TENDER DOCUMENT

FOR

Supply, Installation, Testing, and Commissioning of Grid Connected Roof Top Solar Power Plant of Capacity 30 KWp at ICAI Bhawan – Kollad situated at Kottayam Branch of SIRC of ICAI, ICAI Bhawan, Kollad, Kottayam along with Comprehensive Operations and Maintenance for One Year.

BOOK- II

TECHNICAL

SPECIFICATIONS

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Chapter – A
INTRODUCTION

1 General Information

Project Particulars:

Particulars	Description
Design & Engineering	
Capacity of the solar PV power plant	**30KWp Minimum Target Capacity, may increase as per actual availability at site.**
Technology	(Mono/ Multi crystalline)
Comprehensive O&M Period	5 Years
Design life of PV Power plant	25 years (Minimum)
Location/Site Details	
Location	SIRC OF ICAI,ICAI Bhawan, Kollad P.O,Kottayam-686004
Annual Temperature Range	20°C to 35°C
Type of Land	Institutional
District	Kottayam
State	Kerala
Electrical Interconnection Details	
Interconnection Voltage	415V
Interconnection Point	At Institute Building an HT connection with 160 k VA Transformer placed indoor and HT Metering facility with HT LBSFU & CTPT unit is placed outdoor. All the power cables coming out of Solar PV plant BESS shall be terminated at local busbar at a common voltage level.

Scope of Supply and Work

2 Brief Scope of Work

Scope of Supply & Work includes all design & engineering, procurement & supply of equipment and materials, including testing and commissioning, receipt, unloading and storage at site, associated civil works, services, permits, licenses, installation and incidentals, erection, testing and commissioning of Grid Interactive Solar PV Power Plant with BESS and performance demonstration with associated equipment and materials on turnkey basis at Kottayam District of Kerala and 5 (Five) years comprehensive operation and maintenance from the date of Operational Acceptance.

3 Design and Engineering

a) The contractor shall prepare the detailed design basis report (DBR) along with relevant standards (with respective clause description), PERT Chart and MDL. Contractor shall submit a copy to Employer for evaluation.

b) Submission of basic design data, design documents, drawings, and engineering information including GTP and test reports to Employer or its authorized representative for review and approval in hard copy and soft copy from time to time as per project schedule. The documents typically include, but not limited to, the following:

- Solar insolation data and basis for generation
- Detailed technical specifications (GTP) of all the equipment.
- General arrangement and assembly drawings of all major equipment
- Schematic diagram for entire electrical system
- GTP & G.A. drawings for all types of structures/ components, protection switchgears & other Inter facing panels
- Test reports (for type, routine and acceptance tests)
- Relay setting charts.
- Design calculations and sheets (licensed software as well as design templates)
- Geo technical investigation data
- Overall plant layout
- GA drawings of the entire project including equipment rooms/ inverter control rooms, office cum control room, roads, storm water drainage, sewage networks, security gate, fire protection system, fencing/ boundary wall etc.

- Transmission line drawings and erection plans as per DISCOM/STU guidelines.
- Quality assurance plans for manufacturing (MQP) and field activities (FQP)
- Detailed site EHS plan, fire safety & evacuation plan and disaster management plan.
- Detailed risk assessment and mitigation plan.
- O&M Instruction's manuals for major equipment
- As-built drawings / documents and deviation list from good for construction (GFC)

c) Estimation of the plant generation based on Solar Radiation and other climatic conditions prevailing at site based on P75 values from Energy Yield Simulations.

d) Design of associated civil, structural, electrical & mechanical auxiliary systems includes preparation of single line diagrams and installation drawings, manuals, electrical layouts, erection key diagrams, electrical and physical clearance diagrams, design calculations for Earth- mat, Bus Bar & Spacers indoor and outdoor lighting/ illumination etc., GTP and GA drawings for the major equipment including transmission line, design basis & calculation sheets, and other relevant drawings and documents required for engineering of all facilities within the periphery to be provided under this contract.

e) All drawings shall be fully corrected to match with the actual "as built" site conditions and submitted to Employer after commissioning of the project for record purpose. All as-built drawings must include the Good for Construction deviation list.

4 Procurement & Supply

The equipment and materials for Grid Interactive Solar PV Power Plant and BESS with associated system (Typical) shall include but not limited to the receipt, unloading, storage, erection, testing and commissioning of all supplied material for the following:

i. 1. Adequate capacity of Solar PV modules of suitable rating including module mounting structures (fixed or trackers), fasteners, MMS foundation and module interconnection.

ii. 2. Array Junction boxes, distribution boxes and Fuse boxes: MCBs/ isolators, Surge Arrestors with string monitoring capabilities and with proper lugs, glands, ferrules, terminations and mounting structures.

iii. 3. DC and AC cables of appropriate sizes with adequate safety and insulation Power Conditioning Units (PCU) with SCADA compatibility, common AC power evacuation panel with bus bars and circuit breakers LT & HT Power Interfacing Panels, Plant Monitoring Desk, AC &DC Distribution boards.

iv. Containerized BESS comprising of unit batteries, battery management system (BMS), auxiliaries, such as HVAC and fire suppression systems, step-up transformers to match utility grid, ac switchgear, Control Systems etc. with Power and Energy ratings as specified.

v. Step – up transformers (inverter duty) in relevance with state grid code and inverter manufacturer requirements.

vi. 4. Auxiliary transformer (s) for internal consumption.

i. Metering and protection system along with battery system.
ii. LT Power and Control Cables including end terminations and other required accessories for both AC & DC power.
iii. Internal 415V interconnection & Indoor feeder panels to cater auxiliary needs of plant.
iv. Indoor switchgear and panels having incoming and outgoing feeders with VCBs, CTs, PTs, Bus bars, cables terminals kits and bus section panel. The control and relay panel should form an integral part of the switchgear (i.e. should be physically integrated into one unit). The switchgear will be installed in a separate switchgear room.
v. ABT meters (Main and Check) with all necessary metering rated CT's and PT's at the plant take off point as well as at the substation as per CEA Metering Regulation 2116 as amended time to time and state metering code.
vi. Data acquisition system with remote monitoring facilities. Provision for specific data transfer to the State Load Dispatch Centre (SLDC) shall also be provided.
vii. Lightning arrestors for entire plant area.
viii. PVC pipes, cable conduits, cable trays and accessories/trenches.
ix. Earthing of the entire plant as per relevant standards.
x. Control room equipment
xi. Testing instruments for maintenance and monitoring of equipment.
xii. Spares & consumables, as required or recommended, for the complete O&M period.
xiii. CCTV cameras for plant surveillance
xiv. Fire protection system in buildings and fire extinguishers.

vii. Weather monitoring station shall include but not be limited to the following:

- Pyranometers – for horizontal and tilted plane
- Ultrasonic Anemometer (wind speed and direction)
- Temperature Sensor – Ambient and module surface
- Power source to all sensors
- Data Logger

Construction of suitable structures for termination of transmission line for taking off from plantend and receipt of lines at Substation end.

Design & construction of Transmission line/ cable from plant take off point to the designated substation including right of way (ROW).

Materials and accessories, which are required for satisfactory and trouble-free operation and maintenance of the above equipment.

Any other equipment / material not mentioned but required to complete the Solar Power Plantfacilities in all respect.

5 Construction and Erection Works

The items of civil design and construction work shall include all works required for solar PV project and should be performed specifically with respect to following but not limited to:

i. Conducting geotechnical investigation of the total area.
ii. Construction of foundation for mounting structures for SPV panels.
iii. Civil foundation work of transformers, switchgears, etc.
iv. Civil foundation work and structure designs for BESS.
v. Construction of Equipment room with necessary illumination system and finishing as required.

Suitable arrangement of water shall be ensured to cater to day-to-day requirement of drinking water and permanent water supply for module cleaning and other needs of SPV power Plant during entire O&M period.

Suitable Communication System for SCADA with remote monitoring capabilities and internet facility.
Erection of Perimeter lighting along with all accessories and cabling

Laying of underground / over ground Cables (all types) with proper arrangements along with appropriately sized ferrules, lugs, glands and terminal blocks. Laying of cables inside the building trench and other locations as required shall be over GI cable trays with proper support and accessories.

Construction of transmission line, from take-off point at plant to the delivery point at STU/DISCOM substation.

Suitable earthing for plant along with earth pits as per standards.

All approvals, for equipment, items and works, which are not otherwise specifically mentioned in this document but are required for successful completion of the work in all aspects, including construction, commissioning, O&M of Solar PV Power Plant and guaranteed performance are deemed to be included in the scope of the contractor.

6 Statutory Approvals

Obtaining statutory approvals /clearances on behalf of the Employer from various Government Departments, not limited to, the following.

i. Pollution control board clearance, if required
ii. Mining Department, if required
iii. Forest Department, if required

All other approval, as necessary for setting up of a solar power plant including CEIG/ CEA, connectivity, power evacuation, railways, PTCC etc. as per the suggested guidelines.

All other statutory approvals and permissions not mentioned specifically but are required to carry out hassle free Construction and O&M of the plant prevailing at Site.

Adequate and seamless insurance coverage during EPC and O&M period to mitigate all risk related to construction and O&M of the plant to indemnify the Employer.

The Contractor shall comply with the provision of all relevant acts of Central or State Governments including payment of Wages Act 1936, Minimum Wages Act 1948, Employer's Liability Act 1938, Workmen's Compensation Act 1923, Industrial Dispute Act 1947, Maturity Benefit Act 1961, Mines Act

1952, Employees State Insurance Act 1948, Contract Labour (Regulations & Abolishment) Act 1971, Electricity Act 2113, Grid Code, Metering Code, MNRE guidelines or any modification thereof or any other law relating where to, and rules made there under or amended from time to time.

7 Operation and Maintenance

a) Total Operation & Maintenance of the Plant and Equipment shall be with the Contractor, after commissioning of the plant till final acceptance which shall include deployment of engineering personnel, technicians and security personnel.

b) To provide a detailed training plan for all O&M procedures to Employer's nominated staff, which shall have prior approval from the Employer.

c) Employ and coordinate the training of contractors' personnel who will be qualified and experienced to operate and monitor the facility and to coordinate operations of the facility with the grid system.

d) Discharge obligations relating to retirement/ Superannuating benefits to employees or any other benefit accruing to them in the nature of compensation, profit in lieu / in addition to salary, etc. for the period of service with the contractor, irrespective continuance of employees with the project as employees of Contractor, after conclusion of O&M period.

e) To maintain accurate and up-to-date operating logs, records and monthly Operation & Maintenance reports at the facility. The contractor shall keep the measured daily data at regular intervals and provide the same to Employer in electronic form, compatible in CSV format. The right to use the data shall remain with the Employer.

f) Procurement of spare parts, overhaul parts, tools & tackles, equipment, consumables, etc. required for smooth operation and maintenance of the Plant and Equipment as per prudent/ standard utility practices, OEM recommendations and warranty clauses for the entire O&M period.

g) To up keep all administrative offices, roads, tool room, stores room, equipment, clean, green and in workable conditions.

h) To carry out periodic overhauls or maintenance required as per the recommendations of the original equipment manufacturer (OEM) and to furnish all such periodic maintenance schedules at the time of plant commissioning/ start of O&M contract.

i) Handover the system to maintain an inventory of spare parts, tools, equipment, consumables and supplies for the facility's operation along-with required details of recommended spares list with all associated information regarding replacement records, supplier details, tentative cost, storage details, specifications on the basis of replacement frequency and mean time between failures and mean time to restore at the culmination of penultimate year under O&M period.

j) Availability of vehicles for Employer staff during construction and O&M period as per requirement may be ensured, failing which Employer shall have full right for alternate arrangement at the risk & cost of the contractor.

k) The contractor shall be responsible for all the required activities for the successful running, committed energy generation & maintenance of the Solar Photovoltaic Power Plant covering:

- Deputation of qualified and experienced engineers and technicians at the facility.
- Deputation of Security personnel for the complete security of plant.
- Successful running of Solar Power Plant for committed energy generation.
- Co-ordination with STU/SLDC/other statutory organizations as per the requirement on behalf of Employer for Joint Metering Report (JMR), furnishing generations schedules as per requirement, revising schedules as necessary and complying with grid requirements.
- Monitoring, controlling, troubleshooting, maintaining logs & records, registers.
- Furnishing generation data monthly to Employer by 1st week of every month for the previous month to enable Employer raise commercial bills on consumers.
- Periodic cleaning of solar modules as approved by the Employer and water quality as per the recommendations of OEM.
- Replacement of Modules, Invertors/PCU's and other equipment as and when required during the O&M period without additional cost to Employer.

l) Continuous monitoring the performance of the Plant and Equipment and regular maintenance of the whole system including Modules, PCU's, transformers, overhead line, outdoor/indoor panels/ kiosks etc. are necessary for extracting and maintaining the maximum energy output from the Solar Power Plant.

m) Preventive and corrective O&M of the Plant and Equipment including supply of spares, consumables, wear and tear, overhauling, replacement of damaged modules, invertors, PCU's and insurance

covering all risks (Fire & allied perils, earthquake, terrorists, burglary and others) as required.

n) The period of Operation and Maintenance will be deemed to commence from the date of completion of performance demonstration/Operational acceptance and successively the complete Plant and Equipment to be handed over to the O&M contractor for operation and maintenance of the same. O&M contract shall further be extended on the mutually agreed terms and conditions for the period of a minimum of 5 years.

o) All the equipment required for Testing, Commissioning and O&M for the healthy operation of the Plant must be calibrated, time to time, from the NABL accredited labs and the certificate of calibration must be provided prior to its deployment.

p) The Contractor shall ensure that all safety measures are taken at the site to avoid accidents to his or his sub-contractor or Employer's Workmen. This will include procurement of all safety gadgets during the Construction and O&M period including but not limited to, rubber mats of appropriate grade, PPE, rubber gloves and shoes etc.

8 Operation and Performance Monitoring

I. Operation part consists of deputing necessary manpower necessary to operate the Solar Photovoltaic Power Plant at the full capacity. Operation procedures such as preparation to starting, running, routine operations with safety precautions, monitoring etc., shall be carried out as per the manufacturer's instructions to have trouble free operation of the complete system.

II. Daily work of the operation and maintenance in the Solar Photovoltaic Power Plant involves periodic cleaning of Modules, logging the voltage, current, power factor, power and energy output of the Plant at different levels. The operator shall also note down time/ failures, interruption in supply and tripping of different relays, reason for such tripping, duration of such interruption etc. The other task of the operators is to check battery voltage-specific gravity and temperature. The operator shall record monthly energy output, down time, etc.

