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: 25.02.2023

**Office Memorandum**

**Subject: Comments/ suggestions on Quality Control Manual for Grid Connected Rooftop Solar PV Systems and Solar PV Water Pumping Systems-reg**

Ministry of New & Renewable Energy (MNRE) is supporting installation of grid-connected rooftop solar systems, and for installation of Standalone Solar Pumps / solarization of existing grid-connected agriculture pumps under its schemes/ programmes.

2. To ensure the quality of installation and a structured mechanism for monitoring of the installations, Ministry proposes to bring out quality control manuals for the following

i. Grid-connected Rooftop Solar PV System (Annexure A)
ii. Standalone Solar PV Water Pumping System and Solarization of existing individual agricultural pumps (Annexure B)

3. Draft manual prepared are enclosed herewith for the comments of stakeholders. It is requested that comments/suggestions may please be sent on Annexure A and Annexure B separately in the following format in a word document file only, at rahulkr.1996@nic.in by 5:00 PM, 10.03.2023.

| Sr. No. | Page No. /Clause No./Para No with the description of the item | New Issue/ Comments | Remarks/ Justification |
|---|---|---|---|
| | | | |

-Sd-
(Shobhit Srivastava)
Scientist-D

To

All Stakeholders

(Annexure A)

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

## Proprietary Statement

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It is clarified that the information given in this handbook does not supersede any existing provisions laid down in the MNRE publications. The instructions given are for the purpose of guidance in implementing quality control in the implementation of Grid Connected Solar Rooftop Programme of the Ministry of New and Renewable Energy.



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## Amendment Procedure

i. MNRE may propose amendments to any content/ clause of the manual required with time-to-time revision in technology, policy etc.
ii. Revisions/Update in Quality Control Manual will be issued by the MNRE after internal approvals, as and when required.
iii. It is the responsibility of the copy holders to update the superseded versions of documents and replace the same with new version to ensure against unintended use of obsolete documents.
iv. Any external request for amendments may be submitted to MNRE for review.

Any Amendment to be issued in this manual will be numbered as follows:

| S. No. of correction Slip | Date of Issue | Page No. and item to be modified/ Clause No. | Remarks/ New Issue |
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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

| | |
|---|---|
| **Solar PV Module** | |
| **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<br>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):<br>i. Low-voltage Switchgear and Control-gear, Part1: General rules<br>ii. Low-Voltage Switchgear and Control-gear, Part 2: Circuit Breakers<br>iii. Low-voltage Switchgear and Control-gear, Part 3: Switches, disconnectors switch-disconnectors and fuse-combination units<br>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)**<br>**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<br>IEC 62561-2: Lightning protection system components (LPSC) – Part 2: Requirements for conductors and earth electrodes<br>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 a guide to ascertain compliance in the 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. It ensures that all installation processes and procedures are performed in a consistent and effective manner, resulting in a high-quality, reliable, and safe solar PV system. The scope of the manual typically includes guidelines for project management, site preparation, equipment and material procurement, installation and commissioning, testing and inspection, and documentation. The manual ensures that the work is performed in accordance with industry standards, regulatory requirements, and project specifications.

## 2 Overview-Grid Connected Rooftop Solar PV System

A grid-connected rooftop solar PV system is a type of solar energy system that is installed on the roof of a building or within the premises and connected to the electrical grid and such system usually do not use batteries. The system generates electricity from the sun through solar photovoltaic panels, which is then used to power the building or excess energy is fed back into the grid. The system uses photovoltaic (PV) panels to convert sunlight into electricity, and an inverter to convert the DC electricity generated by the panels into AC electricity that can be used by the building or fed surplus power into the distribution grid. In cases where solar power is not sufficient due to lower irradiance or plant failure etc., the loads are served by drawing power from the 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.

### 2.1 Important Terminologies

**Photovoltaic Effect:** It's a phenomenon of generation of electricity through the movement of electron hole pair/ charge carrier across the junction of doped semiconductor, when exposed to sunlight.

**Solar Cell:** A photovoltaic cell, also known as a solar cell, is a type of semiconductor device that can convert sunlight directly into electricity through the photovoltaic effect. When light incident on the solar cell, it generates both a current and a voltage, which can be harnessed to power an electrical load.

**Solar Panel:** A solar PV (photovoltaic) module, also known as a solar panel, is a semiconductor device composed of multiple interconnected solar cells in series and parallel that convert sunlight into direct current (DC) electricity. The module is designed to produce rated electrical power when exposed to sunlight.

**Solar PV Array:** A Solar PV array is comprised of multiple Solar PV modules that work together to convert solar energy into electrical energy. These modules are connected in a combination of series and parallel connections. The series connection is used to increase the voltage output, while the parallel connection is used to increase the current output.

**Solar Irradiance:** The solar radiation received from the sun per unit area in a given time on the earth is called Solar Irradiance. It is measured in units of power per unit area and expressed as watts per square meter ($W/m^2$).

**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 the optical of the material of cell. It is measured in Ampere (A). It is illustrated in *Figure 1*.

**Current Density ( $J_{sc}$):** Current density is a measure of the amount of electrical current flowing through a unit area of a material. It is defined as the electric current per unit cross-sectional area of a conductor, and is typically measured in units of milliamperes per square centimetre ($mA/cm^2$ . The Jsc of silicon solar cell lies in the range of $45mA/cm^2$ -60 $mA/cm^2$.

**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. The Voc of silicon solar cell lies in the range of 0.5 V-0.6 V.

**Maximum Power Point Tracker (MPPT):** MPPT is an algorithm that is used to optimise the power output from the solar PV array through inverter under a given set of condition. The voltage at which SPV array can produce maximum power is called 'maximum power point' voltage (or peak power voltage).

**Current at Maximum Power Point (Imp):** It represents the current which the solar cell will produce when operating at the maximum Power Point. It is denoted by $I_m$ in *Figure 1*, and its value is always less than the short circuit current ($I_{SC}$). It is measured in ampere (A).

**Voltage at Maximum Power Point (Vmp):** It represents the voltage that the solar cell will produce when operating at the maximum Power Point. It is denoted by $V_m$ in *Figure 1*, and its value is always less than the open-circuit voltage ($V_{OC}$). It is measured in volts (V).

**Maximum Power Point (MPP):** Maximum power point represents the maximum power that a solar cell can produce under any incident irradiance. It is measured in $W_P$. The cell can operate at different current and voltage combinations. But it can only produce maximum power at a particular voltage and current combination.

**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. It determines the maximum power that can be derive from a solar cell. Graphically, the FF is a measure of the "squareness" of the solar cell and is also the area of the largest rectangle which will fit in the IV curve.. The FF is defined as the ratio of the maximum power from the solar cell to the product of $V_{oc}$ and $I_{sc}$

$$\mathbf{FF = \frac{(Vmp\ x\ Imp)*100}{Isc\ x\ Voc}}$$

**Efficiency (η):** The efficiency of the Solar cell refers to the fraction of the input solar irradiance converted to electrical power. The solar irradiance is measured in $W/m^2$. Hence, in order to determine the efficiency, the solar irradiance must be multiplied by the cell's surface area. The efficiency can be calculated as follows:

$$\mathbf{\eta = \frac{[Electric\ power\ (Wp)x100}{Solar\ irradiance \times Area)]}}$$

**Temperature Coefficient:** The power temperature coefficient of photovoltaic (PV) refers to the correlation between the temperature of a solar cell and its output power. The output power of solar panels will decrease with increase in temperature. Hence, the value will be prefixed by a negative sign. It is observed that the power temperature coefficient is roughly -0.4 % to -0.5% per degree Celsius for Si Solar Cell.

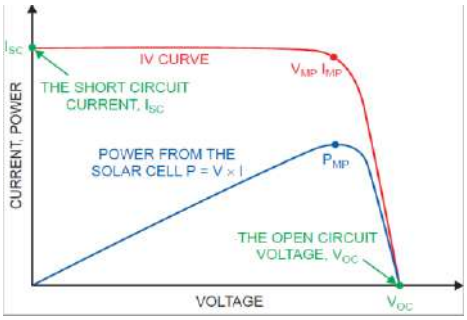



*Figure 1 IV Curve of solar cell*

## 2.2 Solar PV System Components

The main components of rooftop solar PV system can be broadly categorized in the following ways:

I. **Solar PV Module**: A solar PV (photovoltaic) module, also known as a solar panel, is a semiconductor device. The module is designed to produce rated electrical power when exposed to sunlight. A number of PV modules connected in series configuration is entitled to form a string. The purpose of creating a string is to increase the output voltage of the solar PV system. A string is designed such that it provides an output voltage in a range that is compatible with the inverter input voltage range.

II. **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. They are a crucial component of a solar PV system. Inverter must be able to safely withstand array operation in specified temperature band. It converts the direct current (DC) electricity generated by solar panels into alternating current (AC) electricity. Further, the open circuit voltage Voc must not exceed maximum input voltage of the inverter at the lowest temperature.

Solar Inverters are classified based on the interaction with the electrical power grid:

a) Grid-Connected Inverters: A solar on-grid inverter is a type of inverter used in grid-tied solar energy systems. It converts the direct current (DC) electricity generated by solar panels into alternating current (AC) electricity for satisfying electrical load at home and fed surplus power into the electrical grid. The inverter is connected to the utility grid, allowing excess energy generated by the solar panels to be sold back to the grid when it is not needed. This makes the solar energy system more efficient, as it minimizes energy waste and maximizes energy usage. Solar on-grid inverters also have the advantage of being able to draw power from the grid during times when the solar panels are not generating enough electricity, such as during night time or cloudy weather. They are typically more cost-effective and require less maintenance than off-grid inverters, as they do not need batteries to store excess energy.

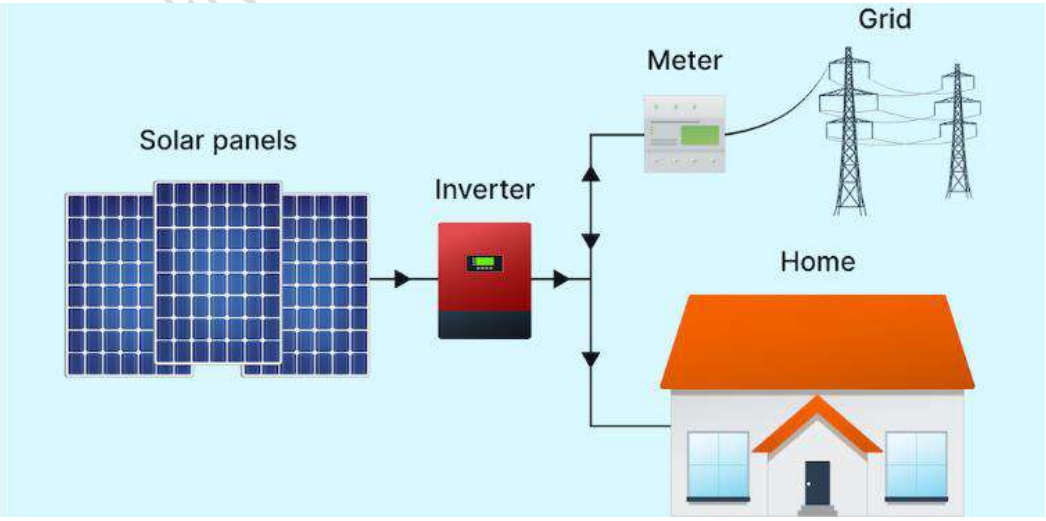



*Figure 2 Grid Tied Solar PV System*

b) Stand Alone or Off Grid Inverters: A solar off-grid inverter is a type of inverter used in standalone solar energy systems that are not connected to the electrical grid. It converts the direct current (DC) electricity generated by solar panels into alternating current (AC) electricity, which is then used to power homes and businesses. Off-grid inverters are typically used in remote locations where access to the electrical grid is not available, and they are designed to work in conjunction with a battery system that stores excess energy generated by the solar panels. When the panels are not generating enough electricity, such as during night time or cloudy weather, the inverter can draw power from the battery system to continue providing electricity. Solar off-grid inverters are more complex and require more maintenance than on-grid inverters, as they must manage the energy storage and usage of the system. However, they provide a reliable source of energy and allow for energy independence in areas without access to the electrical grid.

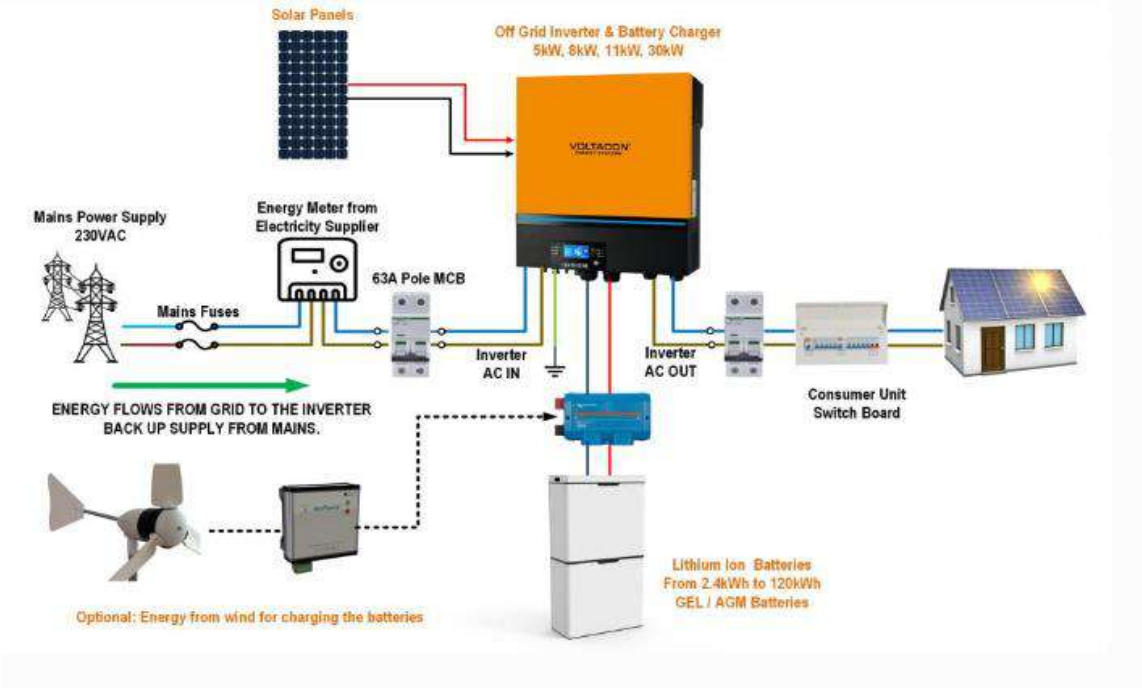



*Figure 3 Off grid Solar PV system*

c) Hybrid Inverters: A solar hybrid grid inverter is a type of inverter that combines the features of both on-grid and off-grid inverters. It converts the direct current (DC) electricity generated by solar panels into alternating current (AC) electricity, which can be used to power homes and businesses. The inverter is connected to both the electrical grid and a battery system, allowing it to operate in both grid-tied and standalone modes. When the solar panels are generating enough electricity, the inverter can feed excess energy back into the grid, while also storing excess energy in the battery system for later use. When the panels are not generating enough electricity, the inverter can draw power

from the grid or the battery system, providing a reliable source of energy.

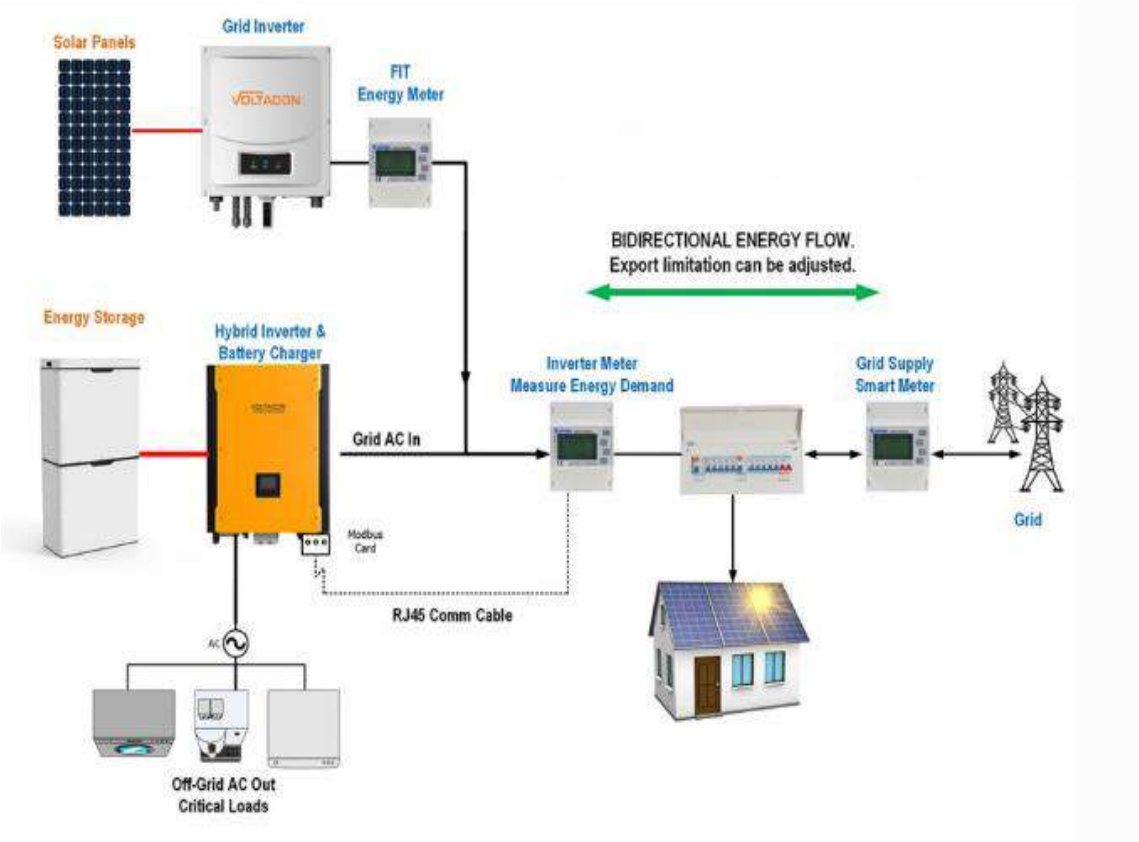



*Figure 4 Hybrid Solar PV System*

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

a) Central Inverter: Central inverters are typically inverters of higher power ratings and have higher number of strings each MPPT as shown in figure 5. Nowadays most central inverters start from power ratings of 250kw. String Inverter has better redundancy as compared to central inverter. Though the central inverter caters difficulty in terms of serviceability but its obvious choice in case of very large plant such of MW scale.

b) String Inverter: String inverters are type of solar inverter that convert direct current (DC) output from the solar panels into alternating current (AC) for either use in homes or export to grid as per specified grid code. Usually referred to as grid tie inverters connected to multiple strings of solar panels.

For Example, of you have 10 solar panels on your terrace, you could have installed 2 rows of 5 panels each. Each row is termed as String. Many of these inverters are equipped with maximum power Point Tracking (MPPT) to optimise the energy produced from the solar panels. A string inverter with multiple MPPT is preferred for better optimisation of DC power from the solar PV panels. Although it's an ideal choice for most the rooftop solar PV Projects but string inverters offers less resilience under partial shading as compared to Micro inverter as shown in figure 6 and figure 7.

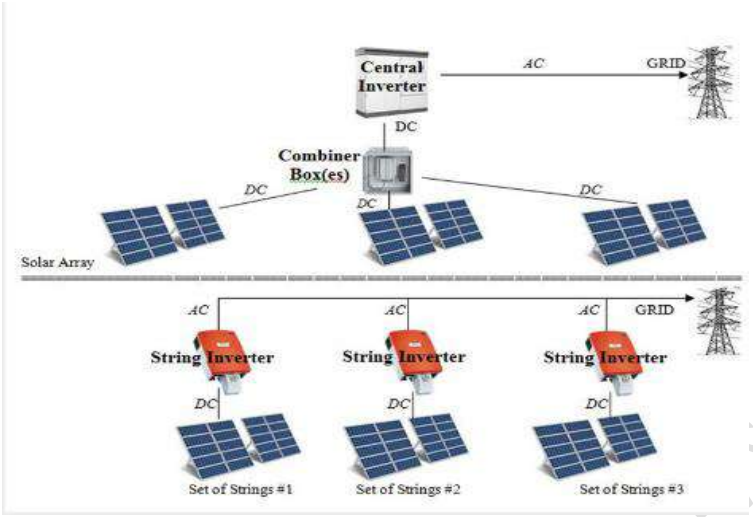



*Figure 5 Central Inverter Vs String Inverter*

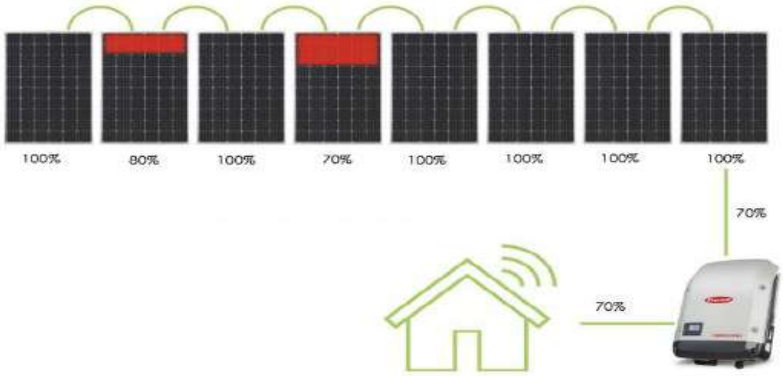



*Figure 6 String Inverter*

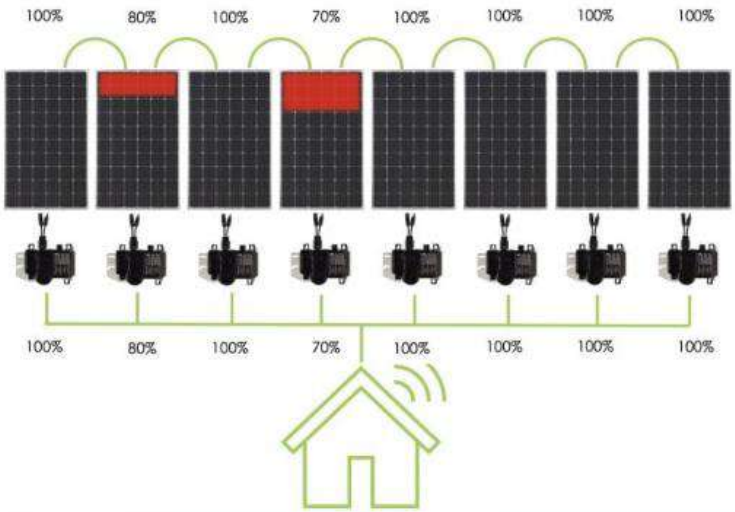



*Figure 7 Micro Inverter*

**It is observed that string inverters are pre-dominant in the residential market. Therefore, this manual mainly deals with the On Grid Solar PV system with a string**

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.

III. **Module Mounting Structure:** Module Mounting Structures (MMS) are used to secure the PV modules in particular orientation to harness maximum sunlight. Module Mounting Structure varies with solar PV module technology and design but structures made of galvanized iron or aluminium are predominant in the residential sector based on the cost , durability and faster installation. Solar mounting structure is primarily categorised into RCC Roof Mounts, Ground Mount, Shed Mount, or Tracking Structure. 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/ corrosive environments or snow loadings.
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.

IV. **Lighting Arrestors**: A lightning arrestor, also known as a lightning diverter or surge arrester, is a device designed to protect electrical and electronic equipment from damage caused by lightning strikes and other electrical surges. It works by providing a low-impedance path for the surge to flow to ground, thereby diverting it away from the protected equipment. While it is desired to protect all PV systems from lightning, so 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.

V. **Earthing:** Earthing, also known as grounding, is an important safety feature for solar PV systems. The purpose of earthing is to provide a low resistance path for electrical current to flow in case of a fault or lightning strike, which helps to protect both people and equipment from electric shock and damage It involves connecting the solar panel array, inverter, and other system components to a grounding electrode or grounding system. Proper earthing also helps to minimize electrical noise and interference, which can improve the performance and lifespan of the solar PV system. It is important to follow local electrical codes and regulations for earthing when installing a solar PV system. 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.

VI. **Secondary Batteries:** Batteries are used in off grid and Hybrid Solar 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, lithium ferrous phosphate, are also gaining popularity. Batteries are sized based on power and energy requirement of the load and often oversized to provide autonomy during non-sunny days. Batteries not only in terms of energy density but also longevity, load characteristics, maintenance requirements, self-discharge, and operational costs.

**Quality Control Manual for off grid & Hybrid Solar PV system will publish separately**

VII. **DC & AC Cables:** DC cables are used to carry DC current from the PV modules right up to the inverter. Single core wires with double insulation are a practical solution to high reliability. The DC cable should be sized to carry the required current (along with necessary safety margins) and also limit the voltage drop as per the local electrical codes.
AC Cables carry the AC power of the PV system from the solar inverter to the metering point, 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.

VIII. **DC & AC Isolators:** It is one of the most important parts for the PV system safety, whose reliability and stability relate to the stable generation and profit of photovoltaic systems, as well as the safe and reliable operation. DC Isolators are required to disconnect the PV modules and strings from the Inverter in cases of faults, fire, or repair. The rated operational voltage of the Isolator should be equal to or greater than the requirements of the solar PV system. DC isolators should be clearly labelled and easily accessible in DC Distribution board. It may consist of DC fuses and surge protection device (SPD) in addition to existing provision in inverter.
AC switchgear isolates the solar PV inverter from the AC supply (grid /AC loads) during maintenance, repair or installation. A circuit breaker in the distribution board, positioned adjacent to the inverter and at the consumer main grid interface can be used to act as an AC isolator.

IX. **Metering:** Metering is billing mechanism of grid interactive solar PV system which requires appropriate metering arrangement to ensure the measurement of electricity imported from the grid and electricity exported to the grid. Metering depends upon the size of the system, consumption pattern and local electricity regulations, which can be either gross, net, or Bidirectional. A solar meter and bidirectional energy meter suitable for the installed solar plant shall be supplied and installed by the contractor after testing and sealing from the respective Division of Discom. The solar energy meter and net energy meter shall be of accuracy as given and CT and PT shall be utilized according to CEA metering regulations 2006 and its amendment. A kWh meter approved by Discom is compulsory for grid tied inverter. The meter should be located where the consumer can readily observe it.

Moreover, the inverter should display/record energy delivered by the PV system (kWh).
Net meter" means the bi-directional energy meter for measuring the quanta of electricity

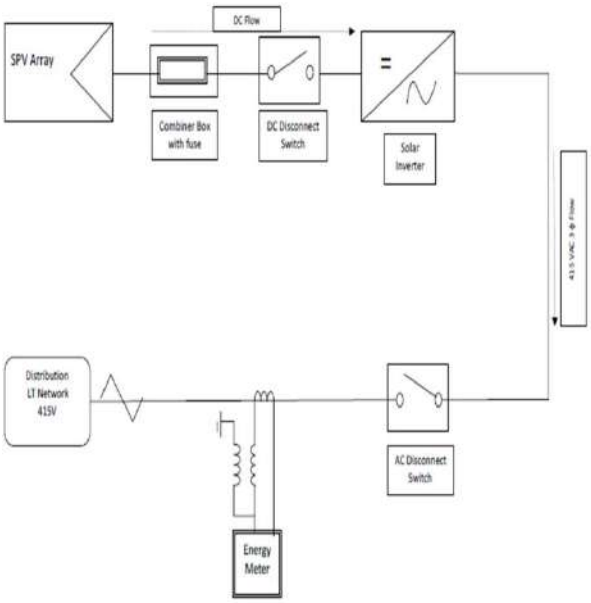



*Figure 8 Gross Metering – Grid Tied*

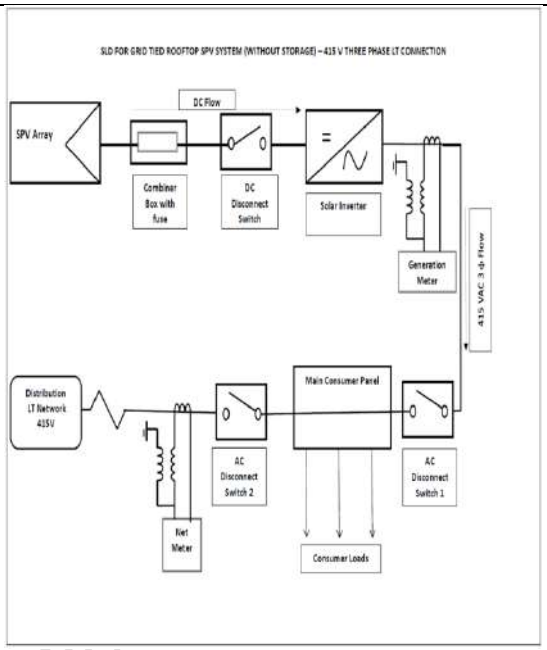



*Figure 9 Net Metering – Grid Tied*

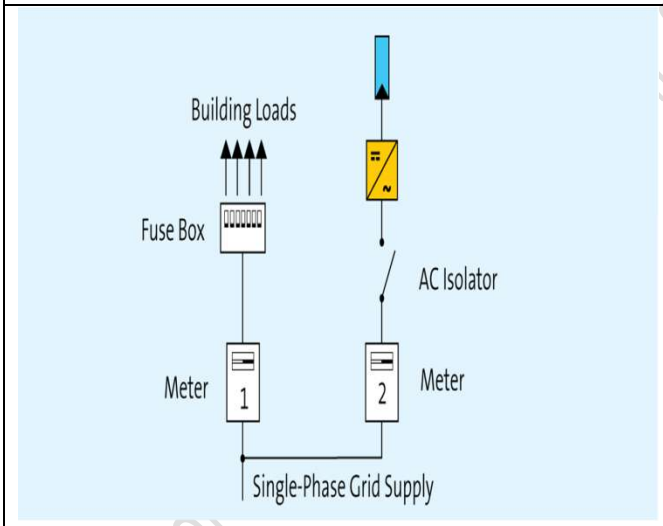



*Figure 10 Gross Metering Using 2 Meters*

This is a gross metered connection and Meter 2 is export meter.

