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Request for Proposal (RFP) : Microgrid Project at Betong District, Yala Province (MGBT)

Tender Reference No. : PEA-MGBT-001/2020

Book 2 Technical Specification and Requirements of Microgrid Controller

	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
1	**Principal Requirement**				
		1.1 MGC shall be able to operate in all use cases as described in Section 3.			

Grid Connected	Islanding
1 Transition from Grid Connected to Islanding	1 Transition from Islanding to Grid Connected
1.1 Intentional Islanding	
1.2 Unintentional Islanding	
2 Black Start	2 Black Start
3 Microgrid objectives	3 Microrid objectives
3.1 Improve reliability	3.1 Improve reliability
3.2 Improve power quality	3.2 Improve power quality
3.3 Peak shaving	3.3 Peak shaving
3.4 Reduce losses in distribution line	3.4 Reduce losses in distribution line
3.5 Volt/Var Control	3.5 Volt/Var Control
3.6 Constraint management	3.6 Constraint management
3.7 GHG emission reduction	3.7 GHG emission reduction
3.8 Increase/decrease in fuel prices	3.8 Increase/decrease in fuel prices
3.9 PV Smoothing	3.9 PV Smoothing
(a) Full sunshine	(a) Full sunshine
(b) Intermittent sunshine	(b) Intermittent sunshine
(c) No sunshine	(c) No sunshine
3.10 Load Shedding	3.10 Load Shedding
3.11 Frequency control	3.11 Frequency control
3.12 Voltage Control	3.12 Voltage Control
3.13 Energy Management	3.13 Energy Management
4 Protection	4 Protection
4.1 Fault Upstream of the line	4.1 Fault inside microgrid area
4.2 Fault inside Microgrid area (FLISR)	4.2 Fault inside Microgrid area (FLISR)
5 Communication Failure	5 Communication Failure
5.1 Between ADDC and MGC	5.1 Between ADDC and MGC
5.2 Within MGC	5.2 Within MGC
6 Maintenance (TAGGING)	6 Maintenance (TAGGING)
6.1 Upstream of the line	6.1 Upstream of the line
6.2 Inside MGC	6.2 Inside MGC
7 Heartbeat failure	7 Heartbeat failure

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		1.2 MGC shall be able to operate to support different objective functions such as reliability, power quality, peak reduction, reduce power losses in distribution line, or Volt/VAR control, etc.			
		1.3 MGC shall be able to give weights or priority to avoid conflict between different objective functions. High priority objective function always has presidencies over lower priority objective function.			
		1.4 MGC shall be able to communicate with the existing ADDC system, the substation, the VSPP (monitoring), the diesel generator controller, the battery storage management system, STATCOM/SVG and SWs.			
		1.5 MGC shall be able to perform fault location, isolation and service restoration (within the boundary of the microgrid).			
		1.6 MGC and ancillary system shall be able to synchronize time with PEA's existing system.			
		1.7 MGC shall be able to control circuit breaker and protection relay in substation, and receive signal.			
		1.8 MGC shall be compliant to some propose part of IEC 62898-1, IEC62898-2.			
		1.9 MGC shall need detailed factory acceptance test in order to verify the functional of MGC before installation at site.			
2	Hardware Requirements				
		2.1 MGC and ancillary equipment shall have redundant server in order to be a highly reliable controller, i.e the MGC shall be able to operate with contingency of controller at least n-1. MGC which is centralized architecture shall have redundant server. MGC, which is distributed architecture, shall be able to operate when one of distributed controllers is failed. No loss station data during system fails. The fail shall occur in period less than 10 second.			
		2.2 MGC controller set shall be industrial grade.			
		2.3 MGC shall have at least 3 human machine interface (HMI) monitors. - Three monitors for operator at control room shall have screen size at least 27". - One monitor for mntor at electric office (EO) room shall have screen size at least 23". - One monitor for displaying at conference room shall have screen size at least 100".			
		2.4 Graphic display on monitor shall support at least both English and Thai language.			
		2.5 All HMI hardware shall be latest available technology and shall have prior approval from PEA before making orders by the contractor.			

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3	Software Requirements				
		3.1 The configuration of power system shall be able to be reconfigured by PEA after commissioning. PEA shall be able to add and/or remove any electrical equipment by PEA personnel. Vendor shall describe in detail the configuration tools use to configure modify microgrid controller.			
		3.2 MGC shall be able to store history operation data for at least 1 year continuously according to First in First out (FIFO) process.			
		3.3 Operating Systems (OS) of HMI and Engineering Workstation shall be latest version of Windows or Linux according to OS of MGC.			
		3.4 The Engineering Workstation at MGC control room shall include these functions: • Real time data historian & analysis • Communication network management • System access control and cyber security management • MGC monitoring, diagnostics and maintenance • Disturbance and fault information handling, analysis and evaluation • Engineering HMI • Web server and interface (for equipment setting) • Sequence of events and alarm analysis • Data archiving, trending and historical analysis • Automatic fault report generation and notification • Substation Protection, Automation and Control system • Substation status display • Substation documentation management • Dashboard status display of overall MGC system • Realtime graphic of system analog • FLISR function; the execution, alarm, and etc.			
		3.5 The operation screen displays for the monitoring and control of MGC shall include: • Detailed equipment status and network configuration information • GIS info graphic of MGC system and shall be able to zoom in/out • Import GIS info graphic from database of PEA • Visual indication of device setting, selection, operation and interlocking • Service and measurement values, including analog measurements and their limit setting • Alarm annunciation • Visual record of system alarms, including fault information and events • A means of displaying the status of devices that are not monitored automatically but are under the substation operator's control such as application of tags or labels • Screen saver mode after 1 hour of keyboard input inactivity • Display detailed equipment and network configuration information according to each use cases			

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		3.6 MGC shall be able to display data at ADDC.			
		3.7 User interface, log report, message or related user interfaces shall be displayed in English.			
		3.8 The contractor shall design HMI according to PEA requirement and shall have prior approval from PEA.			
		3.9 Upgrade and patched management shall be able to be done remotely. Vendor shall describe mechanism of how and when upgrade and patched are available to PEA. PEA shall be notified immediately once the upgrade and patched are available.			
4	Functional Requirements				
	4.1 Islanded	The microgrid EMS will estimate the microgrid load level and the available generation capacities, shed or reduce the loads with lower priorities, re-dispatch the real and reactive power outputs of each generator and energy storage unit so that there is no import/export of real/reactive power between the microgrid and the PEA main grid at PCC, and the microgrid components are managed in the islanded operation as well. Functional requirements : 1) MGC shall be able to maintain distribution network frequency and voltage while microgrid is in islanded mode. 2) MGC shall be able to add or drop generation resources (include private VSPPs) to maintain system frequency and voltage. 3) MGC may have to shed load to maintain system frequency and voltage while in the islanded mode. 4) MGC shall continue to monitor the 33 KV feeder for voltage. If grid voltage is within acceptable limits established by PEA, then MGC shall connect the microgrid to the grid. 5) DMS operator shall be able to send command to MGC to reconnect microgrid to main grid.			
	4.2 Grid Connected	A microgrid must be capable of resynchronizing and reconnecting to the main grid i.e. transition from islanded operation mode to grid-connected operation mode. Once in grid connected mode, Microgrid EMS calculates microgrid economic dispatch. Functional requirements : 1)MGC shall be able to add or drop microgrid resources (include private VSPPs) while in grid connected mode 2)When reconnecting to grid from islanded mode, MGC shall be able do 2 cases: a)all microgrid resources must be disconnected to dead bus state, then reconnect to the grid, b)reconnecting the grid without interruption in microgrid area.			

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	4.3 Black start	During a black start procedure, a microgrid is restored to islanded operation mode after a complete shutdown. The restoration process involves the microgrid central controller (microgrid EMS and microgrid SCADA), multiple resources, loads, and switchgear. Based on the system topology, capacities and sizes of the resources and loads, and the controllability of the devices, the black start procedure can be pre-determined and implemented in the microgrid central controller and other devices. The execution of the black start can be automatic with minimal operator involvement. Functional requirements : 1)MGC shall be able to connect generation sources (include private VSPPs) to dead bus or live bus. 2)MGC shall be able to send control commands to BESS ,DG set's controllers ,and STATCOM/SVG including operating modes, set points (e.g.kW, kVAR), start/stop, etc. 3)The MGC shall be able to black start the microgrid using any or all of the following generation resources: [1] BESS, [2] DG Sets			
	4.4 Peak shaving	Peak shaving is primarily for economic operation of the MGBT power system. Utilization of local resources such as BESS can reduce MGBT demand resulting in reduced power transfer (and line loss) over long distances from substation. Functional requirements 1) The MGC shall implement peak shaving to reduce overall energy costs (use of lower cost resources) by considering load automatically. 2) The MGC shall use peak shaving to maintain system frequency and voltage.			
	4.5 Load shedding	The MGBT shall be able to perform load shedding for stability of power system. Functional requirements : - The MGC shall only use load shedding to maintain system frequency and voltage.			

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	4.6 Frequency control	This function is to balance the generation and loads in a microgrid therefore to maintain the stability of the microgrid by controlling its frequency. It is fast real-time control in the time scale of sub-second. The function is realized by one or more primary sources that are responsible for the frequency control. It is determined by the microgrid SCADA if a microgrid source is operated as a primary source or as other source, and the frequency setting point is also sent by the microgrid SCADA to the primary sources. Functional requirements : 1)System frequency shall be maintained by MGC when in islanded scenarios. In grid connected scenarios, the main grid shall maintain system frequency. 2)MGC shall add or drop generation resources to maintain system frequency 3)The MGC shall shed load to maintain system frequency if all generations sources have been used 4)One or more microgrid sources is assigned to be primary sources that regulate the frequency. The microgrid source control modes and frequency setting point are in the microgrid control commands which are sent by the MGC.			
	4.7 Voltage control	This function regulates voltage at PCC within a specified range. It is fast real-time control in a time scale of sub-seconds. This function is realized by one or more primary sources that are responsible for controlling voltage. It is determined by the microgrid SCADA if a microgrid source is operated as a primary source or other source, and the voltage setting point is sent by the microgrid SCADA to the primary sources. Functional requirements : 1) The MGC shall be able to supply VAR's from BESS or STATCOM/SVG to maintain voltage levels. 2) The MGC may implement load shedding to maintain system voltage levels specified by PEA. 3) The MGC shall add or drop generation resources to maintain voltage levels specified by PEA. 4) The MGC shall be able to send control commands e.g.set points to the voltage regulators on the 33 KV feeder from PEA substation to maintain voltages within the limits set by PEA			

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	4.8 Energy Management	The microgrid EMS is part of the microgrid controller, and the interface/agent between the distribution management system (DMS) and the microgrid. The microgrid EMS manages the power flow, power transaction, energy generation and consumption, voltage/reactive power, and battery charging/discharging in a microgrid. The objective of Microgrid EMS is to coordinate among multiple DERs, storage/battery, main grid and responsive loads to improve the system reliability and reduce the total operation cost. A microgrid has two operation modes, i.e., Grid-connected mode and Islanding mode. The operation conditions, system constraints, and operation objectives could be different in different modes. In Grid-connected mode, the microgrid EMS communicates with the distribution system, manages the microgrid to comply with the utility policies and regulations, makes operation decisions based on the internal conditions as well as the utility requirements, and provides ancillary services under the distribution system's commands. In islanding mode, the primary objectives of the microgrid EMS are to maintain the stability, to regulate the voltage and frequency within certain ranges, and to optimize the microgrid overall performances.			
		Functional requirements : 1)When possible, the MGC shall dispatch generation to reduce losses in distribution network. 1.1)The MGC shall give priority to renewable energy resources such as VSPP and diesel generator. 1.2)Generation cost merit order for dispatching is: Grid, VSPP, diesel generator. 2)The MGC shall add generation resources based on price of energy produced by the sources of generation. 3)Where possible the BESS system shall use renewable sources of power to charge the battery.			

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	4.9 FLISR	FLISR is designed to reduce outage impact and duration i.e. reduce SAIFI and SAIDI by using ·automatic sectionalizing and restoration, and ·automatic circuit reconfiguration By coordinating operation of field devices, software, and dedicated communication networks to automatically determine the location of a fault, and rapidly reconfigure the flow of electricity so that some or all of the customers can avoid experiencing outages. For any fault in one section, FLISR first ·opens closed switches to isolate the faulted section, and then ·restores the non-faulted sections by reclosing feeder breakers and/or closing open tie switches to other feeders. Functional requirements : 1)SW's shall report any fault detected to MGC. 2)FLISR application shall report any fault detected and determine location of the fault, how many kilometers from substation or SW and showed on workstation. The accuracy of the fault location would be discussed with PEA. 3)FLISR application shall isolated faulted feeder section based on fault location. 4)FLISR application shall try and restore service to as many customers as possible after the fault has occurred. Actual section load before fault event shall be considered before load restoration. 5)FLISR application shall suggested switching sequence for isolation and restoration on workstation. 6) FLISR application shall showed execution progress according to suggested switching sequence such as executed already step, current step, and execution result on workstation (Success = all steps executed successfully) (Terminated = control failed ,some conditions not met or etc.) 7) FLISR application shall showed some information at ADDC such as FLISR Started status, execution mode (automatic or manual), execution result			
		8)MGC shall communicate with SW's located at distribution feeder switches SW1 through SW32 via DNP3.0 over IP Protocol.			

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5	Generation Resources				
	5.1 Diesel Generator	Diesel generation will be required to supply/absorb active/reactive power for successful operation of the microgrid. Local controller will be operating autonomously under supervision of the microgrid SCADA. Functional requirements : 1) The DG Operator shall be able to place the DG sets in either manual or automatic mode. 2) The DG's shall be capable of "Load complying" to maintain system voltage and frequency. 3) The MGC shall be able to send set point commands (kW, kVAR or PF) to the local controller. 4) The MGC shall only start/stop the DG's when they are in automatic mode.			
	5.2 BESS	BESS shall provide power and reactive power as requested by functional requirements under multiple scenarios. The key functions are islanding, peak shaving, voltage control, spinning reserve and frequency control. Functional requirements : 1) BESS shall be able to operate in all four quadrants of P/Q spectrum. 2) The BESS may be used for peak shaving. 3) The BESS shall be capable of "Load Following" to maintain system voltage and frequency. 4) The MGC shall control both power and VAR output from BESS to meet system power and VAR requirements. 5) If renewable energy sources are not available batteries shall be charged from the grid during "off peak" periods. 6) Priority shall be given to charging the BESS from renewable energy sources.			
	5.3 Feeder Switches	Feeder switches send operational parameters and their status to microgrid SCADA. Microgrid SCADA sends control command to Recloser as requested by various microgrid functional requirements. Functional requirements : 1) The SW shall be able to open and close the SW based on commands from MGC and ADDC DMS. 2) The SW shall detect faults at the associated SW. 3) The SW shall report status of switch and also report actual section load before fault event to MGC. 4) The MGC shall communicate with the SW's located at the Relcoser 5) If the MGC fails control of the switches is passed to the ADDC DMS. 6) Recloser shall be able to change the group setting by the MGC for both grid connected and islanding condition.			

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6	Performance Requirements				
		6.1 Performance Requirements **Functionality** / **Performance requirement** 1. Automatic transition between Grid connected and islanding — Overall transition time < 1 minute 2. Load shedding — Overall load shedding time < 1 minute 3. Frequency control — Able to maintain frequency +/- 0.5Hz 4. Voltage control — Able to maintain voltage +/- 5% from nominal voltage 5. FLISR — Able to isolate and restore the power in < 45 seconds 6. Load/Generation balancing by the EMS — All the times.			
8	Specification of microgrid controller				
		The proposer shall describe at least on concept, architecture, performance characteristic of microgrid controller. The details of specification of hardware and software of microgrid controller have to be described in details. The necessary development tool for microgrid controller in study mode shall be described.			
9	Spare part recommendations				
		9.1 MGC major equipment and special tools with recommended spare parts.			