III. Earth resistance of Plant as well as individual earth pit is to be measured and recorded every month. If the earth's resistance is high suitable action is to be taken to bring down the same. A maintenance record is to be maintained by the operator/engineer-in-charge to record the regular maintenance work carried out as well as any breakdown maintenance along with the date of maintenance reasons for the breakdown's steps have taken to attend the breakdown duration of the breakdown etc.

IV. The Schedules will be drawn such that some of the jobs other than breakdown, which may require comparatively long stoppage of the Power Plant, shall be carried out preferably during the non-sunny days. An information shall be provided to Engineer-in-charge for such operation prior to start.

V. The Contractor will attend to any breakdown jobs immediately for repair/ replacement/ adjustments and complete at the earliest working round the clock. During breakdowns (not attributable to normal wear and tear) at O&M period, the Contractor shall immediately report the accidents, if any, to the Engineer In-charge showing the circumstances under which it happened and the extent of damage and or injury caused.

VI. The contractor shall at his own expense provide all amenities to his workmen as per applicable laws and rules.

VII. If negligence / mal operation of the contractor's operator results in failure of equipment such equipment should be repaired and replaced by contractor at free of cost.

9 Security services

i. The contractor has to arrange a proper security system including deputation of security personnel at his own cost for the check vigil for the Solar Power Plant. The security staff may be organized to work on a suitable shift system; proper checking & recording of all incoming & outgoing materials vehicles shall be maintained. Any occurrence of unlawful activities shall be informed to Employer immediately. A monthly report shall be sent to the Employer on the security aspects.

ii. All the information shown here is indicative only and may vary as per design and planning by the bidder. The bidder must provide the BOM of the plant as per the design during the time of bidding.

Chapter – B TECHNICAL SPECIFICATIONS

A. Design Philosophy

1 The main objective of the design philosophy is to construct the plant with in-built Quality and appropriate redundancy to achieve high availability and reliability with minimum maintenance efforts. In order to achieve this, the following principles shall be adopted while designing the system.

2 Adequate capacity of SPV modules, PCUs, Junction boxes etc. to ensure generation of power as per design estimates. This will be done by applying liberal de-rating factors for the array and recognizing the efficiency parameters of PCUs, transformers, conductor losses, system losses, site conditions etc.

3 Use of equipment and systems with proven design and performance that have high availability track records under similar service conditions.

4 Selection of the equipment and adoption of a plant layout to ensure ease of maintenance.

Strict compliance with approved and proven quality assurance (QA) systems and procedures during different stages of the project, starting from sizing, selection of make, shipment, storage (at site), during erection, testing and commissioning.

5 Proper monitoring of synchronization and recording, to ensure availability of power to the grid.

6 The plant Data Acquisition and Control System should be designed to ensure high availability and reliability of the plant to assist the operators in the safe and efficient operation of the plant with minimum effort.

It should also provide the analysis of the historical data and help the plant maintenance people to take up the plant and equipment on predictive maintenance.

7 System design shall have intelligent protection mechanisms which may include very fast responsive microprocessor-based relays etc., so that any disturbance from the grid will not cause any damage to the equipment of the Solar Power Plant.

2 The basic and detailed engineering of the plant shall aim at achieving high standards of operational performance especially considering following:

a. SPV power plants should be designed to operate satisfactorily in synchronization with the grid within permissible limits of high voltage and frequency fluctuation conditions. It is also extremely important to safeguard the system during major disturbances, internal and external surge conditions while ensuring safe operation of the plant.
b. Module Mounting Structures shall be designed for stability under design wind load conditions specified in this document while optimizing energy generation.
c. Shadow free plant layout to ensure minimum losses in generation during the daytime.
d. Higher system voltage and lower current options to be followed to minimize ohmic losses.
e. Selection of PCUs with proven reliability and minimum downtime. Ready availability of requisite spares.
f. Careful logging of operational data / historical information from the Data Monitoring Systems, and periodical analysis of the same to identify any abnormal or slowly deteriorating conditions.
g. The designed array capacity at STC shall be suitably determined to meet the proposed guaranteed generation output at the point of interconnection by the contractor in his bid. The contractor shall take care of first year degradation also by installing additional DC capacity as the CUF calculations will not factor in the first-year degradation of the modules.
h. Each component offered by the bidder shall be of established reliability. The minimum target reliability of each equipment shall be established by the bidder considering its meantime between failures and mean time to restore, such that the availability of complete system is assured. The bidder's recommendation of the spares shall be on the basis of established reliability.
i. The bidder shall design the plant and equipment in order to have a sustained life of 25 years with minimum maintenance efforts.
j. The work execution planning for supply, erection, commissioning, and all other allied works forSPV Power Plant shall be such that it is completed within stipulated time from the date of order/ LOI/ NTP, whichever is later.
k. The specifications provided with this bid document are functional ones; any design provided inthis document is only meant as an example. The Contractor must submit a detailed design philosophy document for the project to meet the functional requirements based upon their own design in-line with the above. The bidders are advised to visit the site and satisfy themselves before bidding.

Approval of drawings and documents prepared by the Contractor:

All documents and drawings shall be submitted to the EMPLOYER in soft copies for review and approval. Drawing shall also be submitted in '*.dwg' format, if required. In the case of design calculations done in spread sheet, editable (working) soft copy of the spread sheet shall also be submitted along with 'pdf' copies during every

submission. The EMPLOYER shall return, as suitable, either soft or hard copies to the Contractor with category of approval marked thereon. The drawings/documents shall be approved in any one of the following categories based on nature of the comments/ typeof drawing or document.

Category-I	Approved
Category-II	Approved subject to incorporation of comments. Re-submit for approval after incorporation of comments
Category-III	Not approved. Re-submit for approval after incorporation of comments
Category-IV	Kept for record/ reference
Category-IV(R)	Re-submit for record/ reference after incorporation of comments

Note: Approval of document neither relieves the Vendor/ Contractor of his contractual obligations and responsibilities for correctness of design, drawings, dimensions, quality & specifications of materials, weights, quantities, assembly fits, systems/ performancerequirement and conformity of supplies with Technical Specifications, Indian statutory laws as may be applicable, nor does it limit the EMPLOYER/ Purchaser's rights under the contract).

The Contractor shall submit the complete Master Document & Drawing list (MDL) to the EMPLOYER within 2 weeks after issue of LOA, The MDL shall list all the Drawings& Documents envisaged for submission/ approval from the EMPLOYER and shall also have all the required information like drawing no (both vendor and EMPLOYER's drawing no), title, scheduled date of submission, actual date of submission and approval. The category of approval shall be decided mutually between Contractor and the EMPLOYER at the time of finalization of the MDL which shall be the basis for drawing & document approval process during project execution. The installation/construction shall be done only as per drawings approved under Category – I,II & IV.

B. Electrical System

1 Photovoltaic Modules

Standards and Codes

Photovoltaic Modules shall comply with the specified edition of the following standards and codes.

Standard	Description
IEC 61215-1:2116 Ed.1	Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 1: Test requirements
IEC 61215-1-1:2116 Ed.1	Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 1-1: Special requirements for testing of crystalline silicon photovoltaic (PV) modules
IEC 61731-1:2116 Ed.2	Photovoltaic (PV) module safety qualification - Part 1: Requirements for construction
IEC 61731-2:2116 Ed.2	Photovoltaic (PV) module safety qualification - Part 2: Requirements for testing
IEC 61711:2111 Ed.2	Salt mist corrosion testing of photovoltaic (PV) modules (Applicable for coastal and marine environment)
IEC 62716:2113 Ed.1	Photovoltaic (PV) modules - Ammonia corrosion testing
IEC TS 62814-1:2115 Ed.1	Photovoltaic (PV) modules - Test methods for the detection of potential-induced degradation - Part 1: Crystalline silicon (under conditions of 85°C/85% RH for minimum 192 hours)
As per the Solar Photovoltaics, Systems, Devices and Components Goods (Requirements for Compulsory Registration) Order, 2117, PV Modules used in the grid connected solar power projects shall be registered with BIS and bear the Standard Mark as notified by the Bureau of Indian Standards. Further, PV Modules should be listed in the ALMM, as per MNRE Approved Models and Manufacturers of Solar Photovoltaic Modules (Requirements for Compulsory Registration) Order, 2119 including subsequent amendments/order, if any.	

Technical Requirements

Parameter	Specification
Cell type	(Mono/ Multi crystalline)
Module Efficiency	≥ 21%
Rated power at STC	No negative tolerance is allowed
Temperature co-efficient of power	Not less than -1.4%/°C
Application Class as per IEC 61731	Class A

Component Specifications:

The PV Modules glass panel shall have transmittance of above 91%. The minimum thickness of glass shall be 3.2 mm.

The encapsulant used for the PV modules should be UV resistant and PID resistant in nature. No yellowing of the encapsulant with prolonged exposure should occur. The encapsulant shall have the following properties:

Parameter	Value
Volume resistivity	> 1×11^{14} Ω.cm
Peeling strength with glass	> 41 N/cm

For Crystalline Silicon Glass/Polymer PV Modules, the back sheet used in the PV modules shall be of three-layered structure durable for humid – hot conditions with properties of moisture barrier, elongation retention and UV resistance. The back sheet shall have the following properties:

Parameter	Value
Material Thickness	≥ 311 micron
Water Vapor Transmission Rate	≤ 2 g/m2/day
Partial Discharge Test Voltage	≥ 1511V
Elongation at break	≥ 111%
Adhesion strength with encapsulant	≥ 41 N/cm
Interlayer adhesion strength	≥ 4 N/cm

The Owner reserves the right to conduct Pressure Cooker (PC) test/ Highly Accelerated Stress Test (HAST) to confirm the durability of the back sheet in accelerated conditions.

The sealant used for edge sealing of PV modules shall have excellent moisture ingress protection with good electrical insulation (Break down voltage >15 kV/mm) and with good adhesion strength. Edge tapes for sealing are not allowed.

The module frame shall be made of anodized Aluminum, which shall be electrically & chemically compatible with the structural material used for mounting the modules. It is required to have provision for earthing to connect it to the earthing grid.

The material used for junction box shall be UV resistant to avoid degradation during module life. The degree of protection of the junction box shall be at least IP 67. Minimum three number of bypass diodes and two number of IEC 62852/EN 51521 certified MC4 compatible connectors with appropriate length of IEC 62931/EN 51618 certified 4 sq.mm copper cable shall be provided. The cable length shall be in accordance with the PV Module wiring strategy and adequate to ensure that the cable bending radius standard is not exceeded.

Each PV Module shall be provided with a RFID code which is embedded inside the module lamination and must be able to withstand harsh environmental conditions. The RFID code database shall contain the following information.

(i) Name of the manufacturer of PV Module
(i) Name of the Manufacturer of Solar cells
(ii) Type of cell: Mono
(iii) Month and year of the manufacture (separately for solar cells and module)
(iv) Country of origin (separately for solar cells and module)
(v) I-V curve for the module
(vi) Peak Wattage, Im, Vm and FF for the module
(vii) Unique Serial No. and Model No. of the module.
(viii) Date and year of obtaining IEC PV module qualification certificate.
(ix) Name of the test lab issuing IEC certificate
(x) Other relevant information on traceability of solar cells and modules as per ISO 9111 series.

RFID code scanner and database of all the modules containing the above information shall also be provided.

Warranty

- PV modules must be warranted with linear degradation rate of power output except for first year

(up to 3% including LID) and shall guarantee minimum 81% of the initial rated power output at the end of 25 years from the date of supply.

- The modules shall be warranted for a minimum of 11 years from the date of supply against all material/ manufacturing defects and workmanship.
- The above warranties shall be backed by third party insurance.

Approval

- The Contractor shall provide Guaranteed Technical Particular (GTP) datasheet and Bill of Materials (BOM) of the module that is submitted for approval along with the datasheets of each component. The component datasheet shall contain all the information to substantiate the compliance for component specifications mentioned above.
- The Contractor shall also provide test certificates corresponding to the standards mentioned above along with complete test reports for the proposed module. The tests should have been conducted at a test laboratory compliant with ISO 17125 for testing and calibration and accredited by an ILAC/IECEE member signatory. Laboratory accreditation certificate or weblink along with scope of accreditation shall also be submitted.

Scope of Works.
Standards and Codes

Standard/Code	Description
IEC 61529	Enclosure Ingress Protection
IEC 62262	Enclosure Impact Protection
IEC 61296	Fuse
IEC 61643-11	Surge Protection Device
IEC 62852 or EN 51521	Solar cable connector

Construction

- Enclosure shall be made of UV resistant, fire retardant, thermoplastic material. Enclosure degree of protection shall be at least IP65, and mechanical impact resistance shall be at least IK18.
- No more than two strings can be connected in parallel to a single input of SCB. One spare input terminal along with connector shall be provided for each SCB.
- Every SCB input shall be provided with fuses on both positive and negative side. The rating of the fuses shall be selected such that it protects the modules from reverse current overload. The fuses shall be 'gPV' type conforming to IEC 61269-6.
- DC disconnector switch of suitable rating shall be provided at SCB output to disconnect both positive and negative side simultaneously.
- Type-II surge protective device (SPD) conforming to IEC 61643-11 shall be connected between positive/negative bus and earth.
- MC4 connector conforming to IEC 62852 or EN 51521 shall be provided at each SCB input. Cable gland (double compression metallic) of suitable size for DC cables shall be provided at the SCB output.
- UV resistant printed cable ferrules for solar cables and punched/embossed aluminum tags for DC cables shall be provided at cable termination points for identification.

Warranty

The SCB unit shall be warranted against all material/ manufacturing defects and workmanship for a minimum of 2 (two) years from the date of supply Approval.

Tests

Routine tests and acceptance tests for the assembled unit shall be as per the Quality Assurance Plan (QAP) approved by the Employer.

Solar and DC Cables

Standards and Codes

Cable	From	To	Conductor/ Insulation	Voltage Rating	Applicable Standard
Solar Cable*	Module	SCB	Copper/ XLPO	1.5 kV DC	IEC 62931/ EN 51618
DC Cable	SCB	Power Conditioning Unit	Copper or Aluminum/ XLPE	1.5 kV DC	IS 7198 Part II
* Cable used for module interconnection shall also be referred as solar cable.					

Solar cable outer sheath shall be flaming retardant, UV resistant and black in colour. Solar cable with

positive polarity should have marking of red line on black outer sheath.

