No.: 318/32/2022-Grid Connected Rooftop
Ministry of New and Renewable Energy
Government of India
***

Atal Akshay Urja Bhawan
Opp. CGO Complex,
Lodhi Road, New Delhi-11003
Date: 20.09.2022

Office Memorandum

Subject: Comments/ suggestions on Quality Control Manual for Grid Connected Rooftop Solar PV System-reg

Ministry is implementing the phase- II of Grid Connected Rooftop Solar Programme for achieving cumulative capacity of 40,000 MWp from the Rooftop Solar Projects by 2022. These residential projects are to be installed as per Guidelines of the Rooftop Solar Programme and the specifications issued by the Ministry.

2. To ensure quality of installation and a structured mechanism for monitoring of installations, Ministry proposes to bring out a quality control manual for small grid connected Rooftop Solar PV System. Draft manual prepared is enclosed herewith for comments of stakeholders.

3. It is requested that comments/suggestions may please be sent in following annexure in word document file only at hiren.borah@nic.in and rahulkr.1996@nic.in by **05th October 2022.**

(Hiren Chandra Borah)
Scientist-D

To
All Stakeholders

Annexure: Format for Comments

Sr. No.	Page No. and Clause No. with description of the item	Issue/ Comments	Remarks/ Justification

DRAFT OF QUALITY CONTROL MANUAL
FOR
SMALL GRID CONNECTED ROOFTOP
SOLAR PV SYSTEM

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List of Abbreviations

ACB	Array Combiner Box	IREDA	Indian Renewable Energy Development Agency
ACDB	AC Distribution Box	IS	Indian Standard
AJB	Array Junction Box	I_{SC}	Short-circuit Current
AM	Air Mass	ISO	International Organisation for Standardisation
BIS	Bureau of Indian Standard	kV	Kilo-Volt
BOM	Bill of Materials	kW	Kilowatt
BOS	Balance of System	kWh	Kilowatt-hour
CAPEX	Capital Expenses	KPI	Key Performance Indicator
CdTe	Cadmium Telluride	LCOE	Levelized cost of electricity
CEA	Central Electricity Authority	LeTID	Light and elevated Temperature Induced Degradation
CIGS	Copper Indium Gallium Selenide	LID	Light Induced Degradation
CTU	Central Transmission Utilities	LV	Low Voltage
CUF	Capacity Utilization Factor	MCB	Miniature Circuit Breaker
DC	Direct Current	MCCB	Moulded Case Circuit Breaker
DISCOM	Distribution Company	MMS	Module Mounting Structure
DNI	Direct Normal Irradiance	MNRE	Ministry of New and Renewable Energy
EPC	Engineering, Procurement and Construction	MPPT	Maximum Power Point Tracking
EVA	Ethyl Vinyl Acetate	MW	Megawatt
FAC	Final Acceptance Certificate	NOCT	Nominal Operating Cell Temperature
FAT	Factory Acceptance Test	NABL	National Accreditation Board for Testing and Calibration Laboratories
FIT	Feed-in Tariff	NTP	Notice To Proceed
GHI	Global Horizontal Irradiance	OM	Operation and Maintenance
GI	Galvanized Iron	OEM	Original Equipment Manufacturer
GST	Goods and Services Tax	OPEX	Operational Expenses
Govt.	Government	PBG	Performance Bank Guarantee
GW	Gigawatt	POC	Point of Common Coupling
Hz	Hertz, unit of frequency	PCE	Power Conversion Equipment
IEC	International Electrotechnical Commission	PCU	Power Conditioning Unit
IP	Ingress Protection, Internet Protocol	PGCIL	Power Grid Corporation of India Limited
IPP	Independent power producer	PID	Potential-Induced Degradation
IRR	Internal Rate of Return	PPA	Power Purchase Agreement

PV	Photovoltaic(s)	SLD	Single-Line Diagram
PWM	Pulse Width Modulation	SJB	String Junction Box
PVC	Polyvinylchloride	SMF	Sealed Maintenance Free
PR	Performance Ratio	SNA	State Nodal Agency
QA	Quality Assurance	SPD	Surge Protection Device
QAP	Quality Assurance Plan	STC	Standard Test Conditions (1000 W/m2, 25°C)
QM	Quality Management	THD	Total Harmonic Distortion
RLDC	Regional Load Dispatch Centre	TOD	Time of Day
RCCB	Residual Current Circuit Breaker	V_{AC}	Volt (alternating current)
RE	Renewable Energy	V_{DC}	Volt (direct current)
RESCO	Renewable Energy Services Company	V_{MP}	Voltage at Maximum Power Point
RPO	Renewable Purchase Obligation	V_{OC}	Open-circuit Voltage
ROI	Return on investment	W	Watt
SCADA	Supervisory Control and Data Acquisition	W_P	Watt-Peak
SECI	Solar Energy Corporation of India	XLPE	Cross-linked Polyethylene

List of Suggestive Standards

IEC61215 and IS14286	Design Qualification and Type Approval for Crystalline Silicon Terrestrial Photovoltaic (PV) Modules
IEC 61701:2011	Salt Mist Corrosion testing of Photovoltaic (PV)Modules
IEC: 61853-1:2011/ IS16170-1:2014	Photovoltaic (PV) module performance testing and energy rating–: Irradiance and temperature performance measurements, and Power Rating.
IEC 62716	Photovoltaic (PV) Modules–Ammonia (NH3) Corrosion Testing (as per the site condition like dairies, toilets etc)
IEC61730-1, 2	Photovoltaic (PV) Module Safety Qualification–Part1: Requirements for Construction, Part2: Requirements for Testing
IEC 62804	Photovoltaic (PV) modules – Test method for detection of potential-induced degradation. IEC 62804-1: Part 1: Crystalline Silicon
Solar PV Inverters	
IEC62109 or **IS: 16221**	Safety of power converters for use in photovoltaic power systems –Part1: General requirements, and Safety of power converters for use in photovoltaic power systems Part2: Requirements for inverters. Safety compliance (Protection degreeIP65 or better for outdoor mounting, IP54 or better for indoor mounting)
IS/IEC61683	Photovoltaic Systems – Power conditioners: Procedure for Measuring Efficiency (10%,25%,50%,75%&90-100% Loading Conditions)
IEC 60068-2 /IEC62093	Environmental Testing of PV system–Power Conditioners and Inverters
IEC 62116:2014/ IS16169	Utility-interconnected photovoltaic inverters - Test procedure of islanding prevention measures
Fuses	
IS/IEC60947(Part 1, 2 &3), EN 50521	General safety requirements for connectors, switches, circuit breakers (AC/DC): i. Low-voltage Switchgear and Control-gear, Part1: General rules ii. Low-Voltage Switchgear and Control-gear, Part 2: Circuit Breakers iii. Low-voltage Switchgear and Control-gear, Part 3: Switches, disconnectors switch-disconnectors and fuse-combination units iv. EN50521: Connectors for photovoltaic system-Safety requirements and tests
IEC60269-6:2010	Low-voltagefuses-Part6: Supplementary requirements for fuse-links for the protection of solar photo voltaic energy systems

Solar PV Roof Mounting Structure	
IS2062/IS4759/AA6063 T6	Material for the structure mounting
SURGE ARRESTORS	
BFC17-102:2011/ NFC 102:2011/ IEC 62305	Lightening Protection Standard
IEC 60364-5-53/ IS15086-5(SPD) **IEC 61643- 11:2011**	Electrical installations of buildings-Part5-53: Selection and erection of electrical equipment-Isolation, switching and control Low-voltage surge protective devices-Part11: Surge protective devices connected to low-voltage power systems-Requirements and test methods
Cables	
IEC 60227/IS 694, IEC60502/IS 1554 (Part 1&2)/IEC69947(as applicable)	General test and measuring method for PVC(Polyvinylchloride) insulated cables (for working voltages up to and including1100V, and UV resistant for outdoor installation)
BSEN 50618	Electric cables for photo voltaic systems (BT(DE/NOT)258), mainly for DC Cables
Earthing/Lightning	
IEC 62561/IEC 60634 Series (Chemical Earthing)	IEC 62561-1: Lightning protection system components (LPSC) - Part: Requirements for connection components IEC 62561-2: Lightning protection system components (LPSC) – Part 2: Requirements for conductors and earth electrodes IEC 62561-7: Lightning protection system components (LPSC) - Part 7: Requirements for earthing enhancing compounds
IEC 60529	Junction boxes and solar panel terminal boxes shall be of the thermo-plastic type with IP 65 or better protection for outdoor use, and IP54 or better protection for indoor use

1 Objective

The Quality Control manual will serve as the guide to ascertain compliance in Quality of design, manufacturing, installation operation & maintenance of Rooftop Solar PV system. A strong emphasis on quality aspects is essential for the long-term success of the Rooftop Solar PV System.

2 Grid Connected Rooftop Solar PV System

2.1 Overview

Grid connected Rooftop Solar PV systems are directly connected to the distribution grid, and use grid connected inverters, and usually do not use batteries. These systems can export surplus power into the distribution grid. A grid-connected Rooftop Solar PV system is designed to automatically shut down if it detects anomalies in grid parameters such as voltage, frequency, rate of change of frequency, etc.

In grid connected rooftop or small SPV system, the DC power generated from SPV panel is converted to AC power using power conditioning unit and is fed to the grid either of 33 kV/11 kV three phase lines or of 440/220 Volt three/single phase line depending on the capacity of the system installed at institution/commercial/industrial establishment or residential complex/Government Building etc., and the regulatory framework specified for respective States. These systems generate power during the daytime which is utilized fully by powering captive loads and inject excess power to the grid if grid is available. In cases where solar power is not sufficient due to lower irradiance or plant failure etc., the captive loads are served by drawing power from the grid.

2.2 Definition of Technical Parameters

I. **Photovoltaic (PV) System**: Converts irradiance (solar power) from the sun into electricity.

II. **Solar Array (or PV Array):** A configuration of solar panels arranged and wired together to output power as a single unit.

III. **Solar Irradiance:** The power per unit area received from the sun.

IV. **Array orientation:** The array should be oriented towards the south in Northern hemisphere.

V. **Tilt Angle:** The inclined angle of the solar panels relative to the horizontal.

VI. **Short Circuit Current (I_{sc}):** Short Circuit Current is the maximum current produced by a solar cell when the voltage across the solar cell is zero (i.e., solar cell is short circuited and depends upon area of the cell, number of photons, spectrum of the incident light, optical properties, minority carrier collection probability. It is measured in Ampere (A).

VII. **Open Circuit Voltage (V_{OC}):** Open circuit voltage is the maximum voltage that the cell can produce under open-circuit conditions. It is measured in volt (V). The value of V_{OC} depends on cell technology and the operating temperature of the cell.

VIII. **Maximum Power Point (MPP):** Maximum power point represents the maximum power that a solar cell can produce at the STC (Standard Testing Conditions). It is measured in W_P. Other than STC, the solar cell has MPP at different values of radiance and cell operating temperature. The cell can operate at different current and voltage combinations. But it can only produce maximum power at a particular voltage and current combination.

IX. **Current at Maximum Power Point:** It represents the current which the solar cell will produce when operating at the maximum Power Point. It is denoted by I_{m}, its value is always less than the short circuit current (I_{SC}). It is measured in ampere (A).

X. **Voltage at Maximum Power Point:** It represents the voltage that the solar cell will produce when operating at the maximum Power Point. It is denoted by V_{m}, and its value is always less than the open-circuit voltage (V_{OC}). It is measured in volts (V).

XI. **Fill Factor (FF):** The short-circuit current and the open-circuit voltage is the maximum current and voltage respectively from a solar cell. However, at both operating points, the power from the solar cell is zero. The "fill factor", more commonly known by its abbreviation "FF", is a parameter which, in conjunction with V_{oc} and I_{sc}, determines the maximum power from a solar cell. The FF is defined as the ratio of the maximum power from the solar cell to the product of V_{oc} and I_{sc} so that:

$$\mathbf{FF = [V_{mp}\ x I_{mp} / (I_{SC}\ x\ V_{OC})]\ x\ 100}$$

XII. **Efficiency (η):** The efficiency of the Solar cell refers to the percentage of input solar irradiance converted to electrical power. The solar irradiance is measured in W/m^2. Therefore, to calculate efficiency multiplies solar irradiance by area of the cell. The efficiency can be calculated as follows:

$$\eta = [\text{Electric power } (W_p) / (\text{Solar irradiance} \times \text{Area})]\ x\ 100$$

XIII. **Temperature Coefficient:** The photovoltaic (PV) temperature coefficient of power **indicates dependency of solar out power with cell temperature**, meaning the surface temperature of the PV array. The output power of solar panels will decrease with increase in temperature. Hence, the value will be prefixed by a negative sign.

XIV. **Maximum Power Point Tracker (MPPT):** MPPT is an algorithm that is included in the inverter used for extracting maximum available power from SPV array under a given condition. The voltage at which SPV array can produce maximum power is called 'maximum power point' voltage (or peak power voltage).

2.3 System Components

I. PV Modules: PV Modules convert sunlight directly into DC electricity. Solar cells (which are normally made of crystalline, polycrystalline, or amorphous silicon or other compound semiconductors like Cadmium Telluride CdTe and Copper Indium Gallium Selenide (CIGS) are connected in series and encapsulated in a PV module. PV modules are rated for a particular power capacity at standard testing conditions (STC), which is also indicated on its label.

II. Strings and Arrays: A number of PV modules connected in series is entitled a string. A string is designed such that it provides an output voltage in a range that is compatible with the inverter input voltage range. Strings are then connected in parallel in a PV plant to accomplish the desired DC capacity. When several strings are connected in parallel, it forms an array. Modules in a string (i.e., in series) add up the voltage, and modules in an array (i.e., in parallel) add up the current.

III. Inverters: Inverters are among the most critical components of the PV system that not only perform power-related functions but are also responsible for the intelligence of the PV system.

Solar Inverters are classified as below as per their application:

a) Grid Connected Inverters
b) Stand Alone or Off Grid Inverters
c) Hybrid Inverters

Grid connected Solar Inverters are further classified as below as per their rated capacity:

a) Central Inverter
b) String Inverter
c) Micro Inverter

The major functions of the grid connected PV inverter are to:

a) Convert DC power into AC power and ensure anti-islanding by shutting itself down (and hence the PV generation) in case of grid failure.
b) Synchronize the output AC power with the phase, frequency, and voltage of the available grid in order to feed the PV power into the grid.
c) Ensure protection of the PV system from DC- side (i.e., PV-side) for reverse polarity, overcurrent, overvoltage, and surge.
d) Ensure protection of the PV system from AC-side (i.e., grid-side) for grid-fault (e.g., over/ under-voltage, over/ under frequency, high rate of change of frequency, etc.), ground fault, residual current or fault conditions, etc.
e) Inverters should be rated for appropriate Ingress Protection (IP). Single-phase string inverters, typically up to around 10 kW, give an output of 240 VAC, 1φ, 50 Hz; while three phase string inverters give an output of 415 VAC, 3φ, 50 Hz. It is also a general practice to use three numbers of single-phase inverters to provide a net three-phase output. For larger rooftop PV systems, central inverters of capacities more than 100 kW are often used, in which case the output voltage is stepped up to 11 kV or above using step-up transformers. PV inverters generally have 96-98 percent efficiency.

IV. Module Mounting Structure: Module Mounting Structures (MMS) are used to secure the PV modules in particular orientation to harness maximum sunlight. MMS are designed keeping several structural considerations such as:

a) Load (weight) of the PV system.
b) Typical and maximum wind loads at that location.
c) Seismic zone safety factors
d) Other considerations such as saline or corrosive environments.
e) Most of the physical considerations are governed by Indian Standards. PV modules are often mounted at a tilt angle equal to that of the latitude of the location.

V. Lighting Arrestors: While it is desired to protect all PV systems from lightning, It is highly recommended for PV systems to have dedicated lightning arrestors rather than depending on foreign rods and structures at greater heights that might exist at the time of installation.

VI. Earthing: Earth Pits used in solar PV systems are the same as conventional earth pits used for electrical installations. Separate earthing must be provided for Solar Array structure, Inverter, and Lightning arrestor. This way, the risks from failure of the earthing system can be reduced and a lower earth resistance can be achieved.

VII. **Batteries:** Batteries are used in PV systems to store energy and utilize it when available solar power may not be enough to power the desired load. While lead acid batteries such as flooded electrolyte, gel electrolyte, Sealed Maintenance Free (SMF), etc. are commonly used due to lower cost and high availability, other batteries such as lithium ion are also gaining popularity. Batteries are sized based on power and energy requirement of the load and often oversized to provide autonomy during cloudy days. We scrutinize batteries not only in terms of energy density but also longevity, load characteristics, maintenance requirements, self-discharge, and operational costs.