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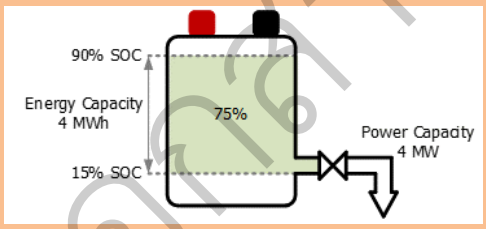
Book 3 Technical Specification and Requirements of Battery Energy Storage System (BESS)

Item	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
1	General				
		BESS shall consist of: • A power conversion system (PCS) suitable for indoor installation on a user-furnished concrete pad or the user-furnished box pad; • An energy storage unit of at least 4 MW/at least 4 MWh at 15%-90% SOC (Note % SOC means % SOC of installation capacity), at least 1 hour at 4 MW to load as described in Fig. 1. • Lithium-ion battery with life expectancy rating of 10 years (minimum installation energy capacity requirement is 5.4 MWh at begin of life (BOL)) under normal operating conditions (ambient temperature of 23C inside battery room, constant power charge and discharge with rated 1C rate, and 1 cycle/day), suitable for indoor installation, and a battery management system (BMS). • Specification requirements of the PCS are further discussed in Section 4.0. Specification requirements of the energy storage unit and BMS are further discussed in Sections 5.0 and 6.0, respectively.			
					
		The BESS shall be connected to the medium voltage 33 kV AC three phase distribution line at a frequency of 50 Hz. A step-up transformer shall be provided to allow connection between the BESS and the 33 kV distribution line. The contractor shall provide and make connection power cable between BESS with PEA substation. Rating of a step-up transformer is at least 5 MVA. The winding type of transformer can be defined by bidder. The vector group of transformer shall be YNd group.			

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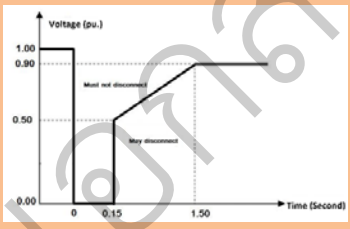
		The PCS shall be designed to operate under the following condition: Phase 3 Rated voltage33 kV Voltage rangeMax 34.65 kV, Min 31.35 kV Voltage fluctuation/FlickerAccording to PEA regulations Rated frequency50 Hz Frequency range50 ± 0.5 Hz HarmonicsAccording to PEA regulations Voltage unbalance< 2%			
		In normal operation, BESS shall operate in current-source mode, providing such functionality as voltage regulation, power factor correction, peak shaving and load following. It shall have the ability to perform four-quadrant control.			
		If the utility power source is interrupted, the BESS shall have low-voltage ride through (LVRT) capability according to PEA Grid connection code 2016 as shown in Fig. 2 to support the transition from grid connected to islanded condition. The energy storage unit and converter shall then power the islanded 4 MW load for at least 1 hour, or until utility service is resumed for the energy storage unit is depleted. 			
		The BESS shall be capable of communicating over a standard protocol, like DNP 3.0 over IP or IEC61850 protocol, furnished and installed by the system manufacturer, which shall permit - communication to the microgrid controller (MGC). This will allow PEA to monitor and control such parameters as battery voltage, current, temperature, state of charge and state of health at the cell/module/tray and rack levels; as well as allow to control charging, discharging and other functions of BESS, as necessary. Battery Management System (BMS) shall connect and transfer data to MGC/ADDC.			

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		The PCS shall communicate with the energy storage unit controller via a standard protocol defined by vendor, e.g. Modbus RTU or Modbus TCP, etc. In case of Modbus communication, all Modbus detail shall be provided.			
		The BESS shall have a maintenance port (serial, WiFi, Bluetooth, etc.) to allow monitoring and control of BESS at local level via a PC.			
		The BESS shall have security access for maintenance battery system room.			
2	Environmental Requirements				
		Operating temperature0°C – 45°C without derating Humidity5 – 95% non-condensing Maximum altitude1,000 m without derating Seismic Rating Uniform Building Code Zone 4 Audible NoiseAudible Noise shall be complied with Thailand environmental standard; Indoor: the noise level inside room shall not be more than 70 dBA. Outdoor: the noise shall not increase more than 10 dBA. Supplier must provide sufficient information specific to their particular product to facilitate utility personnel training and communications with emergency response and environmental agencies. Material Safety Data Sheets (MSDS) shall be provided as applicable.			
3	Power Conversion System (PCS)				
	3.1 General	The PCS may consist of one or more parallel units.			
		The PCS shall be bi-directional converter that can be operated in inverting mode for battery discharging and rectifying mode for battery charging.			
		The PCS shall be cooled, with final rejection of waste heat to the ambient air. The air-handling systems shall include filtering that is adequate to keep dust from the interior of the PCS system. Replacement of filter shall not require special tools or involve more than two hours of labor at the site.			
		The PCS shall consist of a converter area, user-accessible AC termination area, user-accessible DC termination area, and user-accessible control area.			

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		Converter area: Converter shall be modular type. The failure of a converter module within the BESS shall not prevent the operation of the remaining converter modules. The converter area shall contain an AC circuit breaker/disconnector, converter and DC circuit breaker/disconnector. •AC circuit breaker /disconnector– The AC circuit breaker/disconnector shall isolate the power unit from the utility source if needed. •Converter – Upon opening of the AC circuit breaker in response to interruption of the utility source, the three-phase converter shall power the islanded load until utility service is resumed or energy in the battery pack is depleted. •DC circuit breaker/disconnector – The DC circuit breaker/disconnector shall provide isolation of the battery pack, permitting routine maintenance to be performed on PCS.			
		AC termination area The user-accessible AC termination area shall include bus terminal pads for connection of utility source.			
		DC termination area The user-accessible DC termination area shall include terminations for cables from the battery pack.			
		Controls area The user-accessible controls area shall contain the master controls and associated circuitry to support operation. Within the control area shall be the following: •Control panel – The control panel shall include a three-position rotary switch for selecting the control mode of the power unit (MGC or ADDC-enabled, MGC or ADDC-disabled, and Remove from Service). •Master control board – The master control board shall provide the main processing and control functions of the converter. •Power supply – The power supply shall provide the necessary DC control power for the system controls.			

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Item	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
	3.2 System Operation	3.2.1 Start/stop characteristics The PCS starts or stops by pushing buttons “RUN” or “STOP”, respectively, or receiving control commands from a local HMI, or MGC (or ADDC in case MGC fails).			
		3.2.2 Operation during normal condition The following functions shall be required with the PCS for the grid-connected and islanded (off grid) operation. 1.The AC power transformed efficiently from the DC power of the battery arrays shall be bi-directionally transferred to or from the distribution line without causing harmonics higher than the PEA regulation. 2.The following operation modes shall be provided: a.Virtual synchronous generator b.Active and reactive power control c.Voltage and frequency control d.Voltage and frequency droop for parallel operation (BESS may be paralleled with Diesel Gen Set, existing VSPP, and future VSPP) 3.Black start capability 4.The PCS shall contain a remote synchronization feature, as well as the standard synchronization used when starting the PCS online. The remote synchronization feature allows the PCS to synchronize its voltage and frequency to any other remote AC bus or generator. 5.PCS shall be stable against the usual change in voltage and frequency of the grid.			
		Mode selection and control parameter setting shall be done by local HMI, or control command from MGC (or ADDC in case MGC fails).			

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Item	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
		The PCS shall have the following capability: •The PCS shall have the ability to perform four-quadrant control. •The PCS shall be able to perform load following. Voltage shall be maintained at +/- 5% nominal under normal operating conditions and +/- 10% under emergency conditions. •The PCS shall have low-voltage ride through capability to support the transition from grid connected to islanded condition. Please state your compliance to the latest draft of IEEE 1547. •The PCS shall have the synchro-check function to allow parallel operation with the grid, diesel and VSPPs.			
		3.2.3 Operation during abnormal condition The PCS shall operate as follows during abnormal operation: •The PCS stops automatically when serious abnormal conditions are detected. •When not-serious errors are detected, the PCS continues operation with error signals which shall be reported to MGC and ADDC.			
		3.2.4 Operation condition for Black Start The following shall be taken care for proper black start: •UPS back-up shall be sized to ensure proper black starting of BESS system until 2 hours from grid outage. •BESS shall be able to safely shutdown, in case BESS is not able to perform successful black start due to transformer inrush currents in the system. The PCS shall operate as follows during abnormal operation. In the event of a black start, controller shall be able to detect a black bus and bring up BESS system automatically if configured to do so. In this mode, control system shall manage the loads based on the energy available in the battery using load shedding schemes to avoid tripping of BESS system on under-frequency.			

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Book 3 Technical Specification and Requirements of Battery Energy Storage System (BESS)

Item	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
	3.3 Detailed Technical Specifications	PCS shall have following technical specfications			

Details	Technical requirement
AC ratings	
Total rated output power to load @ nominal voltage	− 4 MW (charge) to + 4 MW (discharge) Full four quadrant (P, Q) operation ensuring bi-direction power flows
Reactive power @ nominal voltage	≥4 MVAR
Rate output power of each unit	≥ 500 kW
Real and reactive power control accuracy	±1%
Voltage range	±10%
Type of output	AC three-phase system
Frequency	50 Hz ±1%
VAR production	Full VAR production at rated voltage
Harmonics	according to PEA standards
DC input ratings	
Voltage range	as defined by bidder
Ripple voltage	Less than 4V RMS
Ripple current	Less than 10% of full current peak to peak
Environmental ratings	**See 3. ENVIRONMENTAL REQUIREMENTS**
Functions/Features	
Power flow operation	Yes, support four-quadrant control
Real power control	Yes, positive and negative
Reactive power control	Yes, capacitive and inductive
Combination of real and reactive power control	Yes, with real power taking priority
Load following (renewable smoothing)	Yes, allowing renewable smoothing
Low-voltage ride through	Yes, supporting transition from grid connected to islanded operation
Synchro-check function	Yes, supporting parallel operation with the grid, PV and diesel generator
Operation modes	
Black start	Yes, external command
Commanded power	Yes, external command
Commanded VAR	Yes, external command
Frequency regulation	Yes, external command

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Item	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
		See table below			

Details	Technical requirement
Frequency response	Yes, automatic
Islanding	Yes, automatic (when utility source is lost) or external command (from MGC)
Renewable smoothing	Yes, automatic
Scheduled power	Yes, preconfigured time/date of work power profiles
Voltage regulation	Yes, external command
Response time of PCS to the command received	< 20 ms
Communications	
Communications with MGC	Yes (Described in Book 4)
Communications with ADDC	Yes (Described in Book 4)
Physical systems	
Protection class	The PCS shall be provided in a standard ISO enclosure with suitable access doors that minimize the amount of space required. Enclosure external color shall be [RAL 9010]
Cooling system	Air Cooling/ Liquid cooling (Liquid cooled system shall not require any external chiller units and coolant lines)
Time source	
Time source	Propose to PEA by Contractor
Monitoring and control	
Interface, status and control panel	Yes
Battery voltage (AC/DC)	Yes
Battery current (AC/DC)	Yes
Active power (AC/DC)	Yes
Reactive power	Yes
Energy (AC/DC)	Yes
Capacity (Ah)	Yes
Power factor	Yes
Fault	Yes
Battery information	Yes
Audible alarm	Yes
Battery temperature (average/extreme)	Yes
State of Charge (SOC)	Yes
Warning messages	Yes
UPS backup for control system 2 hours	Yes

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Item	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
		Efficiency | Efficiency of power conversion | ≥ 98% **Protection system** | Under/over voltage (DC and AC) | Yes Under/over frequency | Yes Over current protection | Yes Ground fault protection | Yes Over heat protection | Yes Smoke detection (Trip/Alarm) | Yes Surge protection (DC and AC) | Yes Automatic AC & DC open circuit when fault detection | Yes Insulating monitoring | Yes **Function Features** | Overload capability of 4 MW | 110% 10 minutes 125% 10 seconds Switching frequency | >= 1 kHz Details | Technical requirement Insulation resistance | Over 3 M-Ohm at DC 1000 V (exclude the circuit less than DC 60V) Withstand voltage | AC 2000V 1 minute (exclude the circuit less than DC 60V) Withstand impulse voltage | ± 5000V 1.2 x 50μS each 3 times **Noise level** | **See 3. ENVIRONMENTAL REQUIREMENTS**			

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Item	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
	3.4 Standards	PCS shall be supplied from a manufacturer with ISO 9001:2015 certification or better. PCS manufacturer shall ensure that any sub-suppliers supplying equipment that will form part of the PCS have appropriate levels of quality assurance. The metallic materials for supporting the PCS system shall be resistant to corrosion. The PCS shall comply with IEC62109 or UL 1741: Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources.			
	3.5 PCS Electrical Protection	The PCS shall be protected against thermal overload, over-current and over-voltage. Insulating monitoring ground fault detection shall be provided. The following protective function shall be provided: •DC over-voltage •DC under-voltage •DC over-current •AC over-voltage •AC under-voltage •AC over-current •Anti-Islanding •Battery protection •Internal fault (over temperature, logic failure, etc.) The electrical shield cable shall be adopted for the signal and control cable. The surge absorber shall be connected on both sides. EMC requirement shall meet IEC 61000 or equivalent standard.			

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Item	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
4	Energy Storage				
	4.1 Battery Type	Battery shall be off Lithium-Ion type suitable for utility scale BESS. Different chemistry of Lithium-Ion batteries, such as Lithium Manganese (LMO), Lithium Nickel Manganese Cobalt Oxide (NMC), Lithium Nickel Cobalt Aluminum Oxide (NCA), can be proposed.			
	4.2 Detailed Technical Specifications	Battery shall have technical specification as follows: Details: Energy — Technical requirement: At least 4 MWh at 15%-90% SOC, at least 1 hour to 4 MW load Type — Li-ion Allowable charging capacity — 1C Allowable discharging capacity — 1C Round-trip AC energy efficiency (excluding auxiliaries of BESS in normal operation) at 33 kV side of BESS for 90% to 15% SOC, 4MW charge/discharge, operation at nominal DC voltage and 100% load condition of PCS — > 85% Cycle life (In some conditions, battery shall be able to operate at 5%-100% SOC) — > 5,500 at 15-90% SOC			
	4.3 Standard	Battery shall be supplied from a manufacturer with ISO 9001:2015 certification or better. Battery manufacturer shall ensure that any sub-suppliers supplying equipment that will form part of the battery have appropriate levels of quality assurance. The metallic materials for supporting the battery system shall be resistant to corrosion.			
	4.4 Battery Module/Tray	• Battery module shall consist of many battery cells connected in series/parallel. • Module/tray battery management system (BMS) shall be provided. • Automatic module balancing shall be provided. • Module/tray cooling system shall be provided.			
	4.5 Battery Rack	•Battery modules shall be connected in series/parallel in the battery rack so that the nominal voltage of the DC is more than 480V, suitable for PCS DC voltage. •Rack BMS with battery fuse, DC current measurement devices and contractors shall be provided. •Electrical connection shall be at rack front side. •Many racks shall be connected in parallel to total capacity required for this project.			

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	4.6 Battery Protection	The following protections shall be provided: •Over-charge protection •Over-discharge protection •Over-temperature protection •Over-current protection •Ground-fault detection •Internal battery fault detection •Cell balancing Protective devices should include for DC-side protection: •Battery fuse for each battery cell and module (preferred) •DC contactor for each battery rack •Grounding over current (76G)			
	4.7 Cycle Life	•If the product is sensitive to depth of discharge, the manufacturer must state the limitations and the product should be sized such that the depth of discharge corresponds to the required cycle life. •For purposes of estimating and demonstrating cycle life, cycles are defined in the same manner as system efficiency. •For lifetime assessment the supplier should provide a graph that displays the relationship between depth of discharge and the corresponding number of cycles available within the system's life. •Results of charging and discharging are tested at 1C.			

