |  | C | 60, 70, 58 | 180 | 90 |
|  | Ha. Utheemu |  | C | 160, 100, 80 | 280 | 150 |
|  | Ha. Muraidhoo |  | C | 150, 80, 60 | 240 | 140 |
|  | Ha. Baarah |  | B | 120, 90, 60 | 70 | 162 |
|  | Lh. Olhuvelifushi |  | B | 120, 90, 60 | 70 | 162 |
|  | Lh. Kurendhoo |  | B | 165, 150, 100 | 84 | 300 |
|  | Ga. Villingili |  | B | 300, 500, 300 | 84 | 300 |
|  | Sh. Bilehfa |  | C | 100, 70, 50 | 100 | 150 |
|  | HDh. Finey |  | C | 160, 110, 100 | 60 | 80 |
|  | HDh. Kumundhoo |  | B | 160, 120, 80 | 70 | 100 |