VIII. **DC Cables:** DC cables are used to carry DC current from the PV modules right up to the inverter. The DC cable should be sized to carry the required current (along with necessary safety margins) and also limit the voltage drop (i.e., resistance losses

IX. **AC Cables:** AC Cables carry the AC power of the PV system to the metering point, which is typically at the lower floors and hence must be carefully chosen critically to ensure safety as well as minimize power loss. While copper or aluminium cables can be used, it is highly recommended to use armoured cables. AC cabling practices are common in India, and suitable standards and certifications should be adhered to. As a common practice, AC wiring loss of a PV system should not exceed 2 percent.

X. **DC & AC Isolators:** DC Isolators are required to disconnect the PV modules and strings from the rest of the PV system in cases of faults, fire, or repair. DC isolators are mandated globally; they should be clearly labelled and easily accessible. AC switchgear protects the electrical components of the solar PV system from and isolates whenever there is fault/failures in the system.

2.4 Principle of Working

Solar PV rooftop system is basically a small power plant at your rooftop. The Grid interactive Rooftop Solar Photovoltaic (PV) mainly consists of three major components. These are the solar PV modules, mounting structure for the modules and the inverter or power conditioning units. The solar panels convert solar energy in the form of light into electricity in DC form (Direct Current). The DC electrical energy is converted to AC (Alternate Current) power by the inverter/power conditioning unit which is connected to the power grid through AC distribution board. The AC power output can be measured through a metering panel connected to it. The AC output of the system can be synchronized with the grid and the electricity can be exported to the grid depending upon solar power generation and local consumption.

3 Three Tier Quality Control Mechanism

To ensure proper quality of materials in grid connected rooftop Solar PV System, a three tier Quality Control Mechanism (QCM) has been developed. The major objective of this QCM is to check, monitor, assure, identify issues, and implement rectifications / mitigating options as regards ensuring the quality control for implementation of all the grid connected rooftop Solar PV System across the country.

This three tier QCM is mandatory for any compliance, currently and can be implemented independently by the respective stakeholders to achieve their objectives of ensuring quality and performance aspects of the grid connected rooftop Solar PV System.

QCM could be implemented by Vendor, State Implementing Agency (SIA), Third Party Inspection Agency and MNRE.

Vendor is a firm that supplies solar modules, inverter, and Balance of Systems (BOS) to the consumer. The services offered by, and responsibilities of Turnkey Contractor / Vendor typically include site inspection, feasibility analysis, design, engineering, secure approvals, civil works, supply, erection, testing, commission, operation, and maintenance (on case-to-case basis) of the grid connected rooftop Solar PV System in the country.

State Implementing Agency (SIA) either a Distribution Company (DISCOM) or State Nodal Agency (SNA) or any other State Agency / Department who may or may not have a mandate from Ministry of New and Renewable Energy (MNRE) to implement its Central Financial Assistance Program for promotion of grid connected rooftop solar projects in the State / Union Territory. While DISCOM provides services to its consumers related to net metering (and other types of metering) interconnection for implementing grid connected rooftop solar projects, SNA provides facilitation services (awareness, empanelment of vendors, information access to financing etc.,) to the state citizens related to implementation of grid connected rooftop solar projects. SIA may also be implementing grid connected rooftop solar projects designed by PIA on case-to-case basis.

Third Party Inspection Agency (TPIA) is a firm or an individual expert who could be engaged by MNRE for various services related to inspection, verification, progress monitoring, evaluation etc., of the grid connected rooftop solar PV projects under various stages of pre-dispatch, installation, and post-commissioning.

A matrix of all the three tiers with the stakeholders and the activities (in a typical grid connected rooftop solar PV System) falling under each tier is provided below.

TIER I		
Project Cycle/ Stakeholders	**Pre-Installation**	**Post-installation**
State Implementation Agency (Discoms/SNAs) **(Resources: Utility / SNAs or Authorised Agency)**	**1** Specifications /Bill of Quantities (BOQ) & Quality of Materials (List & Template) (Annexure-9.1) **2** Pre-Dispatch Inspection for Modules, Inverters and BOQs (Annexure 9.2)	**1** Commissioning Report (Annexure-9.3) **2** Synchronization Report (Annexure-9.4: May vary as per state regulation:) **3** Quality Inspection and performance Assessment Report (Annexure-9.5)
TIER II		
Third Party Inspection Agency **(Resources: Third party Agency)**	Applicable based on the terms of engagement between MNRE and TPIA as per the inspection report	Post installation inspection on sampling basis based on the term of engagement between MNRE and TPIA. ***(Annexure 9.5)***
TIER III		
MNRE / Authorised Institutions by MNRE **(Resources: Own Team)**	On Optional and random sampling basis as per the inspection report	On random sampling basis as per the inspection report ***(Annexure 9.5)***

The basic framework of the three tier QCM is provided below.

(i) TIER-I

Under the Tier-I, the activities related to monitoring and assessing the quality control will be implemented by the State Implementing Agency (Discoms/ SNA) from their own quality control team resources or designated institutions authorised by SIA as applicable. These stakeholders may use formats of inspection or modify the templates (as per state regulations) as required to ensure quality of supplied materials from the contractors and workmanship as per the Standards approved by MNRE. The empanelled vendors will ensure the quality of the supplied materials from their respective suppliers in the supply chain of grid connected Rooftop Solar PV system.

State Implementation Agency (SIA) shall be responsible for first tier Quality Control Mechanism (QCM). SIA/designated institutions authorised by SIA shall be responsible for the following: -

i. Shall witness acceptance tests/test reports of all materials of all empanelled vendors at vendors' site / warehouse as per Drawings / Technical Specifications as approved by MNRE and other applicable / prevalent Standards at the pre-dispatch stage
ii. Shall inspect 100% of Grid connected solar PV system installations in its coverage area after its installation
iii. Shall inspect Grid connected solar PV systems on random sampling basis in its coverage area during the first five years of Operation & Maintenance

Quality Assurance shall be undertaken in the following areas of the project implementation: -

i. Quality of material/equipment being supplied at pre-dispatch stage.
ii. Quality of work in the field.

(ii) TIER-II

Third Party Inspection Agency (TPIA) engaged by MNRE shall be responsible for second tier Quality Control Mechanism (QCM) on a random sampling basis.

TPIAs could be engaged typically by MNRE based on their availability of internal resources. The detailed Terms & Condition of the activity to be carried out by the TPIA would be elaborated at the time of engagement.

(iii) TIER-III

MNRE shall be responsible for third tier Quality Control Mechanism. MNRE officials or any authorised Institutions designated by MNRE shall conduct quality checks during Pre-Dispatch and Post Installation levels. The frequency of inspection shall be as and when decided by MNRE. MNRE shall be responsible for the following: -

- MNRE shall randomly inspect vendors empanelled by SIAs in every State at vendors' site / warehouse / Manufacturing facility.
- MNRE shall review test records for major materials like Solar PV module, Module Mounting structure, Inverter etc. as per the MNRE Specifications on a random sampling basis as and when required by MNRE
- MNRE shall inspect Rooftop Solar PV system installations implemented under the Central Financial Assistance in each state to assess the quality of the installations and its performance on a random sampling basis.

4 Quality Control Mechanism at Manufacturing level

These guidelines can serve as a tool for assessing the quality of materials being used in the grid connected rooftop Solar PV system. Vendor can use this as a check during material procurement. The chapter also provides guidance over the Mechanism to be followed during transportation, storage and installation of Grid connected solar PV system.

4.1 Solar PV Modules

4.1.1 The PV modules and Solar Cell used should be made in India for subsidized project.

4.1.2 The PV modules used must qualify to the latest edition of IEC standards or equivalent BIS standards, i.e., IEC 61215/IS14286, IEC 61853-Part I/IS 16170-Part I, IEC 61730 Part-1 & Part 2 and IEC 62804 (PID). For the PV modules to be used in a highly corrosive atmosphere throughout their lifetime, they must qualify to IEC 61701/IS 61701.

4.1.3 The rated power of the solar PV module shall have maximum tolerance up to +3%.

4.1.4 The peak-power point current of any supplied module string (series connected modules) shall not vary by +1% from the respective arithmetic means for all modules and/or for all module strings (connected to the same MPPT), as the case may be.

4.1.5 The peak-power point voltage of any supplied module string (series connected modules) shall not vary by + 2% from the respective arithmetic means for all modules and/or for all module strings (connected to the same MPPT), as the case may be.

4.1.6 The temperature co-efficient power of the PV module shall be equal to or better than - *0.45*%/°C.

4.1.7 Solar PV modules of minimum capacity 300 Wp to be used.

4.1.8 The PV Module efficiency should be minimum 16%

4.1.9 Solar PV modules of minimum fill factor 75%, to be used.

4.1.10 All electrical parameters at STC shall have to be provided

4.1.11 The PV modules shall be equipped with IP 65 or better protection level junction box with required numbers of bypass diodes of appropriate rating and appropriately sized output power cable of symmetric length with MC4 or equivalent solar connectors. The IP level for protection may be chosen based on following conditions:

i. An IP 65 rated enclosure is suitable for most outdoor enclosures that will not encounter extreme weather such as flooding.

ii. An IP 67 rated enclosure is suitable at locations which may encounter temporary submersion at depths of up to one meter.

iii. An IP 68 enclosure is recommended if there may be situations of submergence for extended periods of time and at substantial depths.

4.1.12 All PV modules should carry a performance warranty of >90% during the first 10 years, and >80% during the next 15 years. Further, the module shall have a performance warranty of >97% during the first year of installation—degradation of the module below 1 % per annum.

4.1.13 The manufacturer should warrant the Solar Module(s) to be free from the defects and/or failures specified below for a period not less than five (05) years from the date of commissioning:

4.1.14 Defects and/or failures due to manufacturing.

4.1.15 Defects and/or failures due to quality of materials.

4.1.16 Nonconformity to specifications due to faulty manufacturing and/or inspection processes. If the solar Module(s) fails to conform to this warranty, the manufacturer will repair or replace the solar module(s), at the Owner's sole option.

4.1.17 PV modules must be tested and approved by one of the NABL accredited and BIS approved test centres.

4.1.18 Modules deployed must use a RF identification tag laminated inside the glass. The following information must be mentioned in the RFID used on each module:

i. Name of the manufacturer of the PV module.
ii. Name of the manufacturer of Solar Cells.
iii. Month & year of the manufacture (separate for solar cells and modules)
iv. Country of origin (separately for solar cells and module)
v. I-V curve for the module Wattage, Im, Vm and FF for the module.
vi. Unique Serial No and Model No of the module.
vii. Date and year of obtaining IEC PV module qualification certificate.
viii. Name of the test lab issuing IEC certificate.
ix. Other relevant information on traceability of solar cells and modules as per ISO 9001 and ISO 14001.
x. Nominal wattage +3%.
xi. Brand Name, if applicable.

4.1.19 Other details as per IS/IEC 61730-1 clause 11 should be provided at appropriate places. In addition to the above, the following information should also be provided:

i. The actual Power Output Pmax shall be mentioned on the label pasted on the back side of PV Module.
ii. The Maximum system voltage for which the module is suitable to be provided on the back sheet of the module iii. Polarity of terminals or leads (colour coding is permissible) on junction Box housing near cable entry or cable and connector.

4.1.20 Unique Serial No, Model No, Name of Manufacturer, Manufacturing year, Make in India Logo and module wattage details should be displayed inside the laminated glass

4.2 Inverter/PCU

4.2.1 Inverters/PCU should comply with applicable IEC/equivalent BIS standard for efficiency measurements and environmental tests as per standard codes IEC 61683/IS 61683, IS16221 (Part 2), IS 16169 and IEC 60068-2(1,2,14,30) /Equivalent BIS Std.
4.2.2 Maximum Power Point Tracker (MPPT) shall be integrated in the inverter/PCU to maximize energy drawn from the array. Charge controller (if any) / MPPT unit environmental testing should qualify IEC 60068-2(1, 2, 14, 30)/Equivalent BIS standard. The junction boxes/enclosures should be IP 65 or better (for outdoor)/ IP 54or better (indoor) and as per IEC 529 Specifications.
4.2.3 All inverters/PCUs shall be IEC 61000 compliant for electromagnetic compatibility, harmonics, Surge, etc.
4.2.4 The PCU/ inverter shall have an overloading capacity of minimum 10%.
4.2.5 Typical technical features of the inverter shall be as follows i. Switching devices: IGBT/MOSFET ii. Control: Microprocessor/DSP iii. Nominal AC output voltage and frequency: as per CEA/State regulations iv. Output frequency: 50 Hz v. Grid Frequency Synchronization range: as per CEA/State Regulations vi. Ambient temperature considered: -20°C to 60°C vii. Humidity: 95 % Non-condensing viii. Protection of Enclosure: IP-54 (Minimum) for indoor and IP-65(Minimum) for outdoor. ix. Grid Frequency Tolerance range: as per CEA/State regulations x. Grid Voltage tolerance: as per CEA/State Regulations xi. No-load losses: Less than 1% of rated power xii. Inverter efficiency (Min.): >93% (In case of 10 kW or above with in-built galvanic isolation) >97% (In case of 10 kW or above without inbuilt galvanic isolation) xiii. Inverter efficiency (minimum): > 90% (In case of less than 10 kW) xiv. THD: < 3% xv. PF: > 0.9 (lag or lead) xvi. Should not inject DC power more than 0.5% of full rated output at the interconnection point and comply with IEEE 519.

4.2.6 The output power factor of the inverter should be suitable for all voltage ranges or sink of reactive power, the inverter should have internal protection arrangement against any sustain fault in the feeder line and against the lightning on the feeder.

4.2.7 All the Inverters should contain the following clear and indelible Marking Label Warning Label as per IS16221 Part II, clause 5. The equipment shall, as a minimum, be permanently marked with:

i. The name or trademark of the manufacturer or supplier.
ii. A model number, name, or other means to identify the equipment,
iii. A serial number, code or other marking allowing identification of manufacturing location and the manufacturing batch or date within a twelve-month time.
iv. Input voltage, type of voltage (a.c. or d.c.), frequency, and maximum continuous current for each input.
v. Output voltage, type of voltage (a.c. or d.c.), frequency, maximum continuous current and for a.c. outputs, either the power or power factor for each output.
vi. The Ingress Protection (IP) rating

4.2.8 Marking shall be located adjacent to each fuse or fuse holder, or on the fuse holder, or in another location provided that it is obvious to which fuse the marking applies, giving the fuse current rating and voltage rating for fuses that may be changed at the installed site.

4.2.9 In case the consumer is having a 3-ϕ connection, 1-ϕ/3-ϕ inverter shall be provided by the vendor as per the consumer's requirement and regulations of the State.

4.2.10 Inverter/PCU shall be capable of complete automatic operation including wake-up synchronization & shutdown.

4.2.11 Integration of PV Power with Grid & Grid Islanding:

i. The output power from SPV would be fed to the inverters/PCU which converts DC produced by SPV array to AC and feeds it into the main electricity grid after synchronization.
ii. In the event of a power failure on the electric grid, it is required that any independent power-producing inverters attached to the grid turn off in a short period of time. This prevents the DC-to-AC inverters from continuing to feed power into small sections of the grid, known as "islands." Powered islands present a risk to workers who may expect the area to be unpowered, and they may also damage grid-tied equipment. The Rooftop PV system shall be equipped with islanding protection. In addition to disconnection from the grid (due to islanding protection) disconnection due to under and over voltage conditions shall also be provided, if not available in the inverter.

MCB/MCCB or a manual isolation switch, besides automatic disconnection to grid, would have to be provided at utility end to isolate the grid connection by the utility personnel to carry out any maintenance. This switch shall be locked by the utility personnel.

4.3 Module Mounting Structure (MMS)

4.3.1 Supply, installation, erection, and acceptance of module mounting structure (MMS) with all necessary accessories, auxiliaries, and spare part.

4.3.2 Module mounting structures can be made from three types of materials. They are Hot Dip Galvanized Iron, Aluminium and Hot Dip Galvanized Mild Steel (MS). However, MS will be preferred for raised structure.

4.3.3 MMS Steel shall be as per latest IS 2062:2011 and galvanization of the mounting structure shall be in compliance with latest IS 4759. MMS Aluminium shall be as per AA6063 T6. For Aluminium structures, necessary protection towards rusting needs to be provided either by coating or anodization.

4.3.4 All bolts, nuts, fasteners shall be of stainless steel of grade SS 304 or hot dip galvanized, panel mounting clamps shall be of aluminium and must sustain the adverse climatic conditions.

Structural material shall be corrosion resistant and electrolytically compatible with the materials used in the module frame, its fasteners, nuts, and bolts

4.3.5 The module mounting structures should have angle of inclination as per the site conditions to take maximum insolation and complete shadow-free operation during generation hours. However, to accommodate more capacity the angle of inclination may be reduced until the plant meets the specified performance ratio requirements.

4.3.6 The Mounting structure shall be so designed to withstand the speed for the wind zone of the location where a PV system is proposed to be installed. The PV array structure design shall be appropriate with a factor of safety of minimum 1.5.