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Item	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
5	**Battery Management System (BMS)**				
	5.1 General	BMS is used to monitor, protect, maintain safety and optimal operation of each battery cell, module and rack. BMS consist of: Module/tray BEMS, rack BMS and system BMS.			
	5.2 Minimum Functions of Module/Tray BMS	• Metering and monitoring o Battery cell voltage (all cells) o Battery module voltage o Battery cell temperature (at least one or several measured locations in battery module/tray) o Battery module current • Cell balancing o Module/tray BMS should balance voltage of cells • Safety protection o Module/tray BMS should protect the battery cells and module/tray from: - Over and under voltage - Over current - Short circuit current - Over and under temperature • Data communication: all metering items and contactor status shall be provided for rack BMS control and monitoring system.			

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Item	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
	5.3 Minimum Functions of Rack BMS	• Metering and monitoring o Battery rack voltage o Battery rack current o Battery rack temperature (one or several locations in battery rack)* o Battery SOC of battery modules • Module/tray balancing o Balancing battery modules/trays scheme • Safety protection o Rack BMS should protect the battery rack from: ☐ Over and under voltage ☐ Over current ☐ Short circuit current ☐ Over and under temperature • Data communication: all metering items and contactor status shall be provided for system BMS control and monitoring system.			

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Item	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
	5.4 Minimum Functions of System BMS	• Metering and monitoring o Battery system voltage o Battery system current o Battery rack voltage o Battery rack current o Battery rack temperature (one or several locations in battery rack)* o Battery SOC of each rack and battery system o Battery SOH (state of health) of each rack • Safety protection o System BMS should protect the battery system from: ☐ Over and under voltage ☐ Over current ☐ Short circuit current ☐ Over and under temperature • Data communication: all metering items and contactor status shall be provided for PCS control and monitoring system by a standard protocol, e.g., Modbus RTU or Modbus TCP protocol. Data sampling rate should be configured based on process requirement but not more than 2 seconds. • Preferred functions of system BMS: Controlling individual battery rack TCP protocol.			
		• BMS data communication: All metering items and contactor status shall be provided for PCS control and monitoring system by a standard protocol, e.g., Modbus RTU or Modbus			

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6	**Functional Requirements**				
	6.1 Voltage Regulation	Voltage deviation should be controlled within +/- 1% for a specified sec sampling rate.			
	6.2 Reactive Power Regulation	The system shall maintain a defined VAR flow level within +/- 5%.			
	6.3 Frequency Regulation	Frequency deviation should be controlled within plus/minus ½ cycle per second.			
	6.4 Round-trip Efficiency	The roundtrip AC-AC energy efficiency, measured at the point of common coupling 33 kV system, shall be provided and exclude parasitic and auxiliary losses under worst case conditions. The calculation is as follows: $$\eta = \frac{kWh_{out}}{kWh_{in}} \times 100\% = \frac{(rated\ discharge\ power) \times (discharge\ time)}{(rated\ charge\ power) \times (charge\ time) + losses} \times 100\%$$ Wherein, the discharge time is from a fully charged to fully discharged system, and charge time is from a fully discharged to fully charged system. If the auxiliary power is provided by a separate connection from the energy storage system, these measured values should be reflected in the losses term in the equation.			
	6.5 Self-Discharge	Supplier shall provide self-discharge characteristics.			
	6.6 Basic Insulation Level	The BESS AC system equipment shall have a Basic Insulation Level in accordance with IEC62109/UL 1741and ANSI C62.41.2-2002 standards.			

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7	Alarms and Resets				
	7.1 Alarms	The BESS shall provide the following alarms. •Informational Notification—indicates the status of the unit. •Warning Alarm—indicates a problem with the converter requiring attention (not affecting proper operation). •Converter Inhibit—indicates a problem with the converter affecting proper operation. The converter will stop operation. •Trip Offline Alarm—indicates a severe problem with the converter. The system will not operate. •Isolate Alarm—indicates a problem affecting proper operation of the system. The system will operate with limited functionality. •Fire detection remote alarm status for main fire alarm control panel, and control and monitoring system. These alarms shall be reported to MGC and HMI of BESS system.			
	7.2 Resets	Energy storage unit alarms shall be reset by any of the following means. •Manual Reset—via the reset button located on the control panel, or via a personal computer connected to the control panel Ethernet port. •Auto Reset—automatically performed until reaching a predetermined reset count. •Self Reset—automatically performed whenever require.			

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8	Installation				
		PCS and Battery need to be located inside building with suitable ventilation/HVAC arrangement to maintain environmental condition for proper operation of these equipment. Proper access and maintenance space shall be maintained inside each room. Battery room shall be equipment with complete and failsafe fire detection/extinguishing system and suitable fire detection shall be provided for inverter room. Each equipment should be properly earthed. Necessary access control, hand held fire extinguishers, first aid kit and safety signages to be provided.			
		The following items shall be complied. •A nameplate shall be provided specifying the following: o Manufacturer name o Connection diagram o Unit ratings: Power, energy, voltage, BIL o Specimen data: serial number, date of manufacture •Signage shall indicate Source and Load-Side AC Buses, Neutral Bus, DC Bus, Isolation Contactor, and Module names. Custom signage will be in accordance with specific utility requirements. •All necessary safety signs and warnings as described in ANSI Z535-2002 shall be included on the unit. •All necessary signs and warnings for identification of hazardous materials as described in NFPA 704 shall be included on the unit.			

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9	Safety				
	9.1 General	•The BESS must be compliant with IEEE 1547 or IEC 62619 or UL 1973 or UL9540 as appropriate. Systems must be able to protect themselves from internal failures and utility grid disturbances. •For all BESS equipment, the Supplier shall provide information on specific safety issues related to the equipment, including appropriate responses on how to handle the energy storage system in case of an emergency, such as fires or module ruptures. •The BESS shall be designed and manufactured with safety and environment as a priority. •Battery manufacturer shall have an excellent track record over the last 10+ years of safety and environmental performance. •PCS manufacturer shall have the same model deployed at customers installation for 10+years. •PEA reserves the right to attend the manufacturer's premises to inspect and carry out audits of the BESS during manufacture and the associated QA documentation. The manufacturer shall assist the client to carry out such inspections and audits and shall rectify and defects found in a timely manner. •Ventilation of Hydrogen and Methane shall be concerned when design the building.			
	9.2 Fire Mitigation	Provisions shall be included extinguish internal fires.			
10	Warranty				
		Manufacturer warranty shall be provided for the period of at least thirty-six (36) months from the date of commissioning. Please submit price reduction for 12 months warranty. The warranty shall cover all defects of the PCS and the energy storage unit from manufacturing and non-compliance with the contract; and manufacturer shall repair or replace the defect product at their own cost. The certified warranty issued by battery vendors/manufacturers shall be transferred to PEA before the issuance of Final Acceptance Certificate.			
11	Information Security				
		Supplier shall design the BESS to be hardened against willful attack or human negligence as per NISTIR 7628. Supplier shall contract information/cyber security scans and penetration tests by a 3rd party security company.			
12	Spare part recommendations				

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		BESS major equipment: control, protection, metering, local control system, remote control system, protection relay and special tools with recommended spare parts (Breakdown in price schdule of each items).			

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Book 4 Technical Specification and Requirements of Communication System

	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
1	**Introduction**				
	Scope	This Technical Specifications define the requirements for communication links between MGC, DERs and SWs within the scope of MGBT. The document defines the following aspects ☐ Functionalities and interface requirements between devices. ☐ Physical media of the communication links. ☐ Communication links within the microgrid optical fiber network ☐ Functionalities and interfaces with PEA backbone network			

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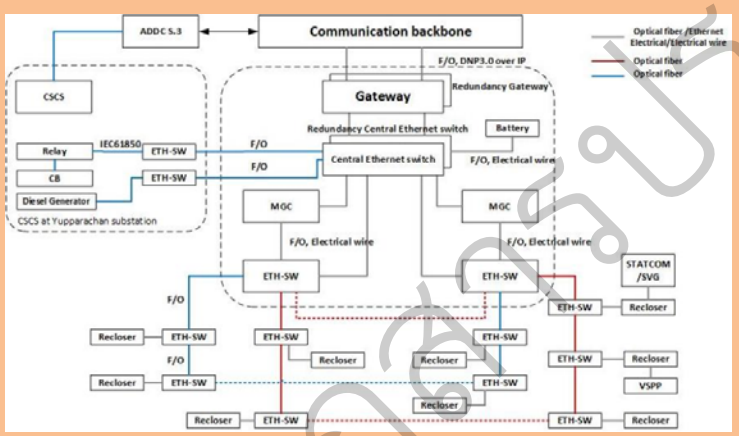
	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
2	Principal Requirement				
	2.1 Overview of the communication system	The Concept of Communication system is illustrated in Fig. 1. Note that this figure is used for classification purpose, the actual implementation may be different from this figure. The contractor shall provide fully working communication system to carry all microgrid functions in all sections. 			
		2.1.1 Communication with the authority's backbone network. This section allows communication between MGCs and ADDC S3 (SCADA/DMS) network via gateway equipment to the backbone network.			
		2.1.2 Communication with Substation, Battery Energy Storage and Diesel Generators.			

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		2.1.3 Communication in Power distribution system within Microgrid, 32 SWs in the boundary. This section allows communication between MGCs and all 32 SWs within the microgrid. The communication system consists of two Ethernet root switches and other switches in ring topology. Due to geographic locations and the number of total switches, the contractor should implement two rings.			
	2.2 Hardware requirements	2.2.1 Communication with the authority's backbone network The Authority's backbone network is in Betong PEA office. The Contractor shall provide the gateway and media between MGC and PEA backbone network, two physical links shall be installed from the gateway where located in Betong PEA Office to different SDH routers. The communication between gateway through ADDC.S3 shall used DNP3.0 Over IP protocol For media communication from Gateway to backbone equipment shall be used optical fiber links which support full-duplex over single mode fiber or better. This links additional equipment must be provided by the contractor to enable seamless connection to the backbone routers, such as electrical-optical media converters. Spare communication ports must be available and installed at both ends of each link in case of malfunction. Central Ethernet switches shall be managing the route of all equipment that connected to MGC controllers. There should be Ethernet Layer3 with hard end grade. If links from Central Ethernet switches to Gateway equipment are only indoor, the links may be electrical cables, otherwise optical fiber links shall be used which support full-duplex over single mode fiber or better.			

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	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
		2.2.2 Communication with Substation Communication with Protection Relay in YRA Substation All of existing protection relays in YRA Substation can support IEC61850 protocol. The Contractor shall apply this protocol to interface through MGCs system. The media Communication between protection relays and MGCs via industrial ethernet switch in YRA Substation shall be optical fiber link which support full-duplex over single mode fiber or better. The contractor shall provide the Ethernet Switch Layer 2 for communicated this section. The distances between YRA Substation to MGC Center are summarized in Appendix B.			
		Communication with Diesel Generator in YRA Substation The existing Diesel Generator Controller is located in YRA Substation. There is DSE8660 controller which support Modbus TCP/IP protocol. The Contractor shall apply this protocol to interface through MGC system. The media Communication between DSE8660 and MGCs via industrial ethernet switch shall use optical fiber link which support full-duplex over single mode fiber or better. For this section, the contractor shall provide the industrial ethernet switch Layer2 which support Modbus TCP/IP protocol in order to communicate with diesel generator system. The distances between Diesel Generator to MGC Center are summarized in Appendix B.			

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		Communication with Battery Energy Storage system (BESS) The Battery Energy Storage system shall be installed in MGC Center as mentioned in Book 9. If the links from BESS to MGC controller are only indoor, the links may be electrical cables, otherwise optical fiber links shall be used which support full-duplex over single mode fiber or better. In the case of additional equipment related to optical fiber links must be provided by the contractor in order to enable seamless connection to the backbone routers, such as electrical-optical media converters.			
		2.2.3 Communication in Power distribution system within Microgrid (32 Switches in Boundary) All 32 SWs shall be connected to the MGCs via 32 industrial Ethernet switches Layer2. The two root Ethernet switches each connected to each MGCs. (shall be ring connected) The contractor shall connect all of Ethernet switches via optical fiber for FLISR function as described in Book2. There are MGCs server and SCADA ADDC(S3) server. The servers have to control these 32 SWs. The distances for all 32 SWs are summarized in Appendix B.			

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		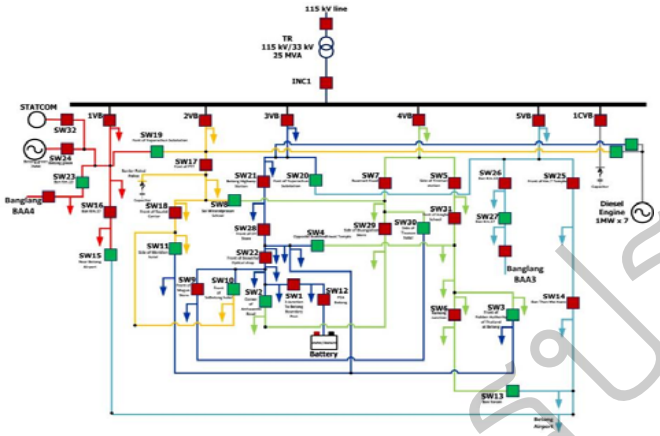			
		2.2.3.1 Ethernet switch location and topology It is required that each Ethernet switch has two physical connection paths in ring topology. The contractor shall design the topology such that the optical fiber length between two adjacent Ethernet switches is below 10 km that satisfies the service level agreement. If necessary, two physical rings should be considered to limit the ring dimension.			

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		2.2.3.2 Optical Fiber Installation Optical cables shall be installed along the PEA distribution power lines. Optical cables shall follow specifications in Appendix A. The number of usable cores shall be 24 cores. Where necessary, attenuation should be inserted in if any fiber section is too short in order that the received optical power is within range. In actual installation, it may be necessary that a ring topology is formed by loop-back along the same route, the loop-back fiber may use a fiber core in a different tube within the same cable. For drop main optical fiber to each SW with ethernet switch, the contractor shall provide the ODF (Optical Distribution Frame) for convert the main optical fiber through the single ethernet switch. Optical Fiber cable installation and Optical Fiber Specification are belong to PEA standard in Appendix A.			
3	**Functional requirements and communication use cases**				
	3.1 Communication with PEA backbone network	The system shall provide seamless communication integration with PEA existing backbone communication and future backbone networks. The communication protocol used in this section of communication system is DNP3.0 over IP. Gateway shall provide heartbeat to ADDC S3 as periodic signal to ensure that MGC is working properly. In case of MGC failure, gateway shall alarm to ADDC S3 immediately.			

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Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
3.2 Communication with CSCS	3.2.1 Normal operation For SWs, spanning tree/rapid spanning tree protocol and ring protocol shall be provided in order to form ring topology. In case of fiber connection to any SWs is not reachable in typical route. MGC shall be able to connect to the affected SWs via the other alternative route. As MGC is working properly in automatic mode, ADDC S3 only receives data from both SWs and diesel generator via gateway. Main control source shall be MGC. The interlock function for control source selector shall be PEA's responsibility.			
	3.2.2 Backbone communication failure Gateway shall be able to store SWs' data during communication failure. MGC shall be able to communicate with SWs and Diesel Generator properly as mentioned in 3.2.1.			
	3.2.3 MGC failure SWs shall be controlled by ADDC S3 via DNP3.0 over IP with fiber optic. While ADDC S3 shall be able to control Diesel Generator via existing control interface. When MGC was recovered, the gateway shall connect back to MGC automatically in order to resume normal operation.			