DC cables shall be single core, armoured, Flame Retardant Low smoke (FRLS), PVC outer sheath conforming to IS 7198-II. DC cable with positive polarity should have a marking of red line on black outer sheath.

In addition to manufacturer's identification on cables as per relevant standard, following marking shall also be provided over the outer sheath.

(i) Cable size and voltage grade
(ii) Word 'FRNC/ FRLS' (as applicable) at every meter
(iii) Sequential marking of length of the cable in meters at every meter

Cables shall be sized based on the following considerations:

i. Rated current of module.
ii. In the case of central inverters, the average voltage drops in the cables (from PV Modules to PCU) shall be limited to 1.5 % of the rated voltage. In the case of string Inverters, the average voltage drops (from PV module to string inverter) shall be limited to 1.5% of the rated voltage drop. The Contractor shall provide voltage drop calculations in excel sheet.
iii. Short circuit withstand capability.
iv. De-rating factors according to laying pattern

Warranty

The cables (Solar and DC) shall be warranted against all material/ manufacturing defects and workmanship for minimum of 1 (one) year from the date of supply.

Tests

Type test, routine test and acceptance tests requirements shall be as per IEC 62931/EN 51618 for solar cables and IS 7198-II for DC cables. As part of Routine tests, cables should also be subject to Cold Bend and Cold Impact Tests.

Installation

a) Cable installation shall be as per IS 1255.
b) Only terminal cable joints shall be accepted. No cable joint to join two cable ends shall be accepted. Cable terminations shall be made with connectors complying IEC 62852
c) / IS 16781. The connectors shall have a degree of protection of IP 68.
d) Solar cables shall be provided with UV resistant printed ferrules and DC cables shall be provided with punched/ embossed Aluminum tags. The marking shall be done with good quality letters and numbers of proper size so that the cables can be identified easily.
e) Cable terminations shall be made with properly crimped lugs and passed through cable glands at the entry & exit point of the cubicles. Bimetallic lugs shall be used for connecting Cu bus bar and Al cables or vice versa.
f) Solar cables, wherever exposed to direct sunlight and buried underground, shall be laid through Double Wall Corrugated (DWC) HDPE conduits. The size of the conduit or pipe shall be selected on the basis of 41% fill criteria.
g) Solar cables shall be aesthetically tied to Module Mounting Structure using UV resistant
h) cable-ties suitable for outdoor application.
i) A.C. and D.C. cables shall be kept in separate trenches.
j) Cable Sealing System: Modular multi-diameter cable sealing system consisting of frames, blocks and accessories shall be installed where the underground and over ground cables enter or leave LCR/MCR enclosures/Buildings. The cable sealing system shall consist of multi-diameter type peel-able blocks of different sizes to suit the various cables. It should be simple, easy and quick to assemble & re-assemble the cable sealing system. Solid blocks shall not be used on frame. Frames & stay-plate material shall be of galvanized steel and for compression, single piece wedge with galvanized steel bolts shall be used. 31% spare blocks on the frame shall be provided for expansion in future. Cable sealing system should have been tested for fire/ water/smoke tightness.

Power Conditioning Unit

The Power Conditioning Unit (PCU) specifications mentioned in this section are applicable for both string & central inverters. The Power Conditioning Unit (PCU) shall comply with the specified edition of the following standards and codes.

Standard	Description
IEC 61683 Ed. 1	Photovoltaic systems - Power conditioners - Procedure for measuring efficiency
IEC 62119-1 Ed. 1	Safety of power converters for use in photovoltaic power systems - Part 1: General requirements
	Safety of power converters for use in photovoltaic power

IEC 62119-2 Ed. 1	systems - Part 2: Particular requirements for inverters
IEC 61111-6-2 Ed. 2	Electromagnetic compatibility (EMC) - Part 6-2: Generic standards - Immunity standard for industrial environments
IEC 61111-6-4 Ed. 2.1	Electromagnetic compatibility (EMC) - Part 6-4: Generic standards - Emission standard for industrial environments
IEC 62116 Ed. 2	Utility-interconnected photovoltaic inverters - Test procedure of islanding prevention measures
IEC 61168-2-1:2117	Environmental testing - Part 2-1: Tests - Test A: Cold
IEC 61168-2-2:2117	Environmental testing - Part 2-2: Tests - Test B: Dry heat
IEC 61168-2-14:2119	Environmental testing - Part 2-14: Tests - Test N: Change of temperature
IEC 61168-2-31:2115	Environmental testing - Part 2-31: Tests - Test Db: Damp heat, cyclic (12 h + 12 h cycle)
CEA Technical Standards for Connectivity to the Grid Regulations 2117 with 2113 and 2119 Amendment	
As per the Solar Photovoltaics, Systems, Devices and Components Goods (Requirements for Compulsory Registration) Order, 2117, Inverters used in the grid connected solar power projects shall be registered with BIS and bear the Standard Mark as notified by the Bureau of Indian Standards.	

Technical Requirements

Parameter	**Specification**
Type	String/Central
Rated AC power	As per design
Maximum input voltage	As per design
Rated AC output voltage	As per design
Tolerance on rated AC output voltage	+/-11%
Rated frequency	51 Hz
Operating frequency range	47.5 Hz to 52 Hz
Power factor control range	1.9 lag to 1.9 lead
European efficiency	Minimum 98%
Maximum loss in Sleep Mode	1.15% of rated AC power
Total Harmonic Distortion	Less than 3% at 111% load
Degree of protection	Central Inverter – IP 21 (Indoor)/IP 54 (Outdoor), String Inverter – IP 65

The rated/ name plate AC capacity of the PCU shall be AC power output of the PCU at 25°C.

Maximum power point tracker (MPPT) shall be integrated in the PCU to maximize energy drawn from the Solar PV array. The MPPT voltage window shall be sufficient to accommodate the output voltage of the PV array at extreme temperatures prevailing at site.

The PCU output shall always follow the grid in terms of voltage and frequency. The operating voltage and frequency range of the PCU shall be sufficient enough to accommodate the allowable grid voltage and frequency variations.

Construction

The Power Conditioning Unit (PCU) shall consist of an electronic three phase inverter along with associated control, protection, filtering, measurement and data logging devices.

Every DC input terminal of PCU shall be provided with fuse / MCB / MCCB of appropriate rating. The combined DC feeder shall have suitably rated isolators for safe start up and shut down of the system. One spare DC input terminal shall be provided for each PCU. String inverters without DC fuse may be acceptable in case not more than two strings are connected to the same MPPT.

Type-II surge protective device (SPD) conforming to IEC 61643-11 / IEC 61643-31 / EN 51539-11 shall be connected between positive/ negative bus and earth.

In case external auxiliary power supply is required, UPS shall be used to meet auxiliary power requirement of PCU. It shall have a backup storage capacity of 2 hours.

Circuit Breaker of appropriate voltage and current rating shall be provided at the output to isolate the PCU from grid in case of faults.

The PCU shall be tropicalized, and the design shall be compatible with conditions prevailing at site. A suitable number of exhaust fans with proper ducting shall be provided for cooling, keeping in mind the extreme climatic condition of the site as per the recommendations of OEM to achieve desired performance and life expectancy.

All the conducting parts of the PCU that are not intended to carry current shall be bonded together and

connected to dedicated earth pits through protective conductor of appropriate size. DC negative terminal shall be grounded. In case DC negative grounding is not possible, an appropriate anti-PID device shall be provided.

A dedicated communication interface shall be provided to monitor the PCU from SCADA. PCU front panelshall be provided with LCD/ LED to display all the relevant parameters related to PCU operation and fault conditions. It shall include, but not limited to, the following parameters.

(i) DC input power
(ii) DC input voltage
(iii) DC input current
(iv) AC output power
(v) AC output voltage (all the 3 phases and line)
(vi) AC output current (all the 3 phases and line)
(vii) Frequency
(viii) Power Factor

In case of outdoor PCU, PCU without LCD display with provision for Data access over Bluetooth /Wi-Fi shall be acceptable.

AC combiner box for string inverter configuration shall comply with Clause 11 of the Technical Specifications with exception of the following.

i. Rated System Voltage – Inverter Output Voltage
ii. IP Rating – IP 55
iii. Metering System
iv. CBCT

Operating Modes

Operating modes of PCU shall include, but not limited to, the following modes. These operating modes and conditions for transition are indicative only. The Contractor shall provide the detailed flow chart indicating the various operating modes and conditions for transition during detailed engineering.

Standby Mode

The PCU shall continuously monitor the input DC voltage and remain on Standby Mode until it reaches the pre-set value.

MPPT Mode

When the input DC voltage is above the pre-set value and AC grid connection conditions are fulfilled, the PCU shall enter into MPPT mode.

Sleep Mode

When the AC output power/DC input voltage decreases below the pre-set value for pre- set time delay, the PCU shall switch into Sleep Mode.

Protection Features

The PCU shall include appropriate self-protective and self-diagnostic feature to protect itself and the PV array from damage in the event of PCU component failure or from parameters beyond the PCU's safe operating range due to internal or external causes. The self-protective features shall not allow signals from the PCU front panel to cause the PCU to be operated in a manner which may be unsafe or damaging. Faults due to malfunctioning within the PCU, including commutation failure, shall be cleared by the PCU protective devices. The PCU shall provide protection against the following type of faults, among others.

i. DC/AC over current
ii. DC/AC over voltage
iii. DC reverse polarity
iv. DC earth fault
v. AC under voltage
vi. AC under frequency/over frequency
vii. Islanding
viii. Over temperature
ix. Lightning surges

Grid Support Functions

Active power regulation

The PCU shall be able to limit the active power exported to the grid based on the set point provided through PCU front control panel. The PCU shall also be able to automatically the limit the active power after an increase in grid frequency above a pre-set value. The ramp rate shall be adjustable during operation and start-up after fault. The applicability of the requirement shall be as per CEA regulation and compliance.

Reactive power control

The PCU shall be able to inject /absorb reactive power to/ from the grid based on the set point provided

through PCU front control panel. The same shall be performed automatically with adjustable ramp rate based on dynamic changes in grid voltage or reactive power reference.

Voltage Ride Through

The PCU shall remain connected to the grid during temporary dip or rise in grid voltage as per the LVRT and HVRT requirements of CEA Technical Standards for Connectivity to the Grid Regulations. The PCU shall also be able to inject/absorb reactive power during the period of voltage dip/surge.

Warranty

The complete Power Conditioning Unit shall be warranted for a minimum of 5 (five) years against all material/ manufacturing defects and workmanship.

Tests

Type Tests

The type test certificates as per the standards mentioned above should be from any of the ILAC/IECEE member signatory accredited Test Centers. Laboratory accreditation certificate or weblink along with scope of accreditation shall also be submitted. It is the responsibility of the Contractor to substantiate the compliance for CEA Regulations using test reports.

Routine Tests

Routine tests and acceptance tests shall be as per the Quality Assurance Plan (QAP) approved by the EMPLOYER.

AC Cables

Standards and Codes

All AC Cables shall conform to the following standards and codes.

Standard	Description
IS 7198-I	Crosslinked Polyethylene Insulated Thermoplastic Sheathed Cables, Part 1: For working voltage up to and including 1111 V
IS 7198-II	Crosslinked Polyethylene Insulated Thermoplastics Sheathed Cables Part 2: For Working Voltages from 3.3 kV up to and including 33 kV

All AC cables shall be flame retardant, low smoke (FRLS) type designed to withstand all mechanical, electrical and thermal stresses develop under steady state and transient operating conditions.

Only terminal cable joints shall be accepted. No cable joint to join two cable ends shall be accepted. However, cable joints may be allowed if the route length is more than maximum available drum length subject to EMPLOYER's approval.

In addition to the manufacturer's identification on cables as per relevant standard, following marking shall also be provided over outer sheath.

(i) Cable size and voltage grade.
(i) Word 'FRLS' at every metre.
(ii) Sequential marking of length of the cable in metres at every metre.

Cables shall be sized based on the following considerations:

i. Rated current the equipment.
ii. In the case of Central inverters, maximum voltage drops in LT cable (from PCU to inverter transformer) shall be limited to 1.5% of the rated voltage. In case of String inverters, maximum voltage drops (from string inverter to LT combiner panel and from LT combiner panel to Inverter duty transformer) shall be limited to 1.5%. For HT cables (from inverter transformer to plant take off point), maximum voltage drop shall be limited to 1.5 % of the rated voltage. The Contactor shall provide voltage drop calculations in excel sheet.
iii. Short circuit withstand capability as per design for 1s.
iv. De-rating factors according to laying pattern

Warranty

All cables shall be warranted for a minimum of 1 (one) year against all material/ manufacturing defects and workmanship from the date of supply.

Testing

Routine test and acceptance tests requirements shall be as per relevant standards for all cable sizes. As part of Routine tests, cables should also be subject to Cold Bend and Cold Impact Tests.

Installation

Cable installation on-shore shall be as per IS 1255.

Cable terminations shall be made with properly crimped lugs and passed through cable glands at the entry & exit point of the cubicles. Bimetallic lugs shall be used for connecting Cu bus bar and Al cables or vice-versa.

All AC cables shall be provided with punched/embossed Aluminium tags. The marking shall be done with good quality letters and numbers of proper size so that the cables can be identified easily.

LT Switchgear

The LT switchgear specifications mentioned in this section are applicable for auxiliary supply distribution panel, AC combiner box and LT switchgear panels in case of string inverter configuration.

Standards and Codes

All equipment provided under LT switchgear shall comply with latest revisions and amendments of the relevant IEC standards and IS codes. In particular, the switchgear shall comply with the following standards and codes.