4.3.7 The upper edge of the module must be covered with a windshield so as to avoid air ingress below the module. Slight clearance must be provided on both edges (upper & lower) to allow air for cooling.

4.3.8 Suitable fastening arrangements such as grouting, and calming should be provided to secure the installation against the specific wind speed. The Inspecting Agency shall ensure that the SPV System withstand high wind velocity within the guarantee period as per technical specification.

4.3.9 The structures shall be designed to allow easy replacement, repairing and cleaning of any module. The array structure shall be so designed that it will occupy minimum space without sacrificing the output from the SPV panels. Necessary testing provision for MMS to be made available at site.

4.3.10 Adequate spacing shall be provided between two panel frames and rows of panels to facilitate personnel protection, ease of installation, replacement, cleaning of panels and electrical maintenance.

4.3.11 The structure shall be designed to withstand operating environmental conditions for a period of minimum 25 years.

4.3.12 Material Structure: Design of foundation for mounting the structure should be as per defined standards which clearly states the Load Bearing Capacity & other relevant parameters for foundation design (As per IS 6403 / 456 / 4091 / 875).

i. Grade of raw material to be used for mounting the structures so that it complies the defined wind loading conditions (As per IS 875 - III) should be referred as follows (IS 2062 – for angles and channels, IS 1079 – for sheet, IS 1161 & 1239 for round pipes, IS 4923 for rectangular and square hollow section)
ii. Test reports for the raw material should be as per IS 1852 / 808 / 2062 / 1079 / 811.
iii. In process inspection report as per approved drawing & tolerance should be as per IS
iv. For ascertaining proper welding of structure part following should be referred:
    a. D.P. Test (Pin Hole / Crack) (IS 822)
    b. Weld wire grade should be of grade (ER 70 S - 6)

v. Foundation Hardware – If using foundation bolt in foundation then it should be as per IS 5624.
vi. For ascertaining hot dip galvanizing of fabricated structure following should be referred:
    a. Min coating required should be as per IS 4759 & EN 1461.
    b. Testing of galvanized material

- Pierce Test (IS 2633)
- Mass of Zinc (IS 6745)
- Adhesion Test (IS 2629)
- CuSO4 Test (IS 2633)
- Superior High-Grade Zinc Ingot should be of 99.999% purity (IS 209) (Preferably Hindustan Zinc Limited or Equivalent)

4.3.13 **The Rooftop Structures may be classified in three broad categories as follows:**

I. Ballast structure

a. The mounting structure must be Non-invasive ballast type and any sort of penetration of roof to be avoided.
b. The minimum clearance of the structure from the roof level should be in between 70- 150 mm to allow ventilation for cooling, also ease of cleaning and maintenance of panels as well as cleaning of terrace.
c. The structures should be suitably loaded with reinforced concrete blocks of appropriate weight made from M25 concrete mixture.

II. Tin shed

a. The structure design should be as per the slope of the tin shed.
b. The inclination angle of the structure can be done in two ways
    i. Parallel to the tin shed (flat keeping zero-degree tiling angle), if the slope of shed in Proper south direction
    ii. With the same tilt angle based on the slope of tin shed to get the maximum output.
c. The minimum clearance of the lowest point from the tin shade should be more than 100mm.
d. The base of the structure should be connected on the Purlin of the tin shed with the proper riveting.
e. All structure members should be of minimum 2 mm thickness.

III. RCC Elevated structure: It can be divided into further three categories:

A. Minimum Ground clearance (300 mm – 1000 MM)

a. The structure shall be designed to allow easy replacement of any module and shall be in line with site requirement. The gap between module should be minimum 30 mm.
b. Base Plate – Base plate thickness of the Structure should be 5 mm for this segment.
c. Column – Structure Column should be minimum 2 mm in Lip section / 3MM in C Channel section. The minimum section should be 70 mm in Web side and 40MM in flange side in Lip section.
d. Rafter - Structure rafter should be minimum 2 mm in Lip section / 3MM in C Channel section. The minimum section should be 70 mm in Web side (y-axis) and 40MM in flange side (x-axis).
e. Purlin - Structure purlin should be minimum 2 mm in the Lip section. The minimum section should be 60 mm in Web side and 40 mm in flange side in Lip section.
f. Front/back bracing – The section for bracing part should be minimum 2 mm thickness.
g. Connection – The structure connection should be bolted completely. Leg to rafter should be connected with a minimum 12 diameter bolt. Rafter and purlin should be connected with a minimum 10 diameter bolt. Module mounting fasteners should be SS-304 only and remaining fasteners either SS-304 or HDG 8.8 Grade.
h. For a single portrait structure, the minimum ground clearance should be 500 mm.

B. Medium Ground clearance (1000 mm – 2000 mm) (for reference only)

a) Base Plate – Base plate thickness of the Structure should be Minimum 6 mm for this segment.

b) Column – Structure Column should be minimum 2 mm in Lip section / 3 mm in C Channel section. The minimum section should be 80 mm in Web side and 50 mm in flange side in Lip section.
c) Rafter - Structure rafter should be minimum 2 mm in Lip section / 3 mm in C Channel section. The minimum section should be 70 mm in Web side and 40MM in flange side in Lip section.
d) Purlin - Structure purlin should be minimum 2 mm in Lip section. The minimum section should be 70MM in Web side and 40 mm in flange side in Lip section.
e) Front/back bracing – The section for bracing part should be minimum 2MM thickness.
f) Connection – The structure connection should be bolted completely. Leg to rafter should be connected with a minimum 12 diameter bolt. Rafter and purlin should be connected with a minimum 10 diameter bolt. Module mounting fasteners should be SS-304 only and remaining fasteners either SS-304 or HDG 8.8 Grade.

C. Maximum Ground clearance (2000 mm – 3000 mm) (for reference only)

a) Base Plate – Base plate thickness of the Structure should be minimum 8 mm for this segment.
b) Column – Structure Column thickness should be minimum 2.6 mm in square hollow section (minimum 50x50) or rectangular hollow section (minimum 60x40) or 3 mm in C-Channel section.
c) Rafter - Structure rafter should be minimum 2 mm in Lip section / 3MM in Channel section. The minimum section should be 80MM in Web side and 50MM in flange side in Lip section.
d) Purlin - Structure purlin should be minimum 2 mm in the Lip section. The minimum section should be 80 mm in Web side and 50 mm in flange side in Lip section.
e) Front/back bracing – The section for bracing part should be minimum 3 mm thickness.
f) Connection – The structure connection should be bolted completely. Leg to rafter should be connected with a minimum 12 diameter bolt. Rafter and purlin should be connected with minimum 10 diameter bolt. Module mounting fasteners should be SS-304 only and remaining fasteners either SS-304 or HDG 8.8 Grade.

D. Super elevated structure (More than 3000 mm) (for reference only)

D.1. Base structure

a) Base Plate – Base plate thickness of the Structure should be 10 mm for this segment.
b) Column – Structure Column minimum thickness should be minimum 2.9MM in square hollow section (minimum 60x60) or rectangular hollow section (minimum 80x40).
c) Rafter - Structure Rafter minimum thickness should be minimum 2.9 mm in square hollow section (minimum 60x60) or rectangular hollow section (minimum 80x40).
d) Cross bracing – Bracing for the connection of rafter and column should be of minimum thickness of 4mm L-angle with the help of minimum bolt diameter of 10mm.

D.2. Upper structure of super elevated structure:

a) Base Plate – Base plate thickness of the Structure should be minimum 5 mm for this segment.
b) Column – Structure Column should be minimum 2 mm in Lip section / 3 mm in Channel section. The minimum section should be 70 mm in Web side and 40 mm in flange side in Lip section.
c) Rafter - Structure rafter should be minimum 2 mm in Lip section / 3 mm in Channel section. The minimum section should be 70 mm in Web side and 40 mm in flange side in Lip section.
d) Purlin - Structure purlin should be minimum 2 mm in the Lip section. The minimum section should be 60 mm in Web side and 40 mm in flange side in Lip section.
e) Front/back bracing – The section for bracing part should be minimum 2 mm thickness.

f) Connection – The structure connection should be bolted completely. Leg to rafter should be connected with a minimum 12 diameter bolt. Rafter and purlin should be connected with a minimum 10 diameter bolt. Module mounting fasteners should be SS-304 only and remaining fasteners either SS-304 or HDG 8.8 Grade.

D.3. If distance between two legs in X-Direction is more than 3 m then sag angle/Bar should be provided for purlin to avoid deflection failure. The sag angle should be minimum 2MM thick, and the bar should be minimum 12Dia.

D.4. Degree - The Module alignment and tilt angle shell be calculated to provide the maximum annual energy output. This shall be decided on the location of array installation.

D.5. Foundation – Foundation should be as per the roof condition; two types of the foundation can be done- either penetrating the roof or without penetrating the roof.

a) If penetration on the roof is allowed (based on the client requirement) then minimum 12MM diameter anchor fasteners with minimum length 100 mm can be used with proper chipping. The minimum RCC size should be 400x400x300 cubic mm. Material grade of foundation should be minimum M20.
b) If penetration on roof is not allowed, then foundation can be done with the help of 'J Bolt' (refer IS 5624 for foundation hardware). Proper Neto bond solution should be used to adhere the Foundation block with the RCC roof. Foundation J - bolt length should be minimum 12MM diameter and length should be minimum.

4.4 Array Junction Box

4.4.1 The junction boxes are to be provided in the PV array for termination of connecting cables. The Junction Boxes (JBs) shall be made of GRP/FRP/Powder Coated aluminium /cast aluminium alloy with full dust, water & vermin proof arrangement. All wires/cables must be terminated through cable lugs. The JBs shall be such that input & output termination can be made through suitable cable glands. Suitable markings shall be provided on the busbars for easy identification and cable ferrules will be fitted at the cable termination points for identification.

4.4.2 Copper bus bars/terminal blocks housed in the junction box with suitable termination threads Conforming to IP 65 or better standard and IEC 62208 Hinged door with EPDM rubber gasket to prevent water entry, Single /double compression cable glands should be provided

4.4.3. Polyamide glands and MC4 Connectors may also be provided. The rating of the junction box shall be suitable with adequate safety factor to interconnect the Solar PV array.

4.4.4 Suitable markings shall be provided on the bus bar for easy identification and the cable ferrules must be fitted at the cable termination points for identification.

4.4.5 Junction boxes shall be mounted on the MMS such that they are easily accessible and are protected from direct sunlight and harsh weather.

4.5 DC Distribution Box

4.5.1 May not be required for small plants, if suitable arrangement is available in the inverter.

4.5.2 DC Distribution Boxes are to be provided to receive the DC output from the PV array.

4.5.3 DCDBs shall be dust & vermin proof compliant having IP 65 or better protection, as per site conditions.

4.5.4 The bus bars are made of EC grade copper of required size. Suitable capacity MCBs/MCCB shall be provided for controlling the DC power output to the inverter along with necessary surge arrestors. MCB shall be used for currents up to 63 Amperes, and MCCB shall be used for currents greater than 63 Amperes.

4.6 AC Distribution Box

4.6.1 AC Distribution Panel Board (DPB) shall control the AC power from inverter, and should have necessary surge arrestors, if required. There is interconnection from ACDB to mains at LT Bus bar while in grid tied mode.

4.6.2 All switches and the circuit breakers, connectors should conform to IEC 60947:2019, part I, II and III/ IS 60947 part I, II and III.

4.6.3 he isolators, cabling work should be undertaken as part of the project.

4.6.4 All the Panel's shall be metal clad, totally enclosed, rigid, floor mounted, air -insulated, cubical type suitable for operation on 1-ϕ/3-ϕ, 415 or 230 volts, 50 Hz (or voltage levels as per CEA/State regulations).

4.6.5 The panels shall be designed for minimum expected ambient temperature of 50 degree Celsius, 80 percent humidity and dusty weather.

4.6.6 All indoor panels will have protection of IP 54 or better, as per site conditions. All outdoor panels will have protection of IP 65 or better, as per site conditions.

4.6.7 Should conform to Indian Electricity Act and CEA safety regulations (2021 or amended from time to time.)

4.6.8 The inverter output shall have the necessary rated AC surge arrestors, if required and MCB/ MCCB. RCCB shall be used for successful operation of the PV system, if the inverter does not have required earth fault/residual current protection.

4.6.9 All the 415 or 230 volts (or voltage levels as per CEA/State regulations) AC devices / equipment like bus support insulators, circuit breakers, SPDs, Voltage Transformers (VTs) etc., mounted inside the switchgear shall be suitable for continuous operation and satisfactory performance under the following supply conditions.

i. Variation in supply frequency: as per CEA/State regulations.
ii. Variation in supply voltage: as per CEA/State regulations

4.7 Cables

4.7.1 All cables should conform to the latest edition of IEC/equivalent BIS Standards along with IEC 60227/IS 694, IEC 60502/IS 1554 standards.

4.7.2 Cables should be flexible and should have good resistance to heat, cold, water, oil, abrasion etc.

4.7.3 Armoured cable should be used and overall PVC type 'A' pressure extruded insulation or XLPE insulation should be there for UV protection.

4.7.4 Cables should have Multi Strand, annealed high conductivity copper conductor on the DC side and copper/FRLS type Aluminium conductor on the AC side. For DC cabling, multi-core cables shall not be used.

4.7.5 Cables should have an operating temperature range of -10°C to +80°C and a voltage rating of 660/1000 V.

4.7.6 Sizes of cables between array interconnections, array to junction boxes, junction boxes to Inverter etc. shall be so selected to keep the voltage drop less than 2% (DC Cable losses).

4.7.7 The size of each type of AC cable selected shall be based on minimum voltage drop. However, the maximum drop shall be limited to 2%.

4.7.8 The electric cables for DC systems for rated voltage of 1500 V shall conform to BIS 17293:2020.

4.7.9 All cable/wires are to be routed in a RPVC pipe/ GI cable tray and suitably tagged and marked with proper manner by good quality ferrule or by other means so that the cable is easily identified.

4.7.10 All cable trays including covers to be provided.

4.7.11 Thermo-plastic clamps to be used to clamp the cables and conduits, at intervals not exceeding 50 cm.

4.7.12 Size of neutral wire shall be compatible to the size of phase wires in a single/ three-phase system to conduct current in balanced as well as unbalanced condition.

4.7.13 The Cable should be so selected that it should be compatible up to the life of the solar PV panels i.e., 25 years.

4.8 Earthing:

i. The earthing shall be done in accordance with latest Standards.
ii. Each array structure of the PV yard, Low Tension (LT) power system, earthing grid for switchyard, all electrical equipment, inverter, all junction boxes, etc. shall be grounded properly as per IS 3043-2018.
iii. All metal casing/ shielding of the plant shall be thoroughly grounded in accordance with CEA Safety Regulation 2021 or amended with time to time. In addition, the lightning arrester/masts should also be earthed inside the array field and the position & height of the lightning arrester/mast should be such that it would cover the entire volume of the SPV Panels to conduct through cable/ GI strip with proper insulation.
iv. Earth resistance should be as low as possible and shall never be higher than 5 ohms.
v. For all grid connected rooftop solar PV systems, separate three earth pits shall be provided for individual three earthing viz.: DC side earthing, AC side earthing and lightning arrestor earthing with proper insulator.

4.9 Lightning Protection System:

4.9.1 The SPV power plants shall be provided with lightning & over voltage protection, if required. The main aim in this protection shall be to reduce the overvoltage to a tolerable value before it reaches the PV or other sub system components. The source of over voltage can be lightning, atmosphere disturbances etc. Lightning arrestor shall not be installed on the mounting structure.

4.9.2 The entire space occupying the SPV array shall be suitably protected against Lightning by deploying the required number of Lightning Arrestors (LAs). Lightning protection should be provided as per NFC17-102:2011/IEC 62305 standard.

4.9.3 The protection against induced high voltages shall be provided using Metal Oxide Varistors (MOVs)/Franklin Rod type LA/Early streamer type LA.

4.9.4 The current carrying cable from lightning arrestor to the earth pit should have sufficient current carrying capacity according to IEC 62305. According to standard, the minimum requirement for a lightning protection system designed for class of LPS III is a 6 mm2 copper/ 16 mm2 Aluminium or GI strip bearing size 25*3 mm thick). Separate pipe for running earth wires of Lightning Arrester shall be used.

4.10 Surge Protection:

4.10.1 Internal surge protection, wherever required, shall be provided.
4.10.2 At the DC Input side of the controller, it should have protection from an External Surge Protection.
4.10.3 For SPDs IEC 63227 and its updated version or amendment should be followed.

4.11 Metering

4.11.1 A Rooftop Solar (RTS) Photovoltaic (PV) system shall consist of following energy meters:

i. Net meter: To record import and export units
ii. Generation meter: To keep record for total generation of the plant.