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Book 4 Technical Specification and Requirements of Communication System

	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
	3.3 Communication with Battery Energy Storage System	3.2.1 Normal operation Battery Energy Storage System (BESS) shall be connected to MGC through Central Ethernet Switch. As BESS was located in the same building with MGC, communication media shall be fiber optic or electrical Ethernet or better. The communication media shall be approved by PEA.			
		3.2.2 MGC failure ADDC S3 shall not be able to control BESS. After MGC was recovered, the gateway shall connect back to MGC automatically in order to resume normal operation.			
4	**Electrical power supplies to the communication equipment**				
		Communication equipment at the microgrid controller building shall be able to use the AC electricity through uninterruptible power supply (UPS) and shall have necessary AC-to-DC converter supply module with redundancy. (See Book9)			
		Communication equipment in outdoor cabinets and at remote sites shall be able to use the power supplied to the SW equipment and shall have necessary backup.			
		All electrical supplies shall have surge protection. Communication racks and cabinets shall have appropriate grounding system.			

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Book 4 Technical Specification and Requirements of Communication System

	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
		All required electricity cabling must be provided and installed meeting safety standards and with tidiness.			
5	**Fiber cabling and other signal cabling**				
		Optical fiber outdoor cables follow all specified items in Appendix A. Cables are laid along the authority's distribution power lines and the installation should adhere to the cable installation manual in Appendix A.			
		The contractor provides all necessary cabling, wiring, terminal blocks, connectors, and other hardware that may be necessary to ensure a fully functioning communication system.			
		Optical cables and signal cables must be installed aesthetically and following industrial safety standards.			
6	**Service Level Agreement**				
	6.1 Continuation guarantee	In the case that a communication port malfunctions, the fiber or communication media should be able to be swapped to a spare port without restarting. Transceiver, transmitter, receiver modules shall be hot-pluggable for replacing purpose. The fiber breakage and re-splicing do not interrupt the unaffected communication links and nodes.			

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Book 4 Technical Specification and Requirements of Communication System

	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
	6.2 Network availability guarantee	The contractor shall guarantee the availability of network service at least 99.9% up time. In the case of topology change such as a single fiber section breakage, the network shall be restored with convergence time according to the spanning tree protocol standard IEEE802.1D-2004 or faster. In the case of double section breakage, the physical link and network availability shall be restored within 24 hours.			
	6.3 Network performance guarantee	The average monthly network latency shall be in the order of 40ms or lower. If the latency is found to be greater than specified, the contractor shall find the cause and rectify the problem within 24 hours after being notified of the problem. The performance parameters of the Ethernet ring network including frame delay, frame jitter and frame loss shall be according to latest IEEE802.1q standard as minimum. In addition, the parameters shall satisfy the requirement of microgrid operation.			
	6.4 Order of transmission of data packets	All links in the communication system shall have standard implementation to ensure that all received data packets at any communication device are interpreted in chronological order as the transmitted data. Consequently, it is necessary that when several commands are issued to a device, the device must respond to the commands in order that they were issued.			

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7	Gateway				
		The gateway is the equipment that enables communication between microgrid and the authority's backbone network. The equipment has protocol conversion capability and security functions including secure communication and firewall. The specification of the gateway is given in Appendix D. Support protocols shall includeIEC61850, and DNP3.0 over IP as minimum with other protocols to support the operation of microgrid under all use cases. There shall be redundant links to both backbone network and MGC (via Ethernet Switch) as in Fig. 1. The gateway contains buffer which store at least 512 events or more. The storage shall be flash memory and the buffer is first in first out. The gateway should have redundancy, where two units are deployed in active-standby mode.			

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Book 4 Technical Specification and Requirements of Communication System

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8	**Deliverables**				
	8.1 List of Deliverables	The list of deliverables shall itemize each hardware and software component. The hardware list shall include associated hardware accessories such as cables and connectors. It shall also include equipment configuration information of sufficient detail that the Authority can procure an identical equipment item from the manufacturer. As a minimum, the document shall include the equipment name, product name, product model, and serial number (or other ID in case some of the equipment does not have a serial number). The software list shall include the name of the software item and its supplier along with the software version number. For each software item, it shall also identify the distribution media and whether or not a software license is required. The Contractor shall provide all such software licenses including a description of any significant restrictions that apply.			
	8.2 Configuration Diagrams	The configuration diagrams shall depict, in detail, the specific equipment comprising each communication sections and the logical and physical interconnection of this equipment operating as an integrated system. The configuration diagrams shall also show how the Contractor-supplied communications equipment interconnects with the equipment supplied by others. This includes, for example, the field device interfaces and the terminal equipment of the Authority's backbone communications system and specific standard compliances.			

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	8.3 Site Installation Drawings and Procedures	Microgrid communication system as well as individual communication component drawings shall be provided. These drawings, including the required as-built drawings, shall show all major components of the system along with individual equipment details and shall include all necessary materials and installation data. As a minimum, the Contractor shall provide: 1) Configuration/assembly drawings for each device showing the placement of all subassemblies. 2) Drawings of the materials for each type of equipment, identifying all subassemblies and components used to assemble the equipment. 3) Equipment internal wiring and/or cabling drawings. 4) Equipment external connection drawings. These drawings shall include the communication ports as used to interconnect the Contractor-provided equipment such as to the backbone network and to PEA substation.			
	8.4 Instruction Manuals	Instruction manuals shall include all information and instructions needed by Authority technicians to maintain the equipment and to troubleshoot and repair the equipment to the level of replacing printed circuit boards and other easily replaceable modules and assemblies.			

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A	**Appendix A: Optical Fiber Specification and installation requirements**				
		Optical fiber specifications shall be referred to the authority's approved specifications according to the given codes. The contractor has the responsibility to ensure the conformance.			
		A.1 ARSS Optical Cable specification The specification for 24 core optical cable of ARSS type shall follow PEA specification. : CDD-OFC-ARSS-G.652D			
		A.2 Suspension for Self-Support Cable The requirement of Suspension for Self-Support Cable of ARSS type cable shall follow PEA Specification : CDD-OFC-ACC-FS01			
		A.3 Optical Fiber Cable Installation Standards ARSS The installation of ARSS type optical fiber cable should abide the standards as specified by PEA in the installation manual number : CDD-MAN-OFC-ARSS-G.652D			

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B	Appendix B: Distances of optical fiber				

Distances of optical fiber

B.1 Distances of optical fiber installation between each switch location in kilometres.

From	To	Distance (km)
SW2	SW1	0.27
SW1	SW12	0.41
SW2	SW29	0.94
SW12	SW9	2.50
SW9	SW10	0.22
SW10	SW18	0.41
SW9	SW30	0.58
SW29	SW30	0.22
SW9	SW22	0.27
SW22	SW18	0.22
SW18	SW28	0.24
SW28	SW8	0.46
SW8	SW30	0.70
SW18	SW11	0.82
SW11	SW4	0.22
SW4	SW31	0.39
SW31	SW3	1.12
SW31	SW5	1.54
SW5	SW21	0.94
SW21	SW17	0.40
SW3	SW6	2.50
SW6	SW13	4.78
SW13	SW14	1.90
SW14	SW25	7.42
SW17	SW19	8.98
SW19	SW20	0.10
SW20	SW25	0.58
SW13	SW15	5.50

From	To	Distance (km)
SW15	SW16	20.74
SW25	SW26	6.82
SW26	SW27	4.66
SW27	SW16	0.46
SW16	SW23	3.46
SW24	SW23	0.76

B.2 Distances of links from gateway Ethernet switch to YRA Substation, Battery and Diesel Generator

From	To	Distance (km)
MGC	YRA Substation	9.00
MGC	Diesel Generator	9.00
MGC	Battery	0.10
MGC	Backbone	0.10

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Book 4 Technical Specification and Requirements of Communication System

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C	Appendix C: Ethernet Switch Specifications				
	Minimum requirements. **Layer 2 switch requirements (or equivalent)**	C 1.1 General features - Gigabit Ethernet Switch Layer 2, IEEE802.3 compliant - IEEE 1588v2 (PTP) Precision Time Protocol for time synchronization of networks - SNMP for device management and monitoring - Spanning tree protocol RSTP/STP, and MSTP - Redundant ring protocol - Port mirroring for online debugging - Support Modbus TCP/IP protocol (for connect DSE8660 only)			
		C 1.2 Switching performance Proposed equipment must cover these aspects. The contractor must design the system with detailed numbers and sizes such that all functional requirements specified in TOR are satisfied. - Store-and-forward, Full wire-speed, non-blocking on all ports - VLANs - VLAN ID - IGMP Groups - MAC Table - Packet Buffer - DRAM - Flash - Jumbo Frame			

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	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
		C 1.3 Mounting type Outdoor Ethernet switch: Offsite Ethernet switches mounting type is DIN Rail. Indoor Ethernet switch: Mounting type for Ethernet switches in MGC Building is rack mount under 2U size (i.e. 1U or 2U).			
		C 1.4 Operating condition Temperature: -10˚C to 60˚C or better (Indoor Ethernet switch) -10˚C to 70˚C or better (Outdoor Ethernet switch)			
		C 1.5 Certification - Safety: UL 60950-1, EN 60950-1 - EMC: EN 55032/24 - EMI: CISPR 32, FCC Part 15B Class A - EMS: - IEC 61000-4-2 ESD: Contact: 4 kV; Air: 8 kV - IEC 61000-4-3 RS: 80 MHz to 1 GHz: 10 V/m - IEC 61000-4-4 EFT: Power: 2 kV; Signal: 1 kV - IEC 61000-4-5 Surge: Power: 2 kV; Signal: 1 kV - IEC 61000-4-6 CS: Signal: 10 V - IEC 61000-4-8 - Rail Traffic: EN 50121-4 (Optional: since this usage is outside the scope of this project) - Shock: IEC 60068-2-27 - Freefall: IEC 60068-2-32 - Vibration: IEC 60068-2-6			

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	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
	Layer 3 switch requirements (or equivalent)	C 2.1 General features - Gigabit Ethernet Switch Layer 3 switching functionality, IEEE802.3 compliant - IEEE 1588v2 (PTP) Precision Time Protocol for time synchronization of networks - VLAN capability with Q-in-Q tagging - DHCP Option 82 for IP address assignment - SNMP protocols for device management and monitoring - IGMP snooping and GMRP for filtering multicast traffic - IEEE 802.1Q VLAN and GVRP protocol - Redundant ring protocol - Spanning tree protocol RSTP/STP, and MSTP QoS (IEEE 802.1p/1Q and TOS/DiffServ) or - better - Port Trunking for optimum bandwidth utilization - TACACS+, SNMPv3, IEEE 802.1X, HTTPS, and SSH - SNMPv1/v2c/v3 for different levels of network management - Bandwidth management prevents unpredictable network status - Lock port function for blocking unauthorized access based on MAC address - Port mirroring for online debugging - LED status & error indicators			

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	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
		C 2.2 Switching performance Static routing, RIP V1/V2, OSPF, DVMRP, PIM-DM Redundancy: VRRP Proposed equipment must cover these aspects. The contractor must design the system with detailed numbers and sizes such that all functional requirements specified in TOR are satisfied. - Store-and-forward, Full wire-speed, non-blocking on all ports - VLANs - VLAN ID - IGMP Groups - MAC Table - Packet Buffer - DRAM - Flash - Jumbo Frame			
		C 2.3 Mounting type **Indoor Ethernet switch: Mounting type for Ethernet switches in MGC Building is rack mount under 2U size (i.e. 1U or 2U).**			
		C 2.4 Operating condition **Temperature: -10˚C to 60˚C or better (Indoor Ethernet switch)**			

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		C 2.5 Certification - Safety: UL 60950-1, EN 60950-1 - EMC: EN 55032/24 - EMI: CISPR 32, FCC Part 15B Class A - EMS: - IEC 61000-4-2 ESD: Contact: 4 kV; Air: 8 kV - IEC 61000-4-3 RS: 80 MHz to 1 GHz: 10 V/m - IEC 61000-4-4 EFT: Power: 2 kV; Signal: 1 kV - IEC 61000-4-5 Surge: Power: 2 kV; Signal: 1 kV - IEC 61000-4-6 CS: Signal: 10 V - IEC 61000-4-8 - Rail Traffic: EN 50121-4 (Optional: since this usage is outside the scope of this project) - Shock: IEC 60068-2-27 - Freefall: IEC 60068-2-32 - Vibration: IEC 60068-2-6			

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Book 4 Technical Specification and Requirements of Communication System

	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
D	**Appendix D: Gateway specification**				
	D.1 General specification	Network protocol: TCP/IP, UDP/IP, SMTP, POP, HTTP, FTP, SNMP, ICMP,DHCP, BOOTP, DNS, ARP, PPPoE Security: NERC/CIP compliant, SSL, SSHv2 Features: -Multi master/SCADA communication capability - protocol conversion capability– DNP3.0 - Automatic startup and initialization following power Restoration - Time synchronization using IEC60870/DNP3/SNTP/NTP/IEEE1588 - Management using SNMP/Webserver			
	D.2 Communication Interface	Ethernet port (copper) 10/100/1000 BaseTX Ethernet Optical port (SFP) Gigabit Ethernet RS232 Serial ports (DB9) 9-pin, DTE, 16550-compatible Redundancy: All port types must have required number and redundancy according to the required specifications of the communication system in this book.			
	D.3 Controller protocol	Master/Client Protocol DNP3.0 Serial and TCP, IEC 60870-5 Slave/Server Protocol DNP3.0 Serial and TCP, IEC 60870-5 Number of supported connections upstream As required Number of supported connections downstream As required			
	D.4 Mounting	Rack mounting under 3U			

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Book 4 Technical Specification and Requirements of Communication System

	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
	D.5 Power supply	Primary supply 100–240 V, 50/60 Hz Hot-plug, redundant supply 100–240 V, 50/60 Hz			
	D.6 Buffer storage	Flash storage for minimum of 512 events			
	D.7 Redundancy	Dual unit (Active-standby) with automatic swapping between two modules.			

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Book 5 Technical Specification and Requirements of DG Integration

	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
1	**Interface of diesel generator controller**				
		This section define the requirements for modified diesel engine within the scope of MGBT. The document defines the following aspects - Upgrade System & Test for Functionalities and interface requirements of diesel generator. - Provide Preheating system and test for diesel generator			
		Contractor shall upgrade the existing diesel generator control system to be able to operate and monitor every needed functions for microgrid system. (Without interfering with existing remote controllers, CPM and ancillary equipment). If the upgraded system needs to add additional devices, the contractor shall provide the ancillary equipment for supporting the upgraded system completely. For example, If the controller have to do peak shaving and the diesel generator system have to install the current transformer (CT) in order to complete the function, the contactor will be in charge of the cost of equipment and installation.			

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Book 5 Technical Specification and Requirements of DG Integration

	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
		Diesel generators shall be controlled and monitored by ADDC S3 via DNP3.0 over IP with Authentication Version 5 (Without using existing remote controllers). Contractor shall redesign the diesel generator system in order to do the functions while MGCs in operation and MGCs failed. During MGCs nonfunction or failed, ADDC S3 shall control and monitor the diesel generator system via DNP3.0 over IP with different communication network of existing remote controllers. Leastwise the capability of diesel generator system for controlling and monitoring shall perform as same as the existing remote control system. (Detail in Appendix C).			
		Diesel generators are controlled by MGC through DSE8660 only. The microgrid controller can connect to master controller DSE8660 via RS232, RS485 or Ethernet. PEA not allow MGC system to connect directly to DSE8610. If modification of connection between DSE8660 and DSE8610 is required, it will be under responsibility of the contractor. Any actions that related and affected to the legacy system, shall be discussed with PEA before proceeding.			
		The microgrid controller shall be able to display and monitor all 7 diesel generators on the display of microgrid controller screen. The contractor shall provide and make connection of power cable, control cable and communication cable between YRA substation, microgrid control center building, and diesel generator area.			