Standard/Code	Description
IS/IEC 61439-1	Low-voltage switchgear and control gear assemblies - Part 1: General rules
IS/IEC 61439-2	Low-voltage switchgear and control gear assemblies - Part 2: Power switchgear and control gear assemblies
IEC 61947-1	Low-voltage switchgear and control gear - Part 1: General rules
IEC 61947-2	Low-Voltage Switchgear and Control gear: Circuit Breakers
IEC 61947-3	Low voltage switchgear and control gear: Part 3 Switches, disconnectors, switch-disconnectors and fuse combination units
IEC 61947-4-1	Low-voltage switchgear and control gear - Part 4-1: Contactors and motor-starters - Electromechanical contactors and motor- starters
IEC 61947-5-1	Low-voltage switchgear and control gear - Part 5-1: Control circuit devices and switching elements - Electromechanical control circuit devices
IEC 62152-11	Electricity metering equipment (a.c.) - General requirements, tests and test conditions - Part 11: Metering equipment
IS 694	Polyvinyl chloride insulated unsheathed-and sheathed cables/ cords with rigid and flexible conductor for rated voltages - up to and including 451/751V
IEC 61869	Instrument Transformers
IS 3143	Code of practice for earthing
IEC 61255	Measuring relays and protection equipment - Part 1: Common requirements

Technical Parameters

System Details	
Rated system voltage	415 V ± 11%, 3 Phase, 4 wire, Neutral Solidly Earthed
Rated frequency	51 Hz ± 5%
System fault current	As per system requirement
Air Circuit Breaker (ACB)	
Type	Air break
Rated Current	As per system requirement
Rated Ultimate Short-Circuit Breaking Capacity & Rated Service Short-Circuit Breaking Capacity	As per system fault current
Rated short-time withstand current duration	1s
Moulded case circuit breaker (MCCB)	
Rated Voltage	415 V
Release	Thermal-Magnetic/Microprocessor
Rated current	As per system requirement
Poles	4 poles
Rated insulation level	691 V
Rated Ultimate Short-Circuit Breaking Capacity & Rated Service Short-Circuit Breaking Capacity	As per system fault current
Rated Short-Circuit Making Capacity	2.1 X Short circuit breaking Capacity
Rated short-time withstand current duration	1s
Utilization category	A
Current transformer (CT)	
Type	Cast Resin Bar Primary
Voltage class and frequency	651 V, 51 Hz
CT Secondary Current	1 A
Class of insulation	Class F
Accuracy class & burden	
a) For Protection	5P21, 5 VA PS Class for REF and core balance CT

	(CBCT)
b) For Metering	Class 1.5, 5 VA (min)
Minimum primary earth fault current to be detected by CBCT	1 A
Instrument Security Factor for metering CT	5
Voltage Transformer (VT)	
Type	Cast Resin
Accuracy Class	1.5
Rated Voltage Factor	1.1 Continuous, 1.5 for 31 seconds
Class of Insulation	E or better
Digital Multifunctional Meter (MFM)	
Accuracy class	1.5 class
Communication with SCADA	RS485 communication with Modbus RTU

Constructional Details

The panel shall be metal enclosed, free standing, floor mounted, modular type with compartmentalized construction having degree of protection of IP 2X (Indoor) and IP 54 (Outdoor) as per IS/IEC 61529. All doors and covers shall be provided with neoprene gaskets to prevent entry of vermin and dust.

All switches, push buttons etc. shall be operated front and shall be flush/semi-flush mounted.

The panel shall be fabricated from 2 mm CRCA sheet steel for frame & load bearing surfaces. Partitions may be fabricated from 1.6 mm CRCA if no components are mounted on them.

Cable entries shall be from bottom. The opening of cable entry shall be covered by 3mm thick glandplates with proper sealing to avoid water and rodent entry.

Earthing bus bar of suitable cross section shall be provided throughout the length of panel.

The panel shall be duly wired with suitable size of 1.1kV, PVC insulated cable and terminals shall be brought out for cable connections. 11% spare terminals subjected to a minimum of one of each rating shall be provided on each distribution switchgear. All wire shall have ferrules as per wiring diagram.

The panel shall be painted with 2 coats of primer after pre-treatment and 2 coats of Polyurethane / epoxy paint with shade as decided by the Owner.

The panel shall be of dead front construction suitable for front operated and back maintained functioning.

241 V, 5 A, 3 pin industrial socket-outlet with ON/OFF switch shall be provided in each panel.

Each panel shall be provided with an LED lamp rated for 241 V, 51 Hz, single phase AC supply for interior illumination controlled by door switch.

Suitable lifting hooks shall be provided for each panel.

Each switchgear panel shall be provided with thermostatically controlled space heaters to prevent condensation within the enclosure. The space heater shall be connected to 241 V, 51 Hz, single phase AC supply through suitable switch and fuse.

Earth leakage relay with Core balance CTs (CBCT) shall be provided on main incoming feeders having phase CT ratio more than 51/1A. CBCT's shall be circular window type with window size based on the overall diameter of the cables, to be finalized during detailed engineering.

Air Circuit Breaker

The circuit breaker shall be three poles, air break, horizontal draw-out type.

The circuit breaker shall have three positions, i.e., SERVICE, TEST and ISOLATED.

The circuit breaker operating mechanism shall be based on motor operated spring charging, and it shall be re-strike free, trip free both electrically and mechanically, with anti- pumping feature.

The rated control voltage of the spring charging motor shall be 111 VDC. The closing coil shall operate atall values of voltages between 85% and 111% of rated voltage. The opening coil shall operate correctly under all operating conditions of the circuit breaker up to the rated breaking capacity and at all values of supply voltage between 71% and 111% of rated voltage.

The spring charging motor shall have adequate thermal rating such that continuous sequence of the closing and opening operations is possible as long as power supply is available to the motor. It shall also be possible to charge the spring manually and close the breaker in the event of failure of motor / control supply to motor. The operating handle shall be provided for charging the operating mechanism. After failure of control supply to the motor, one open-close-open operation shall be possible with the energy contained in the operating mechanism.

The motor rating shall be such that it requires not more than 31 seconds for full charging of the closing spring. The closing action of the circuit breaker shall compress the opening spring ready for tripping. When closing springs are discharged after closing the breaker, they shall be automatically charged for the next operation.

Mechanical indicators shall be provided to indicate OPEN/CLOSE, SERVICE/TEST positions of the circuit

breaker and CHARGED/ DISCHARGED positions of the closing spring. An operation counter shall also be provided.

The circuit breaker shall be provided with microprocessor based front adjustable protection release for overload, short circuit and earth fault.

Mechanical/Electrical interlocks shall be provided to prevent mal-operation and in particular to ensure the following.

i. It shall be possible to close the circuit breaker only if it is in a SERVICE or TEST position.
ii. It shall be possible to open the door only when the breaker is in TEST position.
iii. Movement of the circuit breaker between SERVICE and TEST positions shall be possible only if the breaker is OFF.
iv. Racking in the circuit breaker from TEST to SERVICE position shall be possible only if door is closed.

Telescopic trolley or suitable arrangement shall be provided for maintenance of circuit breaker. The trolley shall be such that the topmost breaker module can be withdrawn on the trolley and can be lowered for maintenance purpose. The telescopic trolley shall be such that all type, size and rating of breaker can be withdrawn/inserted.

The circuit breaker shall have suitable provision for integration with SCADA.

Instrument Transformers

Instrument transformers shall be completely encapsulated cast resin type, suitable for continuous operation at the ambient temperature prevailing inside the switchgear enclosure, when the switchgear is operating at its rated load and the outside ambient temperature is 51°C.

Polarity marks shall indelibly be marked on each instrument transformer and at the lead terminals at the associated terminal block.

HRC fuses of suitable rating shall be provided on the primary side of voltage transformers. For the secondary side, four pole Miniature Circuit Breakers (MCB) shall be provided.

For auxiliary supply switchgear, earth leakage relay with Core balance CTs (CBCT) shall be provided on main incoming feeders having phase CT ratio more than 51/1A. CBCT's shall be circular window type with window size based on the overall diameter of the cables, to be finalized during detailed engineering.

Bus bar

Bus bar shall be made of copper or aluminum with uniform cross section throughout their length. They shall be adequately supported on insulators to withstand electrical and mechanical stresses due to specified short circuit current.

All bus bars joints shall be thoroughly cleaned and anti-oxide grease shall be applied. Plain and spring washers shall be provided to ensure good contacts at the joints and taps. Wherever aluminum to copper connections are required, suitable bimetallic connectors or clamps shall be used.

Bus bars shall be provided with heat shrinkable sleeves of suitable insulation class throughout their length with proper colour coding. All bus bar joints and taps shall be shrouded.

Bus bar support insulators shall be made of non-hygroscopic, arc and track resistant, high strength material suitable to withstand stresses due to over voltage and short circuit current.

The Contractor shall submit busbar sizing calculation for specified continuous and short time current ratings during detailed engineering.

Earthing

An earth bus made of copper or aluminum shall be provided throughout the length of the panel. It shall be bolted to the framework of each panel and brazed to each breaker earthing contact bar.

The earth bus shall have sufficient cross section to carry maximum fault current without exceeding the allowable temperature rise.

All non-current carrying conductors of the panel shall be connected to the earth bus. All joints to the earth bus shall be made through at least two bolts. Hinged doors shall be earthed through flexible earthing braid of adequate cross section. Suitable provision shall be provided at each end of the earth bus for connection with Owner's Earth conductor.

Positive earthing of the carriage and breaker frame shall be maintained when it is in the connected position and in all other positions whilst the auxiliary circuits are not totally disconnected.

All metallic cases of relays, instruments and other panel mounted equipment shall be connected to earth bus by independent copper wires of size not less than 2.5 sq. mm with green colour insulation.

Instrument transformer secondary neutral point shall be earthed at one place only on the terminal block. Such earthing shall be made through links so that earthing of one circuit may be removed without disturbing the earthing of other circuits.

Multi-Function Meter

Digital, flush mounting type Multi-Function Meter (MFM) of 1.5 accuracy class shall be provided. It shall

have provision for integration with SCADA.

MFM shall have provision to display the following parameters.

- Line and phase voltages
- Line and phase currents
- Active power, Reactive power, Apparent power
- Frequency
- Power factor
- Total Harmonic Distortion (THD)

Wiring and Terminal blocks

All internal wiring shall be done with 651 V grade, 1.5 sq.mm. PVC insulated stranded flexible copper wire. For CT secondary circuits, 2.5 sq.mm copper wire shall be used.

Wire terminations shall be made with solderless crimping type tinned copper lugs, which shall firmlygrip the conductor. Insulation sleeves shall be provided at all the wire terminations.

Printed identification ferrules, marked to correspond with panel wiring diagram shall be provided at bothends of each wire. The ferrules shall be firmly located on each wire so that they cannot move or turn freely on the wire. Wire identification shall be done in accordance with IS 11353.

The Contractor shall be solely responsible for the completeness and correctness of the internal wiring and for the proper functioning of the connected equipment.

All internal wiring to be connected to the external equipment shall terminate on terminal blocks. Terminal blocks shall be rated for 651 V, 11 A and made of non-inflammable material.

CT and VT secondary circuits shall be terminated on stud type, disconnecting terminal blocks.

At least 11% spare terminals shall be provided on each panel and these spare terminals shall be distributed on all terminal blocks.

Warranty

LT Switchgear shall be warranted against all material/ manufacturing defects and workmanship for minimum of 1 (one) year from the date of supply.

Testing and Inspection

Type Tests

The switchgear panel shall be of type tested design. Type test reports as per the following standards shall be submitted during detailed engineering. The tests should have been conducted on the similar equipment by NABL accredited laboratory. Validity period of type tests conducted on the equipment shall be as per 'CEA Guidelines for the Validity Period of Type Test(s) conducted on Major Electrical Equipment in Power Transmission'.

Equipment	Standard
Switchgear Panel	Relevant parts of IEC 61439
Air Circuit Breaker	IEC 61947-2
Moulded Case Circuit Breaker	IEC 61947-2
Current Transformer	Relevant parts of IEC 61869
Voltage Transformer	Relevant parts of IEC 61869

In case the contractor is not able to submit the test reports during detailed engineering, the contractor shall submit the reports of type/special tests either conducted by NABL accredited laboratory or witnessed by EMPLOYER.

Routine Tests

Routine tests and acceptance tests shall be as per the Quality Assurance Plan (QAP) approved by the EMPLOYER.

Uninterrupted Power Supply (UPS)

Standards and Codes

Uninterrupted Power Supply shall comply with the following standards and codes or equivalent Indian Standards, wherever applicable.

Standard/Code	Description
IEC 62141-1	Uninterruptible power systems (UPS) – Part 1: General and safety requirements for UPS
IEC 62141-2	Uninterruptible power systems (UPS) – Part 2: Electromagnetic compatibility (EMC) requirements

IEC 62141-3	Uninterruptible power systems (UPS) – Part 3: Method of specifying the performance and test requirements
IEC 62619 / IS 16815	Secondary cells and batteries containing alkaline or other non- acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications
IEC 62621 / IS 16822	Secondary cells and batteries containing alkaline or other non- acid electrolytes – Secondary lithium cells and batteries for use in industrial applications
IEC 61896-21	Stationary lead-acid batteries - Part 21: Valve regulated types - Methods of test
IEC 61896-22	Stationary lead-acid batteries - Part 22: Valve regulated types - Requirements
IS 15549	Stationary valve regulated lead acid batteries - Specification

General Requirements

The Uninterrupted Power Supply (UPS) system shall be designed to supply power to following loads (but not limited to).

(i) Data logger / SCADA / EMS
(ii) Fire Detection/ Alarm Panel
(iii) HMI of SCADA
(iv) Emergency Lighting
(v) Inverter's Auxiliary supply (if applicable)
(vi) HT panel auxiliary
(vii) CCTV

Sizing of UPS shall be done considering the above-mentioned load at power factor of 1.8 lagging inclusive of 11% design margin at 51 °C. System Description.

The UPS shall automatically provide continuous, regulated AC power to critical loads under normal and abnormal conditions, including loss of input AC power. The UPS system shall consist of the following major equipment.

(i) UPS Module
  (a) Insulated Gate Bipolar Transistor (IGBT) Converter
  (b) Insulated Gate Bipolar Transistor (IGBT) Inverter
  (c) Digital Signal Processor (DSP) using Pulse Width Modulation (PWM) for Direct Digital Control (DDC) of all UPS control and monitoring functions
  (d) Static bypass switch

(ii) Battery system for 2 hours
(iii) Battery protective and disconnect device
(iv) Maintenance bypass switch
(v) LCD display panel and LED indications
(vi) Integrated UPS Communications Protocols capable of communicating with SCADA system

The UPS shall meet the following minimum specifications.

Parameter	**Specification**
Topology	Online double conversion UPS
Input	
Voltage	231 V ± 11% AC for UPS Rating of less than 5 kVA 415 V ± 11% AC for UPS Rating of 5 kVA and above
Frequency	51 ± 5 Hz
Power factor	1.95
Output	
Voltage	231 V ± 1% AC
Frequency	51 Hz
Power factor	1.8
Monitoring and communication	
LED Indicators	Load on Inverter, Battery operation, Load on Bypass, Overload, LCD Fault, UPS Fault
Electrical contacts	Closing contacts for each of the following conditions: 1. Unit on Battery 2. Low Battery 3. Summary Alarm 4. UPS On 5. Input Fail

Local Display	LCD/ LED
SCADA communications	RS-485 Interface Port
Overall efficiency	>91%
Electrical Protection	Input/ output under voltage, over temperature, overload, Short circuit, battery low trip

The UPS shall be forced air cooled by internally mounted fans. The fans shall be redundant in nature to ensure maximum reliability. The fans shall be easily replaceable without the use of special tools.