4.11.2 The installation of meters including CTs & PTs, wherever applicable, shall be carried out by the respective Discoms as per the terms, conditions and procedures laid down by the concerned SERCs/DISCOMs.

5 Measuring Equipment's:

5.1 **I-V Tester:** I-V tester is a highly effective tool to check for deterioration in performance of the system. It can be used to identify and locate module or wiring issues and compare power generation performance against previous performance data or product warranty data. I-V curve measurements can also highlight the effect of partial or uniform shading and demonstrate the improvement in performance after module cleaning.

5.2 **Thermography Camera:** IR imaging is done to determine the causes of power deficiencies in several components of the PV plant. O&M personnel can use a number of diagnostic procedures. Thermal imaging of all the PV plant components like PV modules, array junction boxes, inverters, and cables is used to identify faults in the system that may not be visually identified.

5.3 **Clamp Meter:** A clamp meter is an electrical testing tool that combines current sensor with a basic digital multimeter. The clamps measure current and the probes measure voltage. Having a hinged clamp jaw integrated into an electrical meter allows consumers to simply clamp around wire, cables and other conductors at any point in the electrical system and measure its current, without disconnecting it. It measures AC & DC voltage, AC current, continuity, resistance, and with some models, DC current, temperature, capacitance, frequency and more. Typically, they measure to the nearest tenth of a unit making them perfect for electrical work.

5.4 **Pyranometer:** An instrument for measuring the intensity of solar irradiance, normally used to measure global irradiance on a horizontal plane. Pyranometers are generally high precision, high-cost instruments using thermal sensors in a glass dome. The dome on a pyranometer acts as a radiation filter that blocks thermal radiation. The working principle of the pyranometer mainly depends on the difference in temperature measurement between two surfaces like dark and clear. The solar radiation can be absorbed by the black surface on the thermopile whereas the clear surface reproduces it, so less heat can be absorbed. The thermopile plays a key role in measuring the difference in temperature. The potential difference formed within the thermopile is due to the gradient of temperature between the two surfaces. These are used to measure the sum of solar radiation.

5.5 **Multimeter:** A Digital Multimeter is a measuring instrument which can measure several parameters of an electric circuit. The standard measurements it performs is mentioned described in this section. The parts of the multimeter include:

i. Display screen: The screen displays the numerical value of the parameter being measured

ii. Selection knob: A multimeter performs many tasks like reading voltage, current and resistance. The selection knob allows the user to select the required task.

iii. Port: There are two ports on the front of the unit. One is the mAVΩ port which allows the measurement of all the three units: current up to 200 mA, voltage, and resistance. Various types of digital multimeter are commonly used to measure the output of the PV module and string as well as to test ac equipment such as inverters and other circuits.

5.6 **Megger:** The Megger test is a method of testing making use of an insulation tester resistance meter that will help to verify the condition of electrical insulation**.** Insulation resistance quality of an electrical system degrades with time, environment condition i.e., temperature, humidity, moisture, and dust particles. It also gets impacted negatively due to the presence of electrical and mechanical stress, so it has become very necessary to check the IR (Insulation resistance) of equipment at a constant regular interval to avoid any measure fatal or electrical shock. The IR gives a measure of the enduring power of an insulator to bear the service voltage without any current leakage path. It is measured using an instrument named Megger test capable of impressing D.C. voltage between its two probes, automatically calculating and then displaying the IR value.

5.7 **Earth resistance meter:** The purpose of earthing is to minimize the effect of transient voltage that occurred due to a strike of lightning. The method of testing considers three points of ground contacts, 1) an earth electrode, 2) a current probe 3) a voltage probe. Hence the digital earth tester injects current into the tower footing earth electrode under test. An alternating current (I) is passed through the outer electrode I, the voltage is measured by the inner electrode (P) at an intermediary point between the inner and outer electrodes. The current flows from the earth to the remote current probe and returns to the tester. As the current flow, a voltage drop takes place. This voltage drop is proportional to the amount of current flow and the resistance of the earth electrode.

5.8 **Anemometer:** The wind load on the solar panel and mounting structure can be assessed using Anemometer. It uses an electrically animated hot piece of wire similar to the thread in an out-of-date light bulb past which the wind blows. As the wire chills, its electrical confrontation changes can be measured to figure out the amount of cooling and the wind speed.

5.9 **Vernier Calliper:** Vernier calliper can be used to measure the thickness of the mounting structure to check whether the structure is in concurrence with the specifications

6 Occupational & Safety Standards:

Before starting installation work, identify all personal health and safety risks related to the project site. After identifying all possible risks, suggest the ways to mitigate the risks so that they are corrected before proceeding with the installation and commissioning work. A wrong safety assessment will impact the installation schedule and could result in serious injury to the installer and other personnel in the vicinity.

Risk involve during PV system installation are:

i. Falling from the roof.
ii. Electrocution - When the wiring of the PV modules in series creates a solar array with a DC voltage, it reaches a “deadly” voltage (≥120 V DC).
iii. Injuries from lifting and installing heavy inverters.
iv. Injuries from falling objects from roofs.
v. Exposure to the Sun.
vi. Insect bites – some insect may be poisonous.
vii. Cuts and bumps.
viii. Thermal burns.

6.1 Personal safety

i. A work partner (never work alone).
ii. Safety plan & first aid kit.
iii. An understanding of safety practices, equipment, and emergency procedures.
iv. Safety helmet & eye protection.
v. Proper measuring equipment’s: electrical & dimensional.
vi. Appropriate safety harnesses, if working on roof.
vii. Tape, wire nuts or cable connectors to protect cable terminals.
viii. Fire extinguisher.
ix. Appropriate ladder.
x. Appropriate lifting equipment’s.
xi. Suitable labels on all equipment, wiring, etc.

6.2 Electrical Safety: Major causes for these fatal accidents are snapping of conductor, contact with live wire/ equipment, leakage current, defective tools and apparatus,negligence on safety measures and inadequate maintenance of electrical wiring. In a grid connected PV system, multiple numbers of PV modules are connected in series, producing a DC voltage of 150V – 850V as input to the grid tied inverter. Similarly, the output of an inverter will be 230Vor 415V AC. Therefore, in the event of any fault or leakage, any metallic part of a grid connected solar PVsystem can potentially cause severe electric hazards in the form of shock, arcing and fire. Hence only certified electricians trained in solar PV installation are to be engaged to install, operate, and maintain electrical components and equipment in a grid connected PV system.

The following procedures must be followed by the PV system installers and supervisors:

i. Ensure all personnel safety resources are available and in good condition.
ii. Check all electrical measurement equipment for function and accuracy.
iii. Check the existing earthing system at the project site using the earth resistance tester.
iv. Make sure there are no uninsulated electrical cables passing through the installation area.
v. Cordon off the working area during installation and do not allow children to enter.
vi. Never disconnect a wire before you have checked the voltage and current.
vii. Do not presume that everything is connected and working as designed.
viii. Do not trust switches to operate perfectly and do not "believe" schematics.
ix. Always reaffirm isolation procedure.
x. Always "test before you touch" to establish whether circuits are live or not.
xi. Ensure that the earthing structure is completed and tested before fixing the modules.
xii. Do Not connect the module in series while fixing the modules on the structure.
xiii. Strings are connected when the system is ready for commissioning.
xiv. Ensure that no exposed DC cables are hanging and lying on the roof.
xv. Ensure that the string cable joints are not exposed and soaked in water.
xvi. Tighten the string cable joints (MC4 or equivalent) using appropriate tools and NOT by hand.
xvii. Ensure all DC/AC cable joints are protected and inside a combiner box having IP65 or above.
xviii. All DC/ AC cables must be protected from any possible physical damage.

6.3 Fire Safety

A grid connected solar PV system consists of several modules, connected in series which produces DC voltage ranging from 150V to 850V. With such a range of DC voltage, it is very easy for an electric arc to be established and hence subsequent fire as a result of loose connections or short-circuit in the system. Fire in a PV system primarily results from poor installation, wrong system design, underrated cables, loose connection, poor O&M, incorrect or faulty equipment, absence of isolator switches and most importantly, damaged DC cables as a result of mechanical stress, action of animals or vermin.

PV module is a current limiting device and fuses installed in the strings are sized based on current at peak solar irradiance. Since solar radiation level is normally at lower level than the peak value, fuses are not likely to operate under short-circuit conditions. In such case a short circuit fault in the system may be unnoticed and unattended.

Below is the list of general requirements for fire safety in rooftop solar PV systems:

a) **Access**
b) **Pathways**
c) **Smoke Ventilation**

Solar PV system should be installed such that it:

i. Ensures convenient access to the roof.
ii. Provides pathways to specific areas of the roof.
iii. Provides emergency exit from the roof.

Location and Routing of the DC Cable:

i. Ensure that no exposed DC cables are hanging and lying on the roof.
ii. All DC cables must be protected from any possible physical damage.
iii. DC combiner boxes should be located such that conduit runs are minimized
iv. Place DC cables separately from AC cable routes and distinctly marked with "DC cables."
v. Cable trays must be covered by lid and must not have sharp edges and bends.
vi. When cables trays or conduits cross pathways it should be covered by a bridge made of strong and durable material.

System Isolation

i. Load breaking DC isolators must be installed to separate PV array & inverter.
ii. DC isolator must have mechanisms for independent manual operation.
iii. DC isolators will not be polarity sensitive.
iv. Be rated to interrupt full load and prospective fault currents from the PV array and the grid.
v. Be installed in an accessible area.

Marking and Signage: Marking is needed to provide emergency responders with appropriate warning and guidance so that they can work their way around the system and how to isolate it. This can facilitate identifying energized conductors or wires that connect the solar modules to the inverter, as these should not be cut when venting for smoke removal.

IEC 62548 indicates the following signs (using local language or using appropriate local warning symbols)

i. Sign at all points of isolation of all sources of supply (PV array DC isolator, Inverter AC isolator).
ii. Sign at main service disconnection switch.
iii. Sign at the distribution board to which the supply from the inverter is connected.

7 Installation Manual

This module has been compiled with the help of different training materials and resources and reference of relevant IEC and BIS standards. It is largely applicable and adequate for small grid connected rooftop solar PV systems.

This module step-by-step installation and commissioning proceduresof grid connected rooftop PV systems in line with relevant IEC and BIS standards, CEA regulations and international best practices guidelines to ensure reliable system performance and electrical,mechanical, and personal safety. Technical information and approach of this module is based on the predominantly available commercial technologies and components. Before starting the installation process, the installer must go through all installation documents and verify the quantity and availability of listed equipment, accessories, and tools for installation and commissioningof the solar PV system. Verification of the quantity and availability must be done before starting the installation procedure to minimize the risk of project delay or an incomplete job due to non-availability orshortage of the equipment, accessories, and tools. The installation and commissioning procedures for grid connected solar PV systems are presented in twelve steps. These steps are to be followed in sequence.

The installation procedures include twelve steps as below. These steps can be followed in sequence.

i. Site survey and shadow analysis
ii. Installation of PV array mounting structure
iii. Installation and testing of structure earthing system
iv. Installation of PV modules
v. Earthing of PV module frames
vi. DC cabling
vii. AC cabling and installation of inverter
viii. System protection and safety
ix. Placing of signage
x. Pre-commissioning tests
xi. Commissioning the system
xii. Anti-Islanding functionality test

7.1 Step 1: Site Survey and Shadow Analysis

The site parameters that influence performance and reliability of a PV system are - access to solar radiation, near shadow and far shadow, ambient temperature, air flow and ventilation, wind speed, height of building, terrain, orientation, dust level and pollution, salinity, humidity, extreme weather conditions etc. Several parameters are likely to be variable from one site to another even in the same geographical area. Therefore, it is crucial to plan a solar PV project to suit the site parameters and to select the right components and customize the design accordingly to ensure better performance and safety. An inaccurate site assessment will lead to wrong design and installation of a PV system, which eventually follows into poor maintenance, poor performance and unreliable system functioning.

Pre requisite for a Site Survey:

i. Personal protective equipment (as applicable to site condition)
ii. A Solar Pathfinder or Sun eye to identify / determine shadow free area
iii. A compass to record direction (Mobile app is available)
iv. A measuring tape/ digital distance meter to measure distance
v. An angle measuring equipment (Mobile app is available)
vi. A notebook
vii. A working partner (Never survey a site alone)

Tasks to be performed during site survey:

Determine PV array location conducting shadow analysis:

i. Carry out shadow analysis to find the area which is free from shadow in all days of the year
ii. Ensure that the PV array will have safe access for maintenance and fire safety
iii. Ensure that PV array has ample space for air cooling
iv. Ensure that modules are protected from theft and vandalism

Conduct shadow analysis at site:

Objects that come in the path of the incident solar rays any time during the day, will cast shadows and hencereduce the solar generation. A taller object located in the east direction would cast shadows during morningand a taller object located on the west direction would cast shadows during the afternoon. When multiple rows are placed, one row can cast shadow on the other if not properly placed.

> ***Important to Note:***
>
> *Shading does not only lead to lower generation but can also damage the PV modules over a period of time.*
>
> *Objective of shading analysis should not end with loss estimation but to understand and review unavoidable shadow, select appropriate inverter, and optimize string design to minimize loss due to shadow*

Procedure to follow shadow Analysis:

The most accurate and easy method to determine usable and shadow free area is by using a reliable tool. shadows, one can easily determine whether the location is shadow free or if shadow is unavoidable, how much energy will be blocked by the shadow until what time and which months of the year. When the position and height of the object are known, it is easy to calculate shadow length at different times of the day using a simple trigonometry formula as shown below. Azimuth angle and altitude angle can be derived from various web tools that are available in web domain.

To calculate minimum distance from the objects to proposed PV array to avoid shadowing. Consider azimuth and altitude angle on 21st December (Northern Hemisphere)to get maximum distance in the year.

Shadow analysis can also be performed through desktop analysis using simulation software available in the digital platform. However, results from such an analysis solely depends on the accuracy of inputdata i.e., height, breadth of the object and distance from the solar array location. When shadow analysis is performed with software, confirm the actual physical dimension of the objects that potentially cast shadow.

Determine suitable location for inverters and other electrical equipment:

i. Location of string combiner box, inverters and instruments should be such that their access is controlled.
ii. Minimum distance from the PV array to reduce losses.
iii. Protection from the environment as needed by the inverter class.
iv. Inverter should be installed in such a place where there is enough space for cross ventilation, heat dissipation and maintenance. The inverter manufacturer generally recommends this in their installation manual.
v. The location of overcurrent protection devices and/or load breaking disconnecting means shouldbe at the end of the cable that is electrically most remote from the PV modules.

Identify cabling routes and therefore the required cable run distances:
Determine cable routes and hence cable length based on array location, combiner box location, inverter location and location of main switch board. Cable routes are not always the shortest paths of the cables. The cable routes have to be decided based on wiring rules, considering the safety of cables and personnel alike.
Please follow the steps below:

i. Verify the location of equipment and routing of the cable at the site and measure cable length andcompare with the drawing / design documents.
ii. Determine the length of conduit or cable tray required for the installation.
iii. Prepare the cables according to the length and size as determined after site measurement

Prepare and maintain cable cutting schedule as per table below:

Sl. No.	Cable Segment	Length (m)	Size (mm^2)
1	String 1: Array to DC Combiner Box		
2	String 2: Array to DC Combiner Box		
3	String 3: Array to DC Combiner Box		
4	String 4: Array to DC Combiner Box		
6	DC Cable: DC Combiner Box to Inverter		
7	AC Cable: Inverter to Main Switch Board		
8	Conduit for Cable from Arrays and from Combiner Box to Inverter		
9	Structure Earthing Terminal bar and Conductor		
10	Inverter Earthing cable or conductor		

7.2 Step 2: Installation of PV Mounting Structure:

Failure of PV array mounting structures due to strong winds is a rising concern in Indian solar projects today. It is quite common for PV array mounting structures to be conceptualized and designed primarily toenhance energy generation considering area specific tilt angle and use of tracking facility etc. Many solar PV systems are reported to be damaged due to inadequate design consideration for wind loading. Apart from the strength and wind loading capacity, a mounting structure must ensure that the PV array receives optimum solar radiation and reduces temperatures loss by allowing enough air circulation. Itis also important to ensure that factors such as structure design, placement, orientation, tilt, and shading arealigned with electrical string design and choice of inverter.

Wind loading on PV array mounting structure:

according to IS 875 Part 3: Wind Loads on Buildings and Structure. The PV array mounting structure for any site shall be designed to withstand existing wind speed for the areas under that zone.

Design of wind pressure must be calculated over basic wind speed, multiplying by the factors derived for -height of the building, topography, pressure coefficient based on roof type and slope, exposure category and importance factor as per IS 875 (Part 3) or ASCE-7.

Measures to be taken to minimise wind pressure on the mounting structure:

Keep the "effective wind area" as low as possible considering smaller mounting frame size and lower tilt angle.

On a flat RCC roof, keep the tilt angle of module mounting structure less than 15^{o} to minimise wind pressure.