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Book 5 Technical Specification and Requirements of DG Integration

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2	Preheating system for diesel generator				
		1.2.2 Preheating system for diesel generator One objective of MGBT is to improve reliability of system. However, these diesel generators cannot delivery power instantaneously due to diesel engines are starting from idle status. There will take time at least 5 minutes to be ready for delivery power. They can be retrofitted with preheating system that can make these diesel generators to be ready within one minute. Therefore, the MGBT will have diesel generators as available source during interruption or when there are needed. The rating of delivery power of diesel generators is about 70% of its rating depended on working condition of generator (temperature, lubricated oil, etc.). However, it can delivery power up to 80-85% for short period of time. The contractor shall provide preheating system to all diesel generators at Betong area. The preheating system will be needed it for easy engine starts and also immediate full power within one minute. The contractor has to propose the preheating system to PEA for approval.			
		The preheating system will be needed it for easy engine starts and also immediate full power within one minute.			

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<tr><td>2</td><td colspan="5">VSPP Integration</td></tr>
<tr><td></td><td></td><td>To utilize the private VSPP, the contractor shall provide containerize (+/- 6 MVar) STATCOM/SVG air cooling system and ancillary system with foundation and fence at the private VSPP area. PEA will inform the location to install later. Total area to install the whole containerize system (STATCOM/SVG with reactor and other accessories are in container) is about 15x15 meters, including 2 sets of the container with 40 feet container’s size. For outdoor container, the protection class shall be at least IP54. The steel structure and other metallic material shall have corrosion protection. The surrounding area shall be monitored by security camera system, including a digital video recorder, and etc.</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>Technical requirement for STATCOM/SVG
<table>
<tr><th>Item</th><th>Description</th><th>Detail</th><th>Unit/Meaning</th><th>Note/Condition</th></tr>
<tr><td>1</td><td>Rated</td><td>+/- 6</td><td>MVar</td><td></td></tr>
<tr><td>2</td><td>Power losses</td><td>less than 2%</td><td>of rated</td><td>full load capacitive to full load inductive</td></tr>
<tr><td>3</td><td>Response time</td><td>less than 40</td><td>ms</td><td>suddenly increase 10% of rated current to 90% of rated current and suddenly decrease 90% of rated current to 10% of rated current</td></tr>
<tr><td>4</td><td>Over load capability</td><td>more than 15%</td><td>of rated for 1 hour</td><td></td></tr>
<tr><td>4</td><td>Total Harmonic Distortion (current) THDi</td><td>less than 3%</td><td></td><td>at rated</td></tr>
<tr><td>5</td><td>Output reactive power control</td><td>Less than 2%</td><td></td><td>Between reactive output and setting value</td></tr>
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		2.2 Monitoring and control system to MGC Monitoring system of necessary parameters to MGC from private VSPP and STATCOM/SVG compose of active and reactive power and current and others that will be discussed later. The private VSPP would just be controlled to ON/OFF by the MGC via SW. STATCOM/SVG would be local controlled and shall be able to get the setting point from MGC.			
		2.3. Spare Part Recommendations STATCOM/SVG major equipment and special tools with recommended spare parts (Breakdown in price schedule of each items).			

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Tender Reference No. : PEA-MGBT-001/2020

Book 6 Technical Specification and Requirements of Solid Dielectric Three-Phase Automatic Circuit Reclosers, Outdoor Type

	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
1	Scope of works				
		The contractor shall supply the complete set of solid dielectric three-phase automatic circuit reclosers, outdoor type for 33 kV 50 Hz distribution system totally thirty-two (32) sets with the spare parts of reclosers shall not less than three (3) sets. The technical specification and requirements were specified in Appendix A. Latitude and Longitude of each installation location for reclosers will be given by PEA after the final of bid consideration.			
		3. Communication The communication media that connect recloser to each other and to microgrid controller (MGC) shall be fiber optic cable. The communication network and others are described in Book 4 Technical Specification and Requirements of Communication System.			
		4. Demolition and installation Demolition and installation plan shall be provided for approval within 120 days after signed contract. Delivery time is also one of the important factors to be considered. Demolition and installation shall be PEA's responsibility. At least 2 sets of installation tools shall be provided by contractor. Manufacturer's experienced installation supervisor for automatic circuit reclosers shall be prepared at site. The contractor shall have experienced supervisors to witness with PEA team at site, and for more details are in Bidding document.			

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Book 6 Technical Specification and Requirements of Solid Dielectric Three-Phase Automatic Circuit Reclosers, Outdoor Type

	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
		5. Control panel (Refer to Appendix: A, Page: 6, Item: 1c.3.1 Control panel)* The control panel shall be designed and erected for initiating control actions and viewing the status indicators of the reclosers. As minimum, the control panel shall include the following: (4) A Remote/Local switch. While this switch is in the "Local" position, control shall be permitted only from the control panel (i.e. remote control shall be prohibited). While the switch is in "Remote" position, control shall be permitted both the Distribution Management System (DMS) and microgrid controller (MGC).			
		6. Control cabinet (Refer to Appendix: A, Page: 7, Item: 1c.3.2 Control cabinet)* The control cabinet shall include space for mounting the Ethernet switch. The control cabinet shall have a hinged front access door with at least two-point latch locking system and latch operating lockable handle. The control cabinet shall include at least two (2) weather-sealed holes with cable glands, on the bottom of the cabinet for routing communication cable connected to ODF as described in Book 4 and power cable to Ethernet switch.			

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Book 6 Technical Specification and Requirements of Solid Dielectric Three-Phase Automatic Circuit Reclosers, Outdoor Type

	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
		7. Distribution Management System (DMS) and Microgrid Controller (MGC) interface (Refer to Appendix: A, Page 8, Item: 1c.3.3 Distribution Management System (DMS) interface)* The reclosers shall have capabilities to be controlled and monitored by the telecommunication system of the DMS and MGC. The control of the reclosers shall communicate with DMS and MGC via fiber optic cable. The control unit shall have an internal clock for data collection coordination and time tagging. This shall include both sequence of events (SOE) and fault data reporting with a resolution of ±1 ms relative to internal clock. The time that communicated with the DMS shall be configurable to Greenwich Mean Time (GMT) or local time by selecting and the time display on control panel shall be of local time. For physical communication port and network protocol are described in book 4.			

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Book 6 Technical Specification and Requirements of Solid Dielectric Three-Phase Automatic Circuit Reclosers, Outdoor Type

	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
		8. Analog signals (Refer to Appendix: A, Page 9, Item: 1c.3.3.1 Analog signals)* The control unit shall accept voltage input signals with a normal input signal of 110 V AC. The sampling rate for AC quantities shall be at least 12 samples per cycle. The analog-to-digital (A/D) converters shall have a digital resolution of at least 12 bits plus sign. The overall accuracy of the analog input system shall be at least ±0.2 % of full scale over the temperature range 0 to 60 OC. Linearity shall be better than ±0.05 %. The control unit shall be able to report all analog values that have changed by more than a programmable dead-band from the last value, only the last changed value was successfully reported to the DMS and MGC. The dead-band and point type (DI or SOE) shall be specified for each point individually. In addition, the ability of the control unit to alarm analog high and low limit violations is desirable.			
		9. Status signals (Refer to Appendix: A, Page 10, Item: 1c.3.3.2 Status signals)* The state of each status point shall be reported to the DMS and MGC on an exception basis. That is, a status point shall not be reported to the DMS and MGC during normal scanning unless the point state has changed from the last normal scan. The control unit shall also report the state of selected status points upon receipt of a demand scan request from the DMS and MGC. All status point shall be able to be specified point type (DI or SOE) for each point individually.			

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Book 6 Technical Specification and Requirements of Solid Dielectric Three-Phase Automatic Circuit Reclosers, Outdoor Type

	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
		10. Control signals (Refer to Appendix: A, Page 11, Item: 1c.3.3.3 Control signals)* The control unit shall include the following types of control points to support control actions initiated by the DMS master stations and MGC. To support the above capabilities, the control unit shall include momentary control outputs and latching control outputs. Latching outputs shall remain in a given state until a subsequent command changes the control output state. Control point selection by the DMS and MGC shall be canceled if the operate command is not received within a programmable time period measured at the control unit by a "Command Receipt" timer. The control unit's Command Receipt timer shall be in addition to the "Select Verification" timer in the DMS and MGC. The Command Receipt timer shall be adjustable between 10 and 60 seconds. The time period shall initially be set at 10 seconds. All control points shall follow a Select-Check back-Before-Operate (SCBO) procedure for control operation. Control Unit shall able to send the control-related status code to DMS and MGC following the communication protocol as described in Book 4 Technical Specification and Requirements of Communication System.			

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	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
		11. Terminal blocks (Refer to Appendix: A, Page 13, Item: 1c.3.6 Terminal blocks)* Terminal blocks shall be provided for connecting power cables from the control unit and the communication equipment. Terminal blocks shall be of bare wire compression type. The terminal blocks shall be of heavy-duty, moulded block type with moulded insulating barrier between terminals. Each terminal block and individual terminal shall have removable white marking strip for marking circuit designation. No more than two (2) wires shall be connected to any terminal. Adequate space and hardwares shall be provided for routing of the field wiring within the control cabinet.			
		12. Power supply (Refer to Appendix: A, Page 14, Item: 1c.7 Power supply)* The power supply shall supply 12 (+15%, -5%) VDC, 5 A, THD ≤ 3% at rated terminal voltage, to the terminal blocks for the communication equipment, for at least 40 VA, separately and separate ground. The battery charger shall be fully temperature compensated and have the facilities to select input voltage between 110 V AC and 230 V AC. The battery shall be of sealed lead acid or dry type or better.			

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	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
		13. Training (Refer to Appendix: A, Page 16, Item: 1c.11 Training)* Training courses shall be provided by contractor as described in Bidding document.			
		14. ACCEPTANCE TEST (Refer to Appendix: A, Page 20, Item: 1d.3 Acceptance tests)* PEA's acceptance committee will inspect and randomly sampling the reclosers for testing. The number of the samples is described as per Bidding document. *Other Term and Conditions: Book 6: Technical Specification and Requirements of Solid Dielectric Three-Phase Automatic Circuit Reclosers, Outdoor Type and PEA's technical specifications for solid dielectric three-phase automatic circuit reclosers, outdoor type, for 22 kV and 33 kV 50 Hz distribution system (specification no.: RPRO-034/2561) attached in Appendix A hereto as and made a part of this TOR. If there is any conflict between the Book 6 and Appendix A, the Book 6 Technical Specification and Requirements of Solid Dielectric Three-Phase Automatic Circuit Reclosers, Outdoor Type shall prevail.			

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	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
2	**Technical specification and requirements of Solid Dielectric Three-Phase Automatic Circuit Reclosers, Outdoor Type**				
		According to PEA's technical specifications for SOLID DIELECTRIC THREE-PHASE AUTOMATIC CIRCUIT RECLOSERS, OUTDOOR TYPE, FOR 22 kV AND 33 kV 50 Hz DISTRIBUTION SYSTEM (Specification no.: RPRO-034/2561)			

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Book 7 Technical Specification and Requirements of Protection System

	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
	Principal Requirement				
		Grid-connected and isolated microgrids shall have the corresponding protective relaying functions to prevent equipment damage and guarantee safe operation. Optimization of protective relay setting (substation circuit breaker and recloser) shall be considered (if needed) in case of relay group setting cannot be available. PEA will do setting the protective relay, the contractor shall working with PEA.			
		1) The contractor shall provide power system study for both 33kV and 115kV power source such as short circuit study, power flow study, dynamic study of FLISR function. 3 operation modes compose of. a. Grid connected mode with 115kV. b. Grid connected mode with 33kV. c. Islanding mode.			
		2) The contractor shall supply all necessary devices or materials and perform all necessary fabrication, testing, wiring, and interconnection work during the process of assembling and connecting to microgrid controller. The contractor shall provide site acceptance testing (SAT) for every modes of operation of protection system for microgrid system. SAT shall include the test sets in order to demonstrate the readiness of the protection system.			

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Book 8 Technical Specification and Requirements of Cyber Security

	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
1	**Principal Requirement**				
		The Contractor's responsibilities shall include, but shall not be limited to:			
		1) The contractor shall provide designed and engineered of cybersecurity of microgrid operations to meet three fundamental requirements: availability, integrity, and confidentiality for MGDP for PEA approval.			
		2) The contractor shall supply all necessary materials and perform all necessary fabrication, testing, wiring, and interconnection work during the process of assembling and connecting to microgrid controller.			
		3) The contractor shall provide site acceptance testing (SAT) of every mode of operation of cyber security for microgrid system. SAT shall include the test sets in order to demonstrate the readiness of the cyber security system.			
		4) The contractor shall provide training PEA staff so that they will be self-sufficient in designing, testing, and maintaining the cyber security system.			

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Book 8 Technical Specification and Requirements of Cyber Security

	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
	Appendix: Cyber Security Implementation Guideline				
	1 Policies and Procedures	1.1 Microgrid Cyber Security Policies and Procedures The Contractor shall, with PEA management support and guidance, and in accordance with NISTIR 7628 Guidelines for Smart Grid Cyber Security v1.0 – Aug 2010 or a later version, develop cyber security policies and procedures for the Microgrid information system.			
	2 Access Control	2.1 Account Management			
		2.1.1 The Microgrid information system shall automatically terminate temporary and emergency accounts after an organization-defined time period for each type of account.			
		2.1.2 The Microgrid information system shall automatically disable inactive accounts after an organization-defined time period. The awarded Contractor will discuss the use of single sign on at the start of the project in order to agree on the work process with PEA.			
		2.1.3 The Microgrid information system shall automatically audit account creation, modification, disabling, and termination actions and notifies the required individuals. The awarded Contractor will discuss the use of single sign on at the start of the project in order to agree on the work process with PEA.			
		2.2 Access Enforcement			
		2.2.1 The Microgrid information system enforces assigned authorizations for controlling access to the Microgrid information system in accordance with organization-defined policy and risk assessment.			

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		2.3 Least Privilege			
		2.3.1 The Microgrid information system shall enforce different levels of user privilege in interacting with the system.			
		2.3.2 The Microgrid information system shall provide real-time logging and recording of the use of privileged accounts.			
		2.4 Unsuccessful Login Attempts			
		2.4.1 The Microgrid information system shall enforce a login delay after a limited number of consecutive invalid login attempts.			
		2.4.2 The Microgrid information system shall provide real-time logging and recording of unsuccessful login attempts.			
		2.4.3 The Microgrid information system shall provide real-time alerting to a management authority for the Microgrid information system when the number of defined consecutive invalid access attempts is exceeded.			
		2.5 Microgrid Information System Use Notification			
		2.5.1 The Microgrid information system shall display an approved system use notification message or banner before granting access to the Microgrid information system that provides privacy and security notices consistent with applicable laws, directives, policies, regulations, standards, and guidance.			
		2.6 Previous Logon Notification			

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		2.6.1 The Microgrid information system shall, notify the user, upon successful logon, of the date and time of the last logon and the number of unsuccessful logon attempts since the last successful logon.			
		2.7 Concurrent Session Control			
		2.7.1 The Microgrid information system shall limit the number of concurrent sessions for any user on the Microgrid information system			
		2.8 Session Lock			
		2.8.1 The Microgrid information system shall, where feasible, after a defined period of inactivity or when the logged on user is away from the system, lock user access to the system.			
		2.8.2 The Microgrid information system shall retain the session lock until an authorized user reestablishes access using appropriate identification and authentication procedures.			
		2.9 Remote Session Termination			
		2.9.1 The Microgrid information system shall terminate a remote session at the end of the session or after a period of inactivity.			
		2.10 Remote Access			

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		2.10.1 The Microgrid information system shall authorize, monitor, and manage all methods of remote access to the Microgrid information system.			
		2.10.2 The Microgrid information system shall authenticate remote access, and to protect the confidentiality and integrity of remote access sessions.			
		2.10.3 The Microgrid information system shall route all remote accesses through a limited number of managed access control points.			
		2.10.4 The Microgrid information system shall protect wireless access to the Microgrid information system using authentication and encryption. Note: Authentication applies to user, device, or both as necessary.			
		2.10.5 The Microgrid information system shall monitor for unauthorized remote connections to the Microgrid information system.			
		2.10.6 The Contractor shall enable remote access to Microgrid information system component locations (e.g., control center, field locations) only when necessary, approved, authenticated, and for the duration necessary.			
		2.10.7 The Microgrid information system shall employ automated mechanisms to facilitate the monitoring and control of remote access methods.			
		2.10.8 The Contractor shall disable, when not intended for use, wireless networking capabilities internally embedded within Microgrid information system components.			