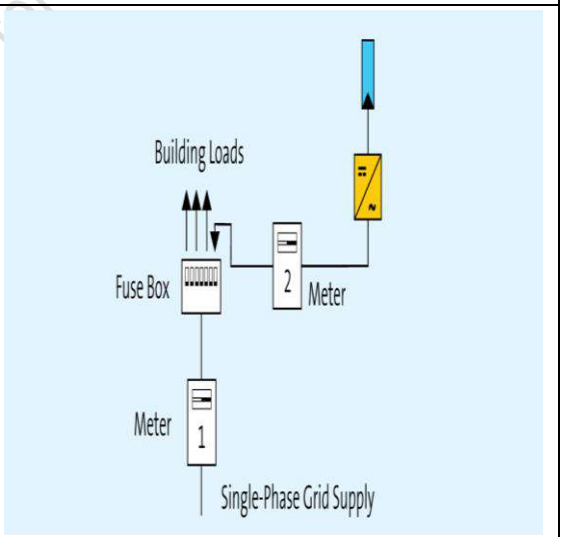



*Figure 11 Net Metering Using 2 Meters*

Meter 1 is net meter (bi- directional) whereas Meter 2 is Solar (Generation) Meter
Note: Number of meters in Net metering connection may vary as per mandated in State regulations

flowing in opposite directions and the net quantum of electricity consumed by the eligible consumer or injected into the distribution system of the licensee; Net metering system" means a system consisting of a solar meter and net meter with their associated equipment.

## 2.3 Principle of Working

Solar PV rooftop system is basically a small power plant at rooftop. It is also known as grid tied solar PV system. 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 installed on the rooftop of the building convert sunlight into DC (Direct Current) electricity. The DC electrical energy is converted to AC (Alternate Current) power by the solar inverter/power conditioning unit which is connected to the electrical loads within the building through AC distribution board. The AC power output can be measured through a metering panel connected to it. A net meter is installed to measure the amount of electricity generated by the solar PV system and export /import of surplus/ deficit to/from the grid. This allows the owner to earn credits for the excess electricity produced, which can be used to offset the cost electricity bills. The on-grid solar PV rooftop system is connected to the power grid, which acts as a backup source of electricity when the solar panels are not producing enough electricity to meet the demand. This ensures that the home or building has a reliable source of electricity at all times. 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. The system is monitored and maintained regularly to ensure that it is functioning properly and efficiently. This includes checking the solar panels for damage, cleaning the panels to ensure maximum sunlight absorption, and checking the inverter for any issues.

Overall, an on-grid solar PV rooftop system is an efficient and cost-effective way to generate clean and renewable energy. By connecting to the power grid, the system ensures a reliable source of electricity at all times while also allowing the owner to earn credits for the excess electricity exported to the grid.

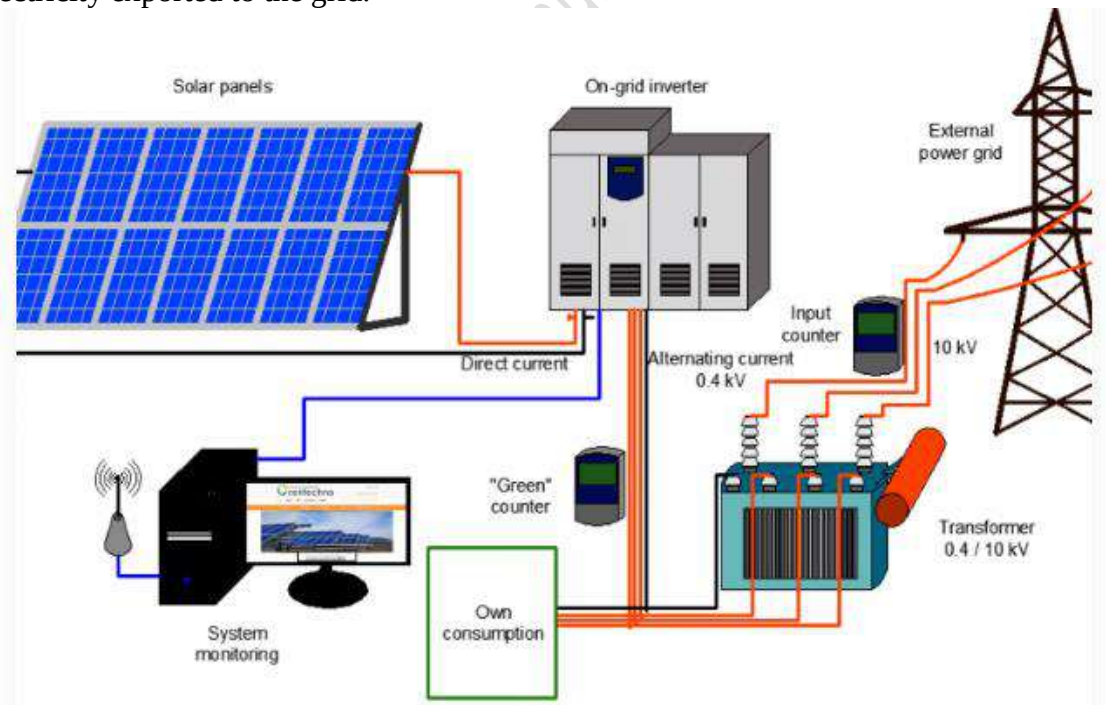



*Figure 12 Working of Grid Tied Solar PV system*

## 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 provide a standard mechanism to check, monitor, assure, identify issues, and implement rectifications / mitigating options so ensure the quality in implementation of all the grid connected rooftop Solar PV System across the country. This QCM also aims to educate all the stakeholders so as to maximise the power from the installed solar PV Plant.

The three tier QCM is mandatory for any compliance, 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. For the purpose of QCM, third party installers/contactor/RESCOs/ System Integrators etc. are called under the definition of vendor.

**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 or State Implementing Agency 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.

**MNRE** will oversee the Program and its Officials may occasionally check the system's quality on a random basis.

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 (Utility/SIA)** | Bill of Quantities (BOQ) with Quality Action Plan (QAP), Annexure I<br>Pre-Dispatch Inspection Annexure II | 1. Commissioning Report Annexure III<br>2. Synchronization Report Annexure IV<br>3. Quality Inspection and performance Assessment Report Annexure V<br>4. Post Installation Inspection Annexure VI |
| **TIER II** | | |
| **Third Party Inspection Agency (TPIA)** | Applicable based on the term of engagement between MNRE and TPIA as per the inspection report<br>Annexure I<br>Annexure II | Post installation inspection on sampling basis based on the terms of engagement between MNRE and TPIA as per the inspection report<br>Annexure III<br>Annexure IV<br>Annexure V<br>Annexure VI |
| **TIER III** | | |
| **MNRE / Authorised institute by MNRE** | Optional and random sampling basis as per the inspection report<br>Annexure I<br>Annexure II | On random sampling basis as per the inspection report<br>Annexure III<br>Annexure IV<br>Annexure V<br>Annexure VI |

## 3.1 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 vendor 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-Installation stage.
ii. Quality of work in the field.

## 3.2 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.

## 3.3 TIER-III

MNRE shall be responsible for third tier Quality Control Mechanism. MNRE officials or any authorised Institutions designated by MNRE may conduct quality checks during Pre-Installation 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.
- MNRE Shall inspect Grid connected solar PV systems on random sampling basis in its coverage area during the first five years of Operation & Maintenance

# 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 12 Dia.**

**D.4. Degree - The Module alignment and tilt angle shall 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:

4.8.1 The earthing shall be done in accordance with latest Standards.

4.8.2 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.

4.8.3 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.

4.8.4 Earth resistance should be as low as possible and shall never be higher than 5 ohms.

4.8.5 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 metering mechanism such as gross or net metering and The installation of meters such as gross or net meter billing mechanism, 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.

4.11.2 All meters installed at the renewable energy system shall comply with the CEA (Installation and Operation of Meters) Regulations, 2006 and subsequent amendments thereof.

4.11.3 All meters shall have Advanced Metering Infrastructure (AMI) facility with RS 485 (or higher) communication port.

## 5 Measuring Equipment's:

I **I-V Tester:** I-V tester (as shown in Figure 9) 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.

II **Thermography Camera: Thermography camera** (as shown in Figure 10) is used in IR imaging 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.

III **Clamp Meter:** A clamp meter (as shown in Figure 11) 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.

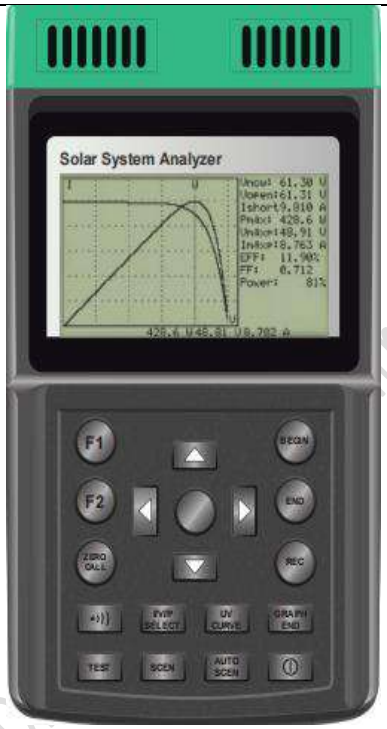



*Figure 13 IV Tester*

*Figure 14 Thermographic Camera*


*Figure 15 Clamp Meter*

IV **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

*Figure 16 Pyranometer*

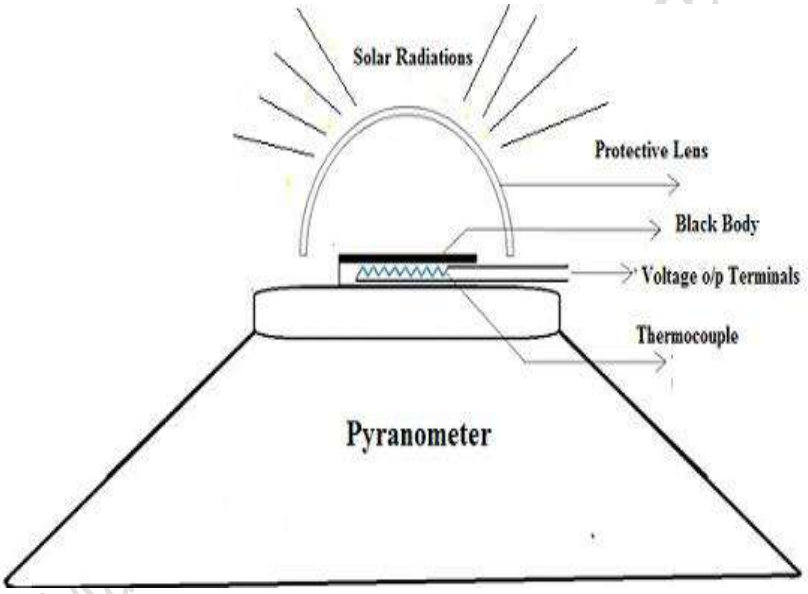



*Figure 17 Working of Pyranometer*

V **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.

*Figure 18 Multimeter*

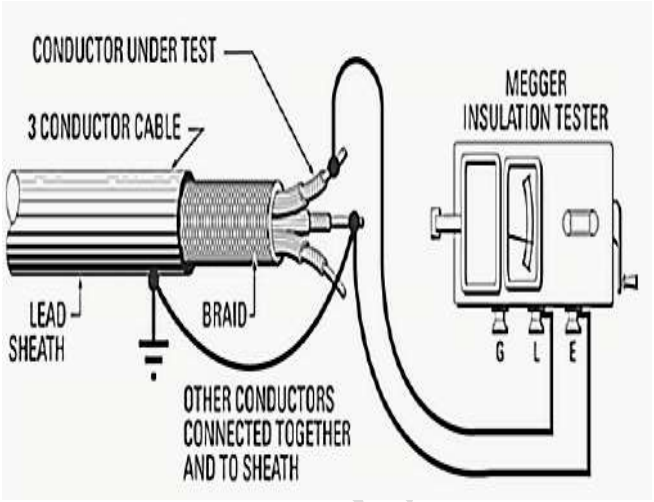



*Figure 19 Testing the insulation through a megger*

VI **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.

VII **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.

VIII **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.

IX **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

*Figure 20 Vernier Calipers*


*Figure 21 Earth Resistance Meter*

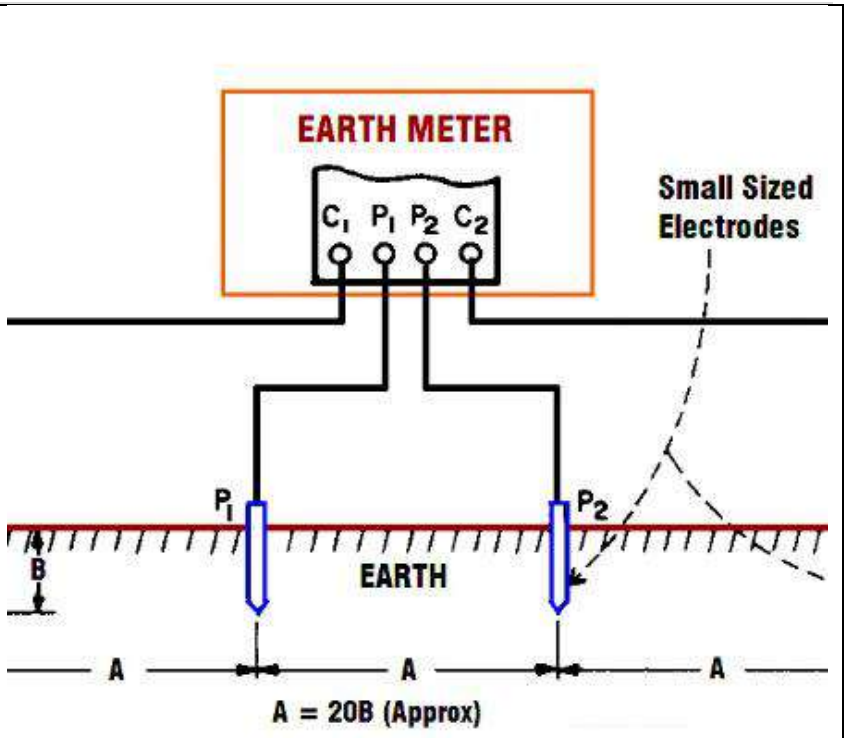



*Figure 22 Measuring earth resistance*



## 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. Never work alone (work with a partner).
ii. Insulated gloves and safety shoes
iii. Safety plan & first aid kit.
iv. An understanding of safety practices, equipment, and emergency procedures.
v. Safety helmet & eye protection.
vi. Proper measuring equipment's: electrical & dimensional.
vii. Appropriate safety harnesses, if working on roof.
viii. Tape, wire nuts or cable connectors to protect cable terminals.
ix. Fire extinguisher.
x. Appropriate ladder.
xi. Appropriate lifting equipment's.
xii. 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.

***Important Note***

*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.

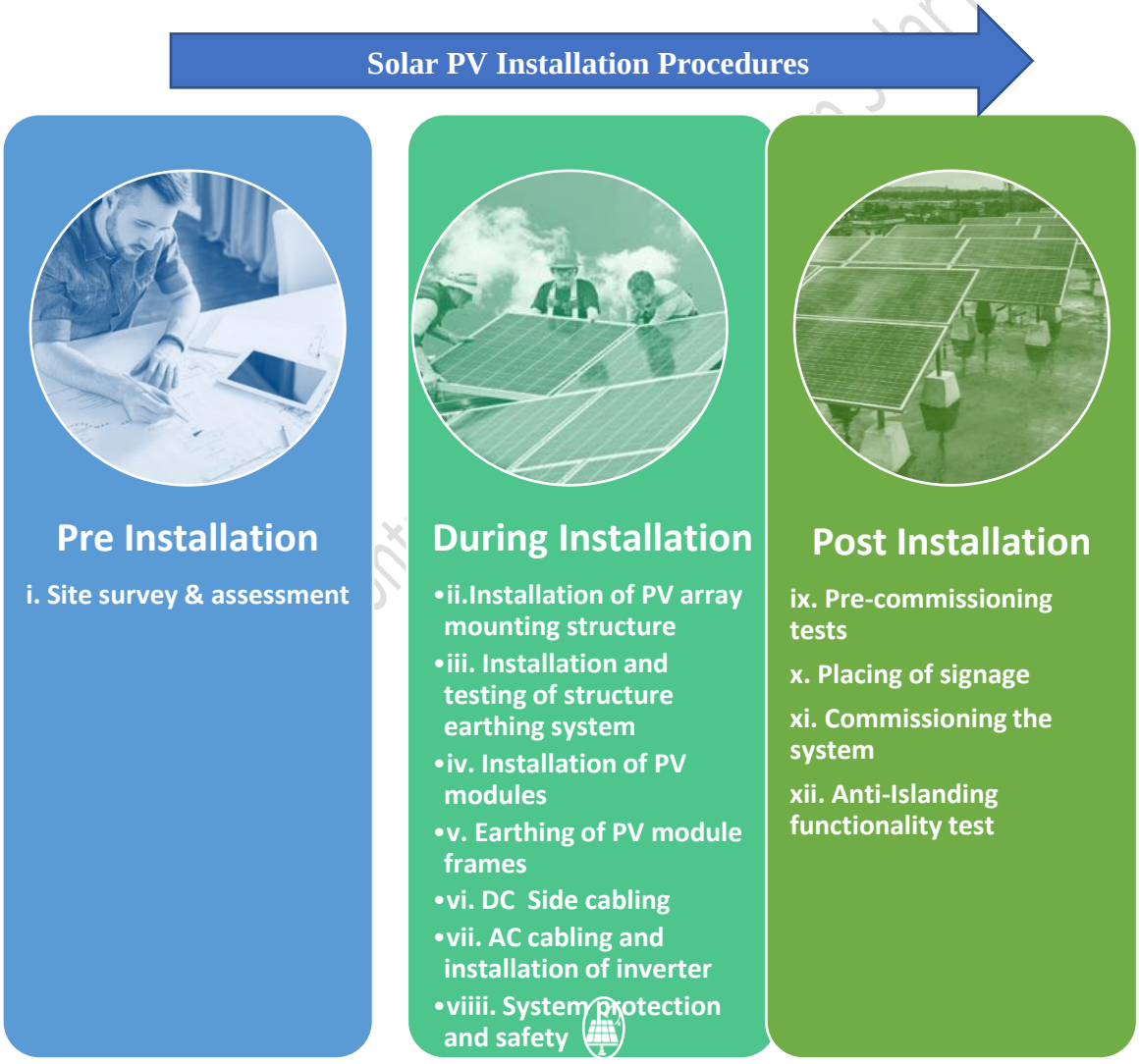
**Marking and Signage:** Marking is needed to provide emergency responders with appropriate warning and guidance so that they can work their way around the system and how to isolate it. This can facilitate identifying energized conductors or wires that connect the solar modules to the inverter, as these 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 connecte

## 7 Installation Manual

Installation of PV system solely relies on the standard of component and workmanship. Hence, installation and commissioning procedures of 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 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 following steps.



## 7.1 Site Survey/ Assessment

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.

**a. Pre requisite for a Site Survey:**

i. Personal protective equipment (as applicable to site condition)
ii. Competent electronics to identify / determine shadow free area
iii. A compass to record direction (Mobile app may be used/available)
iv. A measuring tape/ digital distance meter to measure distance
v. An angle measuring equipment (Mobile app may be used/available)
vi. Format of Site Survey ( Annexure

**b. Conduct shadow analysis:**

Objects that come in the path of the incident solar rays any time during the day, will cast shadows and hence reduces the solar generation. A taller object located in the east direction would cast shadows during morning and 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.*

**Determining shadow free area:**

- The most accurate and easy method to determine usable and shadow free area is by using a reliable tool.
- When the position and height of the object are known, then the azimuth angle and altitude angle can be derived from various web tools that are available in web domain.
- *Consider azimuth and altitude angle between 08:00 AM to 03:00 PM on 21st* December (Northern Hemisphere) to get maximum length of the shadow casted by the obstructed by the adjacent object.

**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.

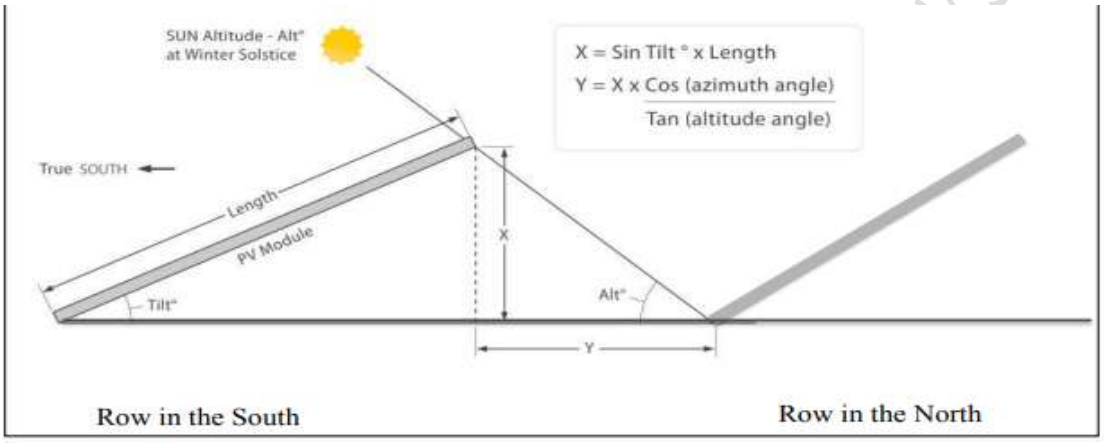



*Figure 11: Calculation space between two rows analysing sun position*

*Figure 23 Calculation space between two rows*

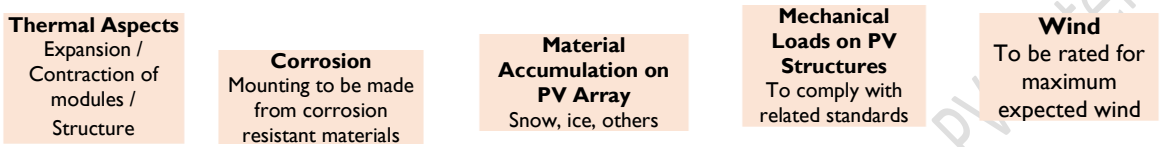
Shadow analysis can also be performed through desktop analysis using simulation software available in the digital platform. However, results from such an analysis solely depends on the accuracy of inputdata i.e., height, breadth of the object and distance from the solar array location. When shadow analysis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

**c. Determine suitable location for inverter, electrical equipments and cabling routes:**

i. Location of string combiner box, inverters and instruments should be such that their access iscontrolled.
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.
v. The location of overcurrent protection devices and/or load breaking disconnecting
vi. Cable routes and hence cable length based on array location, combiner box location, inverter location and location of main switch board
vii. Determine the length of conduit or cable tray required for the installation

## 7.2 Installation of PV Mounting Structure:

The failure of mounting structures for photovoltaic (PV) arrays is becoming a growing concern in Indian solar projects, particularly due to strong winds. While these structures are typically designed to optimize energy generation by considering factors like tilt angle and tracking, many PV systems have suffered damage due to inadequate consideration of wind loading. To ensure optimal performance, a mounting structure must not only be strong enough to withstand wind, but also promote adequate air circulation and minimize temperature loss. Additionally, it's essential to align the structure's design, placement, orientation, tilt, and shading with the electrical string design and inverter selection.




**Designing array mounting structure should comply with IEC 62548**

a) **Wind loading on PV array mounting structure:** To ensure that a photovoltaic (PV) array mounting structure can withstand the wind speed of a particular site, it's essential to design it according to the guidelines set out in IS 875 Part 3: Wind Loads on Buildings and Structures. When modules are installed on an inclined roof, adequate gap between two rows and frames must be kept as such that maintenance personnel can reach to each corner of the modules without stepping on to it.

***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 an inclined roof, use the same tilt as that of the building roof. Another tilt on an inclined surface may be avoided.
- Never mount PV modules at the edges and corners of a building roof (pressure co-efficient zones) to minimise wind pressure.
- An additional walkway may be provided in between the rows to enable safe cleaning and maintenance of PV modules and access to PV module maintenance
- The module mounting structure needs to be verified by structural engineer.

**Protection against corrosion:**

- The steel structure shall be hot dip galvanized and the aluminium structure shall be anodized with appropriate thickness of coatings to protect the structure from corrosion.
- Do not drill, weld, or cut the structure at the site as it damages the coating and accelerate the corrosion of structure *on an inclined roof, use the same tilt as that of the building roof. Another tilt on an inclined surface may be avoided.*
- To prevent corrosion, the use of accessories made of mild steel is strictly prohibited. Instead, it is recommended to use supporting accessories such as nut, bolts, fasteners, washers etc that are resistant to corrosion, such as stainless steel or non-metallic materials.

**b. Tilt angle and orientation:** The recommended tilt angle of a module mounting structure depends on a variety of factors, including the latitude of the installation site, the time of year when energy generation is most critical, and the desired level of energy output. Generally, for fixed-tilt systems, the tilt angle is set to maximize the annual energy output, taking angle equal to the latitude of the site. 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 atthe same tilt and orientation of the roof. A racked mounting structure over an inclined roof is not recommended for strong wind zone.

**Orientation of the Solar PV Module:**

- SPV Modules should be installed south facing in the Northern hemisphere and north facing in the Southern hemisphere. Since India is in the Northern hemisphere, the modules will be installed always- South facing in our country. The directions North-South can be found with the help of Magnetic Compass.

**c. 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. A minimum gap of 0.5m between two rows should be maintained for movement of maintenance personnel for cleaning or other maintenance work.

### d. Foundation block for module mounting structure:

- **Best practices for construction of foundation block and prevent rainwater leakage.**
- Structural engineer who can assess the load-bearing capacity of the roof and provide recommendations for the foundation design based upon the weight of the solar panels, and mounting structure.
- Suitable foundations design such as ballasted, anchored etc. may be constructed as per the building's structure, wind speed/ snow loads, and the type of roofing material.
- Suitable adhesive coating should be used to give ballast dead weight at the structure.
- Foundation blocks must be casted with concrete ratio of M20 or M25.
- J anchor bolts inserted in the foundation block should be of appropriate size and material.
- Avoid drilling RCC roofs, instead use concrete ballast and adhesive materials to fix the structure.
- Use proper flashing methods and sealant materials for metallic and tiled inclined roofs.
- Always fasten the roof attachments on the crest (top of corrugation) to fix the attachment.
- Never drill on the trough (bottom of the corrugation in case of metallic roof)
- The module mounting structure and foundation block has to be verified by structural engineer.

***Measures to be taken to enhance ventilation of PV modules:***

- 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 on a flat RCC roof
- 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.

## 7.3 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. Verify the earthing conductor routing plan.
ii. Prepare earth terminal bar / conductor, lugs, clamps, earthing rod and earth pit as per drawing.
iii. Ensure all module frames and each part of mounting structure are electrically bonded.
iv. Use proper WEEB for bonding.
v. Select the location for earth pit considering the soil wetness. Moist soil will provide least resistivity.
vi. Attach the earthing terminal bar /wire with earthing rod.
vii. Connect terminal bar to structure.
viii. Ensure all the connections are neat and tight.
ix. Test earthing continuity and resistance of earth electrode after installation.
x. Do the earthing for inverter, DCDB, ACDB and lightning arrester in a similar war

***Important to note:***

- The conductor used to earth the exposed metallic frames of the PV array shall have a minimum size of 6mm2 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 16mm2 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 earthresistance 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.

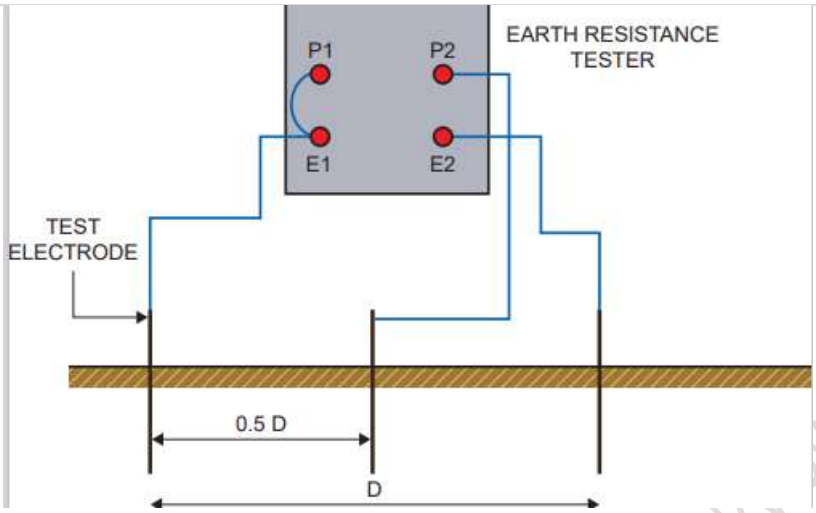



*Figure 24 :Illustration for Earth Electrode resistance testing*

| Position of Middle Electrode | Measured Electrode Resistance(Ohm) |
|---|---|
| 50% of D | |
| 40% of D | |
| 60% of D | |
| Mean | |

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

*Table 1Table format to record the earthing resistance*

## 7.4 Installation of PV Modules.

Installing SPV modules onto mounting structures is a critical step in the implementation of SPV systems. Since minor damage to SPV modules can affect power generation, it should be carefully handled during packing, transportation and unpacking. The earthing system of the mounting structure must be completed before any modules are installed to prevent any potential damage.