On a inclined roof, use the same tilt as that of the building roof. Never create another tilt on a inclined surface.

Never mount PV modules at the edges and corners of a building roof (pressure co-efficient zones) to minimise wind pressure.

Protection against corrosion: The steel structure will be hot dip galvanized and the aluminium structure will be anodized. These coatingsprotect the structure from corrosion. Do not drill, weld, or cut the structure at the site. This will damage thecoating and corrosion will be accelerated.

Tilt angle and orientation: The recommended tilt angle of a module mounting structure to minimize wind pressure is $<15^{o}$ for a flat surface. However, a minimum tilt of 10^{o} should be maintained for natural cleaning of modules. Ideal orientation of a fixed PV Array should face towards true south (in northern hemisphere). However, for structural uniformity and to accommodate more capacity on a limited space of a RCC flat roof, the orientation could be aligned with roof orientation. In case of an inclined roof, PV modules should always be installed at the same tilt and orientation of the roof. A racked mounting structure over a inclined roof is not recommended for strong wind zones.

Mounting frame size:

A mounting frame is a single table of mounting structure where PV modules are fixed either in landscape or portrait position. As design wind load is proportionate to the projected area normal to the wind, selectionof mounting frame size will decide wind pressure on the PV array. Since Assam is situated in very high damage risk wind zones, it is of utmost importance to select the right mounting frame size and module position to minimize wind load and keep the solar plant safe. It is recommended that, for a RCC flat surface,not more than one module in landscape (parallel to the roof surface) should be installed in a racked mountingstructure. Portrait position of module shall be avoided to minimize effective wind area.

Determining space between two rows:

Space between two rows can be determined by analysing the sun's position for winter solstice (21st December). In this case, the object that will create shadow is the PV array (row) on the south. The minimum space between two rows shall be higher than maximum length of the shadow at desired time of the day says, 8.00am in the morning and 3.00pm in the afternoon (local time) for lowest position of sun on 21st December. The length of the shadow will be determined by the azimuth and altitude of the sun during the desired time and differential height of the lowest point of the row in the north and highest point of the row in the south.

Access to PV modules for maintenance: While installing PV arrays on RCC flat roof, leave adequate space from the parapet wall to avoid shadow on the modules as well as for convenient movement of maintenance personnel. This can be determined by analysing sun position and height of the parapet wall as described earlier. A minimum gap of 0.5m betweentwo rows should be maintained for movement of maintenance personnel for cleaning or other maintenancework.

When modules are installed on an inclined roof, adequate gap between two rows and frames must be keptas such that maintenance personnel can reach to each corner of the modules without stepping on to it. An additional walkway may be provided in between the rows to enable safe cleaning and maintenance of PV modules

Ventilation for cooling of PV Modules: The temperature of a crystalline photovoltaic cell increases while PV modules are in operation. As temperature increases, efficiency of the module decreases. Therefore, it is important that there is adequate ventilation for airflow on the backside of the PV modules to remove the generated heat to minimize the power loss due to temperature build-up. It is recommended that, when PV modules are installed on an RCC flat roof, a minimum clearance of the structure from the roof level should be 300 mm.

In case of an inclined roof, a gap of 100 -120 mm should be maintained between roof material and solar modules to ensure natural ventilation and cooling of PV modules. Insufficient cooling will result in high module operating temperatures and lower outputs from the modules

Ensure there is no Leakage on the Roof: Installation of a PV array mounting structure on the roof requires drilling of holes through roofing materialwhich makes the roof vulnerable to leakage in cases of rain. Leakage from the roof after installation of solarPV modules is a common problem because of poor installation practice. Therefore, it is important to understand best practices of installation to prevent rainwater leakage.

The following key points to be kept in mind:

i. Avoid drilling RCC roofs, instead use concrete ballast and adhesive materials to fix the structure.
ii. Use proper flashing methods and sealant materials for metallic and tiled inclined roofs.
iii. Use synthetic sealant which cures under water and can handle temperature up to 100 - 120°C.
iv. Always fasten the roof attachments on the crest (top of corrugation) to fix the attachment.
v. Never drill on the trough (bottom of the corrugation).
vi. Elevate the sealing area above possible water level. In case of low slope roof, seal the base of theflashing.

7.3 Step 3: Installation and testing of structure earthing system

After installation of module mounting structure, the next step is to provide a continuous equipotential bondbetween mounting structure and module frames.

i. Following procedures to be followed:
ii. Verify the earthing conductor routing plan.
iii. Prepare earth terminal bar / conductor, lugs, clamps, earthing rod and earth pit as per drawing.
iv. Ensure all module frames and each part of mounting structure are electrically bonded.
v. Use proper WEEB for bonding.
vi. Find the best location for earthing pit where soil is wet, and resistivity is least.
vii. Attach the earthing terminal bar /wire with earthing rod.
viii. Connect terminal bar to structure.
ix. Ensure all the connections are neat and tight.
x. Test earthing continuity and resistance of earth electrode after installation.

The conductor used to earth the exposed metallic frames of the PV array shall have a minimum size of 6mm^2 copper or equivalent if there is no lightning system installed for the system. When a lightning protection system is installed, minimum size of the conductor shall be 16mm^2 copper or equivalent. PV array bonding conductors should run as close to the positive and negative PV array and or sub-array conductors as possible to reduce induced voltages due to lightning.

Procedure for measurement of earthing continuity and earth electrode resistance using earth resistance tester – Follow in sequence:

i. Short the P1 and E1 terminal of the Earth resistance tester.
ii. Connect the electrode under test to E1 terminal of earth resistance tester.
iii. Using a hammer, dig an electrode at a distance (D) of minimum 30 meter from the test Electrode.
iv. Connect this electrode to E2 terminal of earth resistance tester.
v. Using a hammer, dig another electrode in between both the electrodes at 50% of D.
vi. Connect this electrode to P2 of the terminal.
vii. Take reading by rotating the handle of Earth resistance tester or press push button.
viii. Repeat the above procedure by changing the location of middle electrode to 40% and 60% of D.
ix. To get the resistance of electrode, take mean of these three readings.

Desired electrode resistance is around 1 Ohm and it must be lower than 5 Ohms.

7.4 Step 4: Installation of PV Modules.

Modules should be installed after the earthing system of structure is completely constructed. It is importantfor the installer to know properly about handling, packaging, and storage of PV modules so that modules donot get damaged during the process of installation.

Please follow the instruction given in this handbook carefully while handling, storing, and installing thePV modules.

Important to Note:

Do NOT connect the modules in the strings while fixing the modules in the structure. This will produce high DC voltage, which is extremely dangerous for the installer. Connection will be done at a later stage.

A. Handling and packaging:

i. Solar modules should be stacked, packed, and transported vertically and separator should be placedbetween each module. Horizontal stacking should be avoided.

ii. If due to unavoidable reasons, the modules are required to be stacked horizontally, introduction ofa good buffer material between each module and around the modules is necessary to reduce potential damage. Also, additional protection is to be added to the four corners of each module andnot more than six modules should be packed in one box.

> ***Important to Note:***
>
> *Horizontally stacking the modules causes stress on the modules at the bottom and can lead to micro-cracks that will be not be detected by naked eyes. Even if the separators are used, they are not strong and wide enough to sufficiently separate the modules from each other, thus the upper layers of the stack cause weight stress towards the lower layers that leads to micro-cracks in the cells.*

B. Transport and unloading.

i. Modules may be damaged externally or internally, causing micro cracks while loading, transport and unloading. Any external damage or breakage is visible but internal damage to cells is not visibleby naked eye and therefore precaution during loading, transportation and unloading should not be underestimated if there is no visible damage to the modules.
ii. To avoid breakage and micro-cracks during loading, transportation and unloading of modules, themodules must be packaged properly even if the distance of travel is short. Rough handling duringloading and unloading and walking on the package must be avoided. While carrying the modules in a truck on a bumpy road, the speed of the truck must be controlled and kept at minimum to avoidvibration and jerking.
iii. PV modules should be unpacked in the vertical manner as shown in the diagram by two persons. Also, care should be taken to avoid falling over of one module onto the other inside the packagingbox. Do NOT use a knife to cut the zip-ties, instead, use wire cutting pliers

C. Storage of PV Modules:

i. Similar to packaging, solar modules should be stacked, packed and stored vertically and separatorsshould be placed between each module. Horizontal stacking and storing should be avoided.
ii. If due to unavoidable reasons, the modules are needed to be stacked and stored horizontally, a goodbuffer material should be introduced between each module and around the modules. NOT more than six modules should be stored together.

D. Module Installation.

i. PV modules can be fixed either by bolt method or by the clamp method.
ii. Understand and follow manufacturer installation manual and recommendations.
iii. Use personnel safety equipment while installing the modules.
iv. Use of insulated tools and gloves while working with modules.
v. Do not step on the PV module as this will damage to the solar cells inside the module.
vi. Ensure electrical connectors are well protected from ingression of water and dust.
vii. Do not install/ handle PV modules under gusty winds and if there is rain.
viii. Use appropriate tools and equipment provided/ recommended by manufacturer.
ix. Do NOT connect the modules in the strings (connect in series)

7.5 Step 5: Earthing of PV module frames

After physical installation, PV module frames are to be bonded together and connected to main earthing conductor of the mounting structure. PV array bonding conductors shall run as close to the positive and negative PV array and or sub-array conductors as possible to reduce induced voltages due to lightning. The earthing conductor must be properly fastened to the module frame to ensure good electrical contact. PV module frames have anodized coating which is an aluminum oxide, and it works as insulation. Therefore, appropriate means should be employed, which will crash the aluminum oxide coating and establish electrical bond between PV module frames and the structure.

7.6 Step 6: DC cabling

It is important to minimize voltage drop loss in the cables for a desired performance of solar PV systems. Ensure that aggregate voltage drop in all DC cables is less than 3% as recommended by IEC 62548 PV array design requirements. Voltage drop in DC cables can calculated using formula below:

$$A_{DC\ Cable} = \frac{2\ x\ L_{DC\ Cable}\ x\ I_{DC}\ x\ \rho}{Loss\ x\ V_{mp\ string}}$$

Where,

$L_{DC\ Cable}$= Route length of DC cable in meters (multiply by 2 for total circuit wire length)

I_{DC} = DC current in amperes

ρ = Resistivity of the wire in $\Omega/m/mm^2$ (For copper $\rho = 0.0183\ \Omega/m/mm^2$)

$A_{DC\ Cable}$ = Cross sectional area (CSA) of DC cable in mm^2

$Loss = Voltage\ drop\ in$ %

$V_{mp\ string}$= String Voltage (No. of modules in string x V_{mp} at maximum temperature)

Module wiring or stringing: After physical installation and establishment of earthing bond of the frames, PV modules are connected inseries electrically to form a string.

A. <u>Precautions to take while wiring modules:</u>

i. Only a trained and qualified installer should perform all wiring.
ii. Use stainless steel clamp or UV protected cable tie to fix cables.
iii. DO NOT connect all the module in series to avoid high DC voltage.
iv. Final connection will be done when the system is ready for commissioning.
v. Ensure electrical connectors are well protected against corrosion and soiling.
vi. Ensure that connectors are corrosion free, cleaned with absolutely no gaps between the contacts.
vii. DO NOT allow any inflammable liquids/gases near installation area.

Important to Note:

While connecting modules, each string should have one MC4 disconnected until all wiring to the DC combiner box has been completed. This is to ensure that no one is working on live dangerous DC voltage.

B. *Follow the steps below in sequence for module wiring or stringing:*

i. Review the DC cable wiring diagram.
ii. Review module interconnection (string or series) diagram.
iii. Check that there isn't any bare cable in module wire.
iv. Connect DC cable connector (MC4 or equivalent) properly with crimping tool.
v. Connect number of modules in series in accordance with the wiring diagram provided.
vi. Attach the cables with cable tie wraps to the module frame and/or rails.
vii. Ensure minimum looping in cable.
viii. Ensure NO cable is hanging loose.
ix. Label the terminals with "+" and "-" sign using cable tag.

Four important instructions to follow:

Always verify the voltage and polarity of each individual string before making a parallel connection. Electrical and electronic components can be irreparably damaged if an array string is connected in reverse polarity to another.

If you measure a reversed polarity or a difference of more than 10V between strings then check the string configuration before making the connection.

Minimize the area of conductive loops to reduce the magnitude of lightening-induced overvoltage as shown in the figure below.

Keep bending radius of cables more than 40mm or as recommended by module manufacturer. Maintain correct cable routing as shown in the picture below.

E. Installation of DC Combiner Box: DC combiner boxes are generally installed after installation of your PV and following steps need to be followed:

i. Review the DC combiner box internal wiring diagram.
ii. Prepare the diagram if there is no wiring diagram.
iii. Check all components, such as fuses, DC isolator and SPD (Surge Protective Device).
iv. Ensure the cable glands are of appropriate ratings and size.

v. Check IP (Ingress Protection) rating and verify if there is any violation of IP rating.
vi. If DC combiner box is pre-wired, check if all wiring is done in accordance with the drawings.
vii. Install the combiner box in identified/ marked location.
viii. Install conduit for cabling.
ix. Keep the DC isolator in OFF position.
x. Place the fuse disconnects in the open circuit condition.
xi. Install the SPD (surge protective device).

Installation of DC Cable from PV array to DCDB and DCDB to Inverter: DC cables are installed after installation of DC combiner box, to connect PV arrays on one side and the inverter on the other side. DC cables should be installed within the conduits or cable tray with lid. Installation of DC cables shall be undertaken with care such that the possibility of line-to-line and line-to- earth faults occurring is minimised. All connections shall be verified for tightness and polarity during installation to reduce the risk of faults and possible arcs during commissioning, operation, and future maintenance. Particular attention needs to be given to ensure the protection of wiring systems against external influencesand all cables must be protected from mechanical damage.

Procedures to follow:

i. Review the DC wiring diagram.
ii. Install conduit/ cable tray from roof to DC combiner box.
iii. Secure all conduits/ cable trays to the building.
iv. Pull the DC cables through conduit/ cable tray from roof to the DC combiner box.
v. Leave excess wire at both ends (roof and combiner Box);
vi. Use sealing materials (silicone) to prevent leakage into the conduit and the penetration at roof.
vii. Terminate DC cables in DC combiner box.
viii. Install cable connectors (MC4 or equivalent) at both ends and tag cable with “+” and “-“sign.
ix. Tighten the cable connector using appropriate tools.
x. Test the cables to ensure correct polarity labelling.
xi. Keep all connectors open (OFF).
xii. Use cable glands according to size of the cables.
xiii. Tighten the cable glands using appropriate tools.
xiv. Use EDPM rubber hole stopper to block unused holes in the combiner box.

7.7 Step 7: AC cabling and installation of inverter

When DC cables and DC combiner boxes are installed; the next step is to install AC cables and the inverter.Ensure that total voltage drop in all AC cables is less than 2% according to IEC 62548. Voltage drop in ACcables can be calculated using the formulas below:

For AC cables in single-phase circuit:

$$V_{DROP_{AC}}(V) = \frac{2\ x\ L_{AC\ Cable}\ x\ I_{AC}\ x\ \rho\ x\ \cos\Phi}{A_{AC\ Cable}}$$

Where,

$L_{AC\ Cable}$= Route length of AC cable in metres (Multiply by 2 for total circuit wire length)

I_{AC}= Current in amperes

ρ = resistivity of the wire in Ω/m/mm^2

$\cos\Phi$ = Power factor

$A_{AC\ Cable}$ = Cross section area (CSA) of cable in mm^2

For AC cables in three-phase circuit:

$$V_{Drop(AC)}(V) = \frac{\sqrt{3}\ \times\ L_{AC\ Cable}\ \times\ I_{AC}\ \times\ \rho\ \times \cos\Phi}{A_{AC\ Cable}}$$

Procedures to follow:

i. Install the conduit/ cable tray.
ii. Pull the conductors through conduit or cable tray.
iii. Leave excess conductor or cable near each equipment terminal.
iv. Read inverter installation and operation manual carefully.
v. Ensure that there is adequate ventilation for the inverter.
vi. Ensure that no direct sunlight falls on the inverter.
vii. Mount the inverter with accessories provided by the manufacturer.
viii. Ensure there is no grid supply to the inverter.
ix. Complete the installation from the inverter to the AC isolator and energy meter as per the drawing.
x. Install the earthing connection as per inverter installation manual.
xi. Tighten the cable glands using appropriate tools.

Important to Note:

Adequate clearances between inverter and other objects have to be maintained for ventilation/cooling of inverter. Generally, instruction is given in the manufacturer's installation manual.

In general,

Minimum 20cm clearance to be maintained to the top and bottom of the inverter.
Minimum 10cm clearance to be maintained to the right and left of the inverter.
Keep adequate clearance to access the fans and air filters for regular cleaning.
Keep adequate clearance for cable entry.