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		2.11 Wireless Access Restrictions			
		2.11.1 Where wireless networks are used, the Microgrid information system shall use separate wireless networks for control system, business and guest access.			
		2.11.2 Where wireless networks are used for other than control system communications, the Microgrid information system shall use WPA2-Enterprise or stronger.			
		2.12 Access Control for Portable and Mobile Devices			
		2.12.1 The Contractor shall disable on all Microgrid information system devices physical ports that can accept removable media when not intended for use.			
		2.13 Control System Access Restrictions			
		2.13.1 The Microgrid information system shall employ mechanisms in the MGIS design and implementation to restrict access from PEA's enterprise network. Connections should be proxied through an intervening DMZ.			
		2.13.2 The Microgrid information system shall implement mechanisms to restrict access to the Microgrid information system from PEA's enterprise network to read-only.			
		2.14 Publicly Accessible Content			

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		2.14.1 The Contractor shall remove all nonpublic information from the publicly accessible information systems in the Microgrid information system.			
		2.15 Passwords			
		2.15.1 The Microgrid information system shall, where feasible, employ username and password combinations to gain access to Microgrid information system assets.			
		2.15.2 Passwords shall be a minimum of 8 characters long and contain a combination of uppercase, lowercase, numeric, and special characters, or using an alternative means be of greater strength.			
		2.15.3 The Microgrid information system shall not allow direct user logins using privileged (e.g. with administrator or root) accounts.			
		2.15.4 Passwords shall expire automatically after an organization defined period of time.			
	3 Awareness and Training	3.1 Security Awareness Training			
		3.1.1 The Contractor shall, with PEA management support and guidance, develop a cyber security awareness and training program for the Microgrid information system.			
	4 Audit and Accountability	4.1 Auditable Events			

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		4.1.1 The Contractor shall, with PEA management support and guidance, develop a lists of auditable events for the Microgrid information system			
		4.1.2 The list of auditable events shall be based on risk assessment			
		4.1.3 The list of auditable events shall include execution of privileged functions			
		4.2 Content of Audit Records			
		4.2.1 The Microgrid information system shall generate audit records that at a minimum provide for each event, the date and time of the event, device or component where the event occurred, the type of event, user/subject identity, and the outcome of the event.			
		4.3 Time Stamps			
		4.3.1 The Microgrid information system shall use internal system clocks to generate time stamps for audit records and that the system synchronizes internal Microgrid information system clocks on an organization-defined frequency using an organization-defined time source.			
	5 Security Assessment and Authorization	5.1 Microgrid Information System Connections			
		5.1.1 The Contractor shall identify, document and protect from tampering or damage, all external Microgrid information system and communication connections.			

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	6 Configuration Management	6.1 Component Inventory			
		6.1.1 The Contractor shall provide an accurate inventory of all Microgrid information system components (devices and software) and their base-line configuration settings, either individually or by component class.			
		6.2 Factory Default Settings Management			
		6.2.1 The Contractor shall replace default usernames and passwords whenever possible.			
	7 Identification and Authorization	7.1 Authenticator Management			
		7.1.1 Define initial authentication credential content, such as defining password length and composition, tokens; and establish administrative procedures for initial authentication credential distribution; lost, compromised, or damaged authentication credentials; and revoking authentication.			
		7.1.2 Authentication credentials on publicly accessible devices (e.g smart meters) shall use shall be unique to each device. On other assets, the use of non-unique credentials shall be minimized where feasible.			
		7.2 User Identification and Authorization			

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		7.2.1 The Microgrid information system shall use multifactor authentication for (1) Remote access to non-privileged accounts, (2) local access to privileged accounts, and (3) remote access to privileged accounts.			
		7.3 Device Identification and Authentication			
		7.3.1 The Microgrid information system shall uniquely identify and authenticate devices against an organization-defined list of approved devices before establishing a connection.			
		7.3.2 The Microgrid information system shall authenticate devices before establishing remote network connections using bidirectional authentication between devices.			
		7.4 Authenticator Feedback			
		7.4.1 Authentication mechanisms in the Microgrid information system shall obscure feedback of authentication information during the authentication process.			
	8 Information and Document Management	8.1 Information Exchange			
		8.1.1 When a specific device is required to communicate with another device outside the Microgrid information system, communications shall be limited to only the devices that need to communicate.			
	9 Incident Response	9.1 Incident Handling			

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		9.1.1 The Microgrid information system shall employ automated mechanisms to assist in the tracking of security incidents and in the collection and analysis of incident information.			
		9.2 Microgrid Information System Backup			
		9.2.1 The Microgrid information system shall create backups. If the design to support this requirement needs hardware or software to be deployed, this is the Contractor's responsibility.			
	10 System Development and Maintenance	10.1 Maintenance Personnel			
		10.1.1 Remote maintenance sessions into the Microgrid information system shall be protected through the use of a strong authentication credentials.			
	11 Physical and Environmental Security	11.1 Physical Access Control Authorizations			
		11.1.1 The Contractor shall implement physical access control mechanisms requiring multifactor authentication to gain access to the facility where the Microgrid information system resides. The system shall be installed at the existing facility.			
		11.2 Physical Access Control			
		11.2.1 The Contractor shall employ hardware to deter unauthorized physical access control to Microgrid information system devices. The system shall be installed at the existing facility.			

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		11.2.2 The Contractor shall employ measures to ensure that every physical access control point to the facility where the Microgrid information system resides is guarded or alarmed and monitored on an organization-defined frequency.			
		11.3 Monitoring Physical Access Control			
		11.3.1 The Contractor shall install real-time physical intrusion alarms and surveillance equipment to protect access to facilities where the Microgrid information systems reside. The system shall be installed at the existing facility.			
		11.4 Emergency Power			
		11.4.1 The Contractor shall implement an alternate power supply to facilitate an orderly shutdown of noncritical Microgrid information system components in the event of a primary power source loss.			
		11.4.2 For self-contained Microgrid information system components not reliant on external power generation, the Contractor shall implement alternate power supply for long-term operation. The awarded Contractor will agree on the details with PEA later before the start of the project as PEA will provide the power sources.			
		11.5 Location of Microgrid Information System Assets			
		11.5.1 Microgrid information system assets shall be located to minimize potential damage from physical and environmental hazards.			
	12 Risk Management and Assessment	12.1 Risk Assessment			

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		12.1.1 The Contractor shall provide the results of a cyber security risk assessment from the unauthorized access, use, disclosure, disruption, modification, or destruction of information and Microgrid information systems of the proposed system design.			
		12.1.2 The Contractor shall use the risk assessment to determine the types of security protection and their configuration for the Microgrid information system.			
	13 Services Acquisition	13.1 Software License Usage Restrictions			
		13.1.1 The Contractor shall use software and associated documentation in accordance with contract agreements and applicable copyright laws.			
		13.2 Security Engineering Principles			
		13.2.1 The Contractor shall require the Microgrid information system and its components to be created or modified using secure engineering practices.			
	14 Communication Protection	14.1 Communications Partitioning			
		14.1.1 The Microgrid information system shall partition the communications for telemetry/data acquisition services and management functionality.			
		14.2 Security Function Isolation			
		14.2.1 The Microgrid information system shall isolate security functions from non-security functions.			
		14.3 Denial-of-Service Protection			

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		14.3.1 The Microgrid information system shall mitigate or limit the effects of denial-of-service attacks based on an organization-defined list of denial-of-service attacks.			
		14.3.2 The Microgrid information system shall restrict the ability of users to launch denial-of-service attacks against other Microgrid information systems or networks.			
		14.4 Boundary Protection			
		14.4.1 The Microgrid information system shall have a defined and documented boundary of the Microgrid information system. The awarded Contractor will agree on the details with PEA later before the start of the project as PEA will provide the existing information.			
		14.4.2 The Microgrid information system shall monitor and control communications at the external boundary of the system and at key internal boundaries within the system.			
		14.4.3 The Microgrid information system connects to external networks or information systems only through managed interfaces consisting of boundary protection devices.			
		14.4.4 The managed interface implements security measures appropriate for the protection of integrity and confidentiality of the transmitted information			
		14.4.5 The Contractor shall configure the Microgrid information system to prevent public or other external access into the organization's internal Microgrid information system networks except as appropriately mediated.			

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		14.4.6 The Microgrid information system shall be configured to deny network traffic by default and allow network traffic by exception (i.e., deny all, permit by exception).			
		14.4.7 The Microgrid information system shall check incoming communications to ensure that the communications are coming from an authorized source and routed to an authorized destination.			
		14.5 Communication Integrity			
		14.5.1 The Microgrid information system shall protect the integrity of electronically communicated information including during aggregation, packaging, and transformation in preparation for transmission.			
		14.5.2 The Microgrid information system shall employ cryptographic mechanisms to ensure integrity.			
		14.6 Communication Confidentiality			
		14.6.1 The Microgrid information system protects the confidentiality of communicated information.			
		14.6.2 The Microgrid information system shall employ cryptographic mechanisms to prevent unauthorized disclosure of information during transmission.			

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		14.7 Use of Validated Cryptography			
		14.7.1 All of the cryptography and other security functions (e.g., hashes, random number generators, etc.) that are required for use in the Microgrid information system shall be limited to those algorithms that have received substantial public review and have been proven to work effectively.			
		14.8 Public Key Infrastructure Certificates			
		14.8.1 For Microgrid information systems that implement a public key infrastructure, the organization issues public key certificates under an appropriate certificate policy or obtains public key certificates under an appropriate certificate policy from a PEA approved service provider.			
		14.9 Mobile Code			
		14.9.1 The Microgrid information system shall have the capability to document, monitor, and manage the use of mobile code within the Microgrid information system.			
		14.9.2 The Microgrid information system shall implement detection and inspection mechanisms to identify unauthorized mobile code and takes corrective actions, when necessary.			
		14.10 System Connections			

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		14.10.1 All external Microgrid information system and communication connections are identified and protected from tampering or damage.			
		14.10.2 External access point connections to the Microgrid information system shall be secured. Access points include any externally connected communication end point (for example, dial-up modems).			
		14.11 Security Roles			
		14.11.1 The Microgrid information system design and implementation shall specify the security roles and responsibilities for the users of the Microgrid information system.			
		14.12 Message Authenticity			
		14.12.1 The Microgrid information system shall provide mechanisms to protect the authenticity of device-to-device communications, including message authentication			
		14.13 Secure Name/Address Resolution Service			
		14.13.1 Systems that provide name/address resolution shall be configured to supply additional data origin and integrity artefacts along with the authoritative data returned in response to resolution queries.			
		14.13.2 Systems that provide name/address resolution when operating as part of a distributed, hierarchical namespace, shall provide the means to indicate the security status of child subspaces and, if the child supports secure resolution services, enabled verification of a chain of trust among parent and child domains.			
		14.14 Fail in Known State			

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		14.14.1 The Microgrid information system shall fail to a known state for defined failures.			
		14.15 Microgrid Information System Partitioning			
		14.15.1 The Microgrid information system shall be partitioned into components residing in separate physical or logical domains (or environments).			
	15 Information Integrity	15.1 Malicious Code and Spam Protection			
		15.1.1 The Microgrid information system shall implement malicious code protection mechanisms.			
		15.1.2 The Microgrid information system shall update malicious code protection mechanisms (including signature definitions) whenever new releases are available in accordance with organizational configuration management policy and procedures.			
		15.1.3 The Microgrid information system shall prevent users from circumventing malicious code protection capabilities.			
		15.1.4 Malicious code protection mechanisms in the Microgrid information system shall be centrally managed.			
		15.1.5 The use of mechanisms to centrally manage malicious code protection must not degrade the operational performance of the Microgrid information system			

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		15.1.6 The Microgrid information system shall employ spam protection mechanisms at system entry points and at workstations, servers, or mobile computing devices on the network to detect and take action on unsolicited messages transported by electronic mail, electronic mail attachments, Web accesses, or other common means.			
		15.2 Microgrid Information System Monitoring Tools and Techniques			
		15.2.1 The Contractor shall employ mechanisms to allow events on the Microgrid information system to be monitored to detect attacks, unauthorized activities or conditions, and non-malicious errors.			
		15.2.2 In response to detected activity, the Microgrid information system shall notify a defined list of incident response personnel			
		15.2.3 The Contractor shall configure the Microgrid information system to protect information obtained from intrusion monitoring tools from unauthorized access, modification, and deletion.			
		15.2.4 Individual intrusion detection tools shall be interconnected and configured into a Microgrid system-wide intrusion detection system using common protocols.			
		15.2.5 The Microgrid information system shall provide a real-time alert when indications of compromise or potential compromise occur.			
		15.2.6 The Microgrid information system prevents users from circumventing host-based intrusion detection and prevention capabilities.			
		15.3 Security Alerts and Advisories			
		15.3.1 The Microgrid information system shall receive Microgrid information system security alerts, advisories, and directives from external organizations.			

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	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
		15.3.2 The Microgrid information system shall generate and disseminate internal security alerts, advisories, and directives as deemed necessary.			
		15.3.3 The Microgrid information system shall employ automated mechanisms to disseminate security alert and advisory information throughout the organization.			
		15.4 Security Functionality Verification			
		15.4.1 The Microgrid information system provide the capability to allow the organization, upon Microgrid information system startup and restart, to verify the correct operation of security			
		15.5 Information Input Validation			
		15.5.1 The Microgrid information system shall employ mechanisms to check the accuracy, completeness, validity, and authenticity of information input to the system.			
		15.6 Error Handling			
		15.6.1 The Microgrid information system shall identify error conditions, and generate error messages that provide information necessary for corrective actions without revealing potentially harmful information that could be exploited by adversaries.			

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<tr><th>C/N</th></tr>
<tr><td>1</td><td colspan="5">Principal Requirement</td></tr>
<tr><td></td><td></td><td>Contractor shall build a 2 storey building to be a microgrid control center building. The microgrid control center building will be used as BESS and MGC control room. Since the microgrid system is a new technology for controlling electric power distribution system, PEA will use this building as one of test bed to demonstrate the microgrid concept.</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>Structure of building is reinforced concrete building at least Total area in Table 1. Roof is constructed steel structure using for installation photovoltaic (PV) system. Electrical system is combined with electrical from grid and PV. The construction of the building shall comply with relevant Thailand regulation, law, and standard.

Table 1. Usage areas of microgrid control center.