### A. Handling and packaging:

a. When handling SPV modules, it is best to stack, pack and transport them vertically with separators between them. Horizontal stacking should be avoided

ii. If due to unavoidable reasons, the modules are required to be stacked horizontally, introduction of a 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 and not more than six modules should be packed in one box.

### B. Transport loading 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 visible by naked eye and therefore precaution during loading, transportation and unloading should not be underestimated if there is no visible damage to the modules.

*Figure 25 Module Packing*

*Figure 26Module Stacking*

*Figure 27 Solar module handling and stacking*

*Figure 28 Solar PV Module handling*

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 stored in vertical manner with separators between each one. This will keep them safe during packing and stacking processes.

ii. It is not recommended to stack the SPV modules horizontally or store them that way .

***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.

**D. Module Mounting.**

i. SPV modules should be attached to the array structure using the mounting holes provided by the module manufacturer

ii. Stainless steel screws, washers and nuts should always be used to fasten the modules to the array frame.

iii. The module frame must be electrically isolated from the steel using a layer of non-conductive material.

- **Important Notes.**
- Avoid handling and installing SPV modules in windy or rainy conditions to ensure safety.
- It is advisable to refrain from stepping on the SPV module since it can result in permanent harm to the SPV cells contained within.
- Appropriate measures must be taken to safeguard the electrical connectors from water and dust getting inside them
- Stainless steel screws, washers and nuts should always be used to fasten the modules to the array frame.

## ⥵ Earthing of PV module frames

i. Following the installation of SPV modules, their frames should be bonded together and then connected to the main earthing conductor of the mounting structure.

ii. To guarantee an optimal electrical link, the earthing conductor must be securely attached to the module frame.

iii. Anodized coating of SPV module frames consists of aluminum oxide, which acts as a form of insulation. To establish an electrical bond between the frames and the structure, it is important to employ a suitable method to remove the aluminum oxide coating. Manufacturers may mark certain connection points without such insulation to provide way for connection.

iv. The earth/grounding cable should be installed alongside the SPV array cables (positive and negative) and pump controller cables, until connected to an earth rod connected in the ground.

After physical installation and establishment of earthing bond of the frames, SPV modules are connected in series electrically to form a string.

## 7.6 DC Side 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.


### *A. Precautions to take while wiring modules:*

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. The steps may be followed 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.

- **Important Notes.**

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

- Minimize the area of conductive loops to reduce the magnitude of lightening-inducedovervoltage.

- Keep bending radius of cables more than 40mm or as recommended by module manufacturer.

**C. 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).

D. **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 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.

**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.*

- *Minimum clearance to be maintained to the top and bottom of the inverter.*
- *Minimum 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 System protection and safety

The purpose of grounding any electrical system is to prevent unwanted currents from flowing (especially through people) and possibly causing equipment damage, personal injury, or death. Lightning, natural and man-made ground faults, and line surges can cause high voltages to exist in an otherwise low-voltage system. Proper grounding, along with over current protection, limits the possible damage that a ground fault can cause.

**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 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 over current & over voltage***

- 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.
- Design requirements for photovoltaic arrays, the rating of fault current protection device for each string should be as per IEC
- According to IEC62548, over current protection devices shall be installed in both positive and negative conductors.
- 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.

## Points to remember

i. The Earthing shall be done in accordance with the IS 3043 including its amendment and updated versions.

ii. The Earthing system should be designed in such a way that its should able to restrict the potential of each conductor according to the level of insulation applied and magnitude of the current conducted through human body should be less than the value that can cause ventricular fibrillation of heart.

iii. Earth connections shall be done in such a way that they are visible for inspection and all the earth electrodes can easily be tested at any point of time.

iv. It is recommended to keep the value of resistance of earth electrode less than 5 ohms.

v. All the materials, fittings etc. used for doing earthing shall conform to the Indian standard, wherever exists.

vi. The actual value of soil resistivity should be considered while designing the earthing system at the site and for reference, selection criteria of the site, for any type of soil treatment to improve earth electrode resistance, etc. the IS 3043 shall be referred.

vii. The electrode material should be selected according to the corrosivity of the soil in which it is used, for the relation between resistivity and corrosivity of the soil and method to safeguard the conductor against excessive corrosion the IS 3043 shall be referred.

viii. It is recommended for selection of type and installation of the earth electrode the provisions of the IS 3043 should be considered. However, the pipe or rod-type earth electrode is preferable.

ix. In case of the two-earth electrode or more the separation among them should be twice the length of the electrode driven in the ground. Except in special conditions (for e.g.- where the soil is hard to dig out), a number of electrodes in parallel are to be preferred to a single long electrode.

x. The provisions given in the IS 3043 should be considered while selecting or connecting the earthing/protective/grounding conductor from the components to the earth pit.

xi. Separate earthing conductor shall be provided for the controller, pump-motor set and SPV array etc. for its connection to the earthing pit and it should be continuous in nature for electrical conductivity. However, even for the earthing of light current equipment (for example, high voltage testing equipment) the cross-sectional area of the earthing lead shall not be less than 6 mm2.

xii. For the maintenance of the earth electrode and measurement of the Earth electrode resistance the provisions of IS 3043 shall be referred.

**Lightning Protection System (LPS)**

i. Lightning Arrestor is installed nearer to the SPV water pumping system to divert the electrical surge due to lightning towards ground thereby protecting the system components against damage. Lightning protection shall be provided as per IEC 62305 and IEC 63227 standards including its amendments and updated versions.

ii. An external lightning Rod, whose height should be more than the highest point in the system with a lightning protection system (LPS) designed to comply with class III or higher shall be installed, based on the site requirement which in turn depends on the area-specific lightning activity, etc. parameters.

iii. Arrangement and positioning of the separate air-termination systems can be determined using different methods given in the IEC 62305-3. While determining the position following points are to be considered such as: -

a) The structure to be protected is fully located within the protected volume provided by the air-termination system.

b) There should be separation distance between the air-termination system and PV power supply system to prevent dangerous sparking against parts of the PV power supply system in case of direct lightning. The separation distances determined in accordance with IEC 62305-3 & IEC 63227 shall preferably be maintained.

c) The possibility of the PV modules being shadowed by air-termination systems shall be taken into account and distance from the PV modules can be calculated using the IEC 63227.

iv. A separate earth electrode is required for the dispersion of the lightning current into the ground with suitably low value of the earthing resistance i.e., less than 5 ohm. And the minimum length (l1) of vertical earth electrodes for lightning protection level III or higher shall be determined according to the IEC 62305-3.

v. The cross-section of the metal sub-structures used for the connection of the lightning arrestor to the earth electrode should be no less than 16 mm2 Cu or 25 mm2 Al or GI of equivalent current carrying capacity should be used, which will also depend upon the class of the Lightning protection system.

vi. The earth pits given with the SWPS {i.e., Earth pit(s) for the BoS system (other than LA) and Earth Pit for LA} should be made equipotential bonded to each other

## 7.9 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 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 VOC (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.

| **Interconnection with grid parameters** | | |
|---|---|---|
| **Parameters** | **Reference** | **Requirement** |
| Synchronization | IEEE 519 and CEA (Technical Standards for Connectivity of the Distributed Generation Resources) Regulations 2013 | Every time the generating station must be synchronized to the grid. Voltage fluctuation < ± 5% at point of inter connection |
| Voltage | IEEE 519 and CEA (Technical Standards for Connectivity of the Distributed Generation Resources) Regulations 2013 | Voltage-operating window should be under operating range of 80% to 110% of the nominal connected voltage. Beyond a clearing time of 2 second, the photovoltaic system must isolate itself from the grid |
| Flicker | IEEE 519 and CEA (Technical Standards for Connectivity of the Distributed Generation Resources) Regulations 2013 | Should not cause voltage flicker in excess of the limits stated in IEC 61000 |
| Parameters | Reference | Requirement |
| Overall Grid Standards | Central Electricity Authority (Grid Standard) regulations 2010 | Compliance |
| Equipment | BIS / IEEE / IEC | Compliance |
| Meters | Central Electricity Authority (Installation and Operation of Meters) Regulation 2006& Amendments thereof, OERC Generic Tariff Order 2013 | Compliance |

| | | |
|---|---|---|
| Safety and Supply | Central Electricity Authority (Measures of Safety and Electricity Supply) Regulation 2010 | Compliance |
| Harmonic Current | IEEE 519 and CEA (Technical Standards for Connectivity of the Distributed Generation Resources) Regulations 2013 | shall not exceed the limits specified in IEEE 519 |
| Frequency | IEEE 519 and CEA (Technical Standards for Connectivity of the Distributed Generation Resources) Regulations 2013 | When the Distribution system frequency deviates outside the specified conditions (50.5 Hz on upper side and 47.5 Hz on lower side), there should be over and under frequency trip functions with a clearing time of 0.2 seconds. |
| DC injection | IEEE 519 and CEA (Technical Standards for Connectivity of the Distributed Generation Resources) Regulations 2013 | Should not inject DC power more than 0.5% of full rated output at the interconnection point |
| Power Factor | IEEE 519 and CEA (Technical Standards for Connectivity of the Distributed Generation Resources) Regulations 2013 | While the output of the inverter is greater than 50%, a lagging power factor of greater than 0.9 should operate |
| Islanding and Disconnection | IEEE 519 and CEA (Technical Standards for Connectivity of the Distributed Generation Resources) Regulations 2013 | In the event of fault, voltage or frequency variations the PV system must island / disconnect itself within IEC standard on stipulated period |
| Overload and Overheat | IEEE 519 and CEA (Technical Standards for Connectivity of the Distributed Generation Resources) Regulations 2013 | The inverter should have the facility to automatically switch off in case of overload or overheating and should restart when normal conditions are restored |
| Paralleling Device | IEEE 519 and CEA (Technical Standards for Connectivity of the Distributed Generation Resources) Regulations 2013 | Paralleling device of photovoltaic system shall be capable of withstanding 220% of the normal voltage at the interconnection point. |

| Pre Commissioning Tests | | |
|---|---|---|
| **Sr. No.** | **Item type** | **Remarks** |
| 1 | Capacity of installed system | Check AC capacity that is equal to Inverter capacity. The solar array capacity can be same or higher |
| 2 | Installation Layout – is it as per drawing? | This will confirm the locations of all protective features and it also rechecks the capacity installed is as per approved capacity. |
| 3 | Inverter IS / IEC standards qualified | Check applicability of each certificate to actual model as used in the system and the validity of all such certificates |
| 4 | PV panel IS / IEC standards qualified | Check applicability of each certificate to actual model as used in the system and the validity of all such certificates |
| 5 | PV isolators / PV cables IS / IEC standards qualified | Check applicability of each certificate to actual model as used in the system and the validity of all such certificates |
| 6 | String level and cumulative protections are provided for over-current and surges | Over current protection (OCP) needs to be checked for its specifications, locations and standards. OCP needs to be installed for each string and also for each combination of strings. The capacity of OCP fuse needs to be 1.56 times the short circuit current of the string or string combination, depending on where this OCP is located. |
| 7 | Surge protections are provided at all specific locations in the system. | Surge protection devices (SPD) need to be provided on DC side in AJB / SCB / DCDB and on AC side in ACDB / Grid interface panel, if not in-built in inverter on either side. The type of SPD to be used depends on inverter and also on distance between solar array and lightning arrestor. Normally, these will be Type 2 SPDs. |
| 8 | DC side isolator switch between solar array and inverter | It is essential to have facility to disconnect DC side from the inverter in case inverter needs to be worked upon during day time. Solar array would be energized and only by operating disconnect switch one can safely work on inverter. |
| 9 | AC disconnect manual switch provided with locking arrangement | AC side isolator needs to be installed before interconnection point and access to this disconnector / switch should be free to Discom personnel. It should be possible to easily isolate complete system from the grid in case of grid line maintenance or fault or possible accident to the grid. |
| 10 | Meters approved by concerned authority | If consumer has procured net meter and solar meter, it is mandatory that these meters are tested and certified by Discom meter testing laboratory. It should be checked whether installed meters are certified and sealed. |

| | | |
|---|---|---|
| 11 | Earthing protections for DC, AC and lightning arrestors | Earthing must be provided for DC, AC and for lightning arrestor. It is necessary to interconnect AC and DC side earthing pits underground to achieve equi-bonding. This eliminates chances of high potential difference between components, thereby preventing sparking, burning and accidents. Also, the earth pits soil must be checked for low resistance. Ideally, not higher than 2 ohms while preparing the pits and during their lifetime must be below 5 ohms as per the standard.<br>Some regulations and interconnection processes require redundancy in earthing and in such cases, it must be checked whether this is provided by having two earth pits for each earthing points. |
| 12 | Lightning protection system | LPS consist of lightning arrestor and its earthing that must be separated from other earthings in the systems. It should be checked that the components used, meet the standards and that full array and other components are covered within the effective protection area of the arrestors. |
| 13 | Signages | It is equally important to have warning and specification signs at different components and stages of the system. The sings must be as per net metering regulation of the state. In case there is no specific mention in the regulation, it is essential that industry standard practice is followed. These are crucial for grid engineers and O&M staff. |

| Pre-Commissioning Report/ User Handover Document | | |
|---|---|---|
| **Sl. No.** | **Parameters** | **Descriptions** |
| 1 | **General Information** | |
| 1.1 | Name of the system Owner | |
| 1.2 | Contact phone number of owner | |
| 1.3 | Emails 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 center contact details of implementing company | Land phone contact:<br>Mobile phone contact:<br>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 test lab issuing BIS/IEC certificate | |
| 2.11. | Warranty 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 numbers of inverters installed | |
| 3.5. | AC output voltage and frequency | |
| 3.6. | Installed outdoor or indoor? | |
| 3.7. | IP rating? | |
| 3.8 | Frequency tolerance | |
| 3.9 | Voltage tolerance | |

| | | |
|---|---|---|
| 3.10. | Inverter efficiency | |
| 3.11. | Total Harmonic Distortion | |
| 3.12. | Power factor | |
| 3.13. | Quality and Safety Standard (BIS/IEC) | |
| 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 manufacturing defect and violation of conformity of regulatory requirement | |
| **4** | **Array Structure** | |
| 4.1 | Types of structures 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 | Ratings 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 ratings | |

| | | |
|---|---|---|
| 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** |
| 7.1 | Make | |
| 7.2 | Type and Model | |
| | **Net meter** | |
| 7.3 | Make | |
| 7.4 | 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 materials | |
| 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 result 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 procedure. | |
| | Maintenance and cleaning recommendations | |
| **12** | **Energy generation** | |
| 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 am to 3pm) | |
| 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:** |

## 7.11 Commissioning the system

When the conductors and connections are acceptable and the system has successfully passed 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 and check it complies with local grid code.

| Post Commissioning Tests | | |
|---|---|---|
| **Sr. No.** | **Item type** | **Remarks** |
| 1 | Check whether solar power generation stops automatically when DISCOM supply shut off | This is an important test and is known as Anti-Islanding conformity test. The detailed procedure for this test is provided later in this presentation. |
| 2 | Confirm Bi-directional flow recorded on net meter | The engineer needs to adjust loads in the consumer premises to test bi-directional recording of power by the net meter.<br>• Once consumer load is lower than the generation the meter should record power flow to the grid.<br>• Once consumer load is more than the generation the meter should record power flow from the grid. |
| 3 | Check 'Consumption (Import) only' mode operation | For most of the period of a 24 hours day, the meter shall operate in 'import only' mode when PV system is not generating. This recording also should be tested by shutting down the PV system. |
| 4 | Check operation of Solar (Generation) meter | In most states solar 'generation' meter is also mandatory to be installed by consumer or by Discom. If so, this meter also should be tested for recording power flow. |

## 7.12 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 deviceand record

| Anti-islanding Mechanism | Disconnects inverter from grid when | Grid power supply is disrupted<br>Grid goes outside preset inverter |
|---|---|---|

## 8 General O&M

System maintenance is an important step in ensuring that installed systems are performing as intended. By regularly monitoring the components of the system, any potential issues can be detected before they become a problem. This careful maintenance ensures that the system is able to meet its operational requirements, while avoiding costly repairs or replacements down the line. The preventive actions, if any, could be taken well in advance to save any equipment from damage. The section proposes few periodical checks that can be done to ensure the system performance.

### 8.1 SPV Array

i. Check for any shading due to vegetation or new building over the PV modules.
ii. Check for any dust/ soiling/ scratches over the PV modules.
iii. Check for any visual de-coloration or delamination of EVA.
iv. Check for mechanical alignment of the module frames.
v. Check for suitable earthing arrangement between the PV module frame.
vi. Check whether the datasheet of the module matches with the nameplate.
vii. Check the tightness of the mounted modules
viii. Check that the glass is not broken. If it is, the Module will have to be replaced.
ix. Check the connection box to make sure that the wires are tight and the water seals are not damaged.
x. Check the Hot spots if any using Thermographic Camera
xi. Water used for cleaning should be clean and should be free of salt
xii. Check the Voltage and Current of the Module using Multimeter and Clamp meter.

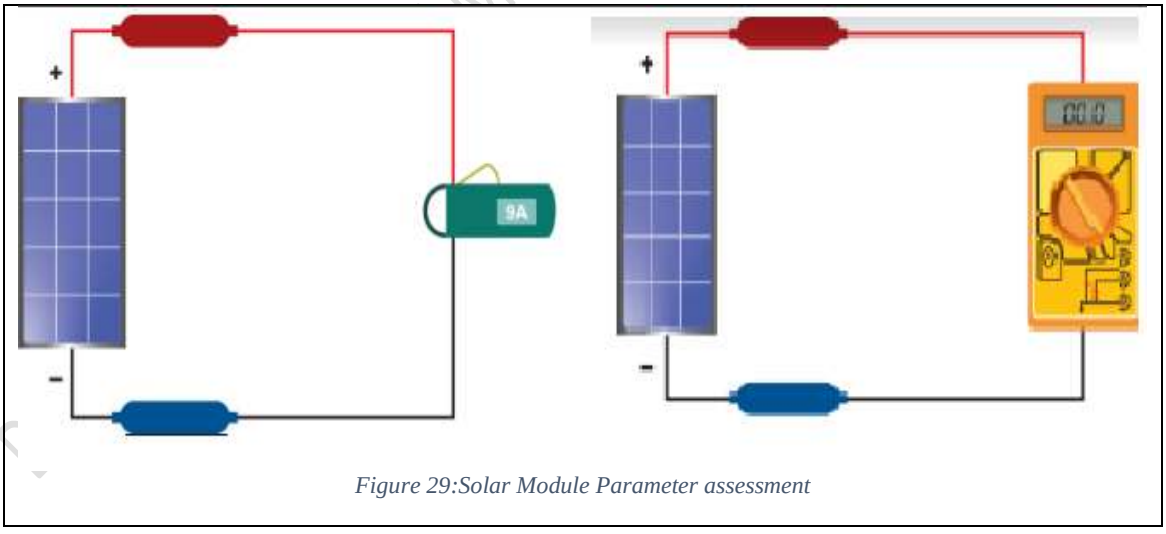



*Figure 29:Solar Module Parameter assessment*

### 8.2 .Mounting Structure

i. Check the area between the arrays for accessibility
ii. Visual check whether all MMS parts are clean and of homogeneous color.
iii. Check whether the nuts and bolts used is made of stainless steel and rust free
iv. Visually inspect the components of the structure are in correct position

v. Check for damages in the foundation. or MMS on flat roofs: Sufficient distance must be provided between roof surface and lowest PV modules for possible water logging.
vi. Ventilation below the structure should be ensured and check for uncontrolled plant growth if any.
vii. Check whether all the clamps are tightened.

## 8.3 DC Cabling & AC Cabling

i. Check the wire covering (insulating sheath) for cracks or breaks. If the insulation is damaged, replace the wire.
ii. Dirt and dust accumulation should be kept to a minimum and cables should be laid out straight without unnecessary loops
iii. If someone has changed the wiring since the last check, make sure that it is the correct size, that it has suitable insulation, that the connections are properly made and that it is fastened securely in its new place.
iv. Check the connections for corrosion and tightness.
v. Check that the junction box of the Module is firmly attached. If it is not, attach it correctly.
vi. All AC cables must be terminated with suitable lugs and the lugs must be correctly crimped.
vii. All cable must be terminated without any undue strain
viii. Conduct Insulation and continuity Test: Insulation values of the cable should be assessed periodically using Megger. If sudden fall in insulation resistance value of conductor is observed, repair or replace the defective cable. Continuity of wire can be checked using Clamp meter with probe adjusted for continuity mark.
ix. DC fuse used should have the correct voltage and current rating for the system.
x. Manual operation of circuit breaker.
xi. Proper IP protection class and intrusion of insects or external rodents in distribution board.
xii. Sufficient space available all around the cabinet.
xiii. Individual MCCB (Moulded Case Circuit Breaker) or switchable fuse with matching current rating and with a B characteristic
xiv. Proper earthing is demonstrated through measurement.

## 8.4 Inverter

i. Check the inverter's display and examine, if there is any warning/fault or alarm
ii. Check the inverter is well ventilated with operational exhausted fan and protected from direct sunshine.
iii. Visually check for any external physical damage to the inverter or corrosion.
iv. Clean all exposed parts of Inverter.
v. Check for loose or cable terminal connections like earthing, DC Side, & AC Side connections.
vi. Check for noise levels like humming sound, then contact service provider.
vii. Following test may be performed depending upon the functionality of the PV system.

1. • **AC circuit(s) test**
2. • **Continuity of protective grounding**
3. • **Polarity test**
4. • **Insulation resistance test**
5. • **String $V_{oc}$ measurement (I-V curve measurement if possible)**
6. • **Inverter start-up sequence**
7. • **PV string operational test (string $I_{mpp}$ measurement)**
8. • **AC power output measurement**
9. • **Loss of mains test**
10. • **Ground-fault troubleshooting test (only if needed)**

## 8.5 Maintenance of Earth Electrodes and Lightning Arrestor

i. Periodically check the resistance of the earthing electrode and maintain records.
ii. Visually inspect the earth electrode connection.
iii. Ensure the moisture content in the ground surrounding the earth pit.
iv. Visually inspect the arrestor for any sign of overheating at connecting points.
v. Clean the insulator of arrestor with dry cloth and check flash mark, surface cracks etc.
vi. Check for burst or puncture. If so, replace with the new arrestor.
vii. Check the earthing resistance of the Lightning arrestor earthing.

## Annexures

### Annexure I

| Bill of quantities ( BoQ) & Quality Action Plan (QAP) | | | | | | |
|---|---|---|---|---|---|---|
| **Si. No** | **Detailed description** | **Unit** | **Qty** | **Inspection** | | **Standard/ Documents for verification** |
| | | | | **At** | **By** | |
| 1 | **2** | **3** | **4** | **5** | **6** | **7** |
| I. | Solar PV Module | Nos. | | | | Datasheet, Warranty Certificate, ISO/IEC Test Certificate as per MNRE specifications |
| II. | Grid Connected Inverter | Nos. | | | | Datasheet, Test Reports, Certificate as per MNRE/BIS |
| III. | DCDB & ACDB | Lot | | | | Protection as per Inverter & Discom Requirement |
| IV. | Energy Meter System | Nos. | | | | Product Catalog, Test Certificate as per Discom requirement |
| V. | Solar DC Cable & AC Cable | Mtr | | | | Type Test certificate as per MNRE t |
| VI. | Module Mounting Structure | Set | | | | Product Catalog & Galvanization as per IS |
| VII. | Foundation Block And Anchoring | Nos. | | | | As per Approved Drawing, Visual Inspection |
| VIII. | Structure Accessories | Set | | | | Test Report in accord with Stainless Steel 304 |
| IX. | Cable Dressing & Conduits | Mtr | | | | Visual Inspection |
| X | Solar Cable Connector | Nos. | | | | Test Certificate |
| XI. | Lighting Arrestor | Lot | | | | Visual Inspection |
| XII. | Earthing | Nos. | | | | Visual Inspection & Measurement |
| XIII. | Commissioning Of Solar Power Plant | Set | | | | Visual Inspection |
| XIV. | Insurance | Nos. | | | | Policy & Invoice |

## Annexure II

### Pre-Dispatch Inspection for Modules, Inverters and BOQs

**Basic Details**

| S. No | Details Required | Response |
|---|---|---|
| 1 | Date Of Inspection | …..... |
| 2 | Name of the Vendor/Supplier/Contractor | …..... |
| 3 | Supplier's Inspection Call No. | …..... |
| 4 | Place of inspection: Address? | Warehouse/OEM |
| 5 | Work order no. and date | …..... |
| 6 | Order Quantity (pls specify ?) | …..... |
| 7 | Name of District and quantity | …..... |
| 8 | Inspection Order Call No. | …..... |
| 9 | Name of Inspecting Officers | …..... |
| 0 | Offered quantity for Inspection. | …..... |

**Solar PV Module**

| 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 S.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 | 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 75properly75. | 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- | Visual/Measurement | Approved drawing | Structure and dimension of the items should be as per the approved drawings given in | Yes/No, If No Please specify the item or structure. **Centre Shaft: -** Outer | |

| | | | | | |
|---|---|---|---|---|---|
| SERC and Certified Structural Engineer | | | MNRE Specification or approved by IIT, NIT, IISC. | Diameter. ThicknessBaseplate 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, Connecting Bracket, SQ Bracket, Bracing, Base Plate | Measurement | As per IS 4759/ASTM A123/approved drawings | minimum 80micron | For each item 10 readings are taken. (1) ……. 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: - | | | | | |

**Annexure III**

| **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.-<br>2- Invoice copy of modules-<br>3- Delivery challan of modules / optional | |
| **4** | Type, Make and year of manufacturing of Modules | | |
| **5** | Each Module data sheet (flash test)<br>Rated power output having tolerance within + 3% | Attached | |
| **6** | PV module qualification test standard (IEC 61215/IS14286 / IEC 61730 / IEC 61701/IS 61701 (for highly corrosive atmosphere) | Document attached | |
| **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<br>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.<br>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<br>1- Modules to inverters, length<br>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<br>(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)<br>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) | 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 | | |

## Annexure IV

| Synchronization report of SRTPV system (Net / Gross metering) | | | | |
|---|---|---|---|---|
| **A** | **Consumer Details** | | | |
| 1 | Name of the Consumer | | | |
| 2 | Category | | | |
| 3 | RR No./Account ID/Connection ID | | | |
| 4 | Pole Number | | | |
| **B** | **Meter Details** | **Bi-directional Meter** | | **Existing meter** |
| | | **Main Meter** | **Check Meter** | |
| 1 | Meter make 1ph / 3 ph. | | | |
| 2 | Type | | | |
| 3 | Serial number | | | |
| 4 | Capacity | | | |
| 5 | Meter constant | | | |
| 6 | Initial reading (Tri vector parameters) | | | |
| | i) Import | | | |
| | ii) Export | | | |
| Note:<br>1. The Bi-directional meter records solar generation and existing meter records installation consumption in case of Gross metering.<br>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. | | | | |
| **C** | **Grid Tied Inverter** | | | |
| 1 | Make | | | |
| 2 | Serial number | | | |
| 3 | Capacity | | | |

| | | |
|---|---|---|
| 4 | Input voltage | |
| 5 | Output voltage | |
| 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<br>• Manual Switch solar side: Yes/No<br>• 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 |

## Annexure V

| | 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. Orientation

| Sl. No. | Parameters | Method/ Tools to use | Findings |
|---|---|---|---|
| 1. | Orientation and Tilt of the PV array | Inclinometer (mobile app) Compass | • Tilt:<br>• Orientation: |
| 2. | Is PV array free from shadow | Use Sun Path finder Camera | • Location affected by shadow:<br>• Object creating shadow:<br>• Months of shadow:<br>• Time of shadow: |
| 3. | Measure Inter-row spacing | Measuring tape | • Distance between closest point between two rows:<br>• 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:<br>• Location of the object:<br>• Height of the object:<br>• 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 | • $P_{max}$:<br>• Tolerance:<br>• $V_{oc}$:<br>• $I_{sc}$:<br>• $V_{mp}$:<br>• $I_{mp}$: |
| 4. | Temperature coefficients | Use datasheet of PV module | • Tc ($\alpha$) for Isc:<br>• Tc ($\beta$) for Voc:<br>• Tc ($\gamma$) 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:<br>• Maximum DC input voltage:<br>• Nominal AC capacity:<br>• Nominal AC voltage & Phase:<br>• Maximum AC output current:<br>• Number of MPPT:<br>• MPPT voltage range:<br>• Number of inputs per MPPT:<br>• Maximum input DC current:<br>• 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:<br>• Type of communication port?<br>• 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?<br>• 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<br>• Check continuity for module to structure<br>• Check continuity for structure to earthing strip<br>• 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?<br>• Whether DC isolators used for array cable?<br>• 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<br>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?<br>• Is there any string cable hanging?<br>• Whether DC cable from PV array is protected by conduit or cable tray?<br>• If conduit, whether it is UV stabilised?<br>• Whether the cable tray is covered?<br>Whether cable tray has sharp edges?<br>Is there any cable lying exposed on the floor? |
| 4. | Is there any exposed DC conductor | Observe and record<br>Take photo | • Look for cable damage and record<br>• Look for cable exposed to sharp metallic objects and record<br>• 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<br>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<br>Take photo | • Inverter installed in outdoor or indoor.<br>• Is the inverter being accessible?<br>• At what height, the inverter is installed?<br>• Gap between inverter and walls?<br>• Does inverter get enough ventilation?<br>• Does the inverter get direct sunlight?<br>• Whether the inverter is installed in a corner or under staircase?<br>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<br>Take photo | • Distance from the PV array?<br>Distance from inverter?<br>Outdoor or indoor?<br>• Height from the floor/ ground?<br>• 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<br>Take photo | • Distance from the inverter?<br>• Distance from main grid panel?<br>• Outdoor or indoor?<br>• Height from the floor/ ground?<br>• Is it protected from rain? |
| 8. | Cable routing and conduit | Observe and record | • Check if conduits / cable tray is intact and UV protected<br>• 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<br>• Perform anti islanding and functionality test |
| 10. | Provision and | Observe | • Whether PV modules are accessible for |

| | | | |
|---|---|---|---|
| | arrangement for system accessibility for maintenance | and record | cleaning?<br>• Whether water is accessible for cleaning of PV modules?<br>• 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:<br>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<br>• 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<br>Torque wrench | • Is there any loose or detached part in the structure?<br>• 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:** | | | |