7.8 Step 8: System protection and safety

A. Earthing System Configurations: Internationally, earthing systems are classified as TN System, TT System and IT System.

TN system - has one or more points of the source of energy directly earthed and the exposed and extraneous conductive parts of the consumer side installation are connected by means of protective conductors to the earthed point(s) of the source, that is, there is a metallic path for earth fault currents to flow from the installation to the earthed point(s) of the source. TN systems are further sub-divided into TN-C, TN-S and TN-C-S systems.

TT system - has one or more points of the source of energy directly earthed and the exposed and extraneous conductive parts of the installation are connected to a local earth electrode or electrodes are electrically independent of the source earth(s).

IT system - has the source either unearthed or earthed through a high impedance and the exposed conductive parts of the installation are connected to electrically independent earth electrodes.

In accordance to IS 3043: Code of Practice for Earthing, Indian distribution system uses an admixture of earthing types mentioned above. Different earthing systems for distribution network and corresponding earthing system for grid connected PV systems connected to the grid network need to be followed.

Protection against overcurrent:

Overcurrent within a PV array can result from earthing faults in array wiring or from fault currents due to short circuits in modules, in junction boxes, combiner boxes or in module wiring.

Sizing Fault current protection device:
As per IEC 62548: Design requirements for photovoltaic arrays, the rating of fault current protection devicefor each string should be

$$1.5 \times I_{SC\ MOD} \leq I_{TRIP} \leq 2.4 \times I_{SC\ MOD}$$

Where, $I_{SC\ MOD}$ is the short circuit current of the module
According to IEC62548, over current protection devices shall be installed in both positive and negative conductors.

B. Protection against effects of lightning and overvoltage:

To protect the DC system, surge protective devices shall be fitted between active conductors and the ground at the Inverter end of the DC cabling and at the array. All DC cables should be installed so that positive and negative cables of the same string and the main array cable are bundled together, avoiding the creation of loops in the system. The requirement for bundling includes any associated earth/bonding conductors.

C. Lightning Protection System (LPS)

The need for a lightning protection system is to be assessed in accordance with IEC 62305-2 and, if required,it should be installed in compliance with IEC 62305-3 or IS 2309. The lightning protection system must be able to provide coverage for full plant.
According to National Building Code of India 2016, vertical air-terminals are required for protecting roof mounted installations such as solar PV system.

7.9 Step 9: Placing of signage

It is important to have appropriate signage at the PV system to minimize any hazardous situations associated with the project site. Place the following signage in appropriate locations, as applicable. The signs should be legible from at least 0.8m.

Procedures to follow:

i. A “SOLAR DC” sign shall be located on all PV array and PV (string) junction boxes.
ii. Sign indicating “Live during daylight” shall be attached to all DC junction boxes and switches.
iii. The double pole isolator (disconnecting means) at the inverter should be labelled “PV Array DC Isolator”.
iv. Fire emergency information sign is required at the main building switchboard.
v. The existing main switch in the switchboard should be labelled “Main Switch”.
vi. The AC Isolator at the inverter should be labelled: “Inverter AC Isolator”
vii. A warning sign at the switchboard should be installed indicating that dual supplies exist and bothnormal and solar supplies should be disconnected when working on the switchboard.
viii. If the grid solar system is connected to a distribution board, then a warning sign should be installed atthat distribution board and at every distribution board back to and including the main switchboard.
ix. A sign informing people of the shutdown procedure should be in a prominent position. Thissign shall state the open circuit voltage and short circuit current of the array.

7.10 Step 10: Pre-commissioning tests

After completion of installation process, a pre-commissioning test must be performed. Conducting a pre-commissioning test is important to ensure there are no wrong connections in the system.

Procedure to follow in sequence:

i. Ensure that the PV arrays (string or strings) are in segments (maintain below 70V).
ii. Remove the string fuses if installed.
iii. Make sure that isolators and circuit breakers are in the ‘OFF’ position.

iv. Ensure that the PV array DC isolator and inverter AC isolator are in the 'OFF' position.
v. Ensure that the inverter is turned OFF.
vi. Measure and confirm that no voltage is present across any string.
vii. Measure and confirm that no voltage is present on the output side of the DC combiner box.
viii. Check continuity of cables and complete the array cabling.
ix. Confirm that the polarity of each of the array connections is correct.
x. Measure and record the open circuit voltage of each string as shown in the table below.
xi. Measure irradiance, ambient temperature, and cell temperature at the same time.
xii. Observe variation between effective (string) voltage and measured (string) voltage.
xiii. If there is a variation greater than 5% in V_{OC} (open circuit voltage) then investigate the problem.
xiv. Check the polarity at the input to the PV array DC isolator.
xv. Measure and record the open circuit voltage (V_{OC}) at the input to the DC isolator.
xvi. Check the polarity and continuity between the PV array DC isolator and the inverter.
xvii. Check the continuity between the inverter and the inverter AC isolator.
xviii. Check the continuity between the kWh meter and the inverter AC isolator.
xix. Measure the voltage of the grid on the output (grid side) of the inverter AC isolator.
xx. Measure the resistance of the earth system.

Format of table to record string voltage:

String No.	Irradiance (W/m^2)	Ambient Temp (°C)	Cell Temp (°C)	V_{OC} Effective (V)	V_{OC} Measured (V)	Variation of V_{OC} (%)	Acceptable (Yes/ No)
String 1							
String 2							
String 3							

7.11 Step 11: Commissioning the system

When you are sure that the conductors and connections are acceptable and the system has successfullypassed the pre-commissioning testing, then it's time to commission the system

Procedures to follow in sequence:

i. Refer to the inverter's system manual and follow the start-up procedure
ii. Check the inverter display and confirm that the solar array is supplying power to the utility grid.
iii. Measure either the AC or DC current using a clamp meter and compare inverter output
iv. Measure the DC input voltage and confirm that it is within the operating limits of the inverter
v. Measure the AC output voltage out of the inverter.

Format for recording information:

Time	Irradiance (W/m^2)	Ambient Temp (°C)	Cell Temp (°C)	V_{MP} Measured (V)	I_{MP} Measured (A)	P_{MP} ($V_{MP} \times I_{MP}$) (W)	AC Power in Inverter display (W)

7.12 Step 12: Anti-Islanding functionality test

Unintentional islanding (anti-islanding) can have undesirable impacts on customer and utility equipment integrity. If unintentional islanding is sustained for a significant period of time, personnel safety could become a cause for concern. To manage these risks, a series of functionality tests to be performed.

i. This test must be conducted during noontime in a sunny day.
ii. PV system shall produce more than 20% of the rated output of the PV array or the inverter –whichever is less.
iii. If there is more than one inverter, tests should be carried out for each inverter.

Tests to be performed in sequence:

A. Test 1: Inverter must cease supplying power within two seconds of a loss of mains

i. STEP 1: Keep DC supply from the solar array connected to the inverter
ii. STEP 2: Place the voltage probe in the inverter side of the AC main switch (on the load side of the switch.)
iii. STEP 3: Turn OFF the AC main switch through which inverter is connected to grid
iv. STEP 4: Measure the time taken for the inverter to cease attempting to export power with timing deviceand record.

B. Test 2: Inverter must not resume supplying power until mains have been present for more than 60seconds.

i. STEP 1: Keep DC supply from the solar array connected to the inverter.
ii. STEP 2: Place the current probe in the inverter side of the AC main switch (on the load side).
iii. STEP 3: Turn ON the AC main switch through which inverter is connected to grid.
iv. STEP 4: Measure the time taken for the inverter to re-energize and start exporting power with a timing device and record

8 Format for system documentation and handover to user.

On successful commissioning of the plant, the below information sheet must be completed and signed jointly with the owner of the plant. A copy of the same must be handed over to the system owner and onecopy should be kept with the installer.

Sl. No.	Parameters	Description
1.	**General Information**	
1.1.	Name of the System Owner	
1.2.	Contact phone number of owner	
1.3.	Email address if any	
1.4.	System location (physical address)	
1.5.	Geo-spatial coordinates (Take GPS data up to 6 decimal place)	
1.6.	System capacity (DC capacity kWp)	
1.7.	Date of commission	
1.8.	Implementing company	
1.9.	Service centre contact details of implementing company	Land phone contact: Mobile phone contact Email contact:
2.	**Solar PV Array**	
2.1.	Make and Model No.	
2.2.	Country of origin (separately for solar cells and module)	
2.3.	Power at STC with Tolerance	
2.4.	Total number of modules	
2.5.	Unique Serial Nos.	
2.6.	Presence of RFID tag	
2.7.	Quality Standard (BIS/IEC)	

2.8.	Safety Standard (BIS/IEC)	
2.9.	Date and year of obtaining BIS/IEC PV module qualification certificate	
2.10.	Name of the test lab issuing BIS/IEC certificate.	
2.11.	Warrantee against any manufacturing or material defect	
2.12.	Warrantee on performance (Power output)	
3.	**PV Inverter**	
3.1.	Make	
3.2.	Model	
3.3.	Capacity	
3.4.	Total number of inverters installed	
3.5.	AC output voltage and frequency	
3.6.	Installed outdoor or indoor?	
3.7.	IP rating?	
3.8.	Built-in meter and data logger for remote monitoring	
3.9.	Frequency tolerance	
3.10.	Voltage tolerance	
3.11.	Inverter efficiency	
3.12.	Total Harmonic Distortion	
3.13.	Power factor	
3.14.	Quality and Safety Standard (BIS/IEC)	
3.15.	Date and year of obtaining BIS/IEC for the inverter	
3.16.	Name of the test lab issuing BIS/IEC certificate	

3.17.	Warrantee against any manufacturing defect and violation of conformity of regulatory requirement	
4.	**Array Structure**	
4.1.	Type of structure used	
4.2.	Material of structure	
4.3.	Frame size and orientation (Portrait / landscape)	
4.4.	Thickness of structure materials	
4.5.	Type of coating	
4.6.	Type of grouting to RCC roof and size of PCC block if used	
4.7.	Material of fasteners (nuts, bolts, clamps, hooks etc.)	
4.8.	Tilt angle	
4.9.	Are the modules are installed facing true south? If not which orientation and angle of deviation from true south.	
4.10.	Clearance of lowest part of structure to the roof in mm	
5.	**DC String Combiner Box**	
5.1.	Make	
5.2.	Materials and IP rating	
5.3.	Rating of DC fuses if used	
5.4.	Rating of DC isolators	
5.5.	Type of and SPDs used	
5.6.	Have you marked cable ferrules for polarity identification?	
5.7.	Have you used one cable gland for one cable?	
5.8.	Have you tightened the cable glands properly?	

5.9.	Height of DCCB from ground/ floor in mm		
6.	**AC Distribution Box/ Board**		
6.1.	Make		
6.2.	Materials and IP rating		
6.3.	Type and Rating of AC isolator between inverter and grid network		
6.4.	Type of and SPDs used		
6.5.	Have you used one cable gland for one cable?		
6.6.	Have you tightened the cable glands properly?		
6.7.	Height of ACDB from ground/ floor in mm		
7.	**Metering**	**Solar meter**	**Net meter**
7.1.	Make		
7.2.	Type and Model		
8.	**Safety and System Protections**		
8.1.	Have you followed all fire safety norms as mentioned in the SOP for installation?		
8.2.	Make, current and voltage rating of DC isolators		
8.3.	Make, current and voltage rating of AC isolators		
8.4.	Earthing conductor material		
8.5.	Size of earthing conductor		
8.6.	Type of earthing rod and earth pit		
8.7.	Means of equipotential bonding of PV module frame and mounting structure (WEEB/ grounding bolt/ clamp)		
8.8.	Measured Earthing Resistance (To be measured as a part of pre commissioning tests)		

8.9.	Type of SPDs used in DC side	
8.10.	Type of SPDs used in AC side	
9.	**DC Cables**	
9.1.	Make	
9.2.	Type	
9.3.	Voltage rating	
9.4.	Size of string cables	
9.5.	Size of array cable from DCDB to inverter	
9.6.	Type of conduit/ cable tray used	
9.7.	Marking of cables/ cable route?	
10.	**AC Cables**	
10.1.	Make	
10.2.	Type	
10.3.	Voltage rating	
10.4.	Size of AC cables from inverter to ACDB	
10.5.	Type of conduit/ cable tray used	
11.	**Drawings & Manuals**	
11.1.	Whether all engineering drawings and SLDs provided?	
11.2.	Whether datasheet of all equipment provided?	
11.3.	Whether test results and commission data of the system provided?	
11.4.	Whether O&M manual / user manual provided which include the following minimum information?	
	Safety instruction	

	Procedures for verifying correct system operation	
	A checklist of what to do in case of a system failure	
	Emergency shutdown and isolation procedures.	
	Maintenance and cleaning recommendations	
12.	**Energy generation and performance ratio**	
12.1.	Projected annual energy generation of the installed PV plant	
12.2.	Estimated and guaranteed performance ratio of the plant	
12.3.	Tested performance ratio of the plant	
13.	**Shadow**	
13.1.	Is the PV array free from shadow (8:30 am to 3:30 pm)	
13.2.	Any object closed to the array that can create noon shadow?	
13.3.	Is there any mountain or tall object away from the system which can create far shadow?	
14.	**Result of anti-islanding functionality test**	
14.1.	Disconnection time for anti-Islanding functionality test	
14.2.	Reconnection time for anti-Islanding functionality test	
Signature of the House owner:		**Signature of the Installer:**
Name of the signatory:		**Name of the signatory:**

9 Annexure

9.1 Specifications / BOQ & Quality of Materials (List & Template)

Sr. No	Inspection item	Guidance	Observations
1	Access	[Access to roof, height of installation, use of ladder, etc for access] [Safety belt/ harness/ personnel lift used to climb the roof]	
2	Condition of roof	[Roof new/old, load carrying capacity, corrosion/leakage/ presence of skylights, provision of lifeline]	
3	Near object details	[Shadow casting object near the PV area]	
4	Far object details	[Any factory/towers/mountain ranges]	
5	MMS	[RCC/PCC, Ballast/Dead weight, etc], [Height [Deformation / corrosion of structures, nuts and bolts]	
5.1	Foundation	[Any crack, reinforcement exposed etc.] [strength of MMS connection to the floor, sharp edges (should not have)]	
5.2	MMS Configuration	[[Fixed/Seasonal/Tracker/Same as roof tilt] [Table / cluster size e.g., row x column]	
6	SPV Module	[Technology- Mono Crystalline, Poly Crystalline, Poly Crystalline, Thin film], [Capacity, Number]	
6.1	Cracks	[Minor/Major cracks]	
6.2	Deformities	[bubbles, holes in back sheet, yellowing of encapsulant, burnt or overheated solar cells, broken or twisted frames]	
6.3	Junction box	[Fixed or detached]	

6.4	Earthing	[Continuity between the modules and the MMS (Continuity meter would be required, which is typically available at the site]	
6.5	Soiling	[Module cleanliness, frequency of cleaning, water treatment, water TDS]	
6.6	Spare modules	[storage, packaging, no. of spare modules]	
7	Combiner box	[Structure mounted/Wall mounted Indoor/outdoor No. of inputs Opaque/transparent front Under canopy/ shade Metal/Polycarbonate/ ABS]	
8	Inverter Details	[Technology (e.g., string, micro, outdoor central, indoor central), make, capacity and no. of inverters]	
8.1	Safety	[Insulation mats, Negative earthing]	
8.2	Installation of inverter	[On structure, under canopy structure, prefab room, concrete room, container]	
9	ACDB / LT Distribution Box	[Floor mounted/Wall mounted With/without canopy Indoor/outdoor No. of inputs Metal/Polycarbonate/ ABS Cable support provided Earthing of body]	
10	Auxiliary Transformer, If applicable	[Block wise quantity Capacity Condition of silica gel]	
11	Inverter Station, if applicable	[Equipment's in the inverter station, check visually for sufficient equipment clearance in all directions, Cable trench covered properly, cable laying, provision of insulation mats, provision of adequate ventilation, provision of smoke detectors, CCTV, provision of lighting]	
12	Main Control Room, if applicable	[Equipment's in the control room, check visually for sufficient equipment clearance in all directions, Layout, AC/DC SLDs	

		displayed, Safety measures posters displayed, Emergency contact details, Cable trench covered properly, provision of insulation mats, provision of adequate ventilation, provision of smoke detectors, CCTV, provision of lighting]	
13	Cables and routing	[Securing of cables, bending radius, provision of conduits, laying of cables (trays, underground etc) Solar Cable- No of cores, cross section (size), Cu/Al. Strings to AJB & Inverter by Solar Cable- Core, Size, Cu/Al, DC Cable from structure to combiner box or string inverter- No of cores, cross section (size) DC Cable from combiner box to inverter- No of cores, cross section (size), armoured or unarmoured AC Cable from string inverter to ACDB - No of cores, cross section (size), armoured or unarmoured]	
14	Evacuation point details	[Location and distance from the plant site Voltage levels Uptime/ availability details Capacity of breaker at the feeder to which the plant is connected Loads connected to the evacuation feeder Presence of APFC panels in the feeder panel or the upstream panel]	
15	Earthing & Lightning Arrester	[Type of LA e.g., ESE type/Conventional, Nos. of LA, Down Conductor size & material, Nos. of earth pits, Type of earth electrode i.e., rod/pipe etc. Random earth resistance values Broken earth strips Redundant earth connections SPD earthing in combiner boxes]	

16	Plant Monitoring System	WMS & SCADA details	
17	Spare parts	[Are spares properly organized, Inventory maintenance register]	
18	HSE	[Emergency contact numbers at the site CCTV Cameras, quantity Fire extinguishers, quantity Fire protection system PPE (helmets and safety shoes) First aid kits in all MCR and ICR]	
19	Record maintenance	Records of module cleaning, breakdown records, preventive maintenance schedule and activities, water quality report, spare and inventory list, work permits, training, safety drills, grievances, accidents, incidents involving birds and animals etc.	
20	Commissioning Status (Applicable only for Commissioned Project)	Date of Commissioning, General details as on the date of visit, Any other sector specific requirement	

9.2 Pre-Dispatch Inspection for Modules, Inverters and BOQs

Basic Details

Details Required	Response
Date Of Inspection	….............
Name of the Supplier/Contractor	….............
Supplier's Inspection Call No.	….............
Place of inspection: Address?	Warehouse/OEM; ....
Work order no. and date	….............
Order Quantity (pls specify ?)	….............
Name of District and quantity	….............
Inspection Order Call No.	….............
Name of Inspecting Officers	….............
Offered quantity for Inspection.	….............