<table>
<tr><th>Item</th><th>Detail</th><th>Area (sq.m) (tentative)</th><th>Storey no# (tentative)</th><th>Note</th></tr>
<tr><td>1</td><td>Transformer room for step up and service transformer</td><td>30</td><td>1</td><td></td></tr>
<tr><td>2</td><td>PCS Room</td><td>40</td><td>1</td><td></td></tr>
<tr><td>3</td><td>Battery system room</td><td>75</td><td>1</td><td>Raised floor</td></tr>
<tr><td>4</td><td>MGC server room</td><td>30</td><td>2</td><td>Raised floor</td></tr>
<tr><td>5</td><td>Control room</td><td>15</td><td>2</td><td></td></tr>
<tr><td>6</td><td>Meeting room</td><td>75</td><td>2</td><td></td></tr>
<tr><td>7</td><td>Restroom</td><td>20</td><td>2</td><td></td></tr>
<tr><td>8</td><td>Service area for M&E room, CDU, water tank and MDB</td><td>86</td><td>B</td><td></td></tr>
<tr><td>Total</td><td></td><td>371</td><td></td><td></td></tr>
</table>
</td><td></td><td></td><td></td></tr>
</table>

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		The microgrid control center shall install smart devices with mobile application both support on android and ios. Precision air condition, projector, audio system and KVM switch are not necessary to support on android or ios application.			
		The building shall have at least key area as following: - Microgrid control room with raised floor and precision air conditioner. - Battery system room with raised floor and air-cooling system together with Hydrogen and Methane ventilation system and gas detection system. - PCS room with air ventilation system. - Step up transformer and service transformer (outdoor type). - Meeting and control room at least 25 people with Audio/Video system and Furniture. - Local operator room. - Restroom/Toilet with sanitary ware. - Smart devices. - Integrated security system. - Automatic fire fighting system. - Wall, doors, and windows for battery system room and PCS room shall be explosive/flammable proof type. '- Main entrance and loading gateway at least for Battery, PCS, Step up transformer, and Service transformer shall install motorized stainless gateway and glass gateway with access control. - Electrical system and Ground grid system. - Communication system such as Telephone system and Network system. - Plumbing system and Building Waste Water system.			

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		All smart devices shall be able to connect to the building Ethernet/WiFi network. In case a converter/gateway is needed to allow smart devices to connect to the building Ethernet/WiFi network, such a converter/gateway shall be provided.			
		1. Precision air condition for microgrid (MGC) server room Air conditioning units (AC) shall be properly sized to provide sufficient cooling needs to the smart building. Please refer to drawing in Building for AC locations. The AC serving the main control room (Computer Room Air Conditioning: CRAC) should be able to provide enough cooling needs and operate 24/7. The set-point and relative humidity of the AC serving the main control room should be set at 22 C and 45%, respectively. The sizing of the main control room AC shall be approved by PEA.			
		2. AIR CONDITIONING (AC) UNIT 2.1 Relevant standards and codes • Thai Industrial Standards Institute (TISI) • Thai Energy Efficiency Standards and Labeling (Label N.5) 2.2 AC locations Air conditioning units (AC) shall be properly sized to provide sufficient cooling needs to the smart building. Please refer to drawing in Building for AC locations. 2.3 Air conditioning specifications Air conditioning units shall obtain the Thai Energy Efficiency Rating of Number 5, and conform to the following specifications.			

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	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
		Table 2. AC specification requirements			

Details	Technical requirement
Type	
Split system	Yes
Power supply	
Voltage input	208-230V or 380 V
Phase	1or 3
Electrical frequency	50Hz
Basic functions	
Inverter power control	Yes
COOL mode	Yes
AUTO mode	Yes
FAN-only mode	Yes
Multiple fan speeds	Yes
ECONO operation	Yes
Indoor unit ON/OFF button	Yes
Self diagnosis	Yes
System ratings – cooling	
Cooling capacity range (BTU/h)	* specified by the bidder to provide sufficient cooling need
SEER	> 13
EER	> 8
Energy Star rated	Yes
Sensor/timer	
Built-in occupancy sensor	Yes
24 hour ON/OFF timer	Yes
Protection	
Low voltage start-up	Yes
Over current protection	Yes
Anti-freeze protection	Yes
High and low pressure protection	Yes
Communication and control	
Remote control	Yes
Communication technology	Ethernet or Wi-Fi connection–required
Android and iOS APP	Yes

Note:

- EER: Energy Efficiency Rating. It measures the ratio of output power to the input power.
- SEER: Seasonal Energy Efficiency Ratio. It provides an annual measure of the efficiency of the air conditioner. Higher numbers use less energy.
- COP: Coefficient of Performance. It is the ratio between the cooling or heating provided and the electrical power consumption.

2.4 Installation

The AC units shall be installed in accordance with the manufacturer's installation instructions.

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	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
		2.5 Field testing and certification The AC units shall be tested in accordance with the following: • Conduct a complete inspection and test of all AC units. This includes testing and verifying all connections. • Provide staff to test all operational features of all AC units for witness by PEA's representatives as applicable. • Correct deficiencies until satisfactory results are obtained. • Submit written copies of test results.			
		2.6 Documentation The following documents shall be provided: • Product Data—This documentation includes catalog sheets and technical data sheets indicating physical data and electrical performance, electrical characteristics, and connection requirements. • Operation and Maintenance—This documentation includes a manual for preparing, operating, and maintaining the AC unit(s). This includes equipment wiring connection outlines and written instruction for troubleshooting. • System Electrical Connection Drawings—This documentation includes drawings for properly connecting electrical wiring at the time of installation. • Installation Instructions—This documentation includes step-by-step installation instructions for properly installing the unit. • Communication set up instruction—This documentation includes step-by-step instructions to connect the device to a communication network. • Device setup instructions on Android/iOS APP			

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	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
		3. SOLAR PHOTOVOLTAICS (PV) system 3.1 Standards and codes • IEC 61730: Photovoltaic (PV) module safety qualification • IEC 61215:Terrestrial photovoltaic (PV) modules – Design qualification and type approval			
		3.2 Array location and orientation • The solar PV array shall be installed on the roof of the microgrid building. • The section of the roof to install solar PV shall have little to no current or anticipated shading. • Care shall be taken to ensure that the solar PV array location is not affected by plumbing or mechanical roof penetrations. • Azimuth of the proposed PV array shall not be deviated more than 45 off of due south, as the energy output of a solar energy system is optimized by setting the array where the roof is oriented due south at 180 azimuth.			
		3.3 PV array specifications PV modules shall conform to the following specifications. Table 3. PV array specification requirements **Details** / **Technical requirement** **PV module** PV module type: Mono/Polycrystalline **PV array** Output: At least 10kWp Grid-tied or Hybrid: Yes Maximum DC voltage: * specified by the bidder Number of PV modules connected in series: * specified by the bidder Number of PV modules connected in parallel: * specified by the bidder			

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	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
		3.4 Balance of system components Balance of system components are a smart inverter, wirings, a PV circuit breaker, disconnects and mounting system. These are described below: • Smart inverter: o See Section 4.0. • DC conduit: o A metal conduit shall be installed from the designated array location to the designated inverter location with the end of the conduit clearly labeled, indicating its intended use. o The conduit shall be located in an area that provides sufficient accessibility and clearance for a solar installer to continue the conduit run above the roof deck to the solar array area at a future point in time. o The conduit shall have three or fewer 90-degree turns from the roof to the designated inverter location, as required by the National Electric Code. o The conduit shall terminate near the edge of the designated inverter location to facilitate the final connections to the balance of system components, or for aesthetic reasons, terminate into a flush mount junction or pull box near the designated inverter location. o Both conduit ends shall be sealed. o The conduit run shall be identified on the electrical and architectural diagrams. • AC conduit: o A metal conduit from the designated inverter location to the main service panel where the system is intended to be tied into the building's electrical service shall be installed. o The conduit should be capped and clearly labeled, indicating its intended use, on the stubbed end near the inverter location. o Both conduit ends shall be sealed. o The conduit run shall be identified on the electrical and architectural diagrams. • Circuit breaker: o A circuit breaker shall be installed in the electrical service panel for use by the solar PV			

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		system. o The circuit breaker shall be labeled for use by the PV system. • Disconnects: o Properly rated DC and AC disconnects shall be provided. • Mounting system: o Mounting system shall be provided to allow PV to be mounted on the rooftop of the smart building. o Voltage drop shall be low enough to allow the inverter to operate as intended. Voltage drop shall be less than 3% overall from the modules through to the interconnection.			

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	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
		3.5 Installation The PV unit shall be installed in accordance with the manufacturer's installation instructions. 3.6 Field testing and certification The PV unit shall be tested in accordance with the following: • Conduct a complete inspection and test of the PV system. This includes testing and verifying all connections. • Provide staff to test the device and all operational features of the PV/inverter system (the inverter is discussed in Section 4.0) for witness by PEA's representatives as applicable. • Correct deficiencies until satisfactory results are obtained. • Submit written copies of test results.			
		3.7 Documentation The following documents shall be provided for the PV system: • PV specifications o Model and spec sheet of solar PV modules o Electrical characteristics of PV modules (maximum power, open circuit voltage, short circuit current, voltage at maximum power point, current at maximum power point) o Number of PV modules connected in series and parallel • Architectural drawings that summarize the installed system equipment: o Location of the solar PV array o Square footage of the solar PV array area relative to the building roof space o Detailed orientation (azimuth) of the array location relative to the roof plane o Inclination (tilt) for the solar PV array o Location of the inverter and balance of system components o Conduit size, type and location			

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	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
		o Electrical circuit panel location and dedicated circuit breaker slots o Length of conduit from the designated array location to the designated inverter location o Length of conduit from the designated inverter location to the electrical service panel o Location and number of necessary pull boxes in line with each conduit run • Electrical drawings of PV system components that provide in sufficient detail to call out the electrical components, the wire types and sizes, number of conductors, conduit type and size, as well as the dedicated location for the mounting of the balance components. The code-compliant documentation of the structural capacity of the roof and of the current dead loads on the roof, demonstrating that the roof has the capacity to support a minimum of 6 pounds per square foot additional dead load for a future PV system.			
		4. Inverter 4.2 Inverter location • The inverter shall be installed in a dedicated area– which shall be free of direct sunlight, excessive heat, or any harsh or extreme weather conditions. The inverter mounting area shall not share a common wall with a working space, such as an office or a meeting room, where slight noise and vibration may be considered a nuisance. • A finished aesthetic to the wall area shall be maintained.			

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		4.3 Inverter specifications The technical specification requirements of the smart inverter are summarized in Table 4. In addition to the inverter, sensors for measuring irradiance, wind speed, ambient temperature and module temperature shall be supplied.			

Table 4. PV inverter specification requirements

Details	Technical requirement
Input	
PV power	At least 10kWp
Maximum DC voltage	1000V DC
Output	
Maximum output power	Compatible with PV output, i.e., 10kW
Grid connection	380V AC
Grid voltage tolerance	10%
Phase	3
Frequency	50Hz
Total harmonic distortion	< 5%
Power factor	0.85-1
Efficiency	
Efficiency	> 95%
Functions/Features	
Maximum power point tracker	Yes
Grid voltage/frequency monitoring	Yes
Islanding condition monitoring	Yes
Fault ride through	Yes (can be enabled or disabled)
Revenue grade meter	Yes – the inverter shall measure the amount of energy fed into the grid in accordance with ANSI C12.1, accuracy class 2%.
Inverter topology	Transformer-less
Cooling	Yes
Night time consumption	< 1W
Control features	
On/off	Yes
Active power control	Yes

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	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
		Reactive power control | Yes Constant power factor control | Yes Limited control from specific IP addresses | Yes **Protective devices** | DC insulation measurement | Yes DC disconnector | Yes Reverse polarity protection | Yes Overload behavior | Yes **Indicators** | Display values, settings, menus | Yes Operating status of PV | Yes Interruption of grid power | Yes Status diagnosis | Yes **Communications** | Communication technology | Wire/Wireless Data logger and webserver | Yes USB | Preferred, data logging External relay control | Optional SMS or email in case of errors | Yes Android and iOS APP | Yes **General** | Installation | Indoor Degree of protection | At least IP54 or equivalent			
		4.4 Installation The inverter shall be installed in accordance with the manufacturer's installation instructions. 4.5 Field testing and certification The inverter shall be tested in accordance with the following: • Conduct a complete inspection and test of the PV/inverter system. This includes testing and verifying all connections. • Provide staff to test the device and all operational features of the PV/inverter system for witness by PEA's representatives as applicable. • Correct deficiencies until satisfactory results are obtained. • Submit written copies of test results.			

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	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
		4.6 Documentation The following documents shall be provided for the smart inverter: • Instruction to connect the device to a Wi-Fi network (if Wi-Fi is used). • Product Data—This documentation includes catalog sheets and technical data sheets indicating physical data and electrical performance, electrical characteristics, and connection requirements. • Operation and Maintenance—This documentation includes a manual for preparing, operating, and maintaining the inverter. This includes equipment wiring connection outlines and written instruction for troubleshooting. • System Electrical Connection Drawings—This documentation includes drawings for properly connecting electrical wiring at the time of installation. • Installation Instructions—This documentation includes step-by-step installation instructions for properly installing the unit. Device setup instructions on Android/iOS APP			
		5. 10kWh lithium BESS for critical load The contractor shall install the 10 kW continuous/10kWh (at least) lithium BESS for critical load with the bypass switch or circuit breaker of the 10 kW/10kWh lithium BESS for critical load and gird.			

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<tr><th>C/N</th></tr>
<tr><td></td><td></td><td>5.4 The battery storage specifications
Battery storage units shall conform to the following specifications.

Table 5. Battery storage system requirements
<table><tr><th>Details</th><th>Technical requirement</th></tr><tr><td>Feature/Performance</td><td></td></tr><tr><td>Type</td><td>Wall mounted/rack</td></tr><tr><td>Battery type</td><td>Li-Ion</td></tr><tr><td>Efficiency</td><td>At least 90% round trip</td></tr><tr><td>Total power output</td><td>At least 10kW con.</td></tr><tr><td>Total storage size</td><td>At least 10kWh</td></tr><tr><td>Inverter</td><td>Provide</td></tr><tr><td>Depth of discharge</td><td>100%</td></tr><tr><td>Operating condition</td><td></td></tr><tr><td>Operating output voltage</td><td>220V or 380V</td></tr><tr><td>Operating frequency</td><td>50Hz</td></tr><tr><td>Installation</td><td>Indoor or outdoor rated</td></tr><tr><td>Interface</td><td></td></tr><tr><td>Communication technology</td><td>Wire or Wireless</td></tr></table></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>5.6 Field testing and certification
The system shall be tested in accordance with the following:
• Conduct a complete inspection and test of the battery systems. This includes testing and verifying all connections.
• Provide staff to test the battery systems and all operational features for witness by PEA’s representatives as applicable.
• Correct deficiencies until satisfactory results are obtained.
• Submit written copies of test results.</td><td></td><td></td><td></td></tr>
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	Details	Requirements	Statement of Compliance C/N	Proposed Data	Referred to Page
		5.7 Documentation The following documents shall be provided: • Product Data—This documentation includes catalog sheets and technical data sheets indicating physical data and electrical performance, electrical characteristics, and connection requirements. • System Electrical Connection Drawings—This documentation includes drawings for properly connecting electrical wiring at the time of installation. • Installation Instructions—This documentation includes step-by-step installation instructions for properly installing the unit. Communication set up instruction—This documentation includes step-by-step instructions to connect the device to a communication network.			

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		6. Lighting (load controller and occupancy sensor for indoor lighting) 6.2 Lighting requirements All lighting fixtures shall be of LED type and provide lighting levels to meet standard illumination requirements in offices.			

Table 6. Lighting type requirements

Lighting type requirement	**Technical requirement**
Lighting type	Dimmable LED
Voltage input	220V
Phase	1
Electrical frequency	50Hz

Table 7. Recommended illuminance by space type

Recommended illuminance by space type (per IES lighting handbook)	**Illuminance (LUX) (fc = footcandle)**
Open offices	30-50fc or 323-538lux
Meeting	30fc or 323lux
Corridors	5fc or 53.8lux
Restrooms	10fc or 108lux
Lobby	10fc or 108lux
General warehousing/storage	10fc or 108lux
Electrical Equipment Manufacturing	30fc or 323lux
IT Administrative tasks	30fc or 323lux
Inactive storage	5fc or 53.8lux
Outdoor	5fc or 53.8lux

There are different lighting requirements in different sections of the building, as described below. Please refer to PEA for the lighting zones.

