2. SPV Modules

The SPV modules used in the project may be sourced from any manufacturer but must comply with technical requirements and certifications as stated in the RfS.

These SPV modules must qualify to the latest edition of any of the following IEC PV module qualification test and equivalent BIS standards.

Crystalline Silicon Solar Cell Modules	IEC 61215
Thin Film Modules	IEC61646

As per the Solar Photovoltaics, Systems, Devices and Components Goods (Requirements for Compulsory Registration) Order, 2017, 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 have been included in the ALMM list as per MNRE Approved Models and Manufacturers of Solar Photovoltaic Modules (Requirements for Compulsory Registration) Order, 2019.

In addition, SPV modules must qualify to IEC 61730 for safety qualification testing at 1000 V DC or higher. The modules to be used in a highly corrosive atmosphere throughout their lifetime must qualify to IEC61701.

3. Identification and Traceability

Each PV module used in any solar power Project must use a RF identification tag. The following information must be mentioned in the RFID used on each module (This can be inside or outside the laminate, but must be able to withstand harsh environmental conditions):

i. Name of the manufacturer of PV Module
ii. Name of the Manufacturer of Solar cells
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 at Standard Test Condition (1000 W/m^2, AM 1.5,25^{0}C)
vi. Wattage, I_m, V_m 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 module as per ISO9000.

SPD would be required to maintain accessibility to the list of Module IDs along with the above parametric data for each module.

4. Power Conditioners/ Inverters

The Power Conditioners/Inverters of the SPV power plant must conform to the latest edition of IEC/ equivalent Standards as specified below:

Efficiency Measurements	IEC 61683
Environmental Testing	IEC 60068-2/ IEC62093
Electromagnetic Compatibility (EMC)	IEC 61000-6-2, IEC 61000-6-4 & other relevant parts of IEC 61000
Electrical Safety	IEC 62103/62109-1&2
Anti-Islanding Protection	IEEE1547/IEC 62116/ UL1741 or equivalent BIS Standards

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

5. 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.

- DC/AC over current
- DC/AC overvoltage
- DC reverse polarity
- DC earth fault
- AC under voltage
- AC under frequency/over frequency

- Islanding
- Over temperature
- Lightning surges

6. Grid Support Functions

a. 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 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.

b. 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.

c. 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 reactive power during the period of voltage dip.

7. Warranty

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

8. Inverter Transformer and Auxiliary Transformer

Inverter transformer and auxiliary transformer, wherever applicable, shall comply with the latest edition of the following standards and codes including amendments.

Standard	Description
IS 2026, IEC 60076	Specification of Power Transformers
IS 11171, IEC 60076	Dry-Type Power Transformers
IS 2099, IEC 60137	Bushings for alternate voltage above 1000 V
IS 335, IEC 60296	Insulating oil
IS3639	Fittings and Accessories for Power Transformers

The Type tests should have been conducted on the similar transformer by NABL accredited laboratory.

9. Module Mounting Structures

- The MMS stub/ column, rafter, purlin, ties and bracing members shall conform to following Indian standards.
    - IS: 2062 – Hot rolled Medium and High tensile structural steel
    - IS: 811 – Cold formed light gauge structural steel sections
    - IS: 1161 – Steel tubes for structural purposes
    - IS: 4923 – Hollow steel sections for structural use
- Dead load, Live load, Wind load and Seismic load for buildings and structures shall be considered as per provisions of relevant BIS standards.
- Basic wind speed at project site shall be taken as per IS 875 (part 3) unless otherwise specified elsewhere.
- The Snow Load shall be considered as per IS: 875 (Part-4).
- The MMS Design shall be certified by a Government Institution like IITs or NABL approved Laboratory.

10. CABLES AND CONNECTORS

All cables and connectors to be used for installation of solar field must be of solar grade which can withstand harsh environment conditions for 25 years and voltages as per latest IEC standards. It is recommended that the Cables of 600-1800 Volts DC for outdoor installations should comply with the BS/ EN EN50618 for service life expectancy of 25years.

11. OTHER SUB-SYSTEMS/ COMPONENTS

Other subsystems/ components used in the SPV Power Plants (Cables, Connectors, Junction Boxes, Surge Protection Devices etc.) must also conform to the relevant international/national Standards for Electrical Safety besides that for Quality required for ensuring Expected Service Life and Weather Resistance

12. AUTHORIZED TEST CENTERS

The PV modules/ Power Conditioners deployed in the Power Plants must have valid test certificates for their qualification as per above specified IEC/ BIS Standards by one of the NABL Accredited Test Centres in India. In case of module types/ equipment for which such Test facilities may not exist in India at present, test certificates from reputed ILAC Member body accredited Labs abroad will be acceptable.