Solar PV Panel

Components/Characteristics	Type of check	Acceptance norm	Response by inspection officer	Remark; If any?
Visual Checks: -				
Make (Logo) & Model No. of PV module	Visual	As per latest ALMM issued by MNRE	….............	
Unique Serial No. of each model	Visual		….............	
Whether reference module (Specific Sr. No.) has valid calibration certificate which is traceable to NABL lab?	Visual	Valid certificate should be present.	Yes/No; IF yes specify the SI.No.-	

IEC Test certificate detail	Visual	Lab should be NABL accredited.	Name of the lab…......................... .... Test Report	
Name of the Manufacturer of Solar cells	Visual		…...............	
Month and year of the manufacture (separately for solar cells and module)	Visual		…...............	
Country of origin (separately for solar cells and module)	Visual		…...............	
Date and year of obtaining IEC PV module qualification certificate	Visual		…...............	
Certificate regarding Made in India Cell and Modules (From Manufacturers)	Visual		…...............	
Maximum peak power (Pm)	Visual	As per MNRE specifications or should be greater than 300Wp.	…...............	
Open circuit Voltage (Voc)	Visual		…...............	
Short circuit current (Isc)	Visual		…...............	
Maximum peak Voltage (Vmp)	Visual		…...............	
Maximum peak Current (Imp)	Visual		…...............	
Power tolerance	Visual	As per MNRE specifications	…...............	
Maximum system voltage	Visual		…...............	
Fire Rating Class	Visual		…...............	
Maximum Series Fuse Rating	Visual		…...............	
Safety Instruction	Visual		…...............	
Size of Module & Weight	Visual		…...............	
Is module frame and glass free from scratches?	Visual	No scratches	Yes/No; If yes Please specify.	

Excessive or Uneven Glue marks Glue Marks on Glass present?	Visual	No traces of uneven glue	Yes/No	
Gap between frame and Glass due to poor sealing present?	Visual	Proper finish	Yes/No	
Bubbles or Dirt Marks present in the module?	Visual	Proper Clean	Yes/No	
Whether the module is free from cracks?	Visual	No crack	Yes/No; If NO please specify.	
Nameplate Type (Waterproof Sticker or Metal plated or else, specify)	Visual	As per MNRE specifications	….............	
RF Identification tag of good quality for each solar module is provided with the module? And its location.	Visual	RFID Tag should be present inside the lamination and able to withstand harsh environment.	Yes/No	
Junction box having IP67 or higher rating with minimum of 3 (three) numbers of bypass diodes of appropriate rating, provided?	Visual	JB with IP rating 67 or above and bypass diode should be present	Yes/No	
Is the module frame is made up of corrosion resistant, electrically resistant anodized aluminium.	Visual	Frame of module should be made up of anodized aluminium.	Yes/No	
Whether the earthing connection spot is properly marked on the frame of the module for its earthing.	Visual	Proper earthing point is present on the panel for doing its earthing.	Yes/No	
Check whether the RFID reader is able to retrieve all the bare minimum (as per IEC Requirement) parameters as per the name plate data of the module?	Visual	It should retrieve all the bare minimum parameters which are necessary.	Yes/No	

Whether the report of the EL image of modules is available?	Visual	There should be no defects present in the cells of module	Yes/No	
TEST/Measurement: -				
Unique Serial No. of each panel	Visual		………………..	
Whether reference module (Specific Sr. No.) has valid calibration certificate which is traceable to NABL lab?	Visual		Yes/No	
Ambient Temperature	Measurement		………………..	
Temperature of Module	Measurement		………………..	
Air mass	Measurement		………………..	
Incident Irradiance (W/m2)	Measurement		………………..	
(Length (mm) X Width (mm))	Measurement		………………..	
Total Area of Solar Panel	Measurement		………………..	
Reference module power rating (Pmp – W)	Measurement		………………..	
Reading of sun simulator of reference module (Pmp- W)	Measurement		………………..	
Difference between claim reference module rating - Reading of sun simulator of reference module in watt	Measurement	As per MNRE specification	………………..	
P max	Measurement	As per MNRE specification	………………..	
Vmp	Measurement		………………..	
Imp	Measurement		………………..	
Voc	Measurement		………………..	
Isc	Measurement		………………..	
% Module Efficiency	Measurement	As per MNRE specification	………………..	
% Fill Factor	Measurement	As per MNRE specification	………………..	
Temperature coefficient				
I-V Curve of the module	Measurement	It should be according to the reference module.	………………..	

Module mounting Structure

Component/Characteristics	**Type of check**	**Reference Documents**	**Acceptance norm**	**Response by inspection officer**	**Remarks. If any by inspecting officer.**
Visual: -					
Is the Raw material Test Certificate available	Visual		Valid certificates	YES/No	
Is Welding of the items is as per standard	Visual	IS 822- Procedure code for the inspection of welds; and check the welding as per the Visual inspection on the page number 11-12.	Welding should be as per IS 822 and the grade of welding wire used should be of ER70S-6.	Yes/No	
Is there is a certificate regarding the grade of the welding wire used is ER70S-6.	Visual		Valid certificate or document which confirms the use of the welding wire.	Yes/No	
Is ISI mark for the IS 4759 available on all items of the 53properly53.	Visual	Certificate/ISI mark	Valid certificate /ISI marks present on all items of structure.	Yes/No	
Is certificate available for use of SS 304 grade in the Anti-theft bolts.	Visual	Certificate	Valid certificate	Yes/No	

Is certificate available regarding the use general hardware for the structure fitment is of the either Stainless steel (SS) then its grade should be 304 or higher, whereas in case of the carbon steel the grade should be 8.8 or higher.	Visual	Certificate	Valid certificate which states that if SS is used than the grade should be 304 or higher whereas in case of the carbon steel the grade should be 8.8 or higher.	Yes/No	
Measurement/Test: -					
Is structure and dimension of the items is as per approved drawings given in MNRE specification or approved by IIT, NIT, IISC, CSIR-SERC and Certified Structural Engineer	Visual/Measurement	Approved drawing	Structure and dimension of the items should be as per the approved drawings given in MNRE Specification or approved by IIT, NIT, IISC.	Yes/No, If No Please specify the item or structure. **Centre Shaft: -** Outer Diameter: - …............ Thickness: - .... Baseplate Thickness, If any?..................... Length: - .... **Rafters Type:** - SHS/RHS **Purlin Thickness: -**	
Thickness of the zinc coating in all the items of structure: - Front Leg, Rear Leg, Rafter, Purlin,	Measurement	As per IS 4759/ASTM A123/appro	minimum 80micron	For each item 10 readings are taken. (1) …..... (2) …..... (3) ….......(4)	

Connecting Bracket, SQ Bracket, Bracing, Base Plate		ved drawings		….....(5) ….... (6) ….......(7) ….... (8) ……. (9) ….......(10) ….….... Unit is in micron	
Is Adhesion of the zinc coating being proper	Hammer impression	As per IS 2629:1985	No removal or lifting of the coating in areas between hammer impression.	Yes/No	
Remarks: -					
Any other observation: -					

9.3 Commissioning Report

Project Commissioning Report			
Date of Commissioning:			
A	Name of the Successful Vendor**:**		
B	Name of the Building Department / Organisation:		
D	Address of SPV power plant installed**:**		
E	Meter Consumer Number: (Electricity bill copy to be attached)		
S. No	**Component**	**Details**	**Remarks**
1	Installed Project capacity in (kWp)		
2	Whether the system is installed in shadow free area or not? If not mention the details.	(Photograph Attached)	
3	PV modules as per latest ALMM list	1- Undertaking from vendor with Serial Nos.- 2- Invoice copy of modules- 3- Delivery challan of modules / optional	
4	Type, Make and year of manufacturing of Modules		
5	Each Module data sheet (flash test) Rated power output having tolerance within + 3%	Attached	
6	PV module qualification test standard	Document attached	

	(IEC 61215/IS14286 / IEC 61730 / IEC 61701/IS 61701 (for highly corrosive atmosphere)		
7	Wattage of each module and Total No. of modules		
8	Low voltage bypass diodes		
9	Minimum wattages of modules in plant greater than 300 or not?		
10	I-V curve of modules @STC	Documents attached	
11	Module RF identification tag (Inside /outside lamination)		
12	Whether the modules contain information about company name, serial no and year manufacturing etc.	(RFID information attached)	
13	Warranty Certificates (Material Warranty/ Performance Warranty) signed and stamped by bidders	Documents attached	
14	Gap between rows of the modules		
15	Tilt Angle of Modules		
16	Protection class of Junction box of modules (IP- 65)	(Documents attached)	
	ARRAY STRUCTURE		
17	Material of structure	Hot dip galvanized MS / Steel (IS 2062: 1992) / Aluminium 1- Material test report as per IS-. Attached	
18	Galvanisation of mounting structure as per IS 4759		

19	Galvanisation thickness of mounting structure	1- Documents attached. 2- Galvanisation test report as per IS-.	
20	Wind load calculation sheet for wind zone of the location	Documents attached-.	
21	MMS Design certified by a recognized Lab/ Institution		
22	Material of fasteners (Stainless steel)		
23	Load bearing capacity of the roof	OK	
24	Minimum clearance of the structure from the roof	400 mm	
PCU/ Inverter			
25	Guaranteed Technical Particulars for PCU/ Inverter	(Documents attached)	
26	Make, rating of each inverter & No. of Inverters (AC capacity of inverter)		
27	Combined Rated wattage of all inverters in Plant (Total AC rating)		
28	MPPT is integrated in the PCU/inverter		
29	Year(s) of manufacturing of inverters		
30	Switching devices, inverter data sheet	Attached	
31	Protection of Enclosure (IP) and Location of Inverters (outdoor/indoor)	IP-65	
32	Phase of inverter	3 Phase	

33	Whether solar PV plant is synchronized with grid		
34	Inverter standard codes IEC 61683/IS 61683, IEC 60068-2(1, 2, 14, 30) /Equivalent BIS Std.		
35	MPPT standard codes IEC 60068-2(1, 2, 14, 30)/Equivalent BIS std		
36	Anti- Islanding (IEEE 1547/UL1741/IEC 62116)		
For Plants >100 KW			
37	Is Galvanic Isolation provided in the Inverters?	NA	
38	Is separate isolation transformer provided	NA	
DCDB /Junction Boxes (if required)			
39	GTP of JB (duly signed by bidder and manufacturer)	NA	
40	IP protection (Level)	NA	
41	Bus bar material of DCDB	NA	
42	MCB/MCCB installed	NA	
43	Surge arrester, SPDS	NA	
44	Material of sheet and thickness	NA	
45	Test report of DCDB	NA	
46	Height of junction box	NA	
47	Gland’s type	NA	
48	JB Earthing provision	NA	
AC DISTRIBUTION PANEL BOARD/ LT Panel			
49	All switches and the circuit breakers, connectors standards IEC 60947, part I, II and III/ IS60947 part I, II and III)		

50	IP protection (Minimum 54 or better)		
51	Material of LT panel and its details	CRCA Powdered Coated	
52	Change over switch	NO	
53	Lightning protection		
54	Surge protections		
55	Conform the Indian Electricity Act and rules (till last amendment)		
56	Height of LT panel form ground	450 mm	
57	Design and drawing	Attached	
58	Test report of ACDB	Attached	
Lightening arrester			
59	Lighting arrester installed	Documents Attached	
Cables			
60	Meets IEC 60227/IS 694, IEC 60502/IS1554 standards (or other as applicable)	Documents attached	
61	Cable dimension 1- Modules to inverters, length 2- Inverter to LT panels, length		
62	Material & Voltage drop DC cable (Modules to inverters)	Copper, Calculation sheet attached	
63	Material & Voltage drop AC cable (inverter to LT panel or T/F)	Copper, Calculation sheet attached	
64	Cable Routing/ Marking (GI cable tray and suitably tagged and marked with proper manner by good quality ferule)		
Solar Plant Monitoring			

65	Solar Irradiance sensor mounted on Plane of the array. (Optional)	Data sheet attached	
66	Pyranometer calibration certificate (Optional)	Attached	
67	Temperature sensor	Yes/NO, Data sheet attached	
68	Software for future Centralized monitoring		
69	Monitoring mechanism for the installed system		
Transformer (If required)			
70	Transformer rating, Type etc.	NA	
Miscellaneous			
71	Earthling and protections (Array Structure, PCU, ACDB and DCDB) IS:3043-1987		
72	Earthing Resistance less than 5 ohms		
73	NOC from the Concerned DISCOM for the connectivity, technical feasibility, and synchronization of SPV plant	Document Attached	
74	Bidirectional meters installed (for net metering)		
75	Accuracy and burden of Meters	0.5	
76	List of requisite spares during warranty and Operation & Maintenance	Documents attached	
77	Danger boards and signages		
78	Fire extinguishers		
79	Sand buckets in the control room		

80	Tools & Tackles and **spares**		
81	O&M manual (2 sets)		
82	Display Board		
83	Material insurance at time of installation		
Drawings at Site			
84	Layout of solar Power Array As built drawing **(A3 Sheet**)	Attached	
85	Shadow analysis of the roof	Attached	
86	Single line diagram of plant (SLD) **A 3 sheet)**	Attached	
87	Structural drawing along with foundation details for the structure **(A3 Sheet)**	Attached	
88	Itemized bill of material for complete SPV plant covering all the components and associated accessories.	Attached	
89	Soft copy of final drawing		
90	Photographs of sites		
91	Any specific problem(s)		
92	Recommendations		

Format for Performance Ratio (PR)

"Performance Ratio" (PR) means the ratio of plant output versus installed plant capacity at any instance with respect to the radiation measured.

$$PR = \frac{Measured\ Output\ in\ kW}{Installed\ capacity\ in\ kW \times Measured\ radiation\ intensity\ in\ kW/m2} \times\ 100$$

Parameters	Input value	Remarks, if any
Date and Time for PR measurement		
A) Installed Plant Capacity in kW		
B) Measured output in kW		
C) Measured radiation intensity in W/m2		
Performance Ratio (%) $(\frac{B*1000}{A\times C} \times 100)$		

9.4 Synchronization report of SRTPV system (Net / Gross metering)

<table>
<tr><td>A</td><td>Consumer Details</td><td colspan="3"></td></tr>
<tr><td>1</td><td>Name of the Consumer</td><td colspan="3"></td></tr>
<tr><td>2</td><td>Category</td><td colspan="3"></td></tr>
<tr><td>3</td><td>RR No./Account ID/Connection ID</td><td colspan="3"></td></tr>
<tr><td>4</td><td>Pole Number</td><td colspan="3"></td></tr>
<tr><td rowspan="2">B</td><td rowspan="2">Meter Details</td><td colspan="2">Bi-directional Meter</td><td rowspan="2">Existing meter</td></tr>
<tr><td>Main Meter</td><td>Check Meter</td></tr>
<tr><td>1</td><td>Meter make: 1ph / 3 ph.</td><td></td><td></td><td></td></tr>
<tr><td>2</td><td>Type</td><td></td><td></td><td></td></tr>
<tr><td>3</td><td>Serial number</td><td></td><td></td><td></td></tr>
<tr><td>4</td><td>Capacity</td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>Meter constant</td><td></td><td></td><td></td></tr>
<tr><td>6</td><td colspan="4">Initial reading (Tri vector parameters)</td></tr>
<tr><td></td><td>i) Import</td><td></td><td colspan="2"></td></tr>
<tr><td></td><td>ii) Export</td><td></td><td colspan="2"></td></tr>
<tr><td colspan="5">Note:
1. The Bi-directional meter records solar generation and existing meter records installation consumption in case of Gross metering.
2. The Bi-directional meter records export of solar energy to grid and import of energy by the installation. Existing meter records the total solar energy generated.</td></tr>
<tr><td>C</td><td>Grid Tied Inverter</td><td colspan="3"></td></tr>
<tr><td>1</td><td>Make</td><td colspan="3"></td></tr>
<tr><td>2</td><td>Serial number</td><td colspan="3"></td></tr>
<tr><td>3</td><td>Capacity</td><td colspan="3"></td></tr>
<tr><td>4</td><td>Input voltage</td><td colspan="3"></td></tr>
<tr><td>5</td><td>Output voltage</td><td colspan="3"></td></tr>
</table>