### j. 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:** | | | |



**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 (%) $(\frac{B*1000}{A\times C} \times 100)$ | | |

**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)] |

**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?<br>• Is there any snail trail?<br>• Is there any visible crack or mark on the module<br>• Is there any brown spot or non-uniform 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<br>• 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.<br>• 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 | |

## Annexure VI

### Post Installation Inspection

### General Information

| **Detail of farm where Solar Pump is to be installed:** | **Response given by the inspector** |
|---|---|
| Name of the beneficiary | |
| Name of the vendor who installed the system | |
| Address | |
| Work Order No. | |
| Latitude & Longitude | |
| SPV Capacity installed in kWp | |
| Installed Inverter Capacity | |
| Date of installation | |
| Date of Commissioning | |
| Is User manual and warranty card handed over to customer in local language? | Yes/NO |
| Metering arrangement | |

**Solar PV array**

| **Safety: -Personal Protective Equipment** | | |
|---|---|---|
| 1.Helmet | | |
| 2.Gloves | | |
| 3.Glasses | | |
| 4.Safety shoes | | |
| **Instruments to be carried along for the inspection** | | |
| 1.Multimeter | | |
| 2.Meter tape | | |
| 3.IR Thermal Camera | | |
| 4.Clamp meter | | |
| 5.Inclinometer | | |
| 6.Megger | | |
| **Checklist** | **Response of the inspecting officer** | **Remarks, If any** |
| Manufacture's Name of PV Modules | | |
| Capacity (Wp) of each PV module | | |
| No. of PV Modules | …..Also specify series…... & Parallel…... | |
| Serial number of each module | | |
| Total PV Capacity (Wp) of the array | | |
| Declared maximum peak Voltage (Vmp) of each module | | |
| Declared maximum peak Current (Imp) of each module | | |
| Declared Maximum voltage of the system | | |
| Fire Rating Class | | |
| Maximum Series Fuse Rating | | |
| Whether RFID tag is pasted or not? Location | Yes/NO; ..... | |

| | | |
|---|---|---|
| Nameplate Type (Waterproof Sticker or Metal plated or else, specify) | | |
| Any physical defect present in the Modules/Array? | YES/NO, If Yes? Please Specify. | |
| Is module frame made up of corrosion resistant, electrically resistant anodized aluminium. | YES/NO | |
| Whether the earthing connection spot is properly marked on the frame of the module for its earthing. | YES/NO | |
| Is PV Modules electrical connections being tight and secure? | YES/NO | |
| Is Module to Module wattage mismatch in the SPV array mismatch shall be within ± 3 percent? | YES/NO | |

**Module Mounting Structure**

| **Instruments to be carried along for the inspection** | | |
|---|---|---|
| | | |
| Measuring Tap | | |
| Torque Wrench | | |
| Vernier calliper | | |
| Spirit level | | |
| Compass | | |
| | | |
| **Checklist** | **Response of the inspecting officer** | **Remark; If any?** |
| Is SBC (Soil bearing capacity) lab test available: - | YES/NO | |
| Is Validated foundation drawing and design along with its calculation, as per Safe bearing capacity of site available? | Yes/No | |
| Is foundation hardware being as per IS 5624? | Yes/No; If No then which standard is used (IS 6403 / 456 / 4091 / 875) | |
| Is the Foundation Block size/Pile cap Size being as per the approved drawing | Yes/No? If no Please specify | |
| Is nature of soil being sandy? | Yes/No. If yes, then is the anti-tilt protection is provided in the foundation? | |
| Is all hardware are properly tightened. | Yes/No | |
| All Anti-theft Nuts. | Broken/Not Broken | |
| Is the square type of Washer used in all tightened nut and bolts | Yes/No | |
| Module facing direction: - | | |
| Is Structure Assembly level being vertical, it should not be | Yes/NO | |

| | | |
|---|---|---|
| tilted? | | |
| Is Structure Alignment being free from any defect? | Yes/NO | |
| Is Surface finish free from defect? | Yes/NO | |
| Is Ground clearance should be maintained as per drawing: | Yes/No | |
| Is shadow free area available? | Yes/No | |
| Three times daily tracking | Manual/Automatic/Not present. | |
| Seasonal Tracking | Manual/Automatic/Not present. | |
| Whether the proper gap is 100provided in between the module as per structure drawing | Yes/No | |
| Is alignment of all PV module being in level? | Yes/NO | |
| Is it certified that All Nut bolts, Module Mounting clamps fasteners are of stainless steel of Garde SS 304? | Yes/No | |

**Electrical Connections**

| **Safety: -Personal Protective Equipment** | | |
|---|---|---|
| Helmet | | |
| Gloves | | |
| Glasses | | |
| Safety shoes | | |
| **Instruments to be carried along for the inspection** | | |
| Megger | | |
| clamp meter | | |
| Multimeter | | |
| electrical tape | | |
| thread | | |
| | | |
| **Checklist** | **Response by Inspecting Officer** | **Remark; If any.** |
| No. of Earthing provided | | |
| Earth resistance value of all the pits | | |
| Is the value of earth resistance of all the pits is less than 5ohm | Yes/NO | |
| In case of multiple earth pits | Connected/Independent | |
| LA Pipe height and Size of GI strip/Cable used for connection to ground:- | | |
| Is in case of uPVC/HDPE pipes used as discharge pipe, a separate non-corrosive, low resistance conductor from motor earth terminal to control Module earth terminal shall be provided for earthing? | Yes/NO | |
| Is Connections of earthing 101properly done? | Yes/NO | |
| Is PV module wiring routing properly with UV rated cable tie? | Yes/NO | |

| | | |
|---|---|---|
| Is chemical Earthing done as per IS-3043? | Yes/NO | |
| Is PVC conduit pipe of suitable size ISI make or black drip pipe used for covering Module wiring and which is buried in the ground by 1 foot? | Yes/NO | |
| Is Electrical continuity of PV module is maintained? | Yes/NO | |
| Is LA positioning behind structure & height greater than highest structure peak | Yes/NO | |
| Is Array connection to controller done through JB/MCB? | Yes/NO | |
| Is Polarity correct in connection? | Yes/NO | |
| Is proper lugs used for the connection of the wire? | Yes/NO | |
| Is there any loose wire or connection available? | Yes/NO; If yes please specify | |

## 9 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

Annexure B

नवीन एवं
नवीकरणीय ऊर्जा मंत्रालय
MINISTRY OF
**NEW AND**
**RENEWABLE ENERGY**

सत्यमेव जयते

# Quality Control Manual for
# Solar Photovoltaic Water Pumping System

# Proprietary Statement

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It is clarified that the information given in this handbook does not supersede any existing provisions laid down in the MNRE publications. The instructions given are for the purpose of guidance in implementing quality control in implementation of Solar Photovoltaic Water Pumping System Programme of Ministry of New and Renewable Energy.

# Amendment procedure

i. MNRE may propose amendment to any content/ clause of the manual required with time to time with revision in technology, policy etc

ii. Revisions in Quality Control Manual will be issued by the MNRE after internal approvals as and when required.

iii. It is the responsibility of the copy holders to update the superseded versions of documents and replace the same with new version to ensure against unintended use of obsolete documents.

iv. Any external request for amendments may be submitted to MNRE for review.

Any Amendment to be issued in this manual will be numbered as follows:

| S. No. of correction Slip | Date of Issue | Page No. and item to be modified/ Clause No. | Remarks/ New Issue |
|---|---|---|---|
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# List of Abbreviations

| | |
|---|---|
| MNRE | Ministry of new & Renewable Energy |
| QCM | Quality Control Mechanism |
| SIA | State Implementing Agency |
| TPIA | Third party Implementing Agency |
| SPV | Solar Photovoltaic |
| AC | Alternating Current |
| DC | Direct Current |
| STC | Standard Testing Condition |
| USPC | Universal Pump Controller |
| MMS | Module mounting Structure |
| BOS | Balance Of System |

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# 1. Objective

The Quality Control Manual for Solar Photo Voltaic(SPV) Water Pumping System is to serve as a guide to ensure quality of the SPV water pumping system installed, including its components, under the Schemes of the Ministry of New & Renewable Energy(MNRE). It also enumerates stakeholders' responsibilities and provides a structured approach in assessing the quality of installations under such scheme(s). The Quality control Mechanism(QCM) and inspection procedures can check the efficiency of the system and serve as a tool for optimization.

# 2. SPV Water Pumping System

## 2.1. Overview

The Standalone SPV Water Pumping system operates the Surface (Mono-set) / Submersible Motor-pump sets through collected photovoltaic energy as opposed to grid electricity or diesel run water pumps. The electricity generated by Solar Photovoltaic system can be utilized to operate the Motor-Pump set to lift water from shallow wells, ponds, canals or Tube wells with Solar Photovoltaic Pump Controllers and other electrical accessories as intermediaries.

In SPV water pumping system, the DC power generated from SPV Module can either be utilized directly in case of DC Motor- pump set or can be converted to AC for operating AC Motor-pump set. Depending upon the Head and discharge requirement of the site, the system can be designed as per the specifications.

## 2.2. Definition of Technical parameters

i. **Solar Irradiance**: The amount of solar energy incident on a unit area measured in terms of $W/m^2$

ii. **Solar Photovoltaic (SPV) System**: The System generates electricity by utilizing Solar irradiance available through Solar Photovoltaic(SPV) Module

iii. **Solar Photo Voltaic (SPV) Array:** A collective assembly of SPV Module configured and wired together to generate electricity as a single unit

iv. **Array orientation:** The array should be oriented towards the south in Northern hemisphere and should be tilted at an angle equal to that of latitude of the location.

v. **Tilt Angle:** The angle of inclination of the SPV Module with respect to Horizontal surface

vi. **Open Circuit Voltage ($V_{OC}$):** Open circuit voltage is the maximum voltage that the Solar Photovoltaic(SPV) cell can produce under open-circuit conditions. It is measured in volt (V).

vii. **Short Circuit Current ($I_{sc}$):** Short Circuit Current is the maximum current produced by a SPV cell under short circuit condition. It is measured in Ampere (A).

viii. **Maximum Power Point (MPP):** The Maximum Power Point(MPP) is the maximum power that a (SPV) cell can generate under Standard Testing Conditions(STC). It is measured in $W_P$. Other than STC, the SPV cell has MPP at different values of irradiance and operating temperature. The cell can generate power at different current and voltage combinations. However the cell produces maximum Power only at a particular Voltage and Current combination.

$$MPP = I_{mp} \times V_{mp}$$

ix. **Current at Maximum Power Point($I_{mp}$):** It is the current which the SPV cell will produce when operating at the maximum Power Point. The value will always be lesser than the Short circuit Current**($I_{sc}$)**

x. **Voltage at Maximum Power Point($V_{mp}$):** It represents the voltage that the SPV cell will produce when operating at the maximum Power Point and its value is always lesser than the open-circuit voltage ($V_{OC}$)

xi. **Fill Factor (FF):** It represents the area covered by $I_{mp} – V_{mp}$ rectangle against the area covered by $I_{SC} – V_{OC}$ rectangle in terms of percentage. The fill factor represents the squareness of the I – V curve and higher the value better is the cell.

$$FF = [MPP/ (I_{SC} \times V_{OC})] \times 100$$

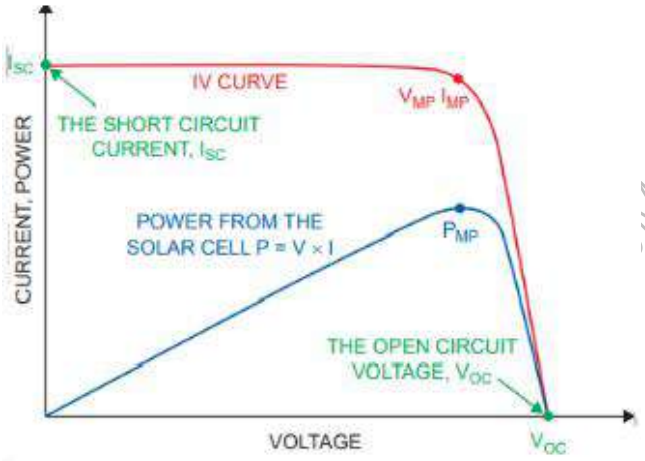



*Figure 1:IV Curve*

xii. **Module Efficiency (η):** The efficiency of the SPV Module refers to the percentage of solar irradiance gets converted to electrical power. The efficiency will be calculated as follows:

$$\eta_{module} = [Electric\ power\ (W_p) / (Solar\ irradiance \times Area)] \times 100$$

xiii. **Temperature Co-efficient:** The Temperature coefficient of power indicates the variation in power generation with respect to per unit change in surface temperature of the SPV Module The power generation decreases with increase in temperature.Hence the value will carry negative sign.

xiv. **Maximum Power Point Tracker (MPPT):**MPPT is an algorithm that is included in the SPV pump controller 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.

xv. **TDH:** Total Dynamic Head is the total elevation lift (including friction loss and fitting loss) required in the water Pumping system

xvi. **Static Water Depth:** It is the depth of water level below the ground level when the pump is not in operation.

xvii. **Draw-Down:** It is the elevation difference between the depth of static water level and the consistent standing water level in tube well during operation of Pump.

xviii. **Submergence:** It is the minimum height of water level after draw-down above the pump suction casing.

xix. **Manometric Suction Lift:** Manometric suction lift is the vacuum gauge/suction manometer reading in meter of water column when pump (Surface Mono-set) operates at suction lift.

xx. **Static Suction Lift:** Static suction lift/head is the vertical distance between sump water level and center of Surface Mono-set inlet.

xxi. **Daily Water Output:** It is the total water output on a clear sunny day with three times tracking SPV Module, under the "Average Daily Solar Radiation" condition of 7.15 KWh / m2 on the surface of SPV array (i.e., coplanar with the SPV Modules). .

***Note:-***

***Pump Head Calculation***

*Total Dynamic Head(Submersible Pump)(metre) = Static Head + Draw down + Friction Head + Fitting loss + Pressure Head*

i. ***Static Head(metre)****: It is the depth of water level below the ground level when the pump is not in operation.*
ii. ***Draw-Down(metre)****: It is the elevation difference between the depth of static water level and the consistent standing water level in tube well during operation of pump.*
iii. ***Friction Head(metre)****: The head loss incurred due to friction encountered by water flow in the Pipe line*
iv. ***Fitting Loss(metre)****: Head Loss incurred due to joints*
v. ***Pressure Head(metre)****:The pressure at which water has to be delivered, which varies with the type of irrigation system*

*Total Dynamic Head(Surface Mono set)(metre) = Static Suction Head + Draw down + Static Delivery Head + Friction Head + Fitting loss + Pressure Head*

***i.*** **Static suction head(metre)** : It is the vertical distance between the water below the ground level when the Mono-set is not in Operation and the center of the Mono-set Inlet.

***ii.*** **Static delivery head(metre)** : It is the vertical distance between the centre of the Mono-set and the point of discharge

**The concept of Draw-Down, Friction Head ,Fitting loss and Pressure Head are similar to that of Submersible Pump..*

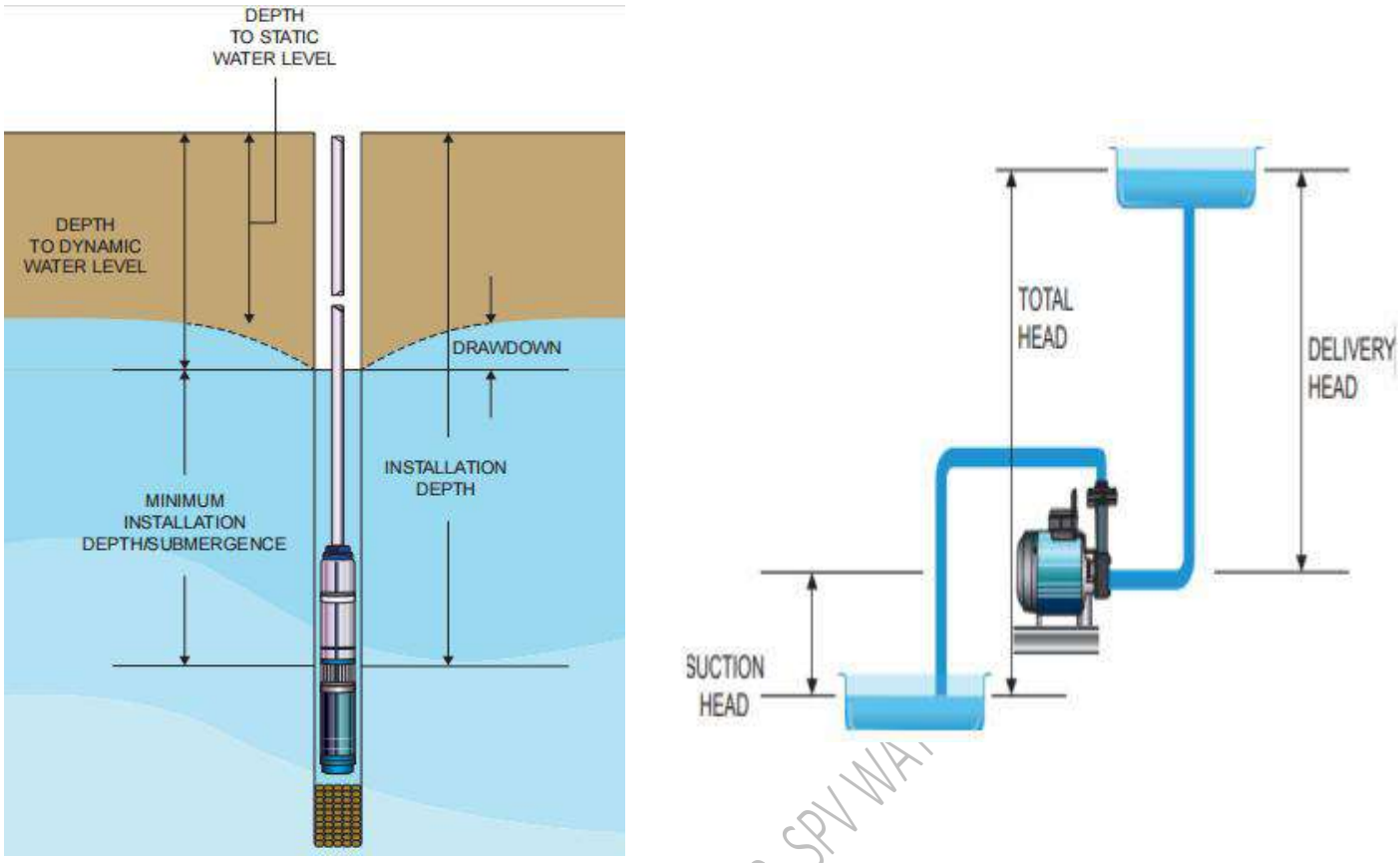



*Figure 2: Head Calculation*



## 2.3 System Components

### i. SPV Modules

SPV Modules convert solar radiation directly to DC electricity. The SPV Module is an assembly of SPV cells,which are normally made of crystalline or amorphous compounds. The SPV modules are rated for a particular power capacity at STC. The other parameters of SPV Module are $V_{oc}$, $V_{mp}$, $I_{sc}$, $I_{mp}$ and Temperature coefficient.

### ii. SPV Arrays

Modules can be connected either in series or parallel. For voltage requirement they has to be connected in series and for the current requirement , the modules has to be connected in parallel to form the arrays of the modules in series or parallel. And the group of the modules connected in series is also known as String.

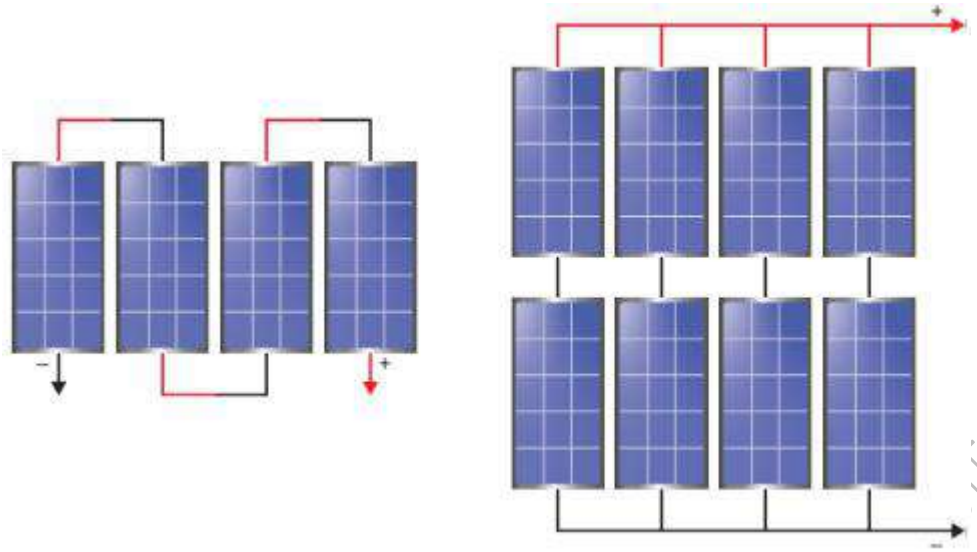


*Figure 3:Arrangement of SPV Modules*

### iii. DC Isolators

DC Isolators are required to disconnect the SPV array from the rest of the SPV system.These manual disconnection switches provide a way to safely cut off electricity generated by the SPV array and protect the other components of the System during emergency situations or while performing maintenance and servicing tasks.

### iv. SPV Pump Controller and Remote Monitoring System

SPV pump Controller is among the most critical components of the SPV water pumping system that not only perform power-related functions but are also responsible for the intelligence of the SPV system. For protection from foreign matters and moisture, the controller should be rated for appropriate Ingress Protection (IP). The IP number has two digits with first number mentioning the level of protection against solids and the second number indicating protection against liquids. The Remote Monitoring System aids in the real time transmission and monitoring of the data supporting remote control and system performance analysis.

The major functions of the Pump Controller are to:

- Extract maximum power from the SPV modules through MPPT for maximizing the water discharge
- Convert DC power into AC power (In case of AC Motor-Pump-set) or convert DC power into the desired DC power as per the motor-pump set requirement
- Ensure protection of the solar powered motor- pump-set during operation

### iv. Universal Pump Controller(USPC)

The USPC supports the optimum utilisation of SPV system installed for water pumping application.Apart from Pump operating hours, the electricity generated from SPV system can be utilised

through USPC for agrarian applications such as , apple grading and polishing system, wheat (grain) flour grinding machine / aata chakki, cutter/chaff, deep-fridger / cold storage, blower fan for cleaning of grains, heating loads and any other standard voltage (400/415V) three phase motor/equipment of capacity not more than the capacity of SPV water pumping system.

### v. AC/DC Cables

DC cables are utilized to transmit DC electricity from the SPV array to the controller, while AC/DC Cables are used between the Pump Controller and AC/DC Motor-Pump-set accordingly.The maximum current carrying capacity of any conductor under specific installation condition and cable properties is defined by its Ampacity. The cable sizing should be in such a way that the current flow should not exceed the ampacity of the conductor and the voltage loss should be within the prescribed limit. It is recommended to use armoured cables since it provides better protection than unarmoured one.

### vi. Module Mounting Structure(MMS)

Module Mounting Structures (MMS) are used to mount and secure the SPV modules in particular orientation and tilt angle equal to the latitude to the location to harness maximum irradiance.The MMS design takes into consideration the following criteria:

- Load (weight) of the SPV Modules
- Typical and maximum wind loads at that particular location
- Seismic zone safety factors
- Other considerations such as saline or corrosive environments

### vii. Lightning Arrestor

A lightning arrester is a device used in electrical systems to protect the system components from the damaging effects of lightning.Similar to other Electrical requirements, stand alone SPV water pumping system is vulnerable to lightning and it is recommended to have a dedicated Lightning Arrestor with Copper tips near the air terminal, in order to protect the system from direct lightning strikes.

### viii. Earth Pits

Earth Pits provide a low resistance path for any leakage current in the SPV water pumping systems thereby protecting the components of the System.The earthing pits should be constructed as per the relevant standard(s) to protect the system against damage.All the components such as SPV Module, MMS, Pump Controller and Motor-Pump set should be properly earthed and it is recommended to have separate earthing for Lightening Arrestor.

### ix. Motor-Pump Set

The Motor-pump set consists of the pump (driven part )and the Electric motor(driving part) of AC or DC type.Based on the water source and installation requirement, either submersible type or Surface Mono-set can be selected.The submersible type motor-pump set can be submerged in water which can serve the purpose for Borewell application and Mono-sets can be utilized for pumping

water from Surface water source like pond, well, etc. The head and discharge requirement of the site plays a major role in selecting the motor- pump set capacity and thereby the SPV system.

### ix. Pipes & Fittings

The pipes and fittings used in the SPV water pumping system for delivering water should have appropriate pressure rating in order to withstand the pressure of water being pumped. The diameter of suction pipe should be equal to the pump inlet size and the delivery pipe diameter should be at least equal to that of Pump outlet and should provide minimal resistance to water flow thereby maximizing the energy utilization**.** The pipes and fittings should be accessible for maintenance and should be protected from physical damage.

## 2.4 Principle of Working

Solar Water Pumping System is a revolutionary technology that enables us to use solar power for pumping water from an open well or bore well,etc. It is an energy-efficient and environment-friendly alternative to conventional diesel or electric pumps. The Solar Water Pumping System provides the convenience of using renewable energy sources while reducing the energy costs associated with traditional pumping systems.The systems rely on a combination of three major components: SPV modules, SPV pump controller and motor-pump set. Each component plays an essential role in the overall system performance, allowing the systems to provide reliable and sustainable water sources.SPV module converts the solar energy into electricity in the form of DC. This DC electrical energy can then be used directly for operating DC motor-pump set or can be converted into AC for powering AC motor-Pump set using the pump controllers,which are an essential tool in the operation of SPV pumping systems. By synchronizing the operation of the motor-pump set with the power generated from the SPV array, these controllers assist to optimize energy production and efficiency. The electricity generation will be altered according to the sun shine hours and cloud cover accordingly the water discharge from motor-pump set will vary.

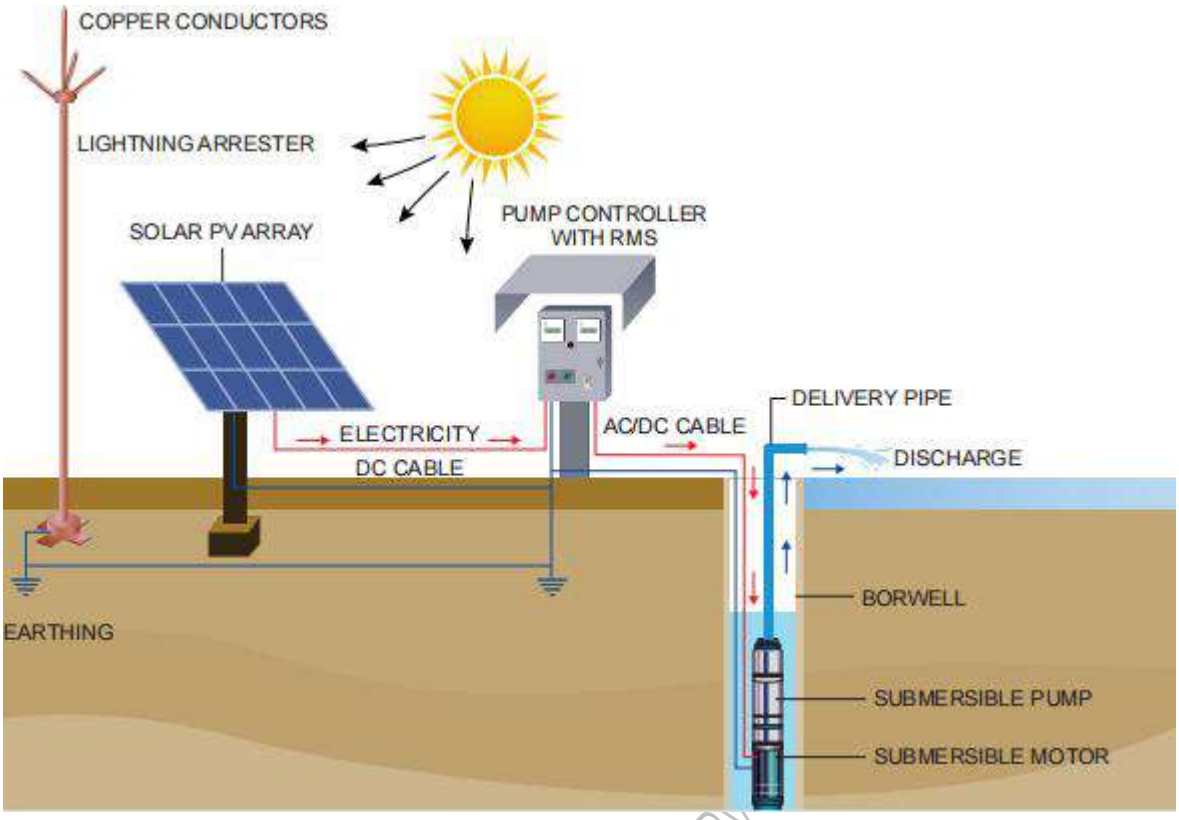



*Figure 4:SPV Water Pumping System(Submersible Motor-pumpset)*

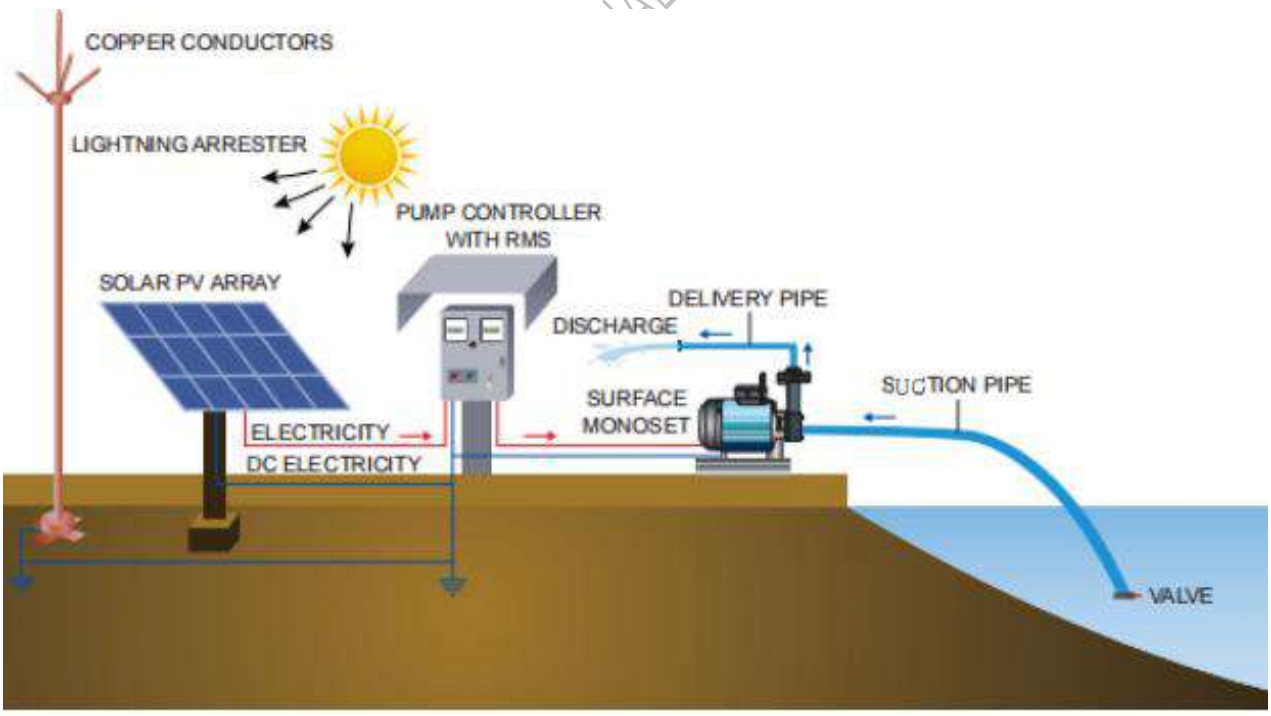



*Figure 5:SPV Water Pumping System( Surface Mono-set)*

## 3. Three Tier Quality Control Mechanism

In order to ensure quality of SPV Water Pumping Systems, a three tier Quality Control Mechanism (QCM) has been developed. This three tier QCM is mandatory for systems installed under MNRE Schemes.The mechanism can also be used by stakeholders to ensure quality and performance of the SPV Water Pumping Systems installed beyond MNRE Schemes.