13. WARRANTY

(a) PV modules used in grid connected solar power plants must be warranted for peak output wattage, which should not be less than 90% at the end of 10 years and 80% at the end of 25 years.

(b) The modules shall be warranted for at least 10 years for failures due to material defects and workmanship.

(c) The mechanical structures, electrical works and overall workmanship of the grid solar power plants must be warranted for a minimum of 5years.

(d) The Inverters/ PCUs installed in the solar power plant must have a minimum warranty for 5 years.

14. PERFORMANCE MONITORING

(a) The SPD shall maintain the list of Module IDs along with performance characteristic data for each module.

(b) The SPDs must install necessary equipment to continuously measure solar radiation on module plane, ambient temperature, wind speed and other weather parameters and simultaneously measure the generation of DC power as well as AC power generated from the plant. They will be required to submit this data to REMC Ltd. and Nodal Railway online and/or through a report on regular basis every month for the entire duration of PPA. All data shall be made available as

mentioned above for the entire duration of thePPA.

(c) The SPDs shall provide access to REMC Ltd./NR or their authorized representatives for installing any additional monitoring equipment to facilitate on-line transfer of data.

(d) Web-based monitoring should be available, which should not be machine dependent. The web-based monitoring should provide the same screens as available in the plant. Also, it should be possible to download reports from a remote web-client in PDF or Excel format.

The plant SCADA should be Open Platform Communications (OPC) compliant with standard DNP3/IEC 60850 and Modbus control interfaces over TCP/ IP having the provision to add protocol converters to implement custom and secure communications protocol standard for providing real time online generation data.

All data should be accessible through this OPC server for providing real time online data (including but not limited to irradiance, plant generation (instantaneous / daily / monthly / yearly), daily peak generation, weather monitoring station data - temperature, wind speed etc., BESS parameters etc.) to REMC Ltd./NR. This time series data (with minimum 1 min resolution) shall be available from the Plant Facilities SCADA to facilitate monitoring and should include among others as stated before, below parameters to facilitate daily, monthly and annual Report for performance monitoring.

Parameter	**Units**	**Description**
Timestamp	DD/MM/YYYY hh:mm:ss	IRIG standard time codes
Active power from SPV Plant	MW	Total SPV Plant power
Active power to/from batteries	MW	Total AC power for all battery PCUs
Total active power	MW	Total system power
RMS AC voltage –phase1	kV	line-to-ground Voltage at the point of common coupling (PCC)
RMS AC voltage –phase2	kV	line-to-ground Voltage at the point of

		common coupling (PCC)
RMS AC voltage –phase3	kV	line-to-ground Voltage at the point of common coupling (PCC)
Grid frequency	Hz	Grid frequency
Reactive power to/from solar	MVAR	Total solar plant reactive power
Reactive power to/from batteries	MVAR	Total reactive power for all inverters
Total reactive power	MVAR	Reactive power at PCC
Battery State of Charge	%	Stored battery energy as a % of total energy capacity of the BESS

Note: The BESS Data acquisition and Control system should have the ability to transfer time series data with appropriate resolution over suitable communication protocol to the Plant SCADA system.

15. BESS specifications:

The BESS shall be capable of continuous operation under variable voltage, frequency and phase imbalance conditions at the Point of Common Connection (PCC). Information on available fault current and other characteristics of the Host Utility grid should be obtained from the Host Utility. The SPD shall confirm that this information has been received and understood during the engineering phase. The provision for a Battery Energy Storage System (BESS) with the Solar PV Project has been incorporated in the Scheme with the objective of providing constant power at 7 MW for upto 2 (two) hours in the non-solar hours in the evening. In addition, it shall support stable and secure operation of the grid. The system should ensure synchronization with the grid for smooth operation.

a. Codes and Standards

The BESS must conform to the latest edition of IEC/ equivalent Indian Standards as specified below, as applicable, for selected battery storage technology:

Standard/ (equivalent IS code)	**Description**
IEC 61427-2/IS 16270	Secondary cells and batteries for renewable energy storage for On-grid applications
IEC62485-2	Safety requirements for secondary batteries and battery installations - to meet requirements on safety aspects associated with the erection, use, inspection, maintenance and disposal: Non-chemistry Specific (applicable to all secondary battery types) Functional Safety of Electrical / Electronic / Programmable
IEC 61508	Electronic Safety-related Systems: Applicable for all Battery Energy StorageSystemsSecondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications
IEC 62619:2017	Safety of primary and secondary lithium cells and batteries during transport: Applicable for storage systems using Lithium-Ion chemistries
IEC62281/UN 38.3	Communications networks and management systems
IEC 61850/DNP3	(Plant SCADA and the BESS control system communication) Electrical energy storage (EES) systems
IECTS62933-5-1:2017- Part 5-1:	Safety considerations for grid-integrated EES systems – General specification

b. Nameplate Ratings and Requirements

Table below specifies project-specific BESS capabilities and ratings for the Projects.

Table 1: Supply-Specific Ratings and Requirements

Item Description	Requirement
Battery Technology	Any battery technology with totally Maintenance Free characteristic suitable for operation in site-specific climatic conditions can be used.
Rated No. of cycles (minimum)	4000 cycles at rated energy capacity at minimum 80% Depth of Discharge (DOD) 25^0C and up to C/3 Rate of Discharge at the time of Commissioning and overall4000 cycles during the battery life i.e. 10years
Power rating*, AC(X),	7MW, continuous,
Watt-hour (Energy) rating, AC(Y)	• 14MWh, dispatchable at 7MW net AC output at the beginning of life and not less than 80% of this capacity at any point of time up to End of Battery Life. • The SPD shall replace/augment the batteries to maintain the Energy rating up to the End of BatteryLife and End of Project Life
Annual BESS Availability Guaranty	98%
System AC-DC-AC efficiency*:	>80%
Use case requirements	1. Shifting supply peak 2. Supply constant power for specific period during non-generation hours in the evening
Peak Management	In the Shifting supply peak Use Case scenario, power generated during the solar hours shall be partly used to charge the BESS and partly to export to the grid. While exporting to the grid, the power may not meet full requirement at all the time. In the evening non-solar hours, BESS shall export to the grid a constant power at 7 MW for minimum 2 hours. At the End of Battery Life, the BESS shall export constant power at 7 MW for minimum1.5hours. The BESS stored energy shall be only from PV plant generation.
Charge-Discharge Cycles	One discharge cycle per day is envisaged
VAR compensation / volt support (VC / VS)	Yes, to supply reactive power support so as to maintain the power factor between 0.95 leading and lagging.

Grid Charging	No
**To be verified as per the procedure described in Annexure B to this Section for Performance Guarantee Tests.*	

c. Battery End of life:

End of battery life is that point in time when the BESS can no longer meet the power and/or energy discharge requirements of this specification due to age or non-repairable malfunction of the battery subsystem, and/or non-replaceable components. When the system is no longer able to provide these requirements, the system has reached its end of life. Battery End of life shall not be less than 10 years from the date of Commissioning.

Note: The detailed methodology for BESS Characterization and Performance Assessment is provided at Annexure B.

d. BESS Power Conditioning Unit (PCU)

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

Standard	Specifications
IEC 61683Ed.1	Photovoltaic systems - Power conditioners - Procedure for measuring efficiency
IEC 62109-1Ed.1	Safety of power converters for use in photovoltaic power systems - Part 1: General requirements
IEC 62109-2Ed.1	Safety of power converters for use in photovoltaic power systems - Part 2: Particular requirements for inverters
IEC 61000-6-2Ed.2	Electromagnetic compatibility (EMC) - Part 6-2: Generic standards - Immunity standard for industrial environments
IEC 61000-6-4Ed.2.1	Electromagnetic compatibility (EMC) - Part 6-4: Generic standards - Emission standard for industrial environments
IEC 62116Ed.2	Utility-interconnected photovoltaic inverters - Test procedure of islanding prevention measures
IEC 61727Ed.2	Photovoltaic (PV) systems - Characteristics of the utility interface
IEC60068-2-1:2007	Environmental testing - Part 2-1: Tests - Test A: Cold

IEC60068-2-2:2007	Environmental testing - Part 2-2: Tests - Test B: Dry heat
IEC60068-2-14:2009	Environmental testing - Part 2-14: Tests - Test N: Change of temperature
IEC60068-2-30:2005	Environmental testing - Part 2-30: Tests - Test Db: Damp heat, cyclic (12 h + 12 h cycle)

e. Inclusions in BESS:

The BESS shall include an HVAC or ventilation system designed to maintain battery temperatures at levels acceptable to the Contractor's normal battery warranty conditions, conducive to acceptable battery life, and as required to maintain battery capacity for all seasons/climatic conditions at the site.

f. BESS Commissioning test procedure:

The Commissioning tests shall include, as a minimum, the following:

- Verification of sensors, metering, and alarms
- Verification of all control functions, including automatic, local, and remote-control Verification that the performance criteria in the specification can be met.
- Demonstration of all of the intended uses. Demonstration of protection and Control functions.

g. BESS Warranty

- Warranty shall cover parts warranty including battery nominal capacity ratings in order to meet the End of battery Life condition described in this specification.
- Warranty replacement shall be required for individual unit batteries that degrade in performance to the point at which the BESS cannot meet the requirements specified in this specification up to the End of Battery Life and/or for unit batteries that materially degrade the availability, reliability, safety, or functionality of the BESS.
- The warranty shall guarantee the availability of battery replacements delivered to the site during the battery warranty period.

h. SAFE DISPOSAL OF SOLAR PV MODULES AND BATTERY

The SPD will ensure that all Solar PV modules and Batteries from their plant after their ‘end of life’ (when they become defective / non-operational / non-repairable) are disposed in accordance with the “e-waste (Management and Handling) Rules, 2011” notified by the Government and as revised and amended from time to time.

ANNEXUREB: BESS CHARACTERIZATION ANDPERFORMANCE ASSESSMENT

1. System rating

BESS rating including rated power, energy available at rated power, and the performance of the BESS associated with different performance metrics mentioned herein taken at the beginning of life shall be based on a set of ambient operating conditions specified by the BESS Original Equipment Manufacturer (OEM) for the Project site. The SPD shall also provide an indication of how the performance of the BESS with respect to the metrics is expected to change over time, to account for time and use of the system, and report the same periodically.

An energy capacity test shall be performed at the time of Commissioning, in accordance with procedure mentioned below and is intended to be used to determine the dispatchable energy capacity (throughput) of the BESS at the time of commencement of Operation. In conducting the energy capacity test, the SPD shall provide a detailed and documented charging procedure within the specifications of the BESS. The energy capacity tests conducted on the BESS shall be documented to allow for tracking performance degradation.

<u>Measurement</u>

The BESS shall be discharged and charged at rated power between the lower and upper SOC* limit (as recommended by the OEM for current application). Power during charge and discharge shall be recorded at regular intervals of time documented by the OEM to provide a statistically valid resolution. The associated energy input (Ei), including all BESS functional, parasitic and auxiliary consumption and energy output (Eo) of the BESS shall be calculated from the recorded power.

* *SOC recorded, shall be as reported by the Battery Management System.*

The above process shall be repeated multiple times, with minimum rest period between charging and discharging, if so recommended, so as to record data for a specified no. of cycles (n). The reference performance test value for stored energy shall be calculated as the mean of the values of Eo and Ei as measured for discharge and charge respectively.

The procedure shall be repeated (one cycle each) with power levels at 75%, 50%, and 25% of rated power and documented.

Criterion: BESS stored Energy capacity shall be at least total energy dispatchable as specified in the RfS at the time of commissioning. Also, during annual verification, the BESS Energy capacity shall not be less than 80% of the rated capacity.

2. Round-trip energy efficiency (RtE, η) shall be determined as a function of the charge and discharge power and calculated using the following formula:

$$\eta_p = \frac{\sum Eo}{\sum Ei}$$

where,

∑Ei is the sum of Energy input to the BESS over n cycles,

∑Eo is the sum of Energy output from the BESS over n cycles,

η_p is the Round-Trip Efficiency at charge/discharge Power P, (expressed as a percentage of rated power)

Eo and Ei shall be determined as per point 1. above.

Criterion: η_p, as determined through the process described above shall be >80% at the time of commissioning.

Note: The tests are intended to be carried out on a single day. The value of n shall be at least 3 for 100% rated Power and 1 for 25%, 50% and 75% of rated power as per procedure laid down in this document.