Contractor shall provide the Operation & Maintenance Manual and mandatory spare parts list along with the equipment.

Warranty

UPS shall be warranted for minimum of 5 (five) years and batteries shall be warranted for a minimum of 2 (two) years against all material/ manufacturing defects and workmanship from the date of supply.

Tests

Routine tests and acceptance tests on final product shall be done as per QAP approved by the EMPLOYER.

On completion of installation and commissioning of the equipment on site tests shall be carried out with the max. available load, which does not exceed the rated continuous load. An on-site test procedure shallbe submitted by contractor include a check of controls and indicators after installation of the equipment.

Earthing

Standards and Codes

Earthing system shall comply with latest revisions and amendments of the relevant IEC standards and IS codes. In particular, earthing system shall comply with the following standards and codes.

Standard/Code	Description
IS 3143	Code of Practice for Earthing
IEEE 81	IEEE Guide for Safety in AC Substation Grounding
IEC 62561-2	Requirements for conductors and earth electrodes
IEC 62561-7	Requirements for earthing enhancing compounds
IEEE 142	IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems
Indian Electricity Rules	

General Requirements

Earthing system shall be designed based on system fault current and soil/water resistivity value obtained from geo-technical investigation/hydrography report. Earth grid shall be formed consisting of number of earth electrodes sufficient enough to dissipate the system fault current interconnected by earthing conductors.

The earth electrode shall be made of high tensile low carbon steel rod, molecularly bonded by high conductivity copper on outer surface with coating thickness not less than 251 micron as per relevant standards. Suitable earth enhancing material shall be filled around the electrode to lower the resistance to earth. Inspection chamber and lid shall be provided as per IS 3143.

Earth conductors shall be made of copper bonded steel or galvanized steel of sufficient cross section to carry the fault current and withstand corrosion.

Earth conductors buried in ground shall be laid minimum 611 mm below ground level unless otherwise indicated in the drawing. Back filling material to be placed over buried conductors shall be free from stones and harmful mixtures.

Earth electrodes shall not be situated within 1.5 m from any building whose installation system is being earthed. Minimum distance between earth electrodes shall be two times the driven depth of theelectrode.

Transformer yard and switchyard fence shall be connected to the earth grid by one GS flat and gates by flexible lead to the earthed post.

All welded connections shall be made by electric arc welding. For rust protection the welds should be treated with red lead compound and afterwards thickly coated with bitumen compound.

PCU Earthing

DC negative bus bar of the PCU shall be earthed to avoid Potential Induced Degradation (PID). DC negative bus bar and PCU equipment earth shall be bonded to the PCU earth bus and connected to earth electrodes through flexible copper cable of sufficient cross section as mentioned by the manufacturer. Theinterconnection of PCU earth electrodes with DC earth grid shall be as per PCU manufacturer recommendation.

In case earthing of DC negative bus bar of PCU is not allowed by the manufacturer, suitable anti-PID

device shall be provided with the consent of PV Module and PCU manufacturer. However, PCU equipment earth shall be connected to earth electrodes through flexible copper cable of sufficient cross section as mentioned by the manufacturer.

Transformer Earthing

Inverter transformer neutral shall be floating, not to be earthed. However, recommendation of inverter manufacturer shall also be taken into account.

Transformer body, cable box, marshalling box and all other body earth points shall be earthed.

Inverter transformer shield shall be earthed separately using minimum two no. of earth electrodes. Earthing conductor between shield bushing and earth electrodes shall be copper flat of suitable size not less than 25 x 6 mm.

Neutral and body of the auxiliary transformer shall be earthed.

Main Control Room Earthing

Metallic enclosure of all electrical equipment inside the main control room shall be connected to theearth grid by two separate and distinct connections.

Cable racks and trays shall be connected to the earth grid at minimum two places using galvanized steelflat.

SCADA and other related electronic devices shall be earthed separately using minimum two no. of earth electrodes.

Switchyard Earthing

The metallic framework of all switchyard equipment and support structures shall be connected to theearth grid by means of two separate and distinct connections.

The switch yard shall be shielded against direct lightning stroke by provision of overhead shield wire orearth wire or spikes (masts) or combination thereof as per CEA 2111(Technical standards)- 42(2)(c).

Tests

Type test reports for earthing electrode, earth enhancing compound and its associated accessoriesshall be submitted during detailed engineering for approval.

On completion of installation, continuity of earth conductors and efficiency of all bonds and joints shall be checked. Earth resistance at earth terminations shall be measured and recorded.

The earth plate shall be provided to facilitate its identification and for carrying out periodical inspection.

Lightning Protection System

Lightning Protection System (LPS) for the entire plant against direct and indirect lighting strokes shallbe provided as per IS/IEC 62315:2111.

Lightning Protection Level for the entire plant shall be Level – III.

Air terminals, down conductors and earth termination system shall be designed as per relevant parts of IS/IEC 62315:2111.

Necessary foundation/anchoring for holding the air terminals in position to be made after giving due consideration to shadow on PV array, maximum wind speed and maintenance requirement at site in future.

The product shall be warranted for minimum of 2 (two) years against all material/ manufacturing defects and workmanship.

Type test reports as per IS/IEC 62315:2111 shall be submitted during detailed engineering for approval.

Communication Cables

Optical Fibre Cables

Optic Fibre cable shall be 4/8/12 core, galvanized corrugated steel taped armoured, fully water blocked with dielectric central member for outdoor/ indoor application so as to prevent any physical damage.

The cable shall have multiple single-mode or multimode fibres on as required basis so as to avoid the usage of any repeaters.

The outer sheath shall have Flame Retardant, UV resistant properties and are to be identified with the manufacturer's name, year of manufacturing, progressive automatic sequential on-line marking of length in meters at every meter on outer sheath.

The cable core shall have suitable characteristics and strengthening for prevention of damage during pulling. All testing of the optic fibre cable being supplied shall be as per the relevant IEC, EIA and other international standards.

The Contractor shall ensure that minimum 111% cores are kept as spare in all types of optical fibre cables. Cables shall be suitable for laying in conduits, ducts, trenches, racks and underground buried installation.

Spliced/ Repaired cables are not acceptable. Penetration of water resistance and impact resistance shall be as per IEC standard.

Communication Cable (Modbus)

Data (Modbus) Cable to be used shall be shielded type with stranded copper conductor. Cable shall have minimum 2 pair each with conductor size of 1.5 Sq.mm. Cable shall be flame retardant according to IEC 61332-1-2.

Cable shall be tested for Peak working voltage of not less than 311 V and shall be suitable for serialinterfaces (RS 422 and RS 485).

Communication cable shall be laid through suitable HDPE ducts.

Control Cables

Control Cables shall have stranded copper conductor, PVC insulation, PVC inner sheath, FRLS PVC outersheath according to IS 1554-1. Colour of the outer sheath shall be grey in colour.

The minimum cross section of the conductor shall be 2.5 sq.mm.

At least one (1) core shall be kept as spare in each control cable of 4C, 5C or 7C size whereas minimumno. of spare cores shall be two (2) for control cables of 11C or higher size.

Illumination

Standards and Codes

LED luminaires shall be tested at independent laboratory as per the following test standards.

Standard/Code	Description
LM 79-18	Electrical and Photometric Measurements of Solid-State Lighting Products
LM 81-15	Measuring Luminous Flux and Color Maintenance of LED Packages, Arrays and Modules

General Specification

This specification covers design, supply and installation of Illumination system along the peripheral & internal roads, main control room & inverter rooms, switchyard and other facilities including entry points/gate(s) inside the plant area.

The Contractor shall furnish Guaranteed Technical Particulars of the LED luminaires, from renowned brands available in the market for approval of EMPLOYER.

Lighting system shall work on the auxiliary supply and same shall be incorporated in auxiliary loads. The Contractor shall provide minimum 21% of total lighting points as emergency lighting points, fed from UPS DB or DCDB as per scheme adopted by the Contractor. Indoor and outdoor emergency lights shall be provided at each inverter room, main control room, security room and main gate.

Weather Monitoring System

As a part of weather monitoring system, the Contractor shall provide the following measuring instruments with all necessary software.

Pyranometer

The Contractor shall provide Class-A pyranometers (ISO 9161:2118 classification) along with necessary accessories for measuring the incident solar radiation at horizontal and inclined plane of array. Specification of the pyranometer shall be as follows.

Parameter	Specification
Spectral Response (51% points)	1.31 to 2.8 micron
Operating temperature range	1°C to +81°C
Ingress Protection	IP 67
Resolution	Minimum +/- 1 W/m^2
Output	Analog output: 4 – 21 mA Serial output: RS485

Each instrument shall be supplied with necessary cables. Calibration certificate with calibration traceability to World Radiation Reference (WRR) or World Radiation Centre (WRC) shall be furnished along with the equipment. The Contractor shall provide instrument manual in hard and soft form.

Temperature Sensor

The Contractor shall provide minimum 3 (three) temperature sensors (1(one) for ambient temperature measurement with shielding case and 2 (two) module temperature measurement). The temperature sensor shall be Resistance Temperature Detector (RTD)/ Semiconductor type with measurement range suitable for site. The instrument shall have valid calibration certificate.

Anemometer

The Contractor shall provide minimum one no. of ultrasonic wind sensor (no moving parts) for wind speed and direction monitoring.

Parameter	Specification

Velocity range with accuracy limit	1 – 61 m/s with +/-2% accuracy; Resolution: 1.11 m/s
Wind direction range with accuracy limit	1 to 361° (No dead band) with +/-2° accuracy; Resolution: 1°
Mounting Bracket	Anodized Aluminium bracket to reduce corrosion, all mounting bolts of SS
Protection Class	IP 66
Output	RS 485

Testing Instruments

The Contractor shall provide the following set of instruments for on-site testing.

Earth resistance tester

Parameter	**Specification**
Display	Backlit LCD or LED display
Range	Earth Resistance: up to 2111 Ω Earth Voltage: 211 V
Accuracy	± (2% + 5)
Safety Ratings	IP 56
Programmable Limits setting	Enabled
Accessories	
Earth Ground Stakes – 4 Nos.	
Cable Reels – 3 Nos.	
Battery – 2 set	
Carry Case with sufficient space for accommodating accessories	

Array tester

Parameter	**Specification**
Display	Backlit LCD or LED display
Functionality	All electrical tests required by IEC 62446- 1:2116
Memory	Up to 211 records & USB downloadable to Computer
Accessories	
A set of two, 4mm fused leads for extra protection during installation tests.	
Leads which enable the array tester to connect directly to PV arrays	
Battery – 2 set	
Carry Case with sufficient space for accommodating accessories	

Insulation tester

Parameter	**Specification**
Display	Backlit LCD or LED display
Insulation Test Range	1.1 MΩ to 11 GΩ
Test Voltage	251V, 511V, 1111V, 5111V
Test Voltage accuracy	+21% on positive side only no negative variation is allowed
Accessories	
Heavy duty Test Leads with Alligator Clips – 1 set	
Battery – 2 set	
Carry Case with sufficient space for accommodating accessories.	

Digital Multimeter

Parameter	**Specification**
Voltage Range	1511 V DC / 1111 V AC (True RMS)
Display	4 ½ digits, Backlit LCD or LED
Measuring Category	1111V CAT III as per IEC 61111-1
Additional Functions	Resistance, Temperature, Continuity, Diode, Capacitance, Frequency, Duty cycle measurement
Accessories	
Temperature Probe – 1 No.	
Test Leads with Alligator Clips – 1 set	
Battery – 2 set	
Carry Case with sufficient space for accommodating accessories.	

Clamp meter

Parameter	**Specification**
Current Range	411 A DC / 1111 A AC (True RMS)
Display	Backlit LCD or LED display

Measuring Category	1111V CAT III as per IEC 61111-1
Additional Functions	Active, Reactive and Apparent Power, THD, PF
Accessories	
Test leads – 1 set	
Battery – 2 set	
Carry Case with sufficient space for accommodating accessories.	

Power Evacuation System

Design, Construction, Testing and Commissioning of the power evacuation system and its integration to the designated substation via either overhead transmission line or underground cables at specified grid voltage with all necessary infrastructure such as protection switchgears and metering systems shall be as per the requirement of the STU/EMPLOYER.

The Contractor shall get the route approval from the EMPLOYER/Architect prior to start of the construction. Any changes in the route or scheme at any point of the time prior to commissioning shall be complied with without any additional cost to the EMPLOYER.

Only ICAI approved components shall be used for construction of transmission lines and underground cables.

C Civil, Mechanical and Plumbing Works

General Requirement

This section of Technical Specifications describes detailed technical and functional requirements of all civil, structural, mechanical & plumbing works included in the scope.

Standards & Codes

All design and construction of civil works shall confirm to relevant Indian standards such as BIS, IRC, MORTH, NBC etc.

The design of steel structures shall conform to IS: 811, 811 or 812 as applicable. The design of concrete structures shall conform to IS: 456. For design of liquid retaining structure IS: 3371 shall be followed. Only in case of non-availability of Indian standard, equivalent American or British standard may be used for design with prior approval of the Engineer and the contractor shall submit proper justification for the same along with his request to the Engineer for review and approval, and the decision of the Engineer shall be final and binding.

All the design/ drawings shall be prepared/ approved either by in-house Engineering Team of the contractor (or by his Engineering Consultant) with qualified engineering staff with relevant experience in successful design of solar SPV plants.

The design calculations for MMS, RCC structure, Steel structure, Foundation system, Road work, Drainage work, etc. shall be submitted for prior approval of Engineer before commencement of construction.

As per project requirements, the Employer may ask for approval of all civil designs and drawings by a Chartered Civil/ Structural Engineer.

The design calculations shall be supplemented with a neat sketch showing the structure geometry, node and member nos., lengths of various typical members, support points and type of supports, types of materials & type of sections with properties considered in analysis & design. The report shall also include back-up calculations for various loads adopted in design, brief write-up on primary load cases and design load combinations considered and conclusions on design results (with supporting sketches) for easy reference and clarity. Where a computer program (other than STAAD) is used for analysis and design, the contractor shall include a write-up on the computer program used along with examples for validation check. Design Input (format suitable to the programme used and also in STAAD format) and output file shall also be given in the design report and in soft copy to facilitate its review and approval by the Engineer.