QCM needs participation of Vendor, State Implementing Agency (SIA),Third Party Inspecting Agency and MNRE.

a) **Vendor** supplies SPV modules, pump controller, Motor-Pump set and Balance of System (BOS) to the consumer. The Vendor is responsible for site inspection, feasibility analysis, design, engineering, civil works, supply, erection, testing, commission, operation and maintenance of the SPV Water Pumping System.
b) **State Implementing Agency (SIA)** is the designated implementation agency for the Scheme(s) of MNRE in respective State / Union Territory. SIA implement, oversee and monitor installation and performance of SPV Water Pumping projects across the State.
c) **Third Party Inspecting Agency (TPIA)** is a firm or an individual expert engaged by MNRE for various services related to inspection, verification, progress monitoring, evaluation etc., of the SPV Water Pumping projects under various stages of pre-dispatch, installation and post-commissioning.
d) **MNRE** will oversee the Program and its Officials may occasionally check the system's quality on a random basis.

A matrix of all the three tiers with the stakeholders and the activities (in a typical SPV Water Pumping System) falling under each tier is provided below.

| TIER I | | |
|---|---|---|
| **Project Cycle/ Stakeholders** | **Pre-Dispatch** | **Post-installation** |
| **State Implementation Agency (Utility/SIA)** | Pre-Dispatch Inspection for Modules, Controller, Motor-pumpset and BOS ***(Annexure I)(I A-I C)*** | Post installation inspection ***(Annexure II)(II A-II E)*** |
| **TIER II** | | |
| **Third Party Inspection Agency(TPIA)** | Applicable based on the term of engagement between MNRE and TPIA as per the inspection report ***(Annexure I) (I A-I C)*** | Post installation inspection on sampling basis based on the terms of engagement between MNRE and TPIA as per the inspection report ***(Annexure II)(II A-II E)*** |
| **TIER III** | | |
| **MNRE / Authorised institute by MNRE** | Optional and random sampling basis as per the inspection report ***(Annexure I)(I A-I C)*** | On random sampling basis as per the inspection report ***(Annexure II)(II A-II E)*** |

*Table 1:Three Tier Quality Control Mechanism*



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

## TIER-I

Under the Tier-I, the activities related to monitoring and assessing the quality control will be implemented by State Implementing Agency from their own quality control team resources or designated institutions authorized by SIA as applicable. The SIA shall make arrangement or acquire if needed the sufficient resources to implement the provisions under the QCM.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 Vendors and workmanship as per the Specifications issued by MNRE at the time of installation and relevant national and international standards. The empanelled Vendors will ensure the quality of the supplied materials from their respective suppliers in the supply chain of SPV Water Pumping System.

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

- Check acceptance tests/test reports of all materials of all empanelled vendors at vendors' site / warehouse as per Drawings / Technical Specifications as issued by MNRE at the time of installation and other applicable / prevalent Standards at the pre-dispatch stage
- Shall inspect 100% of SPV water Pumping System installations in its coverage area after its installation

- Shall inspect SPV Water Pumping Systems on random sampling basis or inputs from the remote monitoring systems, in its coverage area during the five years of CMC period.

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

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

## TIER-II

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

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

## TIER-III

MNRE will be responsible for third tier QCM. MNRE officials or any authorised Institutions designated by MNRE shall conduct quality checks at 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 SIA in every State at vendors' site / warehouse / Manufacturing facility.
- MNRE shall review test records for major materials like SPV module,Pump controller, MMS,motor-pump set,etc. as per the MNRE Specifications issued at the time of installation on a random sampling basis as and when required by MNRE
- MNRE shall inspect SPV water Pumping system installations implemented under the Central Financial Assistance in each state to assess the quality of the installations and its performance on random sampling basis.

# 4. Quality Control Plan during installation

Quality control plans are essential to ensure the installation of SPV water pumping systems is done properly. The quality control plan can be used to assess the quality and accuracy of the installation process, as well as the performance and reliability of the System. By utilizing the procedure, Vendors can install the SPV water pumping system in a safe and proper manner. It outlines the safety measures to be taken, as well as best practices for ensuring that the system is efficiently installed. Additionally, it also outlines the necessary steps involved in transportation,handling and installation of the components.

## 4.1. General Safety Guidelines

Ensuring safety and having all the necessary equipment before installation is of utmost importance. It is important to take the time to do all the necessary safety and equipment availability checks prior to any installation. This will help ensure that the process runs smoothly and safely, while also avoiding costly repairs or replacements down the line.

Before beginning the installation , the health and safety of all personnel involved must be taken into consideration. Identifying potential risks associated with the project site is essential for ensuring the safety of all workers. It is important to take time to assess the surrounding environment and identify any potential hazards that could cause harm or injury during the installation process. By doing so, necessary precautions can be taken to reduce or eliminate risks before work begins.

### Personal safety resources:

- A work partner (never work alone);
- Safety plan & first-aid kit;
- An understanding of safety practices, equipment and emergency procedures;
- Safety helmet & eye protection;
- Proper measuring equipment: electrical & dimensional;
- Fire extinguisher;
- Suitable labels on all equipment, wiring, etc
- Any other appropriate equipment for specific purposes

## Electrical and Fire Safety

Work site accidents due to electrical hazards pose serious risks to the safety of workers and can result in catastrophic outcomes. The majority of these accidents are caused by snapping of conductors, leakage current, defective tools and apparatus, carelessness on safety measures and inadequate maintenance of electrical wiring. It is important for workers to recognize the potential risks associated with electricity and ensure that appropriate safety protocols are in place.Since, SPV system generated high voltage, in the event of any fault or leakage, any metallic part of a SPV System can cause electric shock or fire. Fire in SPV system is a serious safety concern caused by a number of factors. Improper system design,Poor installation, underrated cables, loose connections, poor Operation and Maintenance (O&M), incorrect or faulty equipment, and most importantly damaged cable can all lead to fire in an SPV system. While the consequences of such fires can be devastating, understanding what causes them is key to preventing them from occurring.Hence, electricians trained and certified in SPV installation has to be engaged in installation, operation and maintenance of the components of the system.

## Points to Remember:

i. Check that all staff safety resources are readily accessible and in good condition.
ii. Ensure that all electrical measuring devices are functioning correctly and accurately.
iii. Use the earth resistance tester to inspect the pre-existing earthing system at the project site, if any.
iv. Verify the structure earthing before installing the modules.
v. Electrical connections between modules and in between strings shall be made only when the system is ready for commissioning.
vi. Make sure that all DC/AC cables to pass through UPVC pipe and is buried inside the ground.
vii. Make sure cable joints are not exposed to water and wet.;
viii. Tighten the cable joints (MC4,etc) with the appropriate tools and not manually.

## 4.2. SPV Water Pumping System Installation

The procedures for installing and commissioning the SPV Water Pumping System are described in the following 11 steps, which must be followed in sequence for proper functioning of the system.

Step 1: Site Assessment

Step 2: Installation of Module Mounting Structure

Step 3: Earthing of Module Mounting Structure

Step 4: Installation of SPV modules

Step 5: Earthing of SPV Module Frames

Step 6: Installation of Pump Controller

Step 7: Motor-pump set installation

Step 8: DC & AC Cabling

Step 9: System protection & Safety

Step 10:Pre-commissioning tests

Step 11: Commissioning the system

### Preparation for Installation

In addition to the system components, the following are common tools used in SPV water pumping system installation:

- Flashlights
- Magnifying glass
- Metre Tape
- Compasses
- Inclinometer
- Instrument for shade analysis
- IV Teseter
- Clamp meter
- Pyranometer
- Megger
- Earth resistance Tester
- Multi meter
- Calculator
- Wire stripper
- Screwdrivers
- Hammers
- Pliers
- Any other instruments required for proper installation





***Note:***

- ***Assess whether the SPV array installation area satisfies the location criteria as per guidelines of the scheme***
- ***Ensure that the variation in water level is taken into consideration before motor-pump set installation.***
- ***Make sure whether the ground around the water source is stable against collapse for motor-pump set installation***
- ***Check whether the bore well is flushed properly to restrict sand entry in the pump***
- ***Ensure that the pipe and cable dimensions are in line with the requirement.***

## Step-1 Site Assessment

The initial visit to the site is a critical step in the system installation process that should not be overlooked. While the actual setup and configuration of the system will be done later, the initial visit is an important part of making sure everything runs smoothly. During this visit, technicians can check out the physical environment and assess any potential problems that may arise during installation. It serves to confirm feasibility of the installation and aids in planning of the system installation. In carrying out the site visit, apart from identifying the proper beneficiary the following factors need to be checked/confirmed/assessed:

1. Shadow free Space availability
2. Site layout
3. Site orientation
4. Water source details including the distance between array location & water source, depth of water source, depth of pump installation, Soil condition, etc.

## Factors to be considered for SPV array location

Positioning the SPV array requires careful consideration of factors such as location, orientation and tilt angle. Selecting the right location is key to ensuring maximum power generation – it should be clear, dry, level and is free of obstacles like tree or buildings through out the day. Setting the proper orientation and tilt angle will maximize the efficiency by ensuring that the Solar radiation is perpendicular to the SPV Modules . The performance of the SPV array is influenced by:

### 1. Shading

SPV Modules being shaded either in whole or part by buildings or tress, will generate lesser energy and ultimately results in decreased performance. As SPV cells are connected in series, shade in any part will reduce the current and voltage output of the whole system. In the tropics shading could vary due to the sun being in both North and south parts of the sky at different times of the year. Any object on the East will cast shade during morning and on the West will cast shade during Evening. So, it is recommended to conduct shade analysis, which could determine shade free area through out the day

***Note: -Shading not only hinders the power production of SPV Modules, but also harms them in the long run.***

*Figure 6:Shadow on SPV Module*

## 2. Orientation

SPV Modules should be installed south facing in the Northern hemisphere and North facing in the Southern hemisphere. Since India is in the Northern hemisphere, the modules will be installed always-South facing in our country. The directions North-South can be found with the help of Magnetic Compass.

## 3. Tilt

Maximum performance can be achieved on tilting the SPV array towards the sun. Adjustment of the tilt angle can be done in both tracking and non-tracking system where the optimum tilt angle is determined by the location (latitude)

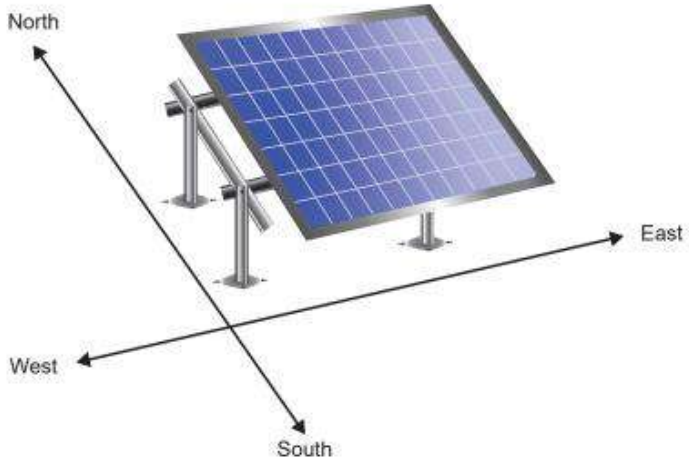



*Figure 7: SPV Module Orientation*

**1) Determine PV array location:**

a) Conduct shadow analysis using highly accurate and user –friendly tools.

b) Check the location accessibility for installation and maintenance

c) Make sure the SPV array has sufficient space for air cooling

d) Ensure that SPV array is nearer to the motor-pump set

**2) Determine suitable location for SPV Controller**

a) Location of Pump controller should be such that it is accessible for operation

b) Ensure that the Pump Controller is at a minimum distance from SPV array

c) The controller location should have protection from extreme environmental factors.

d) Controller should be installed in such a place where there is enough space for heat dissipation and maintenance.

**3) Identify cabling and pipe line routes:**

Determine cable routes and hence cable length based on SPV array, controller and motor-pump set location. Minimum distance between the array & controller and between controller & motor-pump set is preferred.Assess the length of pipe line to be laid to satisfy the discharge need of the site and ensure that the pipe line route is accessible for repair and maintenance. Ensure that the the diameter of suction pipe(For Mono-set) is equal to that of the pump inlet size and the delivery pipe diameter is at least equal to that of Pump outlet, so that head loss due to friction is minimized.



***The following shall be ensured before inclusion of a beneficiary under the Scheme:***

*1. Beneficiary should not have an electricity connection at the farm.*

*2. Installation of the new pumps is not allowed in the notified areas issued by the Central Ground Water Board.*

*3. Priority to be given to small and marginal farmers.*

*4. Preference be given to the farmers using Micro irrigation systems or covered under Micro irrigation schemes or who opt for micro irrigation system.*

## Step-2 Installation of Module Mounting Structure(MMS)

The SPV array design plays a major role in maximizing the energy generation of the SPV Modules by tilting the Modules at optimum angle and by tracking the sun path.In addition to its ability to handle SPV module and wind load, MMS must ensure that the SPV array receives

optimum solar radiation and permit free flow of air across the modules thereby reducing the module temperature. It is also important to ensure that factors such as structure design, orientation, tilt and shading are aligned with the electrical string design.

## Points to remember

i. Details of Module Mounting Structure and its specifications for motor-pump set of capacity 1HP and above is attached at ***Annexure-III*** or the structure design should be as per specified in the certificate issued by IIT/NIT/IISc

ii. Ensure that the mounting structure is hot dip galvanized and it is not recommended to drill, weld or cut the structure at the site. This will damage the coating and corrosion will be accelerated.

iii. The orientation of a SPV Array should be towards South (in Northern hemisphere)

iv. The area under the modules should be accessible for repair and maintenance

v. The tilt angle should be equal to the latitude of the location.

vi. Foundation should be as per the site condition, based on the properties of soil. Foundation can be done either with the help of 'J Bolt' (refer IS 5624 for foundation hardware) or direct pilling, it should be decided as per the site and relevant IS i.e., IS 6403 / 456 / 4091 / 875 should be referred for foundation design.

vii. The Design of foundation should be such that the safe Bearing Capacity of Soil (as obtained at site) is not exceeded. The work includes necessary excavation, concreting, curing, piling (if necessary), back filling, shoring, shuttering etc.

viii. The foundations should be designed considering the weight and distribution of the MMS and assembly and a wind speed of 150 km per hour and it should protect the MMS against any fall or jerk.

ix. Seismic factors for the site have to be considered while making the design of the foundation.

x. In case of more than one array, the spacing should be such that the array is protected from adjacent arrays shade.

## Procedures for Installation of Mounting Structure

1. Check the direction using compass
2. Mark the reference points on ground for column erection along east west direction so that the Modules are oriented towards south.
3. Dig the ground for foundation along the marked points.
4. The foundation design for the columns should be as per the diagram attached in the Annexure IV. or should be as per certificate issued by IIT/NIT/IISc as per structure design requirement.
5. Ensure that the structure direction and angle is as per design before concreting.
6. Fill the pit with concrete mixture whose composition should be as per M20 standard. Water used should be of clean and clear water with suitability for drinking purpose. The mixture should be well mixed for adequate period and uniformity should be ensured. While pouring concrete mix,

care should be taken that the concrete is devoid of air pockets. Sufficient curing time shall be provided for the concrete.

7. Bolt the main column to the foundation and assemble the structure. At each and every stage, ensure the perpendicularity of the column**.**
8. Assemble and fasten the structure and ensure that drilling and welding is prevented.

## Step-3 Earthing of Module Mounting Structure

After the installation of module mounting structure , a continuous equipotential bond should be provided between the mounting structure and the module frames.

### Following procedures to be followed:

1. Verify the earthing conductor routing plan.
2. Prepare earthing wire terminal bar / conductor, lugs, clamps, earthing rod and earth pit.
3. Ensure all module frames and each part of mounting structure are electrically bonded.
4. Select the location for earth pit considering the soil wetness. Moist soil will provide least resistivity.
5. Attach the earthing wire with earthing rod and make connection with the Mounting Structure
6. Ensure all the connections are neat and tight
7. After connections , check the continuity and resistance of earth electrode
8. Do the earthing for controller and Motor-pump set in a similar manner after their installation

### Earthing Continuity and resistance measurement using Earth resistance tester(Megger)

1. Short the P1 and E1 terminal of the Earth resistance tester;
2. Connect the electrode under test to E1 terminal of earth resistance tester;
3. Using a hammer, dig an electrode at a distance (D) of minimum 30 meter from the test Electrode;
4. Connect this electrode to E2 terminal of earth resistance tester;
5. Using a hammer, dig another electrode in between both the electrodes at 50% of D;
6. Connect this electrode to P2 of the terminal;
7. Take reading by rotating the handle of Earth resistance tester or press push button;
8. Repeat the above procedure by changing the location of middle electrode to 40% and 60% of D;
9. To get the resistance of electrode, take mean of these three readings.

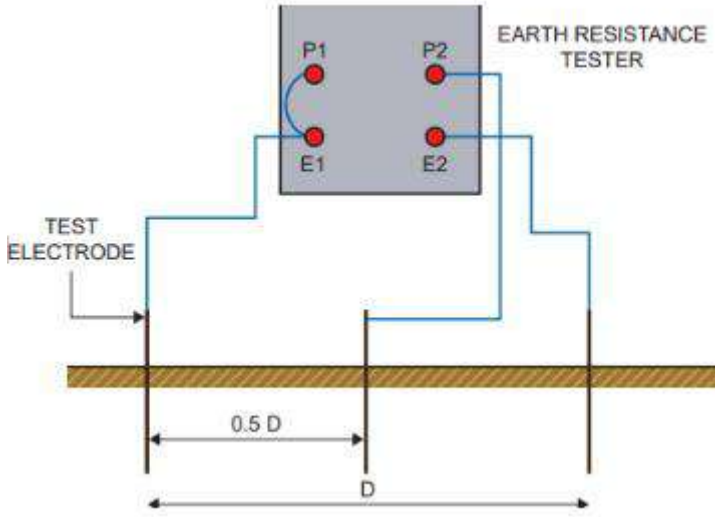



*Figure 8:Illustration for Earth Electrode resistance testing*

**Format of table to record results**

| Position of Middle Electrode | Measured Electrode Resistance(Ohm) |
|---|---|
| 50% of D | |
| 40% of D | |
| 60% of D | |
| Mean | |

*Table 2: Table format to record the earthing resistance*

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

## Step-4 Installation of SPV modules

Installing SPV modules onto mounting structures is a critical step in the implementation of SPV systems. Since minor damage to SPV modules can affect power generation, it should be carefully handled during packing, transportation and unpacking. The earthing system of the mounting structure must be completed before any modules are installed to prevent any potential damage.

### ❖ Handling and Packaging:

a) When handling SPV modules, it is best to stack, pack and transport them vertically with separators between them.Horizontal stacking should be avoided

b) Protection should be provided at the corners of each module

*Figure 9: SPV Modules packing*

## ❖ Loading, transport and unloading:.

a) Rough handling during loading and unloading and walking on the package must be avoided. While transporting in truck, it is essential to maintain a slow speed with the truck to prevent damage due to jerks. Keeping it minimum will be beneficial.

b) SPV modules should be carefully unpacked by two people in a vertical manner to avoid any potential damage. Additionally, care must be taken to make sure one module does not fall over the other within the box.

*Figure 10: SPV Modules Handling*

## ❖ Storage of SPV modules:

a) Similar to packaging, the modules should be stored in vertical manner with separators between each one.This will keep them safe during packing and stacking processes.

b) It is not recommended to stack the SPV modules horizontally or store them that way .

## ❖ Module Mounting

a) SPV modules should be attached to the MMS using the mounting holes provided by the module manufacturer

b) The mounting of the modules should allow for the expansion and contraction of the modules due to temperature changes under the expected operating conditions.

c) The module frame must be electrically isolated from the steel using a layer of non-conductive material.

d) Stainless steel screws, washers and nuts should always be used to fasten the modules to the array frame.

***Note:-***

- ***Avoid handling and installing SPV modules in windy or rainy conditions to ensure safety.***
- ***Use Insulated tools and gloves while dealing with modules as it can help reduce the risk of electric shock.***
- ***Stepping on the SPV module should be avoided as it can cause irreparable damage to the SPV cells within***
- ***Appropriate measures must be taken to safeguard the electrical connectors from water and dust getting inside them***

## Step-5 Earthing of SPV Module Frames

i. Following the installation of SPV modules, their frames should be bonded together and then connected to the main earthing conductor of the mounting structure..

ii. To guarantee an optimal electrical link, the earthing conductor must be securely attached to the module frame.

iii. Anodised coating of SPV module frames consists of aluminium oxide, which acts as a form of insulation. To establish an electrical bond between the frames and the structure, it is important to employ a suitable method to remove the aluminium oxide coating. Further, In case manufacturers provided connection points without such insulation to provide way for earthing, then that has to be used.

iv. The earth/grounding cable should be installed alongside the SPV array cables (positive and negative) and pump controller cables, until connected to an earth rod connected in the ground.

After physical installation and establishment of earthing bond of the frames, SPV modules are connected in series electrically to form a string.

### ❖ Series Connection of SPV Modules

a) For increased voltage requirement, SPV Modules shall be connected in series.

b) SPV Modules shall be connected in series as per the voltage requirement of the motor-pump set. The maximum number of modules that can be connected in series can be fixed such that the sum of the voltage of the Modules should not exceed the Voltage rating of the controller**.** In this type of connection, current remains the same.

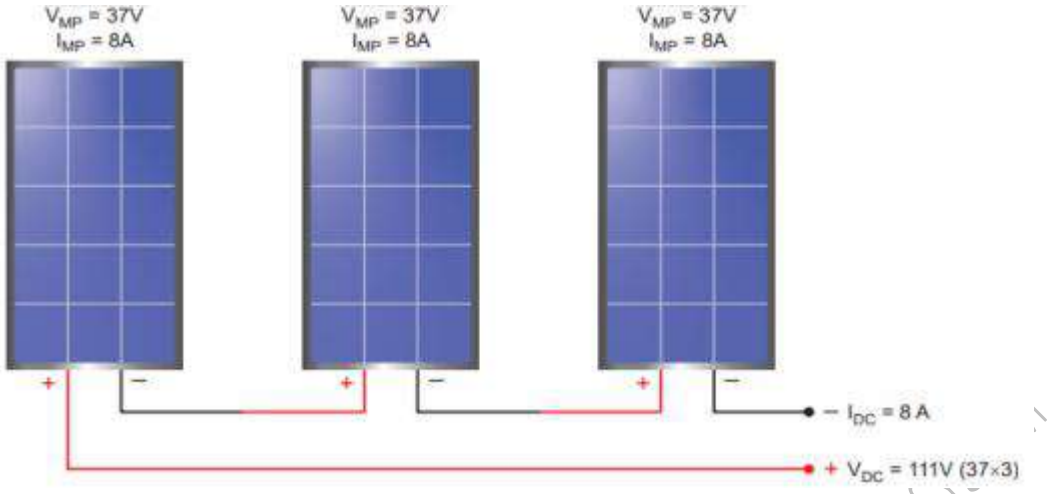



*Figure 11:SPV Modules in series Connection*

## ❖ Parallel Connection of SPV Modules

a) For increased current requirement, SPV Modules shall be connected in parallel.

b) The strings containing series connected Modules can be connected in parallel to match the current requirement of the pumpset. The summation of the current arrived should not exceed the current rating of the controller.

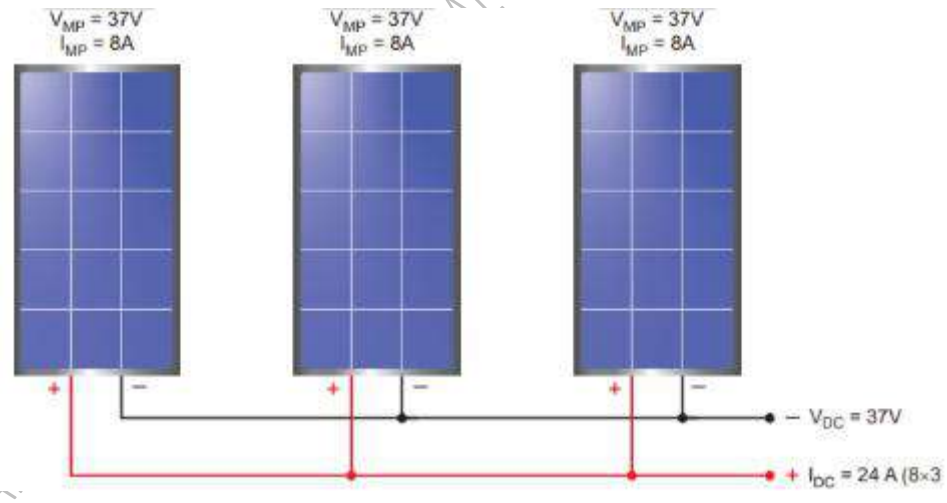



*Figure 12:SPV Modules in Parallel Connection*

*Note: The SPV Modules connected in series and parallel should be identical in all specifications*

### Precautions to be taken while wiring modules:

i. Only a trained and qualified installer should perform all wiring;

ii. Use UV protected cable tie to fix cables;

iii. Final connection should be done only when the system is ready for commissioning;

iv. Ensure electrical connectors are well protected against corrosion and soiling;

v. Ensure that connectors are corrosion free, cleaned with absolutely no gaps between the contacts;

vi. Do not allow any inflammable liquids/gases near installation area.

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

### Points to Remember:

1. Carefully examine the DC cable wiring and module inter-connection schematic.
2. Connect MC4 connectors properly.
3. Connect the modules as per the Voltage and Current requirement of the system.
4. Secure the cables to the module frame and/or rails using cable tie wraps and ensure minimum cable loops.
5. Check all cables to ensure they are properly secured in place and not loose or dangling.
6. The cable bending should not strain the joints.
7. Label the terminals with "+" and "-" sign accordingly.

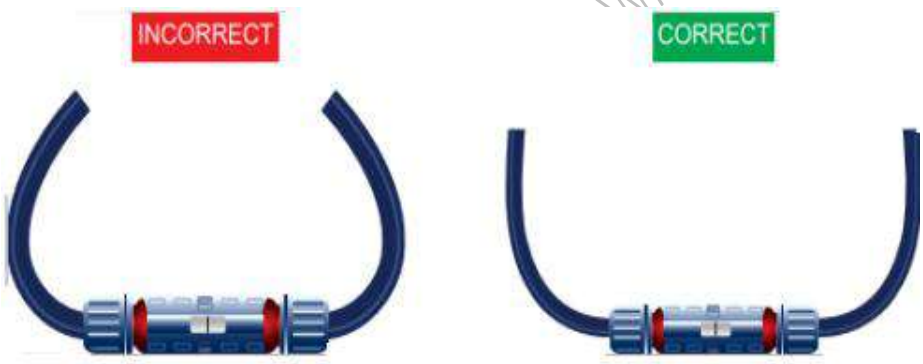



*Figure 13:Cable routing*



***Note: -***

- ***Before connecting two strings in parallel , make sure the voltage and polarity of each one. The wrong combination can lead to ir-repairable damage to any electrical and electronic components.***
- ***Maintain correct cable routing***

## Step–6 Installation of Pump Controller

### Points to remember

i. Temperature is detrimental for controller operation. It is recommended to position the controller in a secured place such that it gets protected from direct sunlight and other extreme weather events.

ii. Adequate insulation shall be provided to controller from thermal, electrical and mechanical loads/ shocks.

iii. Controller should be vertically mounted.
iv. Proper ventilation of air should be ensured.