6	Whether Anti-islanding feature is in working condition	Yes/No
D	**PV Module**	
1	Make	
2	Serial number	
3	Type of module	
4	Capacity of each module	
5	Number of modules	
6	Total capacity of module	
E	Earthing verified: DC earthing, AC earthing, LA earthing of SRTPV system	Yes/No
F	Details of protective system available	• AC & DC DB: Yes/No • Manual Switch solar side: Yes/No • Relay operated automatic switch at net-meter side: Yes/No
G	DISCOM inspection & approval letter obtained	Yes/No
H	Work completion report of SRTPV system obtained from agency	Yes/No
I	Date of synchronizing with DISCOM grid	dd/mm/yyyy

9.5 Quality Inspection and Performance Assessment Report

Sl. No.	Parameters	Method/ Tools to use	Description
1.	Name of the system owner	MNRE list	
2.	System location (physical address)	MNRE list	
3.	Geo-spatial coordinates	Record by GPS at site	
4.	Type of consumer	Implementing Agency	As per category mentioned in the list provided by Discoms
5.	Sanctioned load	As per the electricity bill	
6.	Implementing company	SNA/Discoms	
7.	EPC company/ installer	MNRE list	
8.	Date of installation	MNRE list	
9.	Date and time of PV inspection	Record	
10.	Total energy generated till the time of inspection	Check and record from Inverters	Check the inverter data. If there are multiple inverters, check all inverters and add to total
11.	Inverter Power at the time of inspection Ψ	Check and record	Check the inverter data. If there are multiple inverters, check all inverters and add to total
12.	Irradiance at the time of inspection	Check and record	
13.	Temperature of inverter at the time of inspection	Check and record	Check the operating temperature of the inverter and check if cooling fan is working or ventilation is blocked for each inverter. Check for all inverters

Ψ When inverter does not have a digital display, measure V_{mp} and I_{mp} at the inverter and record cell temperature at the time of measurement to calculate DC power.

A. System Design and planning

a. Orientation

Sl. No.	Parameters	Method/ Tools to use	Findings
1.	Orientation and Tilt of the PV array	Inclinometer (mobile app) Compass	• Tilt: • Orientation:

2.	Is PV array free from shadow	Use Sun Path finder Camera	• Location affected by shadow: • Object creating shadow: • Months of shadow: • Time of shadow:
3.	Measure Inter-row spacing	Measuring tape	• Distance between closest point between two rows: • Dimension of row: H (min) H (max)
4.	Any object closed to the array that create shadow	Measuring tape/ distance meter/ camera	• Type of object: • Location of the object: • Height of the object: • Distance from nearest point on PV array:

b. PV Module:

Sl. No.	**Parameters**	**Method/ Tools to use**	**Description of findings**
1.	Make & Model No.	Visual Take photo	
2.	Type of cell	Visual Take photo	
3.	Module name plate information	Read and collect information Take photo	• P_{max}: • Tolerance: • V_{oc}: • I_{sc}: • V_{mp}: • I_{mp}:
4.	Temperature coefficients	Use datasheet of PV module	• Tc (α) for Isc: • Tc (β) for Voc: • Tc (γ) for Pmp:
5.	Total Number of Modules	Count and record	

c. Inverter:

Sl. No.	**Parameters**	**Method/ Tools to use**	**Findings**
1.	Make and Model No.	Read and record/ photo	Take photo
2.	Type of inverter	Visual	Micro, string, optimizer, semi central
3.	Name plate information	Read nameplate Take photo Use inverter datasheet	• Maximum DC capacity: • Maximum DC input voltage: • Nominal AC capacity: • Nominal AC voltage & Phase: • Maximum AC output current: • Number of MPPT: • MPPT voltage range:

			• Number of inputs per MPPT: • Maximum input DC current: • IP rating: Certification:
4.	Total number of inverters installed	Count and record	
5.	Number of modules in one string	Count and record	
6.	Total Number of Strings connected to one inverter	Count at DCCB or inverter	
7.	Number of optimizers connected to one inverter	Count and record	Applicable optimizer-based inverter
8.	Remote monitoring System	Observe and record	• Make and model: • Type of communication port? • Medium of communication:

d. DC and AC cable sizing

Sl. No.	**Parameters**	**Method/ Tools to use**	**Findings**
1.	DC and AC SLD	Collect SLD or draw	Use separate sheet to draw DC and AC SLD
2.	String cable Size	Read and record	
3.	Array Cable Size (DCCB to inverter)	Read and record	
4.	DC cable route length Array to Inverter	Measure	
5.	AC Cable size (Inverter to ACDB)	Read and record	
6.	Placement of strings according to shadow profile and orientation of plan	Observe and record	If the array is affected by shadow, whether strings are arranged to minimise shadow loss?

e. System protection for over current and over voltage as per site conditions

Sl. No.	**Parameters**	**Method/ Tools to use**	**Findings**
1.	Fuse Ratings	Read and record	• Type and ratings

2.	SPD Type	Read and record	• Type and ratings
3.	DC Isolator	Read and record	Type and ratings
4.	Lightning protection system	Observe and record take photo	• Is there a LPS installed? • If yes what type of LPS?

f. Electrical Safety

Sl. No.	**Parameters**	**Method/ Tools to use**	**Findings**
1.	Earthing continuity for equipotential bonding	Multimeter	• Check continuity for module to module • Check continuity for module to structure • Check continuity for structure to earthing strip • Check continuity to earthing rod at earth pit
2.	Type and size of earthing cable/ strip	Observe and record	•
3.	Condition of earthing conductor	Observe and record	• Observe if there is rust and poor connection/ joints on the earth conductor which can potentially disrupt the continuity
4.	Is there separate earthing for DC side, AC side and LPS	Observe and record	•
5.	System Isolation	Observe and record	• Whether DC isolators used for string cable? • Whether DC isolators used for array cable? • Isolation between inverter and main panel
6.	Signage and warnings	Observe and record	Is there warning sign for DC cables, isolators, inverters, and shutdown procedure?
7.	Location of lightning protection system	Observe and record Take photo	

g. Fire and Safety Compliances

Sl. No.	**Parameters**	**Method/ Tools to use**	**Findings**
1.	Access, pathways, and smoke ventilation	Observe and record	Does the system block any fire exit/ fire protection equipment/ pathways or smoke ventilation?
2.	Protection of long DC cables	Observe and record	If DC cables are longer than 50 m, or terminals of the cable are not at the sight, whether disconnectors are installed on both ends?

3.	Protection of DC cable (String and array cable)	Observe and record	• Whether strings cables are tied properly? • Is there any string cable hanging? • Whether DC cable from PV array is protected by conduit or cable tray? • If conduit, whether it is UV stabilised? • Whether the cable tray is covered? • Whether cable tray has sharp edges? • Is there any cable lying exposed on the floor?
4.	Is there any exposed DC conductor	Observe and record Take photo	• Look for cable damage and record • Look for cable exposed to sharp metallic objects and record • Look for exposure of cables that may be damaged by rodent / squirrel
5.	Loose connections in cable joints	IR camera/ IR gun	Check the temperature of the joints and record
6.	Cable glands	Observe and record Take photo	Observe is there is loose or open cable glands
7.	Signage and warnings	Observe and record	Is there warning sign for DC cables, isolators, inverters, and shutdown procedure?
Comments on design and planning:			

h. Installation

Sl. No.	**Parameters**	**Method/ Tools to use**	**Findings**
1.	Distance from PV array to inverter	Measure	
2.	Location of inverter	Check and verify Take photo	• Inverter installed in outdoor or indoor. • Is the inverter being accessible? • At what height, the inverter is installed? • Gap between inverter and walls? • Does inverter get enough ventilation? • Does the inverter get direct sunlight?

		• Whether the inverter is installed in a corner or under staircase? If inverter is protected by a cover or box what kind of cover or box is used?
3.	Inverter operating temperature	Measure and record	• Check operating temperature of the inverter and record. If there is more than one inverter record operating temperature of all inverters
4.	DCCB	Check and verify Take photo	• Distance from the PV array? • Distance from inverter? • Outdoor or indoor? • Height from the floor/ ground? • Is it protected from rain?
5.	No. of DCCB with system protection	Record	• Mention No. IN and No. OUT
6.	No. of DCCB without protection	Record	• Mention No. IN and No. OUT
7.	ACCB	Check and verify Take photo	• Distance from the inverter? • Distance from main grid panel? • Outdoor or indoor? • Height from the floor/ ground? • Is it protected from rain?
8.	Cable routing and conduit	Observe and record	• Check if conduits / cable tray is intact and UV protected • Check if there is any cable not protected by conduit or cable tray
9.	Grid instability and set points of inverters	Interview the owner use Stopwatch	• Ask owner if there is unstable (very low and very high) grid voltage • Perform anti islanding and functionality test
10.	Provision and arrangement for system accessibility for maintenance	Observe and record	• Whether PV modules are accessible for cleaning? • Whether water is accessible for cleaning of PV modules? • Whether the inverter can be accessed for maintenance?

i. Mounting Structure

Sl. No.	Parameters	Method/ Tools to use	Findings
1.	Height of building	Estimate	
2.	Type of mounting structure	Observe and record	Ballast type, Racking, flush mount, carport type raised structure etc
3.	How are modules attached to the mounting structure?	Observe and record	What type of fixing accessories used to fix modules? Clamps/ nut-bolt/ clip
4.	Size of the table	Count and record	Measure based on number on modules on a table and mention the landscape / portrait
5.	Height of PV array from the base	Measure	Maximum height from the base: Minimum height from the base:
6.	Surrounding terrain of the plant side	Observe	Whether the surrounding area is open of obstructed by other buildings or structure
7.	Effective wind area	Calculate	Exposed area vertical to the wind flow
8.	Material of mounting Structure	Observe and record	MS, Galvanised Iron (GI), Aluminium
9.	Size of concrete block	Measure	
10.	Basic wind speed at the site	IS 875 Pt.3	Refer the basic wind map of India
11.	Thickness of structure	Use vernier calliper	• Thickness of purlin • Thickness of rafter
12.	Thickness of coating	Ultrasonic thickness gauge	Measure in 3-4 locations of purlin and rafter
13.	Structural integrity	Observe and record Torque wrench	• Is there any loose or detached part in the structure? • Check tightness of the clamp nuts for tightness
14.	Corrosion	Observe and record	Check if any part of the structure is corroded

Comments on mounting structure:

B. System performance

a. Estimation of Performance Ratio (PR)

Sl. No.	Parameters	Method/ Tools to use	Findings
1.	Instantaneous performance Ratio (PR) Measurement	Use the method given below	Record calculation as per the formula
2.	Short duration performance ratio (PR) estimation	Use the method given below	Record calculation as per the formula
3.	Long duration performance ratio (PR) estimation	Use the method given below	Record calculation as per the formula
4.	Loss of performance due to grid outage	As the owner and estimate	
Comments on system performance:			

b. Method for evaluation of Performance Ratio:

Instantaneous performance Ratio (PR) Measurement	[(Power output from inverter in kW ÷ DC capacity of plant in kW) x (1000 Watt/m^2 ÷ Measured solar irradiance in Watt/m^2)] Both inverter power and solar irradiance should be measured at the same instance
Short duration performance ratio (PR) estimation	[Energy delivered by the inverter for # number of days ÷ (# number of days x average daily PSH for those days x DC capacity of plant)]
Long duration performance ratio (PR) estimation	[Energy delivered by the inverter for # number of days ÷ (# number of days x average daily PSH for those days x DC capacity of plant)]

c. String and Module level performance

Measurement using multimeter/ clamp meter:

Sl. No.	Parameters	Method/ Tools to use	Findings			
1.	String -1	Multimeter/ clamp meter Irradiance meter and IR thermometer	V_{mp}:	I_{mp}:	Irr:	T:
2.	String -2		V_{mp}:	I_{mp}:	Irr:	T:
3.	String -3		V_{mp}:	I_{mp}:	Irr:	T:
4.	String -4		V_{mp}:	I_{mp}:	Irr:	T:
5.	String- 5		V_{mp}:	I_{mp}:	Irr:	T:
6.	String -6		V_{mp}:	I_{mp}:	Irr:	T:

Remarks:

(1) Use separate sheet in case of more than 6 strings
(2) If unexpected lower voltage is observed in any string, collect module level data as below
(3) Record your observation

Note:
Module level test for V_{oc} and I_{sc} to be done if there is major variation of V_{mp} and I_{mp} at string level

7.	Module -1	Multimeter/ clamp meter Irradiance meter and IR thermometer	V_{oc}:	I_{sc}:	Irr:	T:
8.	Module -2		V_{oc}:	I_{sc}:	Irr:	T:
9.	Module -3		V_{oc}:	I_{sc}:	Irr:	T:
10.	Module -4		V_{oc}:	I_{sc}:	Irr:	T:

Remarks:

(Write Module ID)

Measurement using IV tracer

Sl. No.	**Parameters**	**Method/ Tools to use**	**Findings**				
1.	String -1	Use IV tracer	V_{oc}:	I_{sc}:	P:	Irr:	T:
2.	String -2		V_{oc}:	I_{sc}:	P:	Irr:	T:
3.	String -3		V_{oc}:	I_{sc}:	P:	Irr:	T:
4.	String -4		V_{oc}:	I_{sc}:	P:	Irr:	T:
5.	String -5		V_{oc}:	I_{sc}:	P:	Irr:	T:
6.	String -6		V_{oc}:	I_{sc}:	P:	Irr:	T:
Remarks: (1) Use separate sheet in case of more than 6 strings (2) If unexpected lower voltage is observed in any string, collect module level data as below (3) Record your observation							
1.	Module -1	Use IV tracer	V_{oc}:	I_{sc}:	P:	Irr:	T:
2.	Module -2		V_{oc}:	I_{sc}:	P:	Irr:	T:
3.	Module -3		V_{oc}:	I_{sc}:	P:	Irr:	T:
4.	Module -4		V_{oc}:	I_{sc}:	P:	Irr:	T:
Remarks:							

Testing of Modules for micro cracks or damage (Visual, IR and EL Testing)

Sl. No.	Parameters	Method/ Tools to use	Findings
1.	Appearance of PV modules	Observe and record	• Is there any change in colour or browning of modules partially or fully? • Is there any snail trail? • Is there any visible crack or mark on the module • Is there any brown spot ununiform colour on the modules?
2.	Broken module	Count and record	Are there any broken modules in the system?
3.	Module back sheet quality	Observe and record / IR camera	• Observe if there is any bubbles or uneven surface on the back sheet • Observe is there is uneven temperature on the back sheet
4.	Installation practice	Interview with the owner	• Did the installer stepped on the modules while fixing the modules during installation?
5.	IR Imaging	Use IR camera Take photo	Take IR image of modules when you find any one of the issues mentioned in Sl. 1, 2 and 3 above
6.	EL Testing	EL camera	• Identify modules with hotspot. • Conduct EL test for one or two modules which are having severe hotspot
Comments on module testing:			

End of Checklist

Contact details:

Representative from the system owner	(Record name and contact number)
Representative from the Developer/ EPC	(Record name and contact number)
Inspection team members	
Signature of the inspection engineers	

10 Documents Referred.

i. Best Practices in OPERATION AND MAINTENANCE of Rooftop Solar PV Systems in India -JAYA VASITA & AKHILESH MAGAL, Gujarat Energy Research & Management Institute
https://www.germi.org/downloads/GERMI%20O&M%20Handbook%20for%20RTPV%20Systems.pdf

ii. Handbook on "Standard Operating Procedure for Installation of Grid Connected Rooftop Solar Photovoltaic Systems" has been developed under the World Bank SUPRABHA TA Program to support the Assam Energy Development Agency:
https://aeda.assam.gov.in/sites/default/files/swf_utility_folder/departments/aeda_snt_uneecopscloud_com_oid_5/latest/sop_gcpv_installation_c.pdf

iii. Final draft of SBD Document
https://solarrooftop.gov.in/notification/129_notification.pdf