The methodology for construction of MMS and its foundations, Road & drainage works and Procedure for pile load test shall also be submitted for prior approval of Engineer before start of these works.

Other Investigations

The contractor shall also obtain and study other input data at proposed project site for design of the project from metrological department/ local govt. authorities. This shall include data related to Rainfall,Maximum & Minimum ambient Temperature, Humidity, HFL etc.

The contractor shall carry out Shadow Analysis at proposed site and accordingly design strings and array layout with optimum use of space, material and manpower. In case of large variations in topography (3^{o} to the horizontal) the study shall also include the effect of topographical variations on array layout and MMS structure design adequacy and stability. The contractor shall submit all the details/ design to the Engineer for review/ approval.

The contractor shall also identify potential quarry areas for coarse and fine aggregates to be used for concrete and shall carry out the concrete mix design for different grades of concrete to be used before start of work. The concrete mix shall be designed for each source of cement and aggregates as per provisions of relevant BIS Standard. The concrete mix design shall be carried out through NABL accredited Laboratory, or any Govt. agency approved by the Engineer. In case the contractor proposes to use RMC, he shall submit the Concrete mix design report from the RMC supplier for review and approval by the Engineer. (In case of RMC, reports for periodic cube tests from the supply batch shall also be submitted for review and record).

Surface/ Area drainage

The contractor shall design and construct a storm water drainage network for smooth disposal of storm water from the plant to the nearest available drainage outlet.

The storm water drainage system shall be designed and planned to ensure no water stagnation in the plant.

The plant drainage system shall be designed for maximum hourly rainfall intensity and relevant time of concentration.

The design shall confirm to the provisions of IRC SP 42 and best Industry practices. (The design rainfall shall be taken as max.

The coefficient of run-off for estimation of design discharge shall be considered as per catchment characteristics, however it shall not be less than 1.6.

The drainage scheme shall be designed considering the plant plot area and the surrounding catchmentarea contributing to the plant area drainage as per the topography.

The storm water drainage system shall be a network of open surface drains (with rectangular or trapezoidal cross section) and shall generally be designed to follow the natural flow of water and ground contours.

Suitable size plant peripheral drain as per design and requirement (min. 451mm wide x 451mm deep) along inside of plant boundary wall/ fence shall be provided for smooth channelization of outside stormwater and to avoid flooding in the plant. The size of all internal and road side drains shall not be less than 311mm (bottom width) x 311mm (depth).

All trapezoidal drains shall have side slopes not steeper than 1:1. Unlined drains may be provided depending upon the geotechnical characteristics and drainage design in the view of the stability and erosion of drain walls. However, the drain segments near outfalls and drain crossings shall be lined. Thethickness of the lining shall be minimum 115mm for brick masonry, 75mm for concrete slabs, 111mm for RR masonry and 51mm for stone slabs. The lining shall be in CM (1:4) and the joints shall be raked and pointed with CM (1:3), however the joints in lining of plant peripheral drain may be left without pointing.

In case of rectangular drain, the thickness of the wall shall be checked against structural stability under action of the design loads as specified in Cl. No. 11 'Design Loads'. However, the min. wall thickness shall be 115mm, 211mm and 111mm respectively for brick masonry, RR masonry and RCC work, except for garland drain around buildings where the min. wall thickness can be 115mm, 211mm and 111mm respectively for brick masonry, RR masonry and RCC work.

The structural design of drains shall be as per provisions of relevant BIS standards and good industry practice.

The drain outfall shall be connected to the nearest existing natural drain(s)/ water body outside plant premises, and it shall be ensured that the drainage water shall not re-enter the plant nor encroach/ flood in the adjacent property/ plot.

The proposed drainage scheme along with design calculations and drawings shall be submitted to the Engineer for review/ approval before start of construction.

The contractor shall provide a percolation/recharge pit for harvesting water in the MCR area. For the remaining plant facilities, the Contractor shall explore provisions for rainwater harvesting system for water conservation by constructing suitable collection wells along the drains or through provision of detention ponds or percolation/recharge pit etc. at major drainage outfalls. The scheme for rainwater harvesting along with design calculations shall be submitted for approval.

Plant Layout

The contractor shall submit drawing showing proposed Project Plant and SPV module Layout.

4.1 The Plant and SPV module layout shall be a comprehensive drawing showing various requirements of the project like, Reference coordinate grid, Geographical and Plant North, Layout of boundary fence including coordinates of all corner points, Location of main entrance gate and any other access gates as per project needs, Block wise FGL, Layout of main approach road to the plant, Internal and peripheral roads, Security Room/ cabin (s), all Buildings and Open installations with coordinates, Temporary Storage yard/ facility to be used by the contractor during construction, Proposed Array layout, Lightening arrester, UG/Over ground water Tank(s), Storm water drains, Corridor for buried

cables etc.

The cable corridor shall be laid through a clear gap between arrays and shall not be laid belowmodules for easy maintenance.

All the facilities and buildings shall be presented with suitable Legend.

The drawing shall be in suitable scale to have proper representation of the information.

The Plant & SPV module layout drawing shall be submitted by the contractor for review/ approval bythe Engineer.

Design Loads

Unless otherwise specified elsewhere, Dead load, Live load, Wind load, Seismic load and Snow Load for buildings and structures shall be considered as per provisions of relevant BIS standards.

The following minimum imposed load as indicated for some of the important areas shall, however, be considered for the design. If the actual expected load is more than the specified minimum load, then actual load is to be considered.

S. No.	Area	Imposed (Live) Load
1	Roof (Accessible/Non-accessible)	1.51 kN/ Sqm
2	Building floors (GF) & Grade Slab	11.11 kN/ Sqm
3	RCC Floors (General)	5.11 kN/ Sqm
4	Outdoor platforms, Stairs, Landing and Balconies, Walkway, Chequred plate & Grating (except cable trench cover)	5.11 kN/ Sqm
5	Road culverts & allied structures over drain & pipe crossings subjected to vehicular traffic	Design for Class – 'AA' loading (Wheeled & Tracked both) and check for Class – 'A' loading as per IRC Standard
6	Underground structures such as Sump, Pit, Trench, Drain, UG tank etc.	In addition to Earth pressure and Ground water table at FGL, a surcharge of 21kN /Sqm (11kN/Sqm for drains) shall also be considered. The structure shall be designed for following criteria – (a) Inside empty with outside fill+ surcharge and water table at GL & (b) Inside water with no fill & water table outside
7	Pre-cast and chequred plate cover over cable trench	4.11 kN/ Sqm
8	Main access & Internal Roads	As per IRC SP 21 corresponding to vehicular traffic of 151 commercial vehicles per day and critical in-field CBR

Primary Loads

(i) Dead Load (DL)
(ii) Live Load (LL)
(iii) Wind Load (WL) – Both along ±X & ±Z horizontal direction
(iv) Seismic Load (EL) – Both along ±X & ±Z horizontal direction
- Seismic Load is to be considered as per as per IS 1893 Part 4.
- Seismic Zone = IV, Zone Factor Z = 1.24
- Importance Factor, I = 1.5
- Response Reduction Factor, R = 3

(v) Snow Load (SnL) – As per IS 875 (Part 4): 1987
- Ground Snow Load, S_1 = 4 kN/m^2

(vi) Temperature Load (TL)
- Minimum Recorded Temperature = -27.5 °C
- Maximum Recorded Temperature = 12 °C
- Reference Temperature at time of erection for temperature load calculation = 5 °C
- The structure shall be designed for a rise in temperature of 7 °C and for a fall in temperature of 32.5 °C.

Basic wind speed (V_b) at project site shall be taken as per IS 875 (part-3) unless otherwise specified elsewhere.

To calculate the design wind speed (V_z), the factors k_1 (probability factor or risk coefficient), k_2(terrain roughness and height factor) and k_3 (topography factor) shall be considered as per IS 875

(Part-3). However, minimum values for k_1, k_2 and k_3 shall be 1.94, 1.1 and 1.1 respectively.

Topography factor 'k_3' shall be taken as 1.1 upto upwards slope of 3°. For topography with upward slope greater than 3°, the value of 'k_3' shall be calculated as per Annexure- C of IS 875 (Part-3).

To calculate the design wind pressure 'pd', factors 'ka' (area averaging factor) and 'kc' (combination factor) shall be taken as 1.1.

The Seismic Load shall be considered corresponding to Earth quake zone at site as per IS: 1893 (Part- 4) with Importance factor 1.5. Ductile design and detailing as per IS 13921 shall be followed in all RCC structures including MCR, plinth supporting open installations of inverter transformers and control panels at ICR/LCR, BESS Platform, etc.

Notes for Wind Load (WL) Consideration for MMS Design

WL shall be considered as detailed below for estimation of WL under primary loads:

(i) WLx (downward), WLz (downward): Load due to positive pressure on design tilt angles of MMS members for wind acting in both (±X, ±Z) directions.

(ii) WLx (upward), WLz (upward): Load due to negative pressure on design tilt angles of MMS members for wind acting in both (±X, ±Z) directions.

(iii) WLx (member load), WLz (member load): Load due to wind action on side (exposed) face of respective MMS members (drag force) for wind acting in both (±X, ±Z) directions.

- ±WLx (member load, transverse to MMS table): Load due to wind action on column, front and back bracing, longitudinal bracing
- ±WLz (member load, along length of MMS table): Load due to wind action on column, rafter front and back bracing, longitudinal bracing

(iv) For estimation of design wind loads on purlins (Table 8 of IS 875- Part 3), WL (downward) and WL (upward) on modules (laid in the profile of mono slope canopy) shall be applied such that the center of pressure should be at (1.3 × length of canopy) from windward end (for simplicity, the wind load distribution may be taken as triangular with max. value at windward end). Solidity ratio (ø) shall be taken as 1.1. Apart from this distribution, any other distribution of wind load based on wind tunnel studies may be followed subject to the approval of the employer.

Note: Wind tunnel studies shall be specific to the site topography as well as array layout. The wind tunnel studies shall be conducted with appropriate scale model and boundary line tunnels and must be validated from an IIT.

(v) In design of MMS (for height of structures less than 11 m from ground), 21% reduction in wind pressure as per Note under Cl. 6.3 of IS 875 – Part 3 is not permitted in case of purlins (members supporting modules), which shall be designed against action of WL corresponding to full wind pressure.

Design Load combinations

Appropriate Load factors in LSM design for concrete structures and appropriate Factor of safety in WSM design (ASD) for all steel structures including MMS shall be considered as per relevant BIS standard. No increase in permissible stress is permitted in the design of MMS.

Following load combinations shall be considered in design:

- For MMS Design:
  - (i) DL + LL
  - (ii) DL + LL ± WLx (upward) ± WLx (member load)
  - (iii) DL+ LL ± WLx (downward) ± WLx (member load)
  - (iv) DL+ LL ± WLz (upward) ± WLz (member load)
  - (v) DL+ LL ± WLz (downward) ± WLz (member load)
  - (vi) DL+ LL ± ELx
  - (vii) DL+ LL ± ELz
  - (viii) DL+ SnL ± WLx (upward) ± WLx (member load)
  - (ix) DL+ SnL ± WLx (downward) ± WLx (member load)
  - (x) DL+ SnL ± WLz (upward) ± WLz (member load)
  - (xi) DL+ SnL ± WLz (downward) ± WLz (member load)
  - (xii) DL+ SnL ± ELx
  - (xiii) DL+ SnL ± ELz
  - (xiv) DL ± TL ± WLx (upward) ± WLx (member load)
  - (xv) DL ± TL ± WLx (downward) ± WLx (member load)
  - (xvi) DL ± TL ± WLz (upward) ± WLz (member load)
  - (xvii) DL ± TL ± WLz (downward) ± WLz (member load)

- For RCC and Steel structures except MMS:
  (i) DL + LL
  (ii) DL + LL ± WLx
  (iii) DL + LL ± WLz
  (iv) DL + LL ± ELx
  (v) DL + LL ± ELz
  (vi) DL + SnL ± WLx
  (vii) DL + SnL ± WLz
  (viii) DL + SnL ± ELx
  (ix) DL + SnL ± ELz
  (x) DL ± TL ± WLx
  (xi) DL ± TL ± WLz

All buildings, structures and foundations shall be designed to withstand loads corresponding to the worst design load combination.

MMS Foundation

Module mounting structure (MMS) may be supported on Solid Concrete Column/Pier coming from Ground/Footing.

If the Concrete Column are not visible/available, then a solid Concrete base attached with the RCC Member shall be constructed.

Concrete works shall be done as under:

Construction of all RCC works shall be done with an approved design mix as per IS 456 and the materials used viz. Cement, coarse & fine aggregate, Reinforcement steel etc. shall conform to relevant BIS standards.

The min. grade of concrete shall be M25 for MMS piling works, M31 for other RCC works exceptliquid retaining structures like underground water tank, septic tank, etc. where minimum grade of concrete shall be M35.

Cement higher than 43 Grade shall not be used in construction.

Unless otherwise specified elsewhere, PCC shall be of min. grade M11 (nominal mix 1:3:6) except for mud mat, back filling of ground pockets or leveling course which shall be of grade M7.5 (nominal mix 1:4:8).

Reinforcement steel shall be of high strength TMT bars of grade Fe511D conforming to IS:1786.

Unless specified otherwise for grouting works, anti-shrink ready mix grout of approved make or cement mortar (CM) grout with non-shrink compound shall be used. The grout shall be high strength grout having min. characteristic strength of 35 N/mm^2 at 28 days.

Miscellaneous Steel Works

Unless otherwise specified elsewhere, all structural steel work shall be designed as per provisions of IS: 811 with working stress method of design (WSD).

Structural steel hot rolled sections, flats and plates shall conform IS: 2162, structural Pipes shall be medium (M)/ high (H) grade conforming to IS: 1161, chequered plate shall conform to IS: 3512 and Hollow steel sections for structural purposes shall conform to IS: 4923.

Roofing

The roof of all buildings shall be provided with min. slope of 1:111 for effective drainage of rainwater. The slope shall be achieved either by application of screed concrete of grade 1:2:4 (with 12.5mm down coarse aggregate) with min. 25mm thick CM 1:4 layer on top to achieve smooth surface to facilitate application of water proofing treatment.