### Procedures to follow:

1. Read controller installation and operation manual carefully;
2. Ensure that there is proper ventilation of air for the controller
3. Ensure that the controller is nearer to the SPV array
4. Mount the controller with accessories provided by the manufacturer
5. Install the earthing connection as per controller installation manual;
6. Tighten the cable glands using appropriate tools.
7. Connect the DC cable from array to the controller and AC/DC cable from the motor-pumpset at appropriate glands once the Motor-pump set is installed.
8. All connections should be done with proper lugs.

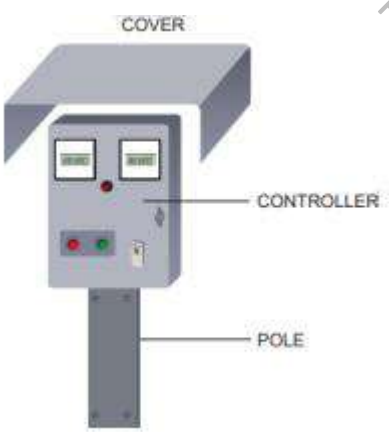



*Figure 14:Pump Controller with cover*



***Note:***

- ***The RMS provided with the controller should aid real time data transmission to online portal***
- ***The GPS module should have horizontal accuracy of 10m***
- ***The parameters like Pump On/Off status, Array Input DC Voltage, DC/AC output Current & voltage, operating frequency, Latest RMS Latitude, Latest RMS Longitude, Pump Capacity (HP), PV Module Capacity (KW), Pump Status, Current Generation (kW), Today Solar Generation (kWh), Cumulative Solar Generation (kWh), Today Runs Hours (Hrs.), Cumulative Pump Run Hours (Hrs.), Cumulative Water Discharged (Litres), Total Water Discharged (Litres), Peak Power (kW) supplied by the controller to Motor-Pump Set should be displayed in the LCD screen***

## Step–7 Motor-Pump set installation

### For Submersible Pumpset

#### ❖ Pre-installation Checks

- Ensure that the inner diameter of the bore well is more than that of the motor & pump diameter.
- Rough spots or sharp edges on the top lip of the bore well casing should be smoothed out to prevent damage to the power cables.
- The power cables and lifting rope shall be clamped to the delivery pipe at specific interval.

**Water Filling** of Water Filled Type Submersible Motor. (The motor has to be filled with clear, cold fresh water only)

**Procedure:**

i. Remove the drain plugs provided at the top of the motor.

ii. Fill the motor completely with clear water.

iii. Ensure that the air bubbles are removed

iv. Fix the drain plugs securely so that zero water leakage is ensured



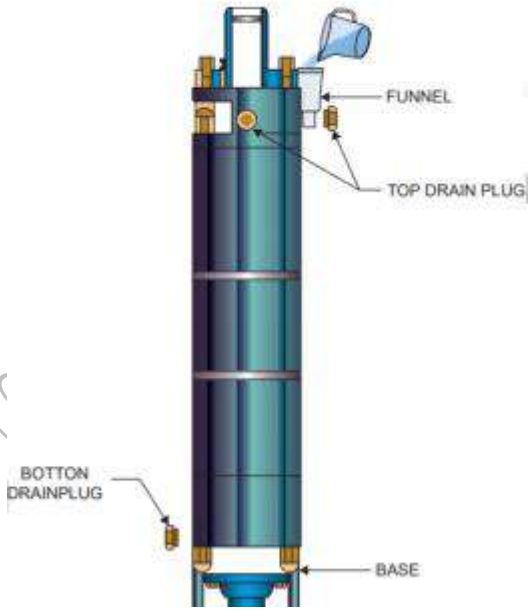



*Figure 15:Submersible Motor-water filling*

#### ❖ Motor and Pump Coupling:

i. Erect a supporting clamp / Tripod stand.

ii. Suspend the pump for coupling with the motor.

iii. Clean the motor and pump seating surface before it is coupled.

iv. Lift and lower the pump on the motor so that the pump shaft with coupling is inserted onto the motor shaft.

v. Tighten all the nuts equally and firmly. Also refer the manufacturers operating manual for any

other type of couplings and procedures.

vi. Check the coupling for free movement.

vii. Fixing of the cable guard and strainer is recommended.

### ❖ Lowering the Motor-Pump-set:

i. Flush the bore well before lowering.

ii. Align the motor-pump set carefully with the borewell casing.

iii. Lower the coupled set slowly without forcing and ensure that the Cable is not damaged while lowering.

iv. Check valves shall be installed at appropriate length of the discharge line to prevent the water travelling back to pump.

v. Motor-pump set should be lowered below the draw down level and it should not rest on the bore well bottom.

vi. Ensure constant flow of water past the motor body in order to protect the motor against raising temperature.



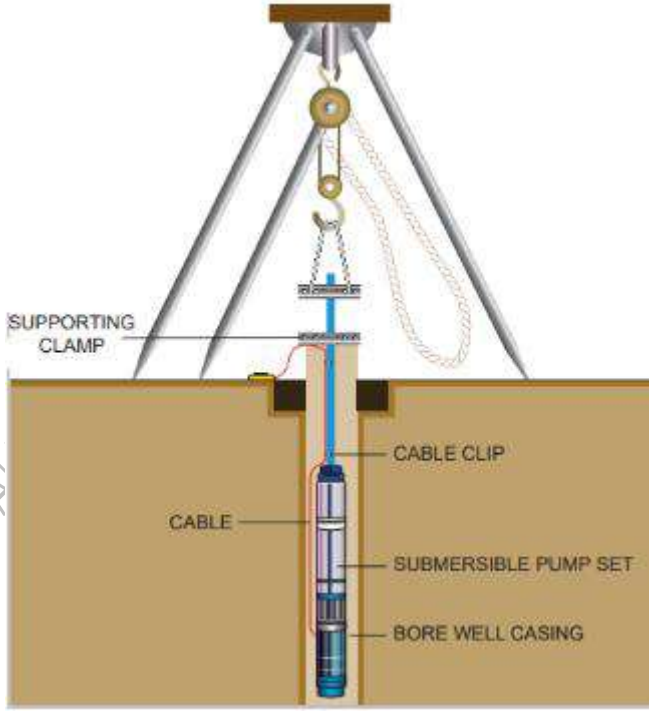



*Figure16:SubmersibleMotor-Pump-set installation*

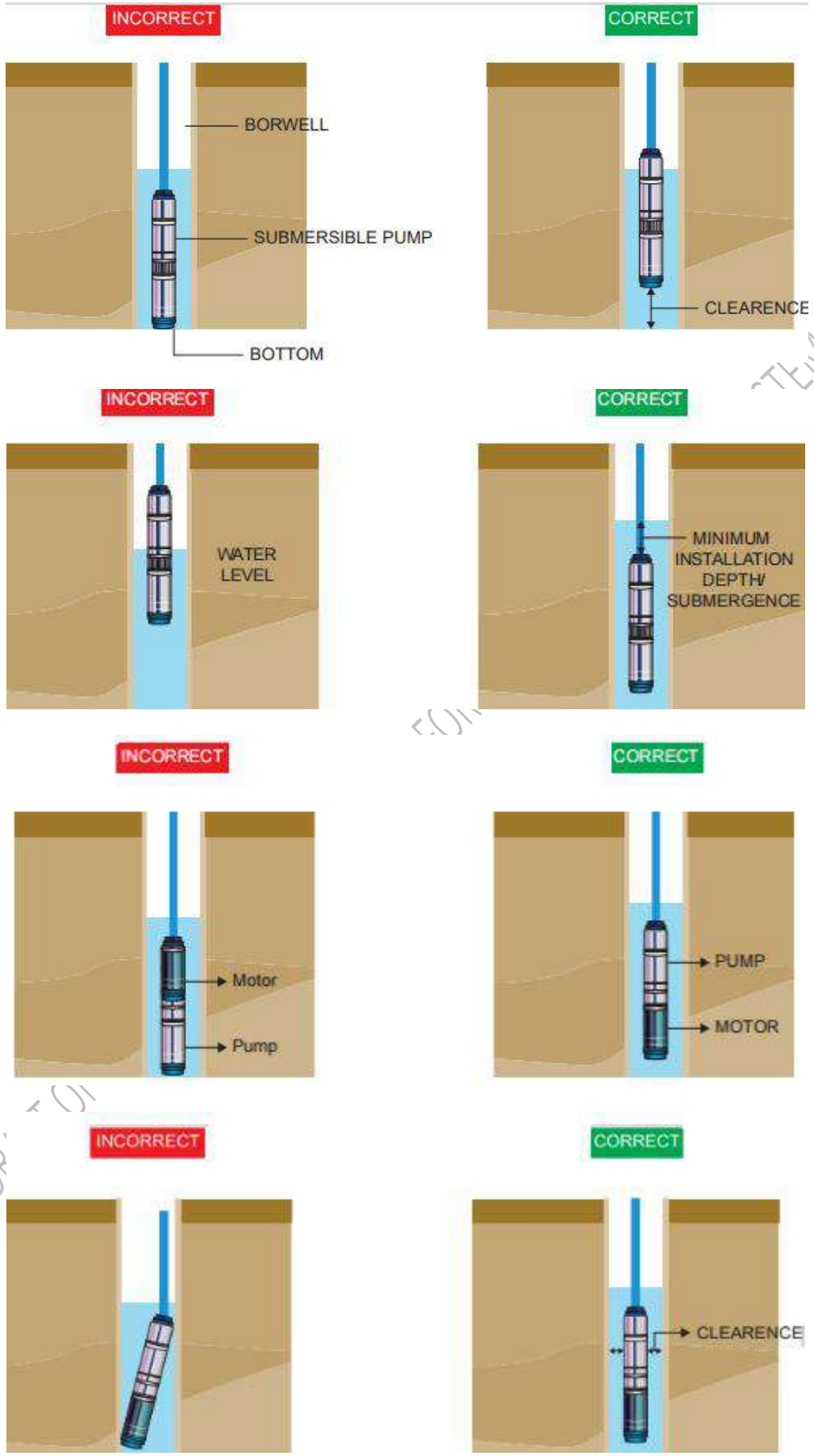



*Figure 17: Incorrect and correct way of Submersible Motor-Pump-set installation*

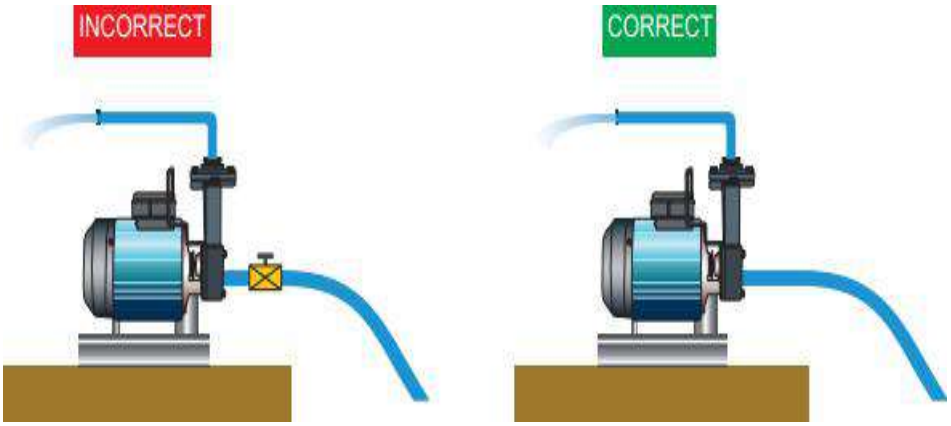
## For Mono-set

The following factors should be taken into consideration while installing Mono-set:

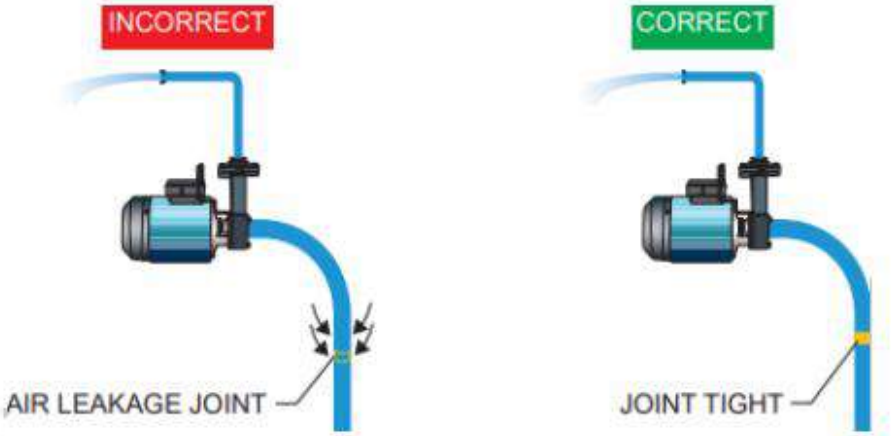
a) The Mono-set location should be selected such that the suction lift can be minimized and ensure that the lift is within the permissible level.
b) Raising slope shall be maintained in the suction pipe so that air pockets and un-prime risks can be avoided.
c) The Mono-set should be placed in a well-ventilated pump house for protection against environmental factors.
d) It should be easily accessible for repair and maintenance.

### Points to remember

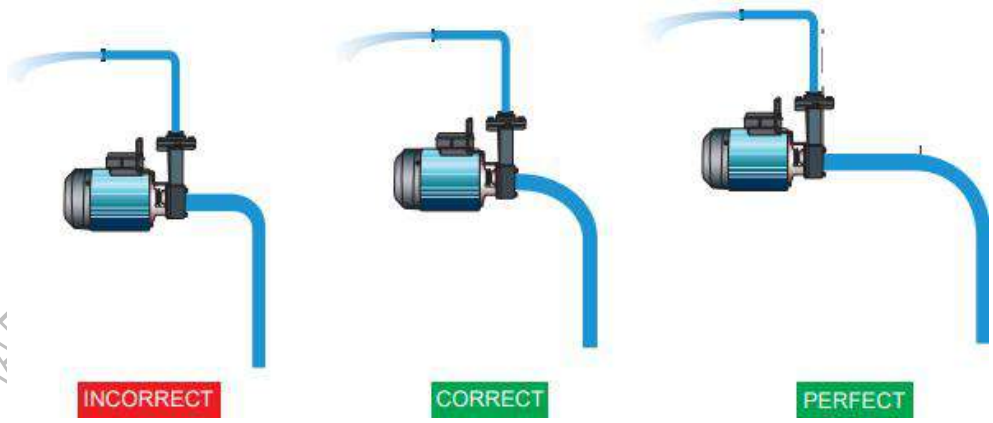
i. Check the insulation resistance using megger
ii. It is recommended to install the Mono-set with rain cover on concrete foundation
iii. Connect the suction and discharge pipes of diameters as recommended by the manufacturer.
iv. It is recommended to have Shorter Suction pipeline
v. Eccentric reducer is preferred and control valve is not advisable on suction side
vi. Large radius air tight smooth curved joints shall be preferred for uniform flow and reduced friction loss.
vii. Check the squareness of the pipe joints.
viii. Provide support and anchor to the pipings independent of the pump, so that the pump casing will be free of strain.
ix. Foot valve with wider mouth and larger area of openings is preferred
x. Properly connect the foot valve at the end of the suction and it should not rest at the bottom of the sump.
xi. Ensure that there is no leakage in the suction pipe.
xii. Avoid air lock through foot valve by ensuring minimum water level in the sump.
xiii. Earth the Mono-set using the provision provided as per IS3043.
xiv. Ensure proper electrical connection between Pump controller and Mono-set.



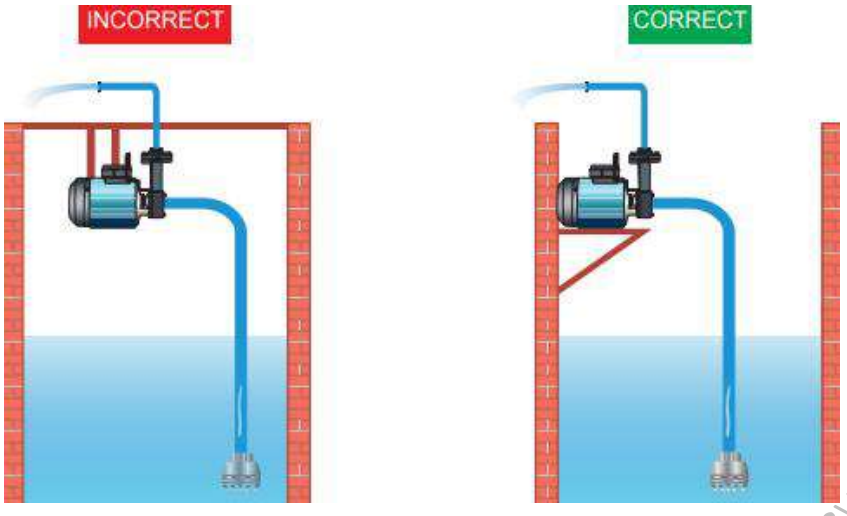

*Control valve should not be provided at the suction pipe



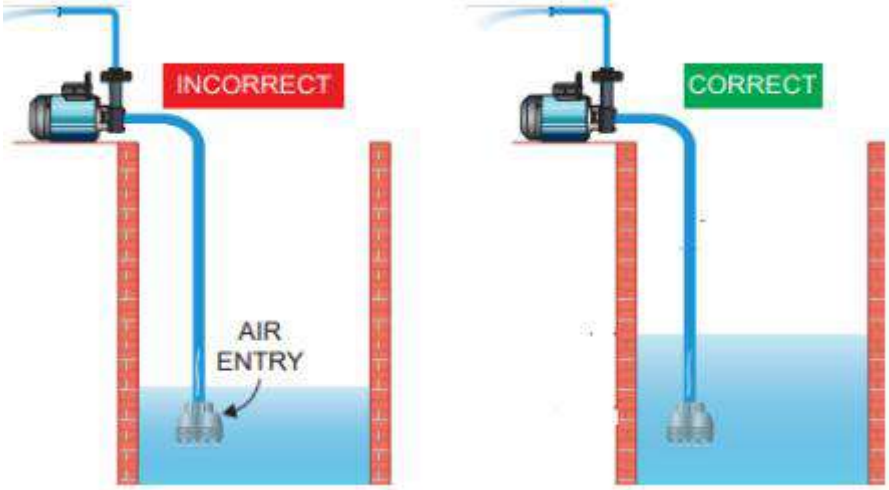

*Joints Must be air tight



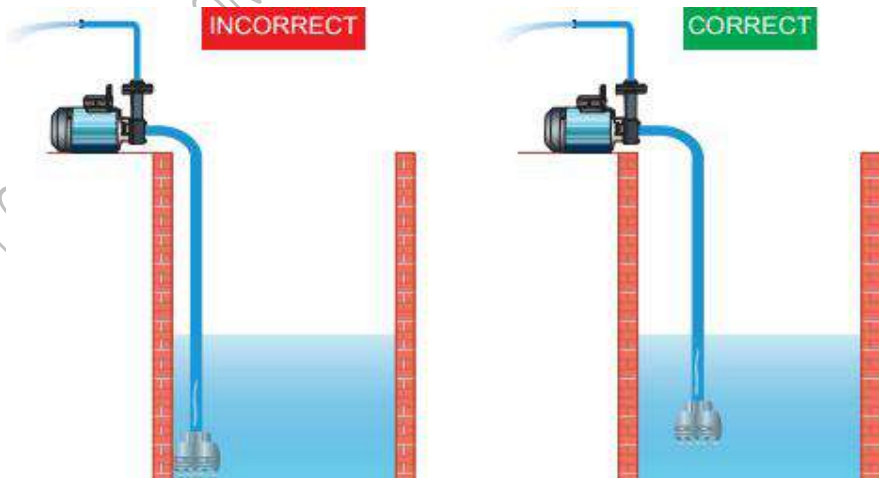

*Squareness of the bends are preferred and it should not be nearer to the Mono-set inlet




*Mono--set should be placed on rigid platform




*Ensure maximum water level above the foot valve




* Ensure clearance between sump bottom and Foot valve

***Figure 18:Incorrect and correct way of Surface Mono-set installation***

## Step–8 DC and AC cabling

Suitable size of cable shall be used in sufficient length for inter-connection between the SPV array to SPV Controller and the Controller to solar powered motor-pump set. Selection of the cable shall be as per IS 14536.Cables should be flexible and should have good resistance to heat, cold, water, oil, abrasion etc. The size of each type of cable selected shall be based on minimum voltage drop. However, the maximum drop shall be limited to 3%.

***Note:***

***The SPV array and Pump Controller should be connected by DC cable and between the Pump Controller and the motor, runs the AC/DC cable depending upon the type of motor.***

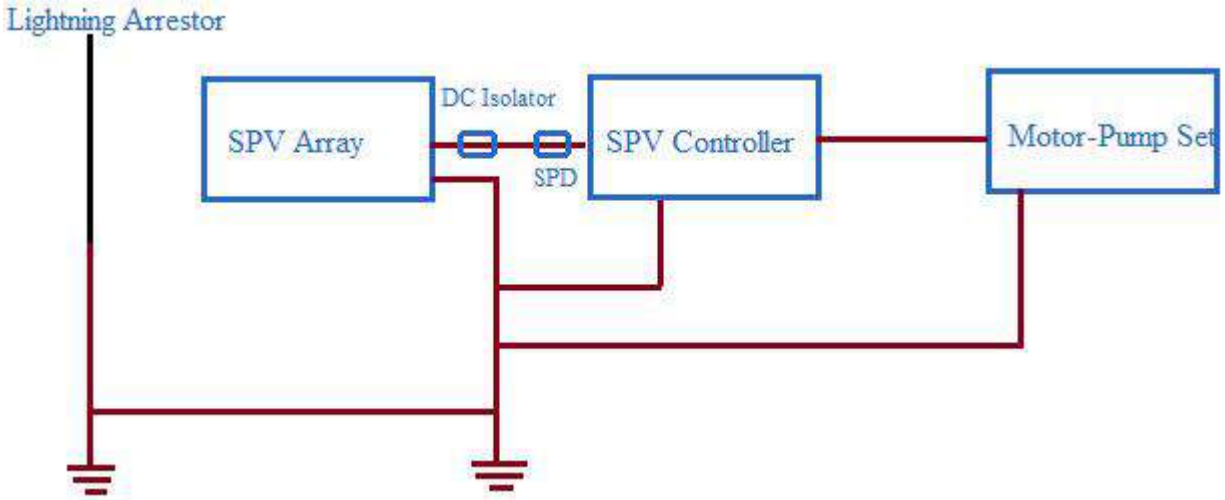



*Figure 19:Single Line Diagram*



### Points to be noted:

1. It is recommended for the cables to run through a PVC conduit of suitable size buried in the ground at a depth of 1 foot
2. All Cables used in the installation should be securely fixed in place to minimize any movement of the cable
3. The connection to a surface mono-set shall be with the connectors provided by the manufacturer.
4. The cable connected to a submersible motor should be suitable for installation in water.
5. The Cable shall not be used to support the weight of the submersible motor-pumpset.
6. The connection to the motor shall use the waterproof connectors provided by the manufacturer.

7. The cable should be clamped to the pump's discharge water pipe (sometimes called the rising main) in case of Submersible motor-pump set.

8. Cables should be protected from Mechanical damage & it should not lie on the ground without any enclosure or conduit.

9. All conduits carrying cable exposed to sunlight should be UV treated

10. Connections should be ensured for tightness and protected against moisture entry.

11. In areas of fauna existence, cable protection measures should take into account the possible damage caused by fauna.

## Step-9 System Protection & Safety

The purpose of grounding any electrical system is to prevent unwanted currents from flowing (especially through people) and possibly causing equipment damage, personal injury, or death. Lightning, natural and man-made ground faults, and line surges can cause high voltages to exist in an otherwise low-voltage system. Proper grounding, along with over current protection, limits the possible damage that a ground fault can cause.

- **Earthing**

### Points to remember

i. The Earthing shall be done in accordance with the IS 3043 including its amendments and updated versions.

ii. The Earthing system should be designed in such a way that its should able to restrict the potential of each conductor according to the level of insulation applied and magnitude of the current conducted through human body should be less than the value that can cause ventricular fibrillation of heart.

iii. Earth connections shall be done in such a way that they are visible for inspection and all the earth electrodes can easily be tested at any point of time.

iv. It is recommended to keep the value of resistance of earth electrode less than 5 ohms.

v. All the materials, fittings etc. used for doing earthing shall conform to the Indian standard, wherever exists.

vi. The actual value of soil resistivity should be considered while designing the earthing system at the site and for reference, selection criteria of the site, for any type of soil treatment to improve earth electrode resistance, etc. the IS 3043 shall be referred.

vii. The electrode material should be selected according to the corrosivity of the soil in which it is used, for the relation between resistivity and corrosivity of the soil and method to safeguard the conductor against excessive corrosion the IS 3043 shall be referred.

viii. It is recommended for selection of type and installation of the earth electrode the provisions of the IS 3043 should be considered. However, the pipe or rod-type earth electrode is preferable.

ix. In case of the two-earth electrode or more the separation among them should be twice the length of the electrode driven in the ground. Except in special conditions (for e.g.- where the soil is hard to dig out), a number of electrodes in parallel are to be preferred to a single long electrode.

x. The provisions given in the IS 3043 should be considered while selecting or connecting the earthing/protective/grounding conductor from the components to the earth pit.

xi. Separate earthing conductor shall be provided for the controller, pump-motor set and SPV array etc. for its connection to the earthing pit and it should be continuous in nature for electrical conductivity. However, even for the earthing of light current equipment (for example, high voltage testing equipment) the cross-sectional area of the earthing lead shall not be less than 6 mm2.

xii. For the maintenance of the earth electrode and measurement of the Earth electrode resistance the provisions of IS 3043 shall be referred.

xiii. Motor shall have suitable provision for earthing to facilitate earthing of the motor as per IS 3043 at the time of installation. In case GI pipes are used for the purpose of earthing the motor, an earthing connection may be made to the discharge pipe clamps. However, in case of HDPE/PVC pipes, a separate metallic cable from the motor to the control Module shall be provided and earthing given as if a four-core cable is used, the fourth core not connected to the terminals can be used for earthing.

xiv. The earth pits given with the SWPS {i.e., Earth pit(s) for the BOS system (other than LA) and Earth Pit for LA} should be made equipotential bonded to each other

## Lightning

Lightning Arrestor is installed nearer to the SPV water pumping system to divert the electrical surge due to lightning towards ground thereby protecting the system components against damage.

i. Lightning protection shall be provided as per IEC 62305 and IEC 63227 standards including its amendments and updated versions.

ii. An external lightning Rod, whose height should be more than the highest point in the system with a lightning protection system (LPS) designed to comply with class III or higher shall be installed, based on the site requirement which in turn depends on the area-specific lightning activity, etc. parameters.

iii. Arrangement and positioning of the separate air-termination systems can be determined using different methods given in the IEC 62305-3. While determining the position following points are to be considered such as: -

a) The structure to be protected is fully located within the protected volume provided by the air-termination system.

b) There should be separation distance between the air-termination system and PV power supply system to prevent dangerous sparking against parts of the PV power supply system in case of direct lightning. The separation distances determined in accordance with IEC 62305-3 & IEC 63227 shall preferably be maintained.

c) The possibility of the PV modules being shadowed by air-termination systems shall be taken into account and distance from the PV modules can be calculated using the IEC 63227.

iv. A separate earth electrode is required for the dispersion of the lightning current into the ground with suitably low value of the earthing resistance i.e., less than 5 ohm. And the minimum length (l1) of vertical earth electrodes for lightning protection level III or higher shall be determined according to the IEC 62305-3.

v. The cross-section of the metal sub-structures used for the connection of the lightning arrestor to the earth electrode should be no less than 16 mm2 Cu or 25 mm2 Al or GI of equivalent current carrying capacity should be used, which will also depend upon the class of the Lightning protection system.

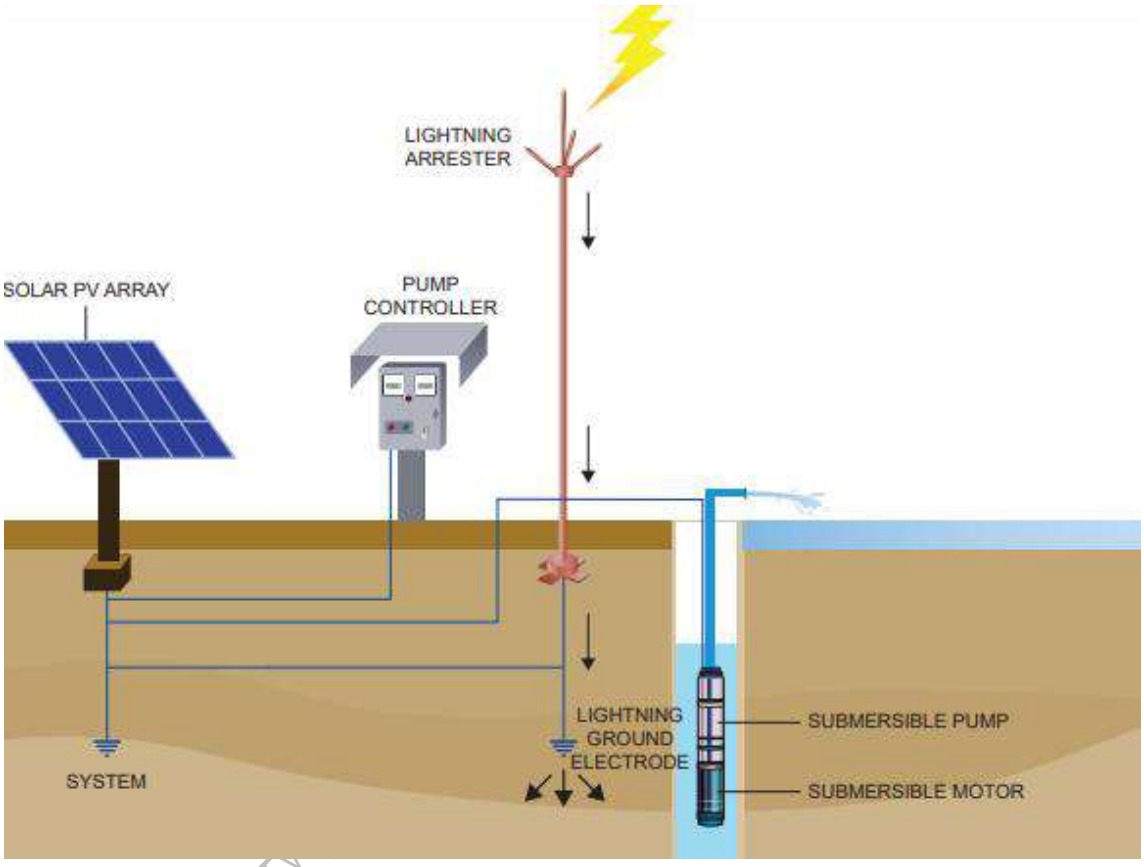



*Figure 20:System protection and Safety*



### Points to remember while handling Lightning Arrester

i. On receipt of the unit, inspect the structure for any visible damage

ii. Lightning Arrestor should be preferably stored indoors

iii. The Arrestor should be handled only in upright position

iv. The line terminal connection should be made without giving an excessive strain to the arrester.

v. Perpendicularity of the Arrestor should be maintained and ensure that the lugs rest solidly on the mounting surface.

vi. Tighten the bolts firmly.