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<tr><th>C/N</th></tr>
<tr><td></td><td></td><td>6.2.1 Control and Meeting room
Lighting in Control and Meeting room shall be divided into several zones. Each zone shall be controlled by a separate wireless smart switch. Occupancy/vacancy sensors are required to automatically turn all lights ON with occupancy detection and OFF after a configurable period of inactivity.

Table 8. Lighting requirements – Control and Meeting room
<table><tr><th>Details</th><th>Technical requirement</th></tr><tr><td>Number of zones</td><td>Setting by PEA</td></tr><tr><td>Light switch for ON/OFF/dimming control</td><td>Yes – wireless smart light switch</td></tr><tr><td>Occupancy/vacancy sensor</td><td>Yes</td></tr><tr><td>Light ON</td><td>Automatic</td></tr><tr><td>Light OFF</td><td>After a configurable period (e.g., 30 minutes) of inactivity</td></tr></table></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>6.2.2 Server Room
Lighting in server room shall be controlled by a smart switch. Occupancy/vacancy sensors are required to automatically turn all lights off after a configurable period of inactivity.

Table 9. Lighting requirements – Server Room
<table><tr><th>Details</th><th>Technical requirement</th></tr><tr><td>Light switch for ON/OFF/dimming control</td><td>Yes – wireless smart light switch</td></tr><tr><td>Occupancy/vacancy sensor</td><td>Yes</td></tr><tr><td>Light ON</td><td>Manually – occupant flips the switch</td></tr><tr><td>Light OFF</td><td>After a configurable period of inactivity (e.g., 30 minutes)</td></tr></table></td><td></td><td></td><td></td></tr>
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		6.2.3 Electrical Equipment Room (Transformer Room, PCS Room, Precision A/C Electrical Room, Battery Room) Lighting in the Electrical Equipment Room shall be occupancy-based. The occupancy sensor shall automatically turn lights on when someone enters the room, and off after a configurable period of inactivity. Table 10. Lighting requirements – Electrical Equipment Room **Details** / **Technical requirement** Number of zones: 1 Light switch for ON/OFF control: No Occupancy sensor: Yes Light ON: Automatically with an occupant entering the storage room Light OFF: After a configurable period of inactivity (e.g., 10 minutes)			
		6.2.4 Restrooms Lighting in each restroom shall be occupancy-based. The occupancy sensor shall automatically turn lights on when someone enters the room, and off after a configurable period of inactivity. Table 11. Lighting requirements – restrooms **Details** / **Technical requirement** Number of zones: One for women restroom and one for men restroom Light switch for ON/OFF control: No Occupancy sensor: Yes Light ON: Automatically with occupant entering the restroom Light OFF: After a configurable period of inactivity (e.g., 10 minutes)			

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<tr><th>C/N</th></tr>
<tr><td></td><td></td><td>6.2.5 Stairs
Stairs lighting shall have control devices to automatically change lighting intensity based on ambient light level (0-50% intensity). The light intensity shall be increased to 100% when occupancy is detected, and change back to illuminance-based control at 0-50% after an adjustable period of inactivity.

Table 12. Lighting requirements – stairs
<table><tr><th>Details</th><th>Technical requirement</th></tr><tr><td>Number of zones</td><td>1</td></tr><tr><td>Light switch for ON/OFF/dimming control</td><td>Yes</td></tr><tr><td>Occupancy sensor</td><td>Yes – one on the first floor; one on the second floor</td></tr><tr><td>Light ON</td><td>• Illuminance-based control 0- 50% intensity
• Increase intensity to 100% when occupancy is detected
• Change to illuminance-based control 0-50% intensity after an adjustable period of inactivity</td></tr><tr><td>Light OFF</td><td>None</td></tr></table></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>6.2.6 Outdoor
Outdoor lighting shall have control devices to automatically turn on and turn off according to sunshine.</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>6.3 Lighting load controller specifications for indoor lighting
Lighting load controllers shall conform to the following specifications.

Table 13. Lighting load controller requirements
<table><tr><th>Lighting load controller details</th><th>Technical requirement</th></tr><tr><td>Type</td><td>In-wall</td></tr><tr><td>Dimmer</td><td>Yes</td></tr><tr><td>Voltage input</td><td>220V</td></tr><tr><td>Phase</td><td>1</td></tr><tr><td>Electrical frequency</td><td>50Hz</td></tr><tr><td>Communication technology</td><td>Wireless</td></tr><tr><td>Android and iOS APP</td><td>Yes</td></tr><tr><td>Certification and listing</td><td>IEC/EC or equivalent certified</td></tr></table></td><td></td><td></td><td></td></tr>
</table>

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<table>
<tr><th rowspan="2"></th><th rowspan="2">Details</th><th rowspan="2">Requirements</th><th>Statement of Compliance</th><th rowspan="2">Proposed Data</th><th rowspan="2">Referred to Page</th></tr>
<tr><th>C/N</th></tr>
<tr><td></td><td></td><td>6.4 Occupancy/vacancy sensor specifications
In some applications discussed in Section 6.2, occupancy sensors are required, while in the other applications vacancy sensors are required. An occupancy sensor automatically turns lights on when one enters a room and off when one leaves. A vacancy sensor also turns off the light when one leaves a room, but the lights need to be manually turned on when one enters a room. Vacancy sensing maximizes the energy savings from the sensor because it is not always necessary to turn lights on when someone walks into a room.

Table 14. Occupancy/vacancy sensor requirements
<table><tr><th>Occupancy/vacancy sensor details</th><th>Technical requirement</th></tr><tr><td>Technology</td><td>PIR, ultrasonic or both – for very fine motion detection</td></tr><tr><td>Adjustable timeout</td><td>Yes – 1, 5, 15 or 30 minutes</td></tr><tr><td>Occupancy/vacancy</td><td>Yes – Auto-on/auto-off and manual-on/auto-off</td></tr><tr><td>Type</td><td>Wall-mounted or ceiling mounted* specified by the bidder</td></tr><tr><td>Power supply/battery</td><td>Wired or wireless; if wireless, at least 5-year battery life is required.</td></tr><tr><td>High-low sensitivity adjustment</td><td>Yes</td></tr></table></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>6.6 Field testing and certification
The lighting/sensor system shall be tested in accordance with the following:
• Conduct a complete inspection and test of the entire lighting/sensor system. This includes testing and verifying all connections.
• Provide staff to test all devices and all operational features of the entire system for witness by PEA’s representatives as applicable.
• Correct deficiencies until satisfactory results are obtained.
• Submit written copies of test results.</td><td></td><td></td><td></td></tr>
</table>

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		6.7 Documentation The following documents shall be provided: • Product Data—This documentation includes catalog sheets and technical data sheets indicating physical data and electrical performance, electrical characteristics, and connection requirements. • System Electrical Connection Drawings—This documentation includes drawings for properly connecting electrical wiring at the time of installation. • Installation Instructions—This documentation includes step-by-step installation instructions for properly installing the unit. • Set up instruction—This documentation includes step-by-step instructions to connect the device to a communication network. Device setup instructions on Android/iOS APP.			
		7. Power Energy Meter 7.2 Meter location Power/energy meter(s) shall be installed next to the main distribution breaker box. The meter(s) shall be used to measure power/energy consumption of the entire smart building, floor#1, floor#2, the CRAC circuit and PV output as shown in Figure 1. Additionally, power/energy meter(s) shall be installed to measure power consumption of (a) lighting circuits; (b) plug load circuits and (c) air conditioning circuits; of each floor as show in Figure 2. Power/energy consumption of critical load circuits shall also be monitored. Note: one power meter may be capable of measuring power/energy consumption of 12 circuits or more.			

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		7.3 Power/energy meter specifications Power/energy meters, including current transformer, shall conform to the following specifications. Table 15. Power/energy meter specification requirements			
		7.5 Field testing and certification The power/energy meter shall be tested in accordance with the following: • Conduct a complete inspection and test of the power/energy meter. This includes testing and verifying all connections. • Provide staff to test all operational features of the power/energy meter for witness by PEA's representatives as applicable. • Correct deficiencies until satisfactory results are obtained. • Submit written copies of test results.			

Details	Technical requirement
Power/energy meter	
Logging values	V, A, W, Wh, Hz, VA, VAr, THD, deg
Voltage	0-460Vrms
Current	Refer to PEA
Phase	3
Electrical frequency	50Hz
Accuracy	ANSI C12.1 –1% with certificate (or equivalent)
Data resolution	Adjustable at 1-second, 1-minute, 15-minute, 30-minute and 1-hour intervals
Internal storage capacity	Capable of storing 1 minute data for at least 1 year
Communication technology	Ethernet or Serial or Wifi
Current transformer	
Type	Split-core
Amperage rating	Refer to PEA
Accuracy	1%
Enclosure	
Degree of protection	At least NEMA 3X (or equivalent)

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		7.6 Documentation The following documents shall be provided: • Product Data—This documentation includes catalog sheets and technical data sheets indicating physical data and electrical performance, electrical characteristics, and connection requirements. • Operation and Maintenance—This documentation includes a manual for preparing, operating, and maintaining the power/energy meter. This includes equipment wiring connection outlines and written instruction for troubleshooting. • System Electrical Connection Drawings—This documentation includes drawings for properly connecting electrical wiring at the time of installation. • Installation Instructions—This documentation includes step-by-step installation instructions for properly installing the unit. • Ethernet network set up instruction—This documentation includes step-by-step instructions to connect the device to an Ethernet network.			
		8. Audio system in the meeting room The contractor shall provide the meeting room sound system with all main seat microphone.			
		9. LED monitor LED monitor. 2 sets of LED monitors (at least 80 inches) for meeting room. 6 sets of LED monitors (at least 32 inches) for control room.			
		10. Integrated Security The integrated security system shall include a network-enabled access control and security camera system.			

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		10.1. Access control An access control system shall be installed for managing the entrance and exit of people through secure areas. The access control system shall be network-enabled and installed at the microgrid control building to allow employees to swipe ID cards to access the building, and scan the cards/fingerprints to access particular rooms in the building according to their access rights. This will provide management, traceability and forensics to building access. The entire system shall support all gateway of card/biometric readers except fire exit. The system shall support at least 20 cards. The card/biometric readers shall be capable of performing authentication based on both card scan and biometric scan. The system shall allow PEA to install additional card and card/biometric readers or fix the readers. Access control management software shall be provided.			
		11.1.1 Relevant standards and codes • UL294 – Access Control System (or Equivalent) • ISO/IEC 27001 – Information Security Management (or Equivalent) 11.1.2 Access control system location Please refer to PEA for the location(s) of the access control devices, at least three (3) card/biometric readers.			

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		11.1.3 Access control specifications The access control system shall conform to the following specifications.			

Table 18. Access control requirements

Access control system details	Technical requirement
Features:	
Support multiple operator workstations via LAN/WAN	Yes
Multi-level password protection	Yes
Provide graphical user interface	Yes
Support industry standard database management systems, which allows edit, add, delete, search, sort and print options for records in the database	Yes
Automatic backup of database files	Yes
Provide encryption	Yes
Ability to activate or deactivate cards	Yes
Monitor and log intrusion system events and send alerts	Yes
Alert:	
Provide a display of the most current transactions in real time	Yes
Send an alert (e.g., email) based on events	Yes
Allow to send an email message selectable per card event type	Yes
Allow an operator to acknowledge and clear alarms	Yes
Access level:	
Provide option to restrict access to sensitive information by user ID	Yes
Provide an option to define specific access time	Yes
Provide an option to define specific readers for access	Yes
Customizable card access level with beginning and end dates	Yes
Report:	
Provide card holder report with filter options to define doors, card holder name	Yes
Generate history report for an alarm point state (e.g., normal, alarm)	Yes
Generate history report of system alarm (e.g., power failure, panel tamper)	Yes
Generate history report for system operator activities	Yes
Generate history report based on the frequency of usage of a card	Yes
Card:	
Contain information inside card shall include at the minimum: First name, last name, card number, activation date, de-activation date, status, note fields and a photo image	Yes
Provide special card options for visitor/temporary use	Yes
Card/biometric reader:	
Card reader	Yes
Biometric	Yes

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		10.2. Camera which can monitor all area indoor and outdoor The security camera system shall include a digital video recorder (DVR) and coverage all area indoor and outdoor except in the rest room and bedroom. For outdoor monitoring, the contractor shall provide the security camera system for MGC control building, STATCOM/SVG and diesel generator. 11.2.1 Relevant standards and codes • Open network video interface forum (ONVIF) or equivalent. 11.2.2 Security camera system location Please refer to PEA for the location(s) of the DVR and security cameras.			
		11.2.3 Security camera system specifications The IP camera system shall be an IP-based wire or wireless solution and conform to the following specifications. Table 19. Security camera system specification requirements			

Security camera system details	Technical requirement
DVR specifications	
Real-time recording on all channels	Yes
Built-in Power-over-Ethernet ports or external power supply	Yes
Automatic detection of all compatible IP cameras in the network	Yes
Video compression	Yes
Pentaplex operation (view, record, playback, back up & remote control)	Yes
Motion detection	Yes
Motion detection alert (by email or upload image snapshot)	Optional
Sound detection	Optional
Sound detection alert (by email or upload image snapshot)	Optional
Schedule recording	Yes

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		Password protection | Yes Support multi-camera operation | Yes Firewall | Supports IP filtering Local storage | Yes FTP or cloud storage | Optional Communications | Communication technology | Ethernet, RJ-45 connection, or WiFi Security camera specifications | Camera power | Power-over-Ethernet connectivity through the DVR or an external power supply Video resolution | At least 2 Megapixels Support night vision | Yes – with IR illuminator IR range | At least 8 meters Pan | Option Tilt | Option Zoom | Yes Hue, brightness, contrast, saturation, sharpness | Adjustable Operating condition | Installation | Both Indoor and Outdoor			
		11.3 Installation The integrated security system including access control and security camera system shall be installed in accordance with the manufacturer's installation instructions.			
		11.4 Field testing and certification The access control and security camera system shall be tested in accordance with the following: • Conduct a complete inspection and test of all installed access control system. This includes testing and verifying all connections. • Provide staff to test all devices and all operational features of the entire access control system for witness by PEA's representatives as applicable. • Correct deficiencies until satisfactory results are obtained. • Submit written copies of test results.			

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		11.5 Documentation The following documents shall be provided: • Manufacturer's Product Data—This documentation indicates systems and components proposed for use. • Shop drawings—This documentation indicates system components and wiring diagrams. • Record drawings—This documentation indicates location of equipment and wiring. • Operation and maintenance data—This documentation includes manufacturer's operation and maintenance data customized to the access control system installed, as well as system and operator manuals. Maintenance service agreement—This documentation includes a copy of manufacturer's maintenance service agreement, including cost and services for a two-year period for PEA review.			

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		11. Automatic fire fighting system The contractor shall install the automatic fire fighting system. The detection system shall be able to locate a source of fire in each compartment and room. In critical room (e.g. battery system room, PCS room, and MGC server room), the gaseous fire suppression agent shall be NOVEC 1230 in order to protect the controllers, servers and all critical equipment. Total flooding system shall be protected according to NFPA 2001. There shall be linear heat detector for battery rack which can monitor temperature at the resolution of 0.1 degree Celsius and of which sensor spacing can be selected. The contractor can choose the suitable type of fire extinguisher for each compartment and room (excluded critical room). In addition, the contractor shall design appropriately for the building and coverage area with fire fighting system, considering the effect of the system when activated. The contractor shall test fire fighting system before install the important equipment (e.g. Battery, PCS, MGC server, and etc.) in accordance with the applicable standards. The contractor shall submit the details design of building and surrounding areas, and bill of materials for PEA approval before starting construction. The automatic fire extinguishers according to safety standards shall be installed in rooms and hallway.			
		12. The Ventilation system The contractor shall install the ventilation system with monitoring system. Especially, the battery system room shall have at least hydrogen gas detector. The contractor shall submit the details design of the system and bill of materials for PEA approval before starting construction.			