The water proofing treatment shall be in situ five course water proofing treatment with APP (Atactic Polypropylene) modified Polymeric membrane over roof consisting of first coat of bitumen primer @ 1.41Kg per sqm, 2nd & 4th courses of bonding material @ 1.21 kg/sqm, which shall consist of blown type bitumen of grade 85/25 conforming to IS : 712, 3rd layer of roofing membrane APP modified Polymeric membrane 2.1 mm thick of 3.11 Kg/sqm weight consisting of five layers prefabricated with centre core as 111 micron HMHDPE film sandwiched on both sides with polymeric mix and the polymeric mix is protected on both sides with 21 micron HMHDPE film. The top most layer (5th layer) shall be finished with brick tiles of class designation 11 grouted with cement mortar 1:3 (1 cement: 3 fine sand) mixed with 2% integral water proofing compound by weight of cement over a 12 mm layer of cement mortar 1:3 (1 cement: 3 fine sand) and finished neat. The water proofing treatment shall be extended over golla/ fillet and inner face of the parapet up to 451mm height.

The corners at parapet wall and slab shall be provided with 51 thick fillet/ golla in CM 1:3 with neat finish.

Required no. of rainwater down take pipes min. 111mm dia. PVC pipes (UV resistant), 451x451mmx15mm deep khurra and MS grill at inlet shall be provided for rain water disposal.

Sign Boards and Danger Boards

The sign board containing brief description of major components of the power plant as well as the complete power plant in general shall be installed at appropriate locations of the power plant as approved by Engineer.

The Signboard shall be made of steel plate of not less than 3 mm. Letters on the board shall be with appropriate illumination arrangements.

Safety signs, building evacuation plans and direction signs, assembly points shall also be placed at strategic locations.

The Contractor shall provide the Engineer with detailed specifications of the sign boards.

Cable Lying

As required, suitable MS insert plates shall be provided on trench wall to support the cable rack/ pipe.

All the cables shall be laid in the Cable trays only. No Cable shall be pinned or hooked with the Wall/other components.

PV Module Cleaning System

Wet Cleaning System

1) The Contractor shall estimate the water requirements for cleaning the photovoltaic modules at least once in two weeks or at a closer frequency as per the soiling conditions prevailing at site. Also, the contractor is required to plan the water storage accordingly with the provision of a tank of suitable capacity for this purpose. However, min. consumption of 2 Ltr / Sqm of surface area of SPV module shall be considered in estimation of required quantity of water storage.
2) A regular supply of suitable quantity of water shall be ensured by the contractor to cater day-to-day requirement of drinking water and for cleaning of PV modules during entire O&M period.
3) Water used for drinking & PV module cleaning purpose shall generally be of potable quality and fit for cleaning the modules with TDS generally not more than 75 PPM. In case of higher salt contents, the water shall be thoroughly squeezed off to prevent salt deposition over module surface. However, water with TDS more than 211 PPM shall not be used directly for module cleaning without suitable treatment to control the TDS within acceptable limits. The water must be free from any grit and any physical contaminants that could damage the panel surface.
4) If required, for settlement of any grit/ unacceptable suspended particles in the water a settling tank shall be installed before the inlet of the storage tank. Suitable arrangement for discharge/ disposal of sediment/ slush shall be provided in silting chamber by gravity disposal in surface drain or with provision of sludge sump and pump of adequate capacity.
5) The module cleaning system shall include construction of RCC tank or supply and installation of Ground mounted PVC tank (s) of required storage capacity, pumps (including 1 No. standby pump), water supply mains and flexible hose pipes, taps, valves (NRV, Butterfly valve, Ball valve, Gate valve, PRV, scour valve etc.), Water hammer arrester(s), pressure gauge, flow meter etc. as per the planning & design.
6) In the case of over ground water storage tank, the contractor shall check its effect on plant performance through shadow analysis. The PVC storage tank shall conform to IS: 12711. The valves shall conform to IS: 778. A suitable metal sheet canopy for protection from direct sunlight shall be provided over the tank area.
7) The water supply mains could be either GI, uPVC or HDPE, however, the vertical pipe connecting supply main to the discharge point shall be of GI.
8) A masonry chamber shall be provided for Main gate valve at pump end. Whereas, as per requirements, at other locations either a masonry or GI/ HDPE pipe chamber may be provided.
9) The module cleaning procedure and pressure requirement at discharge point shall be as per the recommendation of PV module manufacturer. However, discharge pressure at the outlet shall not be less than 5kgf/cm^2 (1.5 MPa).
10) All the pipes thus laid shall be buried in ground at least 151mm below FGL or laid above ground clamping on suitable concrete support blocks. In the case of above ground piping only GI pipes shall be used.
11) The Scope of Supply and installation shall include module cleaning system units, docking stations, communication tools, charging system, spares, remote operation management & analytics tools, SCADA communication tools and any other system related requirement required for successful installation & operation of the system.
12) The system shall be designed for operation under the climatic conditions at site, as specified elsewherein this specification. Module cleaning system shall be effective under a relative humidity of minimum 75% or as per site specific value observed over last 25 years.
13) The Contractor shall ensure the efficacy of the module cleaning system with respect to the local soil. The Contractor shall submit a test report for applicability of proposed cleaning system for site specific soil as per standardized testing procedures from an accredited laboratory.

14) Impact of cleaning brush/microfiber on the coatings of modules shall be tested as per IEC 62788-7-3.
15) Unless specified otherwise in OEMs recommendations, material for docking stations and rails shall be anodized extruded Aluminium (Class designation 64431 and 65132 conforming to IS: 733) or galvanized steel (grades as applicable for MMS). The minimum thickness of anodization coating and galvanization coating shall be 25 microns and 81 microns respectively.

Transportation and Site Setup

Interconnection of the BESS with the grid is at the point of common connection (PCC). The Contractor shall be responsible for all equipment and installation activities up to the system side of the PCC. The Contractor will be responsible for completing the necessary work for the interconnection point.

Installation/Interconnection

For installation/interconnection, the Contractor shall

- Develop drawings, specifications, and calculations for Contractor's scope of installation equipment and services (that is, up to the BESS side of the PCC).
- Develop detailed start-up and site acceptance test (SAT) plans.
- Obtain all permits necessary to transport the BESS to the site.
- Ship the BESS to the project site.
- Assemble BESS components on site to produce a functional system (as required).
- Perform start-up testing and SAT of the BESS.
- Provide on-site Contractor representative during installation and/or interconnection activities by the Employer and during start-up and SAT of the BESS by Contractor.
- Obtain permits necessary to prepare the site and to install and interconnect the BESS to the grid.
- Provide a complete set of as-built drawings.
- Provide a training class for the Employer's technicians and maintenance personnel.

Operation and Maintenance

The employer intends to entrust the operation and maintenance (O&M) of the BESS on comprehensive basis to the Contractor on turnkey for the 5 (Five) years. The rates quoted by bidder for Comprehensive O&M of the Plant Facilities on yearly basis for 5 years shall be inclusive of the replacement costs if any.

Definitions

- **PCC** – Point of common connection, the electrical boundary between the Solar PV Power Plant and the electrical network.
- **Host Utility** –Kerala State Electricity Board Ltd.(KSEBL)
- **Unit battery** – A unit battery is the minimum field-replaceable stored energy component or assembly. It may consist of one or more electrochemical cells, electrically interconnected in any series and/or series–parallel configuration. A unit battery has one (and not more than one) set of positive and negative terminals, by which it is interconnected with the rest of the storage system.
- **FAT** – Factory Acceptance Test
- **BESS** – AC Coupled, containerized energy storage system based on commercially available electrochemical storage solutions, capable of receiving, storing and delivering electrical energy at specified rate(s) suitable for the application laid out in the specifications herein. BESS shall comprise of unit batteries, battery management system (BMS), Bi-directional PCU, Transformers, Auxiliary sub-systems such as HVAC and fire suppression systems, Communication sub-systems etc. to operate at rated capacity.
  Note: Outdoor type Bi-directional PCU and Transformers are acceptable.
- **BMS** - or Battery Management System, is any electronic system that manages a rechargeable battery (cell or battery pack), including protecting the battery from operating outside its Safe Operating Area, monitoring its state, calculating secondary data, reporting that data, controlling its environment, authenticating it and / or balancing it.
- **Available or Dispatchable or throughput energy** is the sum total of energy (kWh) delivered from the BESS at the point of interconnection of the BESS with the Solar PV Array fields.

BESS Interconnection

The BESS will be interconnected with the Host Utility grid at PCC. It is expected that the PCC will be at the Host Utility low-voltage ac bus or feeder or at the low-voltage terminals of a Host Utility distribution class transformer, whichever is applicable. However, the same must be finalized by the Contractor after consultation with the Host Utility.

Grid Characteristics

The BESS shall be capable of continuous operation under variable voltage, frequency and phase imbalance conditions at the PCC, as described in Table-1. Information on available fault current and other characteristics of the Host Utility grid will be provided by the Host Utility. The Contractor shall confirm, for each Host Utility site, that this information has been received and understood during the site-specific engineering phase.

C. Procedure for Plant Testing, Commissioning and Documentation

1 INTRODUCTION

This document lays down the procedures, requirements and templates for conducting commissioning tests and inspection of the Plant Facilities after installation and for subsequent re-inspection, maintenance or modifications in accordance with the Tender Specifications, IEC 62446 standard (Part 1: Grid connected systems – Documentation, commissioning tests and inspection)- and industry best practices.

2 CODES AND STANDARDS

The Testing and Commissioning Procedures shall, in general, comply with the following standards:

1. IEC 62446 standard (Part 1: Grid connected systems – Documentation, commissioning tests and inspection).
2. IEC 61364-6:2116 - Low voltage electrical installations - Part 6: Verification.
3. IEC 61829:2115: Photovoltaic (PV) array - On-site measurement of current-voltage characteristics.
4. IEC 61914-4:2119 Photovoltaic devices - Part 4: Reference solar devices - Procedures for establishing calibration traceability
5. IEC TS 61914-1-2:2119 - Photovoltaic devices - Part 1-2: Measurement of current- voltage characteristics of bifacial photovoltaic (PV) devices
6. IEC 62315-3– Protection against lightning - Part 3: Physical damage to structures and life hazard
7. IS/IEC 61557 : Part 2 : 2117 - Electrical safety in low voltage distribution systems up to 1111 V ac and 1511 V dc - Equipment for testing, measuring or monitoring of protective measures: Part 2 insulation resistance.

3 COMMISSIONING

GENERAL

Objective

The Commissioning Procedure defined in this document aims to:

- Verify that the power plant is structurally and electrically safe
- Verify that the power plant is structurally and electrically robust to operate for the specified lifetime of a project
- Verify that the power plant operates as designed and its performance is as expected

General Requirements before Starting the Commissioning Process

- The modules shall be stabilized (sufficiently exposed after 211 kWh/m² reaching the PV plane)
- The tests shall be conducted under stable weather conditions
- The process shall be witnessed by the Owner or their duly appointed representative.
- Soiling losses shall not be accounted for in the assessment of Results. Therefore, adequate Module cleaning exercise shall be undertaken prior to commencement of Commissioning process.
- The following equipment shall be used during the commissioning process:
    - Earth resistance tester
    - IV curve tracer
    - Insulation tester
    - Digital multimeter
    - Clamp meter
    - Infrared camera
    - Digital lux meter
    - Electroluminescence camera, power supply and accessories
- All testing equipment shall possess valid calibration certificate issued from approved laboratories.

4 Cold Commissioning

DC COMMISSIONING

Visual Inspection

The visual inspection shall be conducted on the system. Unless otherwise specified, Approved Drawings shall be referred for correctness/verification. At least following aspects shall be verified visually on the DC side:

- Sizing of the DC fuses for running conditions, for the maximum voltage and the maximum current.
- Sizing of the string cables including overcurrent protection considering the current carrying capacity under operating conditions.
- Cables protected against mechanical damage.
- Functionality of the main DC switch.
- Fixation of the modules to the mounting structure.
- Termination of the cables to the inverter.
- Where the PV system includes functional earthing of one of the DC conductors, the functional earth connection shall be specified and installed to the requirements of IEC 62548.

- Laying and installation of cables.
- Fixation of the grounding electrodes.
- Grounding of all conductive parts and connected to the equipotential bonding system of the PV plant.
- The torque values in the mounting structure, combiner boxes, bars and joints shall match the manufacturer specifications.
- Where protective earthing and/or equipotential bonding conductors are installed, they shall be parallel to and bundled with the DC cables.
- Electrical circuits and devices shall be labelled.
- The PV modules shall be in a good condition (no visible serial defects such as yellowing, delamination, scratches, etc.).
- Functioning of fire protection equipment.

Acceptance criteria
Each deviation from industrial best practices, norms, standards and good workmanship shall be documented in a punch list. All items shall be categorized as "critical", "important" or "minor".

Pre-Energizing Tests

Measuring instruments and monitoring equipment and methods shall be chosen in accordance with the relevant parts of IEC 61557 and IEC 61111. The following tests shall be carried out on the DC circuit forming the PV array in accordance with a Sampling Plan:

- Electrical Continuity test: This test shall be performed on the earthing and/or equipotential bonding conductors, in the PV array field. Connection of such conductors to earthing pit shall also be verified.
- Polarity test: Polarity of DC cables shall be verified. After verifying the correctness of polarity, marking on cable shall be checked for correctness.
  Note: Polarity test shall be performed before closing the switches or string overcurrent protective devices are inserted
- Combiner box test: The purpose of this test is to ensure all strings are connected correctly to the combiner box. The test procedure is as follows and shall be performed before any string fuses / connectors are inserted for the first time:
  i) Select a voltmeter with voltage range at least twice the maximum system voltage.
  ii) Insert all negative fuses / connectors so strings share a common negative bus.
  iii) Do not insert any positive fuses / connectors.
  iv) Measure the open circuit voltage of the first string, positive to negative, and ensure it is an expected value.
  v) Leave one lead on the positive pole of the first string tested and put the other lead on the positive pole of the next string. Because the two strings share a common negative reference, the voltage measured should be near-zero, with an acceptable tolerance range of ±15 V.
  vi) Continue measurements on subsequent strings, using the first positive circuit as the common connection.
  vii) A reverse polarity condition will be very evident if it exists – the measured voltage will be twice the system voltage.
- String open circuit voltage test, V_{OC} (under stable weather conditions): The purpose of this test is check the modules connection in string as per the design. The V_{OC} of PV string should be measured using suitable measuring device before closing any switch or string overcurrent protective devices, where fitted.
  The measured string V_{OC} will be assessed to ensure it matches the expected value (typically within 5 %) in one of the following ways:
  a) Compare with the expected value derived from the module datasheet or from a detailed PV model that takes into account the type and number of modules and the module cell temperature.
  b) Measure V_{OC} on a single module, then use this value to calculate the expected value for the string.
  c) For systems with multiple identical strings, voltages between strings can be compared.
- String circuit current test, Isc (under stable weather conditions): The purpose of this test to check the correctness of system, operational characteristic and PV array wiring. These tests are not to be taken as a measure of module / array performance. The test procedure will be as follows:
  i) Ensure that all switching devices and disconnecting means are open and that all PV strings are isolated from each other.
  ii) Create a temporary short circuit into string under test by using any of the following method:

(a) use of a test instrument with a short circuit current measurement function (e.g. a specialized PV tester);
(b) a short circuit cable temporarily connected into a load break switching device already present in the string circuit;
(c) use of a "short circuit switch test box" – a load break rated device that can be temporarily introduced into the circuit to create a switched short circuit.

iii) Measure the short circuit current (Isc) using a suitably rated measuring instrument.
iv) After taking the reading, interrupt the short circuit using a suitable load break switching device and check the zero value of current before changing any other connections.
v) Compare the measure value of Isc with the expected value. For systems with multiple identical strings, measurements of currents in individual strings shall be compared. These values should be the same (typically within 5 % of the average string current).