## Step-10 Pre-commissioning Check

After installation of the system, it is imperative to conduct a per-commissioning test for verification. This test will check for any inconsistencies or errors in the connections and make sure that everything is working correctly.

### The Procedure for per-commissioning test is as follows:

1. Make sure all the components of the systems are tested for the desired performance and protection in case of any fault as per the specification of the MNRE and relevant IS/IEC standard. Further, also ensure that the insulation testing of AC and DC cables is done to prevent any leakage of the current.
2. Make sure that DC switch is in the 'OFF' position.
3. Ensure that the controller is turned OFF.
4. Measure and confirm that no voltage is present across any string.
5. Measure and confirm that no voltage is present on the output side of the Pump controller.
6. Check continuity of cables and complete the array cabling.
7. Confirm that the polarity of each of the array connections is correct.
8. Check the polarity and continuity between the SPV array and the Pump controller
9. Check the continuity between the Pump controller and the motor- pumpset.
10. Measure the resistance of the earth system .

## Step-11 Commissioning the system

When the connection is proper and the per-commissioning checks provide acceptable results, commission the system.Refer the controller manual and follow the start-up procedure

**Points to be noted:**

(1) Measure the DC input voltage and confirm that it is within the operating limits of the controller

(2) Measure the output voltage of the controller and ensure that motor-pumpset is operating at rated current

(3) Check the discharge of the pump.

(4) Check the parameters in the LCD screen of the controller and ensure that they are aligned with the system rating and on-site measurement.

(5) Ensure that the data transferred via remote monitoring system to the online portal is in line with the on-site data

***Note:- Fencing can enhance the system protection against physical damage.***

## 4.3. Measuring Equipment

### I. I-V Tester

I-V tester assists in checking the deterioration in performance of the SPV system. Module or wiring issues can be identified and can be used to compare the system performance in terms of power generation against the product warranty data. Effect of partial or uniform shading and performance improvement due to module cleaning can be analysed using IV-Curve.

### II. Thermographic Camera

IR imaging is done to identify the location of fault for power deficiencies in several components of the SPV plant. The thermographic camera can provide thermal imaging of all the SPV plant components like SPV modules, array junction boxes, Pump controller, and cables by assessing the temperature of the component thereby identifying the faults

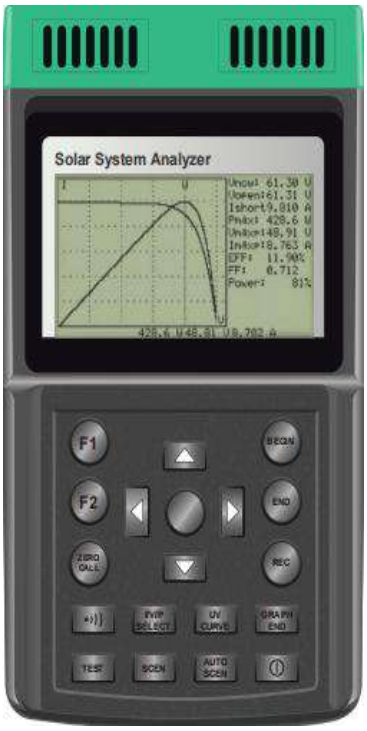



*Figure 21:IV Tester*

*Figure 22:Thermographic Camera*


*Figure 23:Clamp meter*



## III. Clamp Meter

A clamp meter is an electrical testing instrument which aids in measuring the current at any point in the system without disconnecting the wiring. Along with current, it can assist in measuring AC & DC voltage, continuity,resistance, and with some models, temperature, capacitance, frequency and more.

## IV. Pyranometer

Pyranometer is an instrument used to measure the solar irradiance on a horizontal plane. The major elements of pyranometer are domes, black absorber and a thermopile.Basically , black surface heats up when exposed to solar radiation.The hot junction of the thermopile is attached to the black surface and cold junction is located in such a way that it s protected from radiation.Thus the temperature difference thus arises between the junctions generates emf which is used to assess the irradiance.

## V. Multimeter

Several parameters of an electric circuit such as voltage, current, resistance, etc can be measured using Multimeter.The major parts are display screen, port and the selection knob.The knob aids in adjusting the parameter to be measured and the numerical value of the parameter will be displayed on the screen.


*Figure 24:Multimeter*

## VI. Megger

The Megger test is an instrument used to verify the condition of electrical insulation. Various environmental parameters like humidity, temperature, moisture,etc degrades the quality of insulation.Apart from this, electrical and mechanical stress causes damage to insulation.So, it is highly important to check the insulation of the electrical system at a regular interval. The instrument provides a measurement of an insulator's ability to withstand the service voltage without creating any current leakage paths.

## VII. Earth resistance meter

The purpose of earthing is to reduce the impact of transient voltage that results from a lightning strike or due to any other leakage current. The quality of earthing can be assessed by measuring the resistance of earth electrode.By passing an Alternate current, a voltage drop is generated. The Voltage drop thus generated is measured which is proportional to the resistance of the electrode under test.

## VIII. Vernier Caliper

Vernier calliper can be used to measure the thickness of the mounting structure to check whether the structure is in concurrence with the specifications.The measurement can be done by placing the object in between the jaws of the caliper by adjusting the vernier scale. The point of coincidence of the '0' mark of vernier with the main scale will provide the thickness of the object.

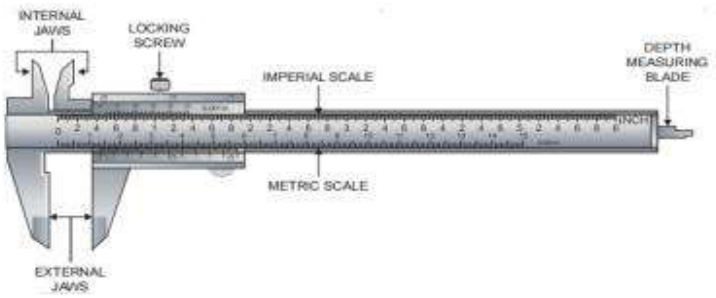



*Figure 25:Vernier Caliper*

## IX. Inclinometer

The angle at which the SPV modules are installed(Tilt Angle) plays a major role in power generation.Thus angle of inclination has to be measured and can be measured by using inclinometer.For measuring the tile, the instrument shall be placed either on the SPV module or on the surface co-planar to the module.

# 5. Routine Maintenance

System maintenance is an important step in ensuring that installed systems are performing as intended. By regularly monitoring the components of the system, any potential issues can be detected before they become a problem. This careful maintenance ensures that the system is able to meet its operational requirements, while avoiding costly repairs or replacements down the line.The preventive actions, if any, could be taken well in advance to save any equipment from damage. The section proposes few periodical checks that can be done to ensure the system performance .

## 5.1. SPV Array

i. Check the tightness of the mounted modules

ii. Check that the glass is not broken. If it is, the Module will have to be replaced.

iii. Check the connection box to make sure that the wires are tight and the water seals are not damaged.

iv. Check the Hot spots if any using Thermographic Camera

v. Check whether there is any shading due to vegetation or new building.

vi. Check the cleaning schedule as dust is detrimental for SPV Module performance. Water used for cleaning should be clean and should be free of salt.

vii. Check the Voltage and Current of the Module using Multimeter and Clamp meter .

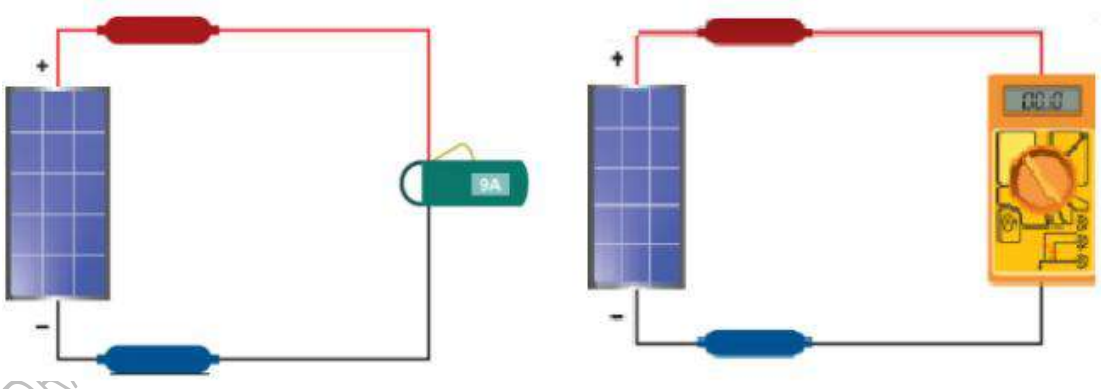



*Figure 26:SPV Module Parameter assessment*

## 5.2. Module Mounting Structure

i. Visually inspect the components of the structure are in correct position

ii. Check for damages in the foundation

iii. The straightness of the column should be assured using plum bob.

Usage of plum bob:

Fix the magnetic reel box of the plum bob on the top of the column and check whether the distance between the plum bob and the column is uniform.

iv. Ventilation below the structure should be ensured and check for uncontrolled plant growth if any.

v. Check for the corrosion in any parts of the structure

vi. Check whether all the clamps are tightened.

vii. Check the area between the arrays for accessibility

## 5.3. Wires

i. Check the wire covering (insulating sheath) for cracks or breaks. If the insulation is damaged, replace the wire.

ii. If someone has changed the wiring since the last check, make sure that it is the correct size, that it has suitable insulation, that the connections are properly made and that it is fastened securely in its new place.

iii. Check the connections for corrosion and tightness.

iv. Check that the junction box of the Module is firmly attached. If it is not, attach it correctly.

v. Conduct Insulation and continuity Test: Insulation values of the cable should be assessed periodically using Megger. If sudden fall in insulation resistance value of conductor is observed, repair or replace the defective cable. Continuity of wire can be checked using Clamp meter with probe adjusted for continuity mark.

## 5.4. Pump Controller

i. Turn on Pump controller and check the display for the mentioned parameters

ii. Check the controller is well ventilated and protected from direct sunshine.

iii. Check the earthing and motor wire connections.

iv. Check that Controller is mounted securely. If loose or incorrectly mounted, attach them securely.

v. Clean all exposed parts of controller.

vi. Check whether the enclosure provide protection against the entry of reptiles like lizard, etc

## 5.5. Motor -Pump Set

### Check for the following conditions:

i. Check the resistance of the motor coil using Megger by connecting one of the Megger terminals to motor cable and the other to the ground. High value resistance indicates the good condition of the Motor coil.

ii. Check the discharge from the pump. Following can be reasons for lesser discharge.

a) Pump may not be completely submerged in water (for submersible motor-pumpset)

b) Operational system head is more than the rated head

c) Choking of strainer/impeller/pipes – Take the motor-pump set out of the Bore well and clean or replace the parts

d) Leakage in pipe line – Fix the leakage in the pipe line

e) In case of zero discharge, check for the electrical connection and coupling damage

f) For Mono-set, in addition to the above points, check and replace the foot valve; prime the mono-set.

g) Any other related cause

iii. Check the current of the motor using clamp meter. Excessive current can be due to the following reasons:

a) Rubbing of rotating parts and stationary parts.

b) Defective cable

c) Any other related cause

iv. Check the excessive vibration of the motor-pump set if any and the reason can be as follows. The reasons can be same for Pump seizure.

a) Improper alignment and corresponding bends in shaft

b) Dry running of pump

c) Foreign bodies lodged in Impeller

d) Improper resting of motor-pump set in the borewell

e) Bearing worn out

f) Air or gas inclusion in water

g) In case of Mono-set, cavitation due to high static head can also be a reason. Reduce the suction lift of the mono-set.

v. Check the presence of sand particles in pumped water. Take the motor-pump set out of the bore well and check for the wearing of parts. Presence of sand may wear out the pump parts.

vi. Take the moto-pumpset out of bore well and replace the defective parts.

vii. Check for the cable joints for proper insulation.

viii. Inspect the pipe and fittings for any damage and leakage.



## 5.6. Earth Electrodes and Lightning Arrestor

i. Periodically check the resistance of the earthing electrode and maintain records and the method can be opted as given in the **Step-3 of installation**.If the resistance is beyond *5Ohm*,appropriate measures should be taken to maintain it with the limit.

ii. Visually inspect the earth electrode connection.

iii. Ensure the moisture content in the ground surrounding the earth pit.

iv. Visually inspect the Arrestor for any sign of overheating at connecting points.

v. Clean the insulator of Arrestor with dry cloth and check flash mark, surface cracks etc.

vi. Check for burst or puncture. If so, replace with the new Arrestor.

vii. Check the earthing resistance of the Lightning Arrestor earthing.

# Annexure I

## Pre-Dispatch Inspection

### Basic Details

| S. No | Details Required | Response |
|---|---|---|
| 1. | Date Of Inspection | …..... |
| 2. | Name of the Supplier/Contractor | …..... |
| 3. | Supplier's Inspection Call No. | …..... |
| 4. | Place of inspection: Address? | Godown/OEM; ..... |
| 5. | Work order No. and date | …..... |
| 6. | Order Quantity (pls specify ?) | …..... |
| 7. | Name of District and quantity | …..... |
| 8. | Inspection Order Call No. | …..... |
| 9. | Name of Inspecting Officers | …..... |
| 10 | Offered quantity for Inspection. | …..... |

# Annexure I-A

**SPV Module**

| Components/Characteristics | Type of check | Acceptance Norm | Response by inspection officer | Remark; If any? |
|---|---|---|---|---|
| | | | | |
| **Visual Checks: -** | | | | |
| Make (Logo) & Model No. of SPV module | Visual | As per ALMM given 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 S.No.- | |
| IEC Test certificate detail | Visual | Lab should be NABL accredited. | Name of the lab….....; Test Report Number ….....; Sr. No of the pump….....; S.No. of the motor…..... | |
| Name of the Manufacturer of SPV cells | Visual | | …..... | |
| Month and year of the manufacture (separately for SPV cells and module) | Visual | | …..... | |
| Country of origin (separately for SPV cells and module) | Visual | | …..... | |
| Date and year of obtaining IEC SPV module qualification certificate | Visual | | …..... | |

| | | | | |
|---|---|---|---|---|
| Maximum peak power (Pm) | Visual | As per MNRE specifications it 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 SPV 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 Module 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 Module | 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 | | …..... | |
| Incident Irradiance (W/m2) | Measurement | | …..... | |
| Length (mm) X Width (mm) | Measurement | | …..... | |
| Total Area of SPV Module | Measurement | | …..... | |
| Reference module power rating ($P_{mp}W$) | 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 | | …..... | |
| % Mod.Effi. | 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. | …..... | |
| Mismatch Factor | Measurement | As per MNRE specification | | |

# Annexure I-B

**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 the all items of the properly . | Visual | Certificate/ISI mark | Valid certificate /ISI marks present on the 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 | 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 | Yes/No | |

| | | | | | |
|---|---|---|---|---|---|
| case of the carbon steel the grade should be 8.8 or higher. | | | should be 8.8 or higher. | | |
| **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, Connecting Bracket, SQ Bracket, Bracing, Base Plate | Measurement | As per IS 4759/ASTM A123/approved drawings | minimum 80micron | For each item 10 readings are taken. (1) ……. (2) ……. (3) ……..(4) ……..(5)…….(6)……..(7) ……..(8)……..(9)……..(10)……. Unit is in micron | |
| Is Adhesion of the zinc coating is 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: - | | | | | |

# Annexure I-C

**Motor-Pump-Set & Controller**

| Components/Characteristics | Type of check | Reference Documents | Acceptance Norm | Response by inspection officer | Remarks; If any? |
|---|---|---|---|---|---|
| **Visual: -** | | | | | |
| Make (Logo) & Model No. and S.No. of pump. | Visual | | | | |
| Make (Logo) & Model No. and S.No. of Motor. | Visual | | | | |
| Type of pump and rating | Visual | | | Surface/Submersible (oil filled)/Submersible (Water filled) ….....HP | |
| Operation of the motor | Visual | | | AC/DC | |
| Is there any defect present on the surface of Casing/Cover (pump & motor). | Visual | | Surface should be free from any kind of defect etc. | Yes/No; If Yes Please Specify. | |
| Is there is any defect present on the Impeller & Guide vane | Visual | | should be free from any kind of defects | Yes/No | |
| Certificate regarding the use of Stainless Steel 304 grade Parts in Pumps | Visual | | Certificate stating that SS 304 is used. | Yes/No | |
| Is Physical condition of Shaft & Shaft sleeve being acceptable | Visual | | should be free from any kind of defects | Yes/No | |
| Is the rotation of the shaft being along the true axis of rotation. | Visual | | Shaft should rotate along the true axis of rotation should not be deviated. | Yes/No | |
| Is valid certificate/internal lab report of Hydro Test of Submersible pump being available | Visual | Standards: IS 8034 clause 9 | Valid test report which states that Pressurization of pump is done to 1.5times the maximum pressure for 2 minutes | Yes/No | |

| | | | | | |
|---|---|---|---|---|---|
| Declaration by the manufacture about the use of the imported parts. | Visual | | | …..... | |
| Which type of material used for the pipe along with pressure ratings. | Visual | MNRE specification | HDPE and uPVC and pressure rating according to the rating of the pump. In case of HDPE pipes the minimum pressure rating of 8 kg/sqcm-PE100 grade for pumps up to 3 HP, 10 kg/sqcm-PE100 grade for 5 HP pumps and further higher minimum pressure rating for above 5 HP as appropriate shall be used. | …....;…..... | |
| Is valid Warranty certificates and calibration certificates being available | Visual | | certificates should be valid. | Yes/No | |
| Is controller being IP protected? | Visual | MNRE specification | Certificate against IP protection and rating should be at least IP65. | Yes/No; If Yes specify IP rating | |
| Is third Party **Type Test** Report available | Visual | Third party type test report. | Type test reports as per IS: 9283 | Yes/No | |
| List of the parameter available on the LCD Screen of controller | Visual | | All the parameter should be available on the LCD screen | Pump status: Running/Standstill | |
| | | | | Array Input DC Voltage: Yes/No | |
| | | | | Array Input DC current: Yes/No | |
| | | | | DC/AC output Current & voltage: Yes/No | |
| | | | | Operating frequency : Yes/No | |
| | | | | Latest RMS Lat & Long:Yes/No | |

| | | | | | |
|---|---|---|---|---|---|
| | | | | Pump Capacity (HP):Yes/No | |
| | | | | SPV Module Capacity (KW):Yes/No | |
| | | | | Current Generation (kW):Yes/No | |
| | | | | Today Solar Generation (kWh):Yes/No | |
| | | | | Cumulative Solar Generation (kWh):Yes/No | |
| | | | | Today Runs Hours (Hrs.):Yes/No | |
| | | | | Cumulative Pump Run Hours (Hrs.):Yes/No | |
| | | | | Cumulative Water Discharged (Litres):Yes/No | |
| | | | | Total Water Discharged (Litres):Yes/No | |
| | | | | Peak Power (kW) Supplied:Yes/No | |
| | | | | Any other than above Please specify: ..... | |
| Randomly check the serial No present physically on pump, motor and controller and match it with the S. No. present in the lot list | Visual | | Serial No. given in the list should match with the physically available one's. | Matching/Unmatching | |
| Is there is any surface defect on the controller | Visual | | Free from any surface defect. | Yes/No; If Yes specify | |

| | | | | | |
|---|---|---|---|---|---|
| Is controller having provision of remote monitoring of inverter data through sim card/Bluetooth | Visual | | | Yes/No | |
| Is required website/mobile app platform, where the user (Consumer) can access the data, provided. | Visual | | | Yes/No | |
| Is all data of controller made available for implementing agency for monitoring by giving web access? | Visual | | | Yes/No | |
| Is GPS Module with less than 10-meter horizontal accuracy is available in the system. | Visual | Mobile application | The Geo location where the GPS device is kept should be accurate on the mobile application | Yes/No | |
| Is under the live status in RMS it must indicate whether the pump is in running condition or standstill? | Visual | | | Yes/No | |
| List of the parameter available on the RMS portal | Visual | | All the parameter should be available on the RMS portal | Pump status: Running/Standstill | |
| | | | | Array Input DC Voltage: Yes/No | |
| | | | | Array Input DC current: Yes/No | |
| | | | | DC/AC output Current & voltage: Yes/No | |
| | | | | Power: Yes/No | |
| | | | | Drive frequency: Yes/No | |
| | | | | Real time energy generation daily: Yes/No | |
| | | | | Water output: Yes/No | |
| | | | | water flow rate: Yes/No | |

| | | | | | |
|---|---|---|---|---|---|
| | | | | Graph representation | |
| | | | | Running hours daily and cumulative: Yes/No | |
| | | | | Any other than above Please specify: ..... | |
| Is Data pushed on Event/Notification: such as when pump on, pump off, protection operated etc. | Visual | | | | |
| Is Declaration from the vendor that there is a provision for data backup of 1year available in the controller. | Visual | | | Yes/No | |
| Is any Faults related to Pump Operation, Solar generation, Controller/Drive faults like overload, dry run, short circuit, etc. is available on the RMS. | Visual | | | Yes/No | |
| Is complaint management system provided in the remote monitoring system. | Visual | | | Yes/No | |
| Is Declaration from the vendor is available which states that RMS have provision for at least two Analog and Digital inputs with 0.1% accuracy to address the requirement of local sensors connectivity if required? | Visual | | | Yes/No | |

| | | | | | |
|---|---|---|---|---|---|
| Is RMS have provision to give remote on/Off command to pump through farmer mobile app. And in case, farmer do not have a smart phone, farmer shall be able to on-off pump thru SMS/missed call. | Visual | | | Yes/No | |
| Is the certificate available for the overload test, dry run, under voltage, over temperature, high voltage test. | Visual | | Valid certificates | Yes/No | |
| **Measurement** | | | | | |
| Type and size of cable used for motor | Visual/Measurement | As per relevant IS Standard | As per the standard based on the rating of the pump. | …. core/….mm2/…....m | |
| Controller Input Current | Measurement | | | …..... | |
| Motor Input Current | Measurement | | | …..... | |
| MPPT voltage range | | | | | |
| Controller Output Current | Measurement | | | …..... | |
| Is Protection Checks for reverse polarity, short circuit, working properly. | Test | | All protection checks should work. | Yes/No | |
| Dimension of the controller box; - Height, Width, Depth, Wall thickness, body thickness | Measurement | | H-500mm; W-450mm; D-250mm; body wall thickness is about 2mm | ….....mm; mm, mm; mm; .....mm | |

# Annexure II

## Post Installation Inspection

### General Information

| **Detail of farm where SPV Pump is to be installed:** | **Response given by the inspector** |
|---|---|
| Name of the beneficiary | |
| Name of the vendor who installed the system | |
| Land Survey number | |
| Work Order No. | |
| Latitude & Longitude | |
| Water Required | |
| Irrigation Area | |
| Village/Taluka/District | |
| HP of SPV Pump Demanded | |
| HP of SPV Pump Installed | |
| SPV Capacity installed in kWp | |
| Total Head in meters (suction + Delivery) | |
| Installed Pump Type (AC/DC) | |
| Installed Pump Sub Type (Submersible Pump (Water filled Motor) / Submersible (Oil filled Motor)/Surface Pump) | |
| Date of Registration | |
| Farmer's Contribution Amount and date of payment | |
| Date of installation of SPV Water Pump | |
| Is User manual and warranty card handed over to customer in local language? | Yes/No |
| Is USPC Installed? | Yes/No |

# Annexure II-A

**SPV array**

| | | |
|---|---|---|
| **Safety: -Recommended Personal Protective Equipment** | | |
| 1.Helmet | | |
| 2.Gloves | | |
| 3.Glasses | | |
| 4.Safety shoes | | |
| **Recommended Instruments to be carried along for the inspection** | | |
| 1.Multimeter | | |
| 2.Meter tape | | |
| 3.IR Thermal Camera | | |
| 4.Clamp meter | | |
| 5.Inclinometer | | |
| 6.Megger | | |
| **Checklist** | **Response of the inspecting officer** | **Remarks, If any** |
| Manufacture's Name of SPV Modules | | |
| Capacity (Wp) of each SPV module | | |
| No. of SPV Modules | …….....Also specify series…..... & Parallel…..... | |
| Serial number of each module | | |
| Total SPV Capacity (Wp) of the array | | |
| Declared maximum peak Voltage (Vmp) of each module | | |
| Declared maximum peak Current (Imp) of each module | | |
| Declared Maximum voltage of the system | | |
| Fire Rating Class | | |
| Maximum Series Fuse Rating | | |

| | | |
|---|---|---|
| Whether RFID tag is pasted or not? Location | Yes/No; ..... | |
| Nameplate Type (Waterproof Sticker or Metal plated or else, specify) | | |
| Any physical defect present in the Modules/Array? | Yes/No, If Yes? Please Specify. | |
| Is module frame made up of corrosion resistant, electrically resistant anodized aluminium. | Yes/No | |
| Whether the earthing connection spot is properly marked on the frame of the module for its earthing. | Yes/No | |
| Is SPV Modules electrical connections being tight and secure? | Yes/No | |
| Is Module to Module wattage mismatch in the SPV array mismatch shall be within ± 3 percent? | Yes/No | |

# Annexure II-B

**SPV Pump Controller**

| **Safety: -Recommended Personal Protective Equipment** | | |
|---|---|---|
| Helmet | | |
| Gloves | | |
| Glasses | | |
| Safety shoes | | |
| **Recommended Instruments to be carried for the inspection** | | |
| Multimeter | | |
| clamp meter | | |

| Checklist | Response by inspecting officer | Remark; If any? |
|---|---|---|
| Power Range in kW for Controller | | |
| Current rating (A) | | |
| Type of Controller | AC/DC | |
| Rating of pump for which controller is suitable for? | | |
| Check for any physical damage to controller? If Yes, Please Specify | | |
| Is controller is mounted on the separate angles? | Yes/No | |
| Is cable for controller to motor connection run through PVC pipe and inside the ground? | Yes/No | |
| IS Customer care information striker pasted on controller for OM related issue? | Yes/No | |
| Is open Circuit Protection working? | Yes/No | |
| Is Short Circuit Protection working? | Yes/No | |
| Is Reverse Polarity Protection working? | Yes/No | |
| Is SPV Controller have IP (65) protection or housed in a cabinet having at least IP (65) protection? | Yes/No | |

| | | |
|---|---|---|
| Is suitable size of cable used in sufficient length for inter-connection between the SPV array to SPV Controller and the SPV Controller to solar powered motor-pump set? | Yes/No; If Yes? Please mention Size and length. | |
| IS SIM card of suitable Internet service provider having sufficient Signal Strength for communication is provided? | Yes/No | |
| Is controller having provision of remote monitoring of inverter data through sim card | Yes/No | |
| Whether website/mobile app platform, where the user (Consumer) can access the data, provided/explained to consumer? | Yes/No | |
| Is all data of controller made available for implementing agency for monitoring by giving web access? | Yes/No | |
| List the values of the parameter available on the RMS portal | Pump On/Off status | |
| | Array Input DC Voltage: | |
| | Array Input DC current: | |
| | DC/AC output Current & voltage: | |
| | Power: | |
| | Drive frequency: | |
| | Real time energy generation daily: | |
| | Water output: | |
| | water flow rate: | |
| | Running hours daily and cumulative: | |
| | Any other than above Please specify:..... | |
| Is Data pushed on Event/Notification: such as when pump on, pump off, protection operated etc. | Yes/No | |
| Check for periodically data updation on the RMS portal after the default interval of at most 15 minutes. For this the readings at the portal can be viewed with the 15mins time gap. | Satisfactory/Unsatisfactory. | |

| | | |
|---|---|---|
| Is Real time latitude and longitude should be captured with an accuracy of less than 10-meter horizontal accuracy. | | |
| Is any Faults related to Pump Operation, Solar generation, Controller/Drive faults like overload, dry run, short circuit, etc. is available on the RMS. | Yes/No | |
| Are the details such as name, agriculture details, service No. Contact Details, etc. is captured? | Yes/No | |
| Are the ratings, Serial Number, Make, Model Number of Motor-Pump set, Module and Controller, IMEI number (of communication module) and ICCID (of SIM) is available at RMS portal? | Yes/No | |
| Is complaint management system provided in the remote monitoring system. | Yes/No | |
| Is RMS have provision for at least two Analog and Digital inputs with 0.1% accuracy to address the requirement of local sensors connectivity if required by SIA/Consumer? | Yes/No | |
| Is RMS have provision to give remote on/Off command to pump through farmer mobile app. And in case, farmer do Not have a smart phone, farmer shall be able to on-off pump thru SMS/missed call. | Yes/No | |
| The value of various parameters presents on the controller screen | Pump status: Running/Standstill | |
| | Array Input DC Voltage: Yes/No | |
| | Array Input DC current: Yes/No | |
| | DC/AC output Current & voltage: Yes/No | |
| | Operating frequency : Yes/No | |
| | Latest RMS Lat & Long:Yes/No | |
| | Pump Capacity (HP):Yes/No | |
| | SPV Module Capacity (KW):Yes/No | |

| | | |
|---|---|---|
| | Current Generation (kW):Yes/No | |
| | Today Solar Generation (kWh):Yes/No | |
| | Cumulative Solar Generation (kWh):Yes/No | |
| | Today Runs Hours (Hrs.):Yes/No | |
| | Cumulative Pump Run Hours (Hrs.):Yes/No | |
| | Cumulative Water Discharged (Litres):Yes/No | |
| | Total Water Discharged (Litres):Yes/No | |
| | Peak Power (kW) Supplied:Yes/No | |
| | Any other than above Please specify: ..... | |