3. BESS Response time: shall be measured as the sum of the following two entities:

The time elapsed between the instant when a command to change set point from rest to discharge is sent to the BESS (T_0) and the instant when the BESS starts responding to the discharge command signal (T_1), the BESS being in active standby state and 50% SOC at T_0 i.e., T_1-T_0

Time elapsed in seconds between the instant the BESS output transitions from nodischarge i.e. 0% (T_1) to discharge and the instant it attains rated power capacity(T_2) (or from no charge (T_1) to charge state and the instant it attains rated charge rate(T_2))i.e. T_2- T_1

RT = (T_2- T_1) + (T_1- T_0) **= T2- T0**

Where T_0, T_1 and T_2 are timestamps:

T_0:	Instant when a command to change set point is received at BESSboundary (to be identified in advance)
Data Format	dd/mm/yyyyhh:mm:ss.00
T_1	Instant when the BESS starts responding to the Command signal
Format	dd/mm/yyyyhh:mm:ss.00
T_2	Instant when the BESS attains 100% of full discharge rate whendischarging or full charge rate
Format	dd/mm/yyyyhh:mm:ss.00

ANNEXURE C: COMMISSIONING PROCEDURE

1. At the time of commissioning, the Commissioning Committee shall verify compliance of technical parameter of the Project as per Annexure A of the RfS document.
2. SPDs shall give to the Buying Entity / REMC Ltd. at least 60 (Sixty) Days advance preliminary written notice and at least 30 (Thirty) Days advance final written notice, of the date on which it intends to synchronize the Power Project to the Grid System. The SPD shall be solely responsible for any delay or non-receipt of the notice by the concerned agencies, which may in turn affect the Commissioning Schedule of the Project.
3. A Solar PV Project will be considered as commissioned if all equipment as per rated project capacity has been installed and energy has flown into the grid.
4. SPD shall ensure that the equipment up to the rated Capacity has been installed and completed in all respects before the Schedule Commissioning Date. The same shall be verified by the Committee during their visit to the Project and documented as per prescribed format.

Documents to be submitted to Buying Entity:

The SPD will have to submit the following documents (duly signed and stamped by authorized signatory) well in advance prior to the scheduled commissioning date. The SPD shall also have to submit the hardcopies to REMC Ltd./NR if asked by REMC Ltd./NR for verification/ crosscheck.

1. Covering Letter
2. Board Resolution for Authorized Signatory.
3. All supporting documents towards meeting the technical compliance along with datasheet/ warranty certificates/ contract agreement etc. as mentioned in Annexure-A of the RfS
4. Installation report duly signed by the authorized signatory as per Annexure D.
5. Plant Layout clearly mentioning the details of rows and number of modules in each row.
6. Electrical Inspector report along with all annexures/ attachments. It would be the

responsibility of the SPD to collect the certificate.

7. SPD shall ensure Connectivity to the grid from concerned TSS authority / Transmission Utility / DISCOM. Connectivity report from such concerned authority.
8. Synchronization Certificate as per prescribed format issued by respective TSS authority / Transmission Utility / DISCOM for ascertaining injection of power into grid.
9. Supporting document for “Consent to Operate”
10. Snap Shots of the Plant from various angles shall be taken for covering installation of important components of the solar power plant and made part of Installation Report. Reading of all the inverters (instantaneous and total generation) along with its serial number of a particular date.
11. Relevant document from Buying Entity / REMC Ltd. acknowledging successful data communication between plant end and Buying Entity / REMC Ltd..
12. After the submission of the documents by SPD, REMC Ltd. shall verify the documents and intimate/ reply with remarks. In case any additional supporting / revised documents are asked by REMC Ltd., the same have to be submitted by the SPD.
13. Only after all the required documents are verified by REMC Ltd., the SPD shall have to submit/ update on the portal the proposed commissioning date along with commissioning order issued by REMC Ltd. / NR.
14. After the proposed commissioning date along with commissioning order is submitted, the commissioning committee shall visit the site within 07 working days to verify the technical compliance on site as per the information submitted by the SPD. In case the committee finds discrepancy / deviation from the information submitted by the SPD during on site verification, the committee shall schedule its next visit only on the next available date as per the availability of all the committee members.
15. SPD shall have to submit the as-built drawing after the commissioning prior to the COD.
16. SPD shall have to push the required plant related data to REMC Ltd. / NR designated server in xml/json formats. Additionally, SPD shall also provide the login details / SCADA login to REMC Ltd. / NR for online real time data monitoring prior to COD.
17. Early Commissioning of a Solar Project prior to the scheduled commissioning date