Note: An I-V curve test can be performed as an alternative to this test (see 4.3).

- Functional tests: The following functional tests shall be performed:
  i) Switchgear and other control apparatus shall be tested to ensure correct operation and that they are properly mounted and connected.
  ii) All inverters forming part of the PV system shall be tested to ensure correct operation. The test procedure should be as defined by the inverter manufacturer.

  Functional tests that require the AC supply to be present (e.g. inverter tests) shall only be performed once the AC side of the system has been tested.
- Insulation resistance of the DC circuits: Test procedure to conduct this test will be as follows:
  i) Before commencing the test adopt the following safety measure to avoid any potential shock hazard
     (a) Isolate the testing area.
     (b) Do not touch any metallic surface, module backsheet or the module terminals when performing the insulation test.
     (c) Appropriate personal protective clothing / equipment should be worn for the duration of the test.
  ii) Isolate the PV array from the inverter (typically at the array switch disconnector)
  iii) Disconnect any piece of equipment that could have impact on the insulation measurement (i.e. overvoltage protection) in the junction or combiner boxes.
  iv) The insulation resistance test device shall be connected between earth and the array cable(s) or combiner bus bar. Connections can be made between earth and array negative followed by a test between earth and array positive or between earth and short circuited array positive and negative.
  v) Follow the IR test device instructions to ensure the test voltage and readings in megaohms. When the system voltage (Voc at STC X 1.25) is higher than 511V, the test voltage shall be 1,111V and the minimum insulation resistance 1 MΩ.
  vi) Ensure the system is de-energized before removing test cables or touching any conductive parts.

Sampling Plan:

At least 2 strings from 2 SMUs shall be randomly chosen by the Owner connected to each Inverter.

Acceptance criteria
The DC commissioning will be passed when the aforementioned verifications are successfully passed in 111% of the sample according to the IEC 62446: 2116 – 5 and IEC 62446:2116 – 6.

AC COMMISSIONING

Visual Inspection

The visual inspection shall be conducted on 5% of the system. In general, the requirements specified in the IEC 61364-6 -6.4.2 apply. At least following aspects shall be verified visually on the AC side:

General requirements

- Protective requirements against electric shock
- Protection against fire and heat
- Choice, setting, selectivity and coordination of protective and monitoring devices
- Sizing of cables regarding voltage drop and ampacity as per approved Drawings.
- Sizing of protective and monitoring devices as per approved Drawings
- The circuit breakers are correctly located
- Selection, location and installation of suitable isolating, overvoltage protective devices and switching
- The equipment and protective measures are appropriate for the external influences and

mechanical stresses

- The diagrams, warning notices or similar information attached to the wall inside the inverter housing or the control room
- Proper fixation of the cables to the collector bars in the AC combiner box
- Proper labelling of all electrical circuits and devices including the neutral conductor and protective conductor as well as correct connection of single pole devices to the phase conductors
- Adequacy of termination and connection of cables and conductors
- The warning labels and technical documentation physically displayed
- Selection and installation of earthing arrangements, protective conductors and their connections
- The existence and correct use of protective conductors and protective equipotential bonding conductors (PEB)
- Measures against electromagnetic disturbances implemented
- Easy access to the operational devices for maintenance
- Any exposed conductive parts connected to the earthing system
- The RCD type has been selected according to the requirements of the IEC 62548
- The isolation means of the inverter on the AC side are functional and correctly sized
- The fire protection requirements according to the approved design shall be given

Requirements for the inverter

- Installation as per manufacturer's instructions and compliance with IEC 62548
- Inverters properly fastened to the ground
- Inverter properly earthed
- Inverter incoming/outgoing cables properly isolated, labelled and connected
- The connections for phase sequence L1, L2, L3 and N in the correct order
- All cable terminations properly done
- Nameplate data. The minimum requirements for name plate are –
  - name and origin of the manufacturer; –
  - model or type name;
  - serial number;
  - electrical parameters: Vdcmax, Vmppmin, Vmppmax, Idcmax, Pac,r, Vac,r, f r , Iacmax;
  - degree of protection;
  - overvoltage category;
  - safety class.
- The displays - check / readout show plausible results
- The filters are clean and properly maintained
- The cooling outputs of the inverters are free from obstruction
- The DC circuit breaker is functional
- The DC insulation monitoring correctly installed
- The fuses at the DC entrance correctly sized
- The location of the inverter(s) in the field matches the approved design
- Protection against self-loosening of clamps and screws
- The string inverter anchored to the mounting structure
- The mechanical assembly is robust
- The inverters are fixed to non-flammable mechanical elements
- The Grid Connectivity Settings are compliant with the Technical Standards for Connectivity and as per the guidelines of the grid operator.

Acceptance criteria

Each deviation from industrial best practices, norms, standards and good workmanship shall be documented in a punch list. All items shall be categorized as "critical", "important" or "minor". The punch list shall represent a maximum value (of item under test) of 1% of the construction price and not have any 'critical' or 'important' item.

Pre-Energizing Tests

Measuring instruments and monitoring equipment and methods shall be chosen in accordance with the relevant parts of IEC 61557 and IEC 61111. The following tests shall be carried out on the AC circuit forming the PV array:

- Continuity of conductors. The requirements in IEC 61364-6:2116 – 6.4.3.2 apply.
- Insulation resistance of the electrical installation. The requirements in IEC 61364-6:2116 – 6.4.3.3 apply.

- Insulation resistance testing to confirm the effectiveness of protection by SELV, PELV or electrical separation. The requirements in IEC 61364-6:2116 – 6.4.3.4 apply.
- Insulation resistance/impedance of floors and walls. The requirements in IEC 61364- 6:2116 - 6.4.3.5 apply.
- Polarity test. The requirements in IEC 61364-6:2116 - 6.4.3.6 apply.
- Testing to confirm effectiveness of automatic disconnection of supply. The requirements of the IEC 61364-6:2116 – 6.4.3.7 apply.
- Testing to confirm the effectiveness of additional protection. The requirements of the IEC 61364-6:2116 – 6.4.3.8 apply.
- Test of phase sequence. The requirements of the IEC 61364-6:2116 – 6.4.3.9 apply.
- Functional tests. The requirements of the IEC 61364-6:2116 – 6.4.3.11 apply.
- Voltage drop. The requirements of the IEC 61364-6:2116 – 6.4.3.11 apply.

Acceptance criteria
The AC commissioning will be passed when the aforementioned verifications are successfully passed in 111% of the sample according to the IEC 62446: 2116 – 5 and IEC 61364 – 6.

Additional Pre-Energizing Tests

All of the below tests shall be conducted in accordance with the supplier's installation/commissioning manuals.

Distribution boards and combiner boxes

Site testing on distribution boards shall include:

- Mechanical functional test of all components including mechanical interlocks
- Electrical functional test of all control and protection wiring against the approved switchgear schematics
- Power frequency overvoltage test (flash test) on the switchgear including circuit-breakers in the test circuit
- Low resistance micro-ohmmeter (Ductor) test on the switchgear including circuit-breakers in the test circuit
- Visual inspection
- Verification of earthing

Inverters

Site testing on inverters shall include:

- Full test procedure as defined by the inverter manufacturer
- A full mechanical functional test of all components including mechanical interlocks
- Verification that the inverter operational parameters have been programmed to technical standards for connectivity and other local regulations
- Electrical functional test of all control and protection wiring against the approved switchgear schematics as per approved MQP/FQP
- Insulation resistance test and earth residual current monitoring test
- Anti-islanding functionality
- High Voltage overvoltage test
- SCADA and metering calibration & functionality test

HT Switchgear

Site testing on outdoor circuit-breakers shall include:

- Functional check of all wiring, interlocks, auxiliaries and pressure devices
- Timing test and travel curve
- Visual inspection

LV/MV transformers

Transformer commissioning shall include:

- Visual inspection, alignment, earthing and labeling
- Functional check of all wiring against the approved transformer schematics
- Testing and calibration of all transformer protection and monitoring devices
- Insulation resistance test
- Functional test of off-circuit/on Circuit tap changer and check of the continuity of all windings

Substation/Power Transformers

- Ratio measurement on all tap changer settings

- Winding resistance measurement on highest, lowest and nominal tap settings
- Insulation resistance between all windings, and each winding to earth
- Insulation resistance core-to-earth
- Oil sample tests: breakdown strength, moisture content, and dissolved-gas content
- Transformer differential protection scheme testing

Acceptance criteria
The test results shall be aligned with the manufacturer specifications stated in the installation manual and Pre-Dispatch Inspection Reports.

IV CURVE TESTING

The requirements of the IEC 62446-1:2116 – 7.2 apply. Following normative references shall be considered while performing the IV curve test:

- IEC 61829:2115 Photovoltaic (PV) array - On-site measurement of current-voltage characteristics
- IEC 61891:2119 Photovoltaic devices - Procedures for temperature and irradiance corrections to measured I-V characteristics Sample Size: 2 % of the module strings shall be measured.

If $\Delta P_{string\ N}>5\%$, all the modules within that string shall be I-V characterized. Modules with $\Delta P_N>5\%$ shall be replaced. If more than 5% of the measured strings of the first sample show $\Delta P_N>5\%$, another 2% shall be inspected. If more than 5% of the measured strings in the second sample show $\Delta P_N>5\%$, another 5% shall be inspected. If more than 5% of the measured strings in the third sample show $\Delta P_N>5\%$, another 11% shall be inspected. If more than 5% of the measured strings in the fourth sample show $\Delta P_N>5\%$, another 11% shall be inspected. The reference power value is the flash list value minus the light induced degradation (LID) value in the datasheet/module warranty.

Acceptance criteria
The power determination analysis will be passed when less than 5% of the modules measured in the last sample show $\Delta P_N<5\%$.

5 Hot Commissioning

INFRARED INSPECTION

Following normative references apply:

- PV array infrared camera inspection procedure **(**IEC 62446-1:2116 - 7.3) and IEC 62446-1 TS Ed.1.1 - Photovoltaic (PV) systems - Requirements for testing, documentation and maintenance - Part 3: Outdoor infrared thermography of photovoltaic modules and plants (draft)
- The infrared inspection shall be applied both to the PV modules and the BOS components. The inspection sample will depend on the project size and shall be agreed with the OWNER. The following values serve as an orientation:
- Large scale ground mounted PV plants
  - PV modules: 11%
  - Inverters: 111%
  - Combiner boxes: 111%

Acceptance criteria
The following conditions shall be met simultaneously:

- 1.2% or less of the inspected modules show thermal gradients at the cell level of T > 11 K
- 1.2% or less of the inspected modules show thermal gradients at the junction box level of T > 11 K
- 1.2% or less of the inspected modules show inactive cell strings
- No PID is detected
- All module strings are connected and producing
- All inverters are connected and producing

INVERTER AVAILABILITY TEST

Calculation of the Operation Time

It shall be calculated on inverter level. The operation time starts as soon as the inverter switches on. Therefore only the logged irradiation values during the operation time of the inverter shall be considered. Irradiation values logged before or after the inverter running time shall be disregarded.

Calculation of the Downtime

The downtime relevant for the availability calculation is any time in which a part or a subpart of the system is not operational. The outage periods shall be considered again on inverter level. Only

complete outages shall be taken into consideration. System black-out periods due to following reasons shall not flow into the calculation (i.e. excluded events):

- A failure in the distribution grid or the transformer substation, making it impossible to transmit the generated power
- Solar radiation below the level needed to obtain the minimum operating voltage to start the inverter operation
- Causes of Force Majeure.
- Occurrences of anomalies in the power supply system (frequency differences or voltage surges) that trigger the protective systems of the plant or the limit settings of the inverter. Any forced disconnection shall be documented and recorded.

Acceptance criteria
The system availability shall be at least 99% during the testing period.

SINGLE AXIS TRACKER AVAILABILITY TEST (IF APPLICABLE)

The tracker availability test shall be carried out in parallel to the inverter availability test and shall have the same duration. During the test, all trackers shall follow the sun according to the angles established in the tracking mechanism. A loss of availability shall be considered when the angle of inclination of one or more trackers deviates by more than 2° from the theoretical angle. The angles of inclination of each tracker shall be recorded with a resolution of 1min via the SCADA system.

Acceptance criteria
The tilt angle of each tracker shall lie within a ±2° range during 99.5% of the operational time.

SCADA AND WEATHER STATION RELIABILITY

Visual Inspection

- Installation of the communication system architecture diagram according to the specifications
- Functional Tests conducted during FAT for Pre-Dispatch Inspection shall be repeated.
- SCADA shall be linked to all protection relays, disturbance recorders and other substation equipment using the communications protocol
- Visual check on the assembly of all joints and on the as-installed condition of all components, including:
  - The irradiation sensor is not shaded and is installed at the correct tilt angle and under CCTV coverage.
  - Ambient temperature and module temperature sensor are installed properly (Reference IEC 61724)
  - Mechanical anchorage of the sensors is robust
- Complete calibration certificates of all the instruments shall be provided

Acceptance criteria
Each deviation from industrial best practices, norms, standards and good workmanship shall be documented in a punch list. The punch list shall categorize all observations as "critical", "important" or "minor". The Punch list shall not have any item classified as 'critical' or 'important'.