# Annexure II-C

**Module Mounting Structure**

| **Recommended Instruments to be carried for the inspection** | | |
|---|---|---|
| | | |
| Measuring Tap | | |
| Torque Wrench | | |
| Vernier calliper | | |
| Spirit level | | |
| Compass | | |
| | | |
| **Checklist** | **Response of the inspecting officer** | **Remark; If any?** |
| Is SBC (Soil bearing capacity) lab test available: - | Yes/No | |
| Is Validated foundation drawing and design along with its calculation, as per Safe bearing capacity of site available? | Yes/No | |
| Is foundation hardware being as per IS 5624? | Yes/No; If No then which standard is used (IS 6403 / 456 / 4091 / 875) | |
| Is the Foundation Block size/Pile cap Size being as per the approved drawing | Yes/No? If No Please specify | |
| Is nature of soil being sandy? | Yes/No. If Yes, then is the anti-tilt protection is provided in the foundation? | |
| Is all hardware are properly tightened. | Yes/No | |
| All Anti-theft Nuts. | Broken/Not Broken | |
| Is the square type of Washer used in all tightened nut and bolts | Yes/No | |
| Module facing direction: - | | |
| Is Structure Assembly level being vertical, it should not be tilted? | Yes/No | |
| Is Structure Alignment being free from any defect? | Yes/No | |
| Is Surface finish free from defect? | Yes/No | |

| | | |
|---|---|---|
| Is Ground clearance should be maintained as per drawing: | Yes/No | |
| Is shadow free area available? | Yes/No | |
| Three times daily tracking | Manual/Automatic/Not present. | |
| Seasonal Tracking | Manual/Automatic/Not present. | |
| Whether the proper gap is provided in between the module as per structure drawing | Yes/No | |
| Is alignment of all SPV module being in level? | Yes/No | |
| Is it certified that All Nut bolts, Module Mounting clamps fasteners are of stainless steel of Grade SS 304? | Yes/No | |

# Annexure II-D

**Pump Assembly**

| **Safety: -Recommended Personal Protective Equipment** | | |
|---|---|---|
| Helmet | | |
| Gloves | | |
| Glasses | | |
| Safety shoes | | |
| **Checklist** | **Response by inspecting officer** | **Remark; If any.** |
| Pump make/Model No./Serial No. | | |
| Motor make/Model No./Serial No. | | |
| Depth to which the pump has been lowered in the Borewell (in case of submersible pump) | | |
| Flushing of bore well before I & C | Yes/No; if Yes then Date? | |
| Dynamic Head | | |
| Types of pipes used for suction and delivery. | UPVC/HDPE | |
| Size of pipe for suction and Delivery | | |
| Length of pipe used in meter. | | |
| Pressure rating of the pipe. | | |
| Has the pump run in the direction of rotation specified by the arrow on metal label of pump | Yes/No | |
| Is adequate length of insulation is removed so that multi-core cable joints can be visually separated with crimped connectors and Rubber sleeve needs to cover the crimped connector for additional protection with electrical protective tape on it. | Yes/No | |
| Is ISI mark present on cable along with its cross section? | Yes/No | |

# Annexure II-E

**Electrical Connections**

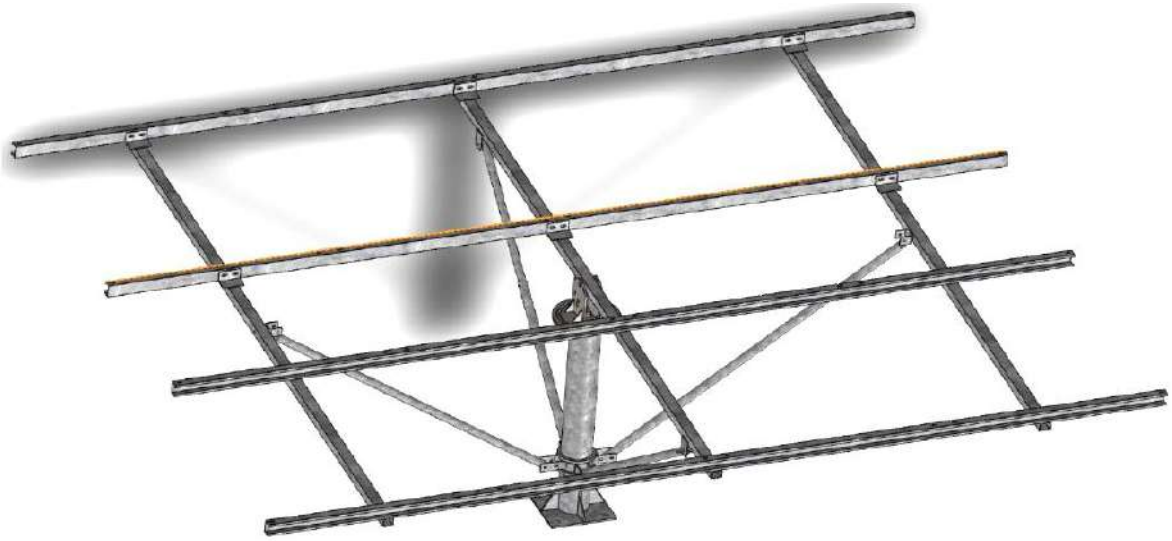
| **Safety: -Recommended Personal Protective Equipment** | | |
|---|---|---|
| Helmet | | |
| Gloves | | |
| Glasses | | |
| Safety shoes | | |
| **Recommended Instruments to be carried for the inspection** | | |
| Megger | | |
| clamp meter | | |
| Multimeter | | |
| electrical tape | | |
| thread | | |
| **Checklist** | **Response by inspecting officer** | **Remark; If any.** |
| No. of Earthing provided | | |
| Earth resistance value of all the pits | | |
| Is the value of earth resistance of all the pits is less than 5ohm | Yes/No | |
| In case of multiple earth pits | Connected/Independent | |
| LA Pipe height and Size of GI strip/Cable used for connection to ground:- | | |
| Is in case of uPVC/HDPE pipes used as discharge pipe, a separate Non-corrosive, low resistance conductor from motor earth terminal to control Module earth terminal shall be provided for earthing? | Yes/No | |
| Is Connections of earthing properly done? | Yes/No | |
| Is SPV module wiring routing properly with UV rated cable tie? | Yes/No | |
| Is chemical Earthing done as per IS-3043? | Yes/No | |
| Is PVC conduit pipe of suitable size ISI make or black drip pipe used for covering panel wiring and which is buried in the ground ? | Yes/No | |

| | | |
|---|---|---|
| Is Electrical continuity of SPV module is maintained? | Yes/No | |
| Is LA positioning behind structure & height greater than highest structure peak | Yes/No | |
| Is Array connection to controller done through JB/MCB? | Yes/No | |
| Is Polarity correct in connection? | Yes/No | |
| Is proper lugs used for the connection of the wire? | Yes/No | |
| Is there any loose wire or connection available? | Yes/No; If Yes please specify | |

# Annexure-III

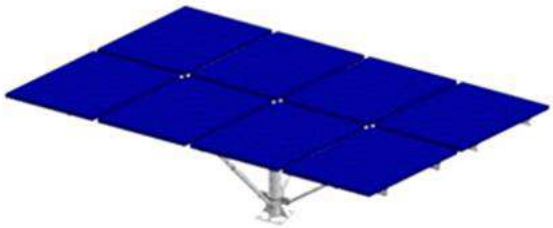
**Specifications for Dual Axis Manual Tracking Type**

**Module Mounting Structure for Solar Water Pumping System**



4 Module MMS

6 Module MMS



8 Module MMS

10 Module MMS

**A-1 Standard MMS for 4, 6, 8 and 10 SPV modules have been specified. These standard MMS may be used in combinations for different capacities of SPV water pumping systems as follows:**

1. Standard MMS of 4 Modules for 1 HP
2. Standard MMS of 6 Modules for 2 HP
3. Standard MMS of 10 Modules or Combination of standard MMS of 4 Modules and standard MMS 6 Modules for 3 HP
4. Combination of two standard MMS of 8 Modules or combination of standard MMS of 10 Modules and standard MMS 6 Modules for 5 HP
5. Combination of three standard MMS of 8 Modules or combination of two standard MMS of 10 Modules and one standard MMS 6 Modules for 7.5 HP

and so on….

**A- 2 Specifications of main parts used in MMS are given below:**

**A-2.1 Centre Shaft**

Centre shaft used in structure shall be of :

a) For 4, 6 and 8 Modules structure - minimum 139 OD with minimum thickness of 4 mm with base plate minimum 10 mm thickness if used and foundation hardware shall be as per IS 5624.
b) For 10 Modules structure - minimum 165 OD with minimum thickness of 4 mm with base plate minimum 20 mm thickness if used and foundation hardware shall be as per IS 5624.

For system without base plate i.e., direct pilling is shall be as per the site condition based on the properties of Soil and refer (IS 6403 / 456 / 4091 / 875) for foundation design.

**A-2.2Rafters**

The Main and secondary rafter used in structure shall be of either SHS & RHS pipe sections.

**A-2.3Purlin**

Mounting Purlins used in the structure shall be made of Cold form steel section as per IS 1079 with minimum thickness of 2 mm.

**A-2.4 Provision for Seasonal Tilt**

In one structure at least four telescopic supports (three may be used in MMS for 4 modules) either round hollow sections or square hollow section to be provided to support the mounting structure.

**A-2.5 Provision for Daily Tracking**

Provision for Daily tracking shall be provided by the way of providing min. 8 mm thick metal sheet with precision cut grooves.

**A-2.6 Module Locking System**

Modules shall be locked with antitheft bolts of SS 304 Grade.

**A-2.7General Hardware for Structure Fitment**

Either SS 304 or 8.8 grade hardware shall be used for fitment.

**A-2.8Hot Dip Galvanizing**

All structure parts shall be hot dip galvanized according to IS 4759.

**A-2.9Tolerance for Fabrication**

Tolerance for fabrication of steel structure shall as per IS 7215.

**A-2.10Welding**

Welding shall be done as per IS: - 822 & grade of welding wire shall be (ER70S-6).

**A-2.11 Raw Material Test Certificates** (MTC)

MTC of all types of raw material used in dual axis manual tracking type MMS as per appropriate Indian Standard shall be submitted along with dispatch documents.

**A-2.12** Square washer to be used for all the nut-bolts arrangement.

**A-2.13** Tests to be performed on Dual Axis Manual Tracking Type MMS for SPV Water Pumping System.

**A-2.13.1** For ascertaining proper welding of structure part following shall be referred.

a) Weld wire grade shall be of grade **(ER 70 S - 6);** and

b) D.P. Test (Pin Hole / Crack) **(IS 822)**

**A-2.13.2** For ascertaining hot dip galvanizing of fabricated structure following shall be referred: -

a)Min coating required shall be as per IS 4759.

b) Testing of galvanized material.

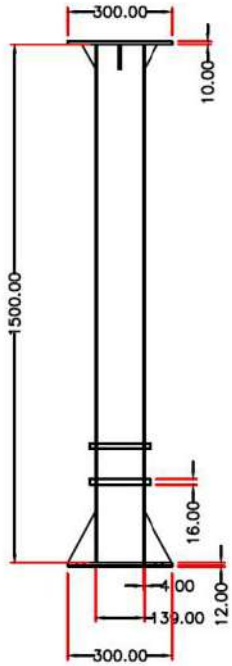
c) PREECE Test (CuSO4 Dip Test) **(IS 2633)**

d) Mass of Zinc **(IS 6745 or IS 4759)**

e) Adhesion Test **(IS 2629)**



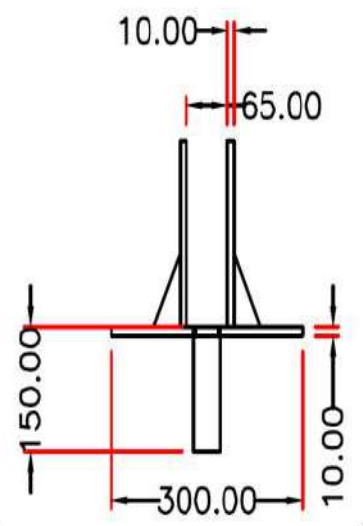
**Part1 – Mail Column**

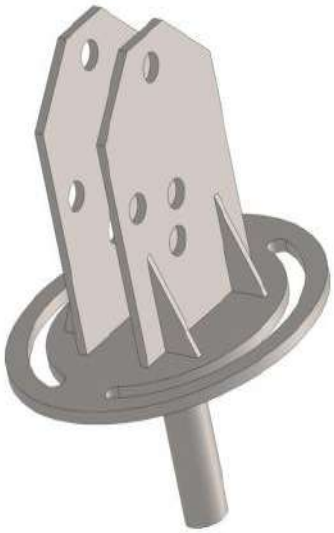



Notes: -

1. All Dimensions are in mm.
2. Main Column material grade should be YST - 240 as per: -IS: 1161 / 1239 & E250 as per: - IS: 1079 / 2062.

**Part 2 – Top Plate**

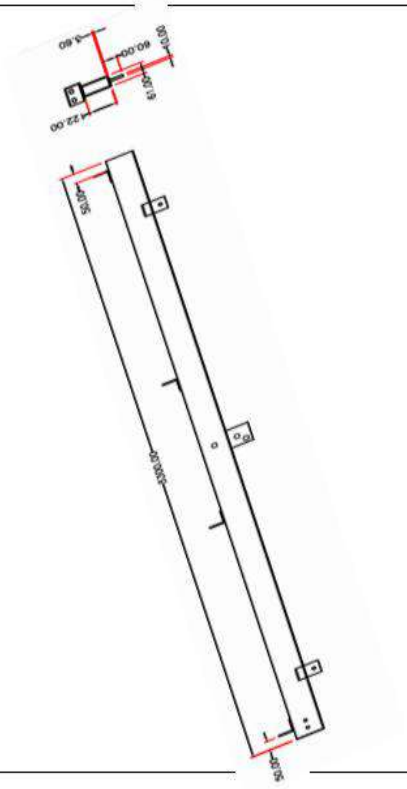


Notes: -

1. All Dimensions are in mm.
2. Top Plate material grade should be YST - 240 as per: -IS: 1161 / 1239 & E250 as per: - IS: 1079 / 2062.

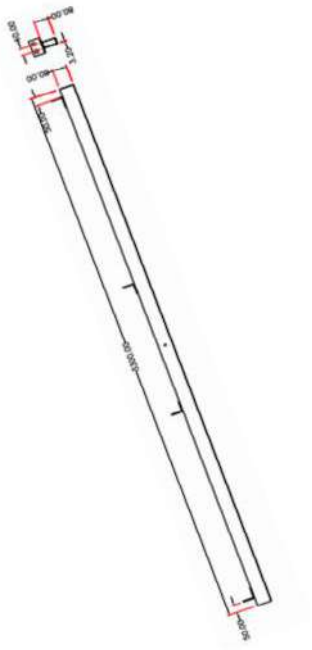
**Part 3 – Main Tube**



Notes: -

1. All Dimensions are in mm.
2. Main Tube material grade should be YST - 240 as per: -IS: 1161 / 1239 & E250 as per: - IS: 1079 / 2062.

**Part 4 – Side Tube**



Notes: -

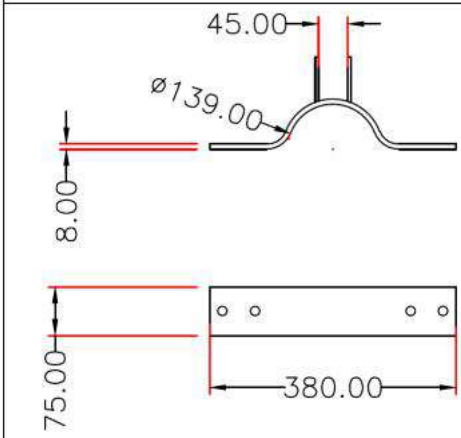
1. All Dimensions are in mm.
2. Side Tube material grade should be YST - 240 as per: -IS: 1161 / 1239 & E250 as per: - IS: 1079 / 2062.

**Part 5 – Purlin**

Notes: -

1. All Dimensions are in mm.
2. Mounting Purlin material grade should be E250 as per: - IS: 1079 / 2062 & IS: 811.

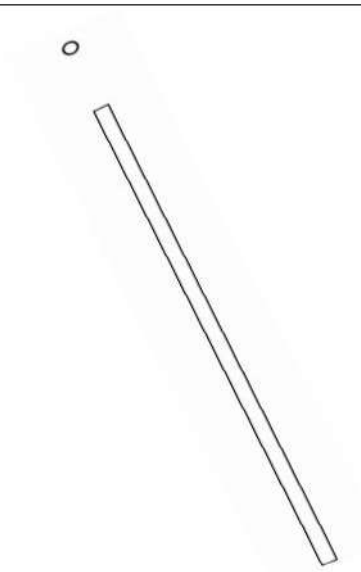
**Part 6 – Clamp with Blade**




Notes: -

1. All Dimensions are in mm.
2. Clamp with Blade material grade should be as per: - IS: 1079 & E250 as per: - IS: 2062.

**Part 7 – Supporting Pipes**



Notes: -

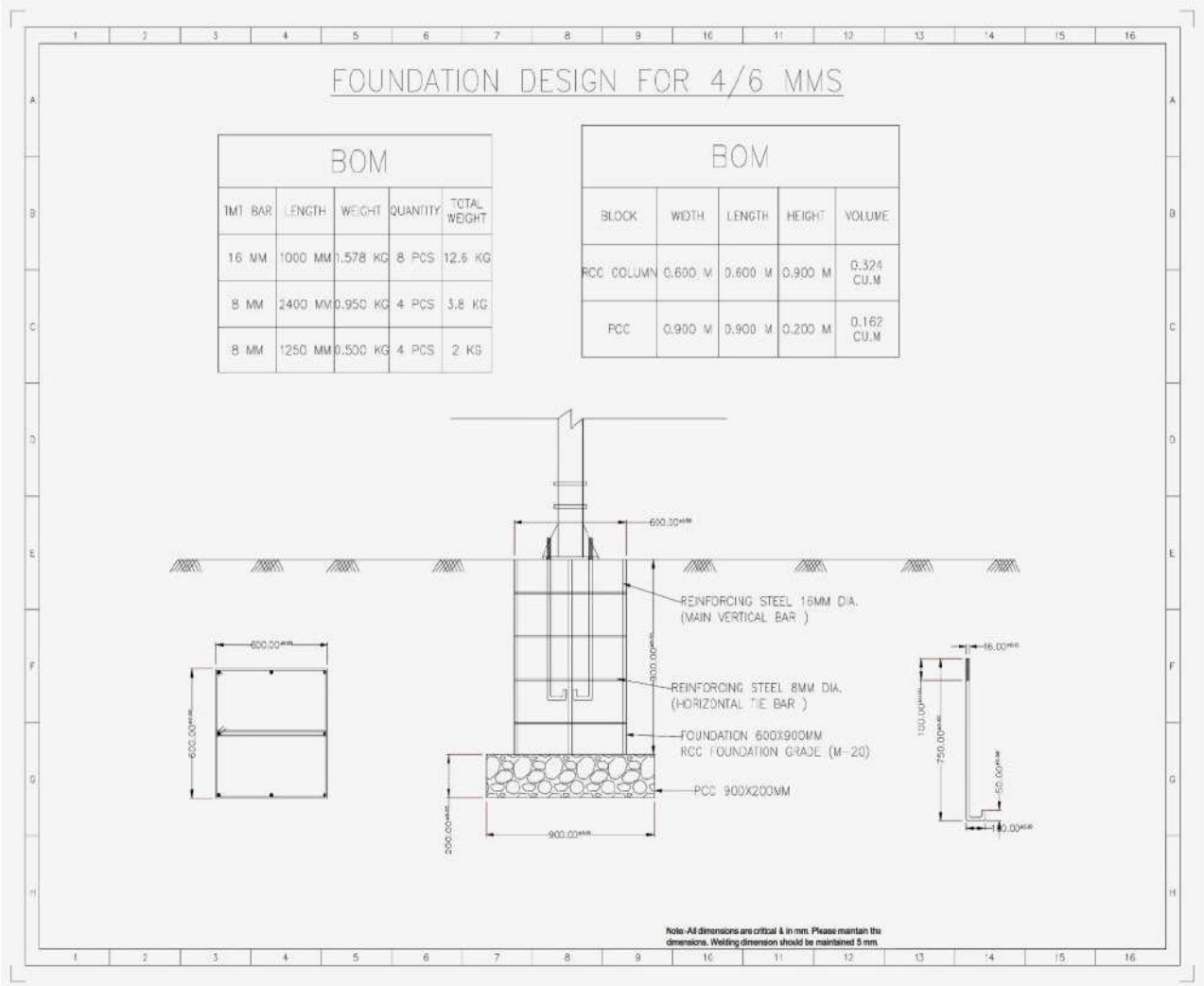
1. All Dimensions are in mm.
2. Supporting Pipes material grade should be YST - 240 as per: -IS: 1161 / 1239 & E250 as per: - IS: 1079 / 2062.

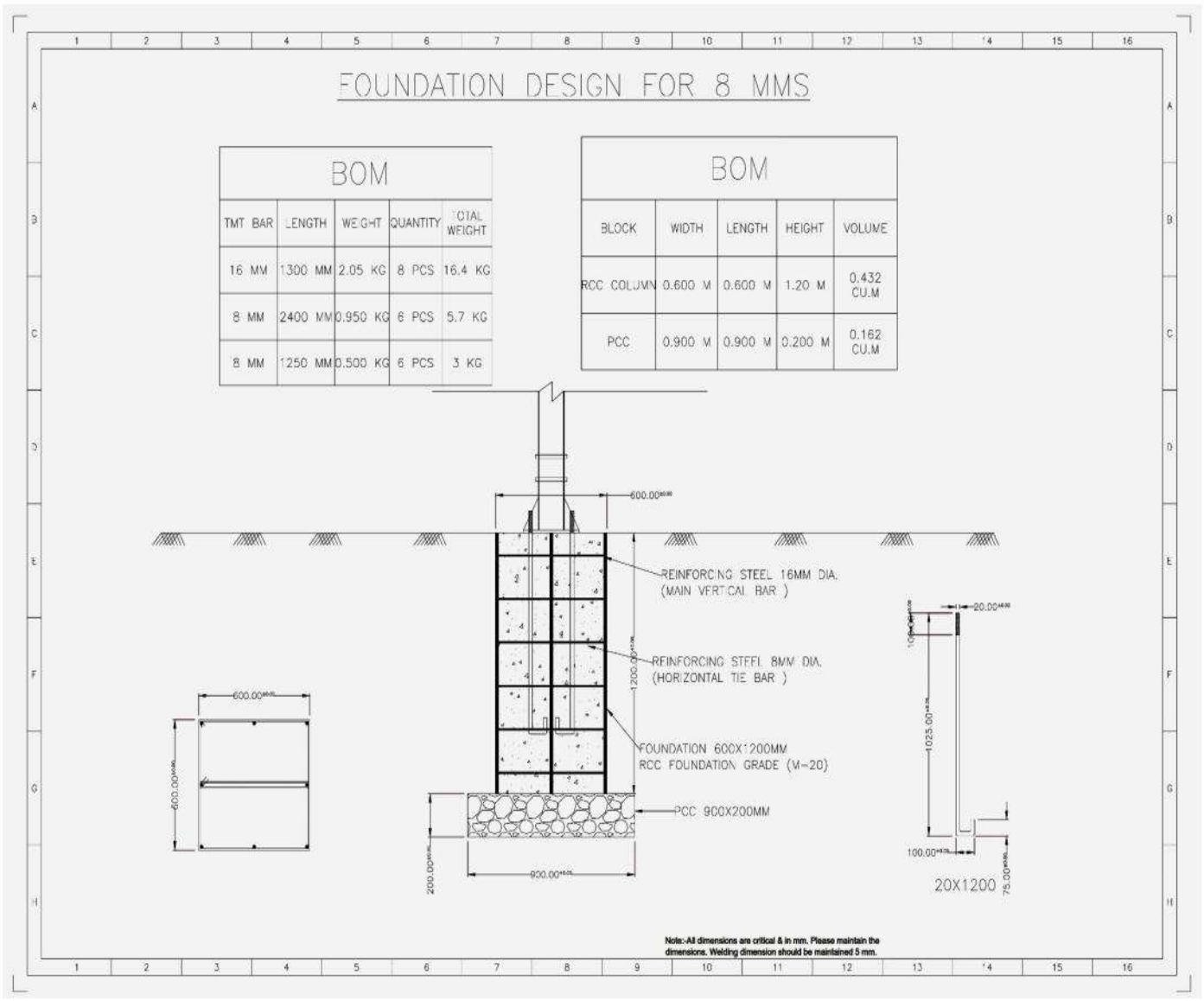
**Main Parts of MMS for SPV Water Pumping System**

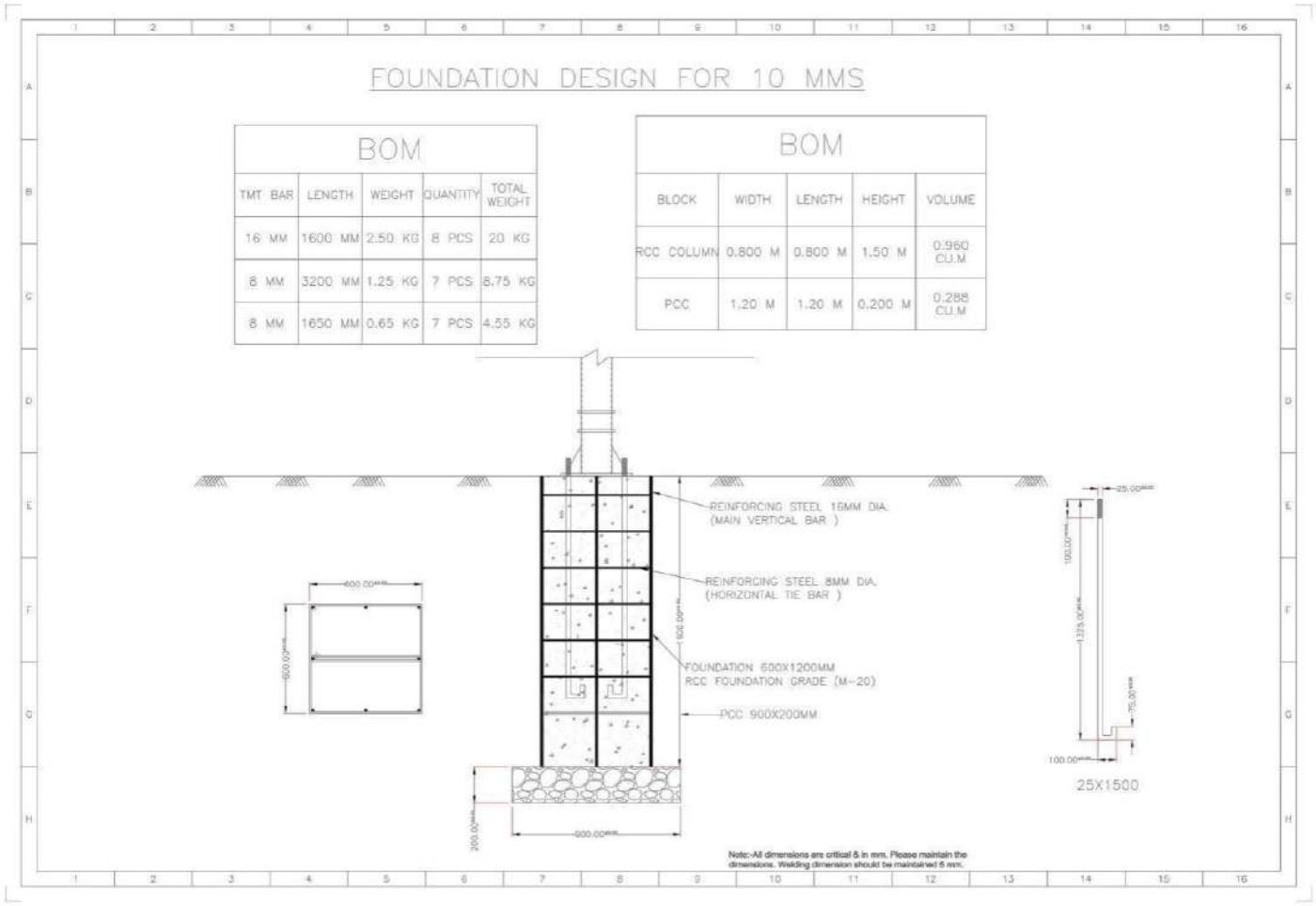
| SR. No. | PART NAME | CROSS SECTION DETAIL | LENGTH (MM) | QUANTITY PER SET |
|---|---|---|---|---|
| 1. | **MAIN POLE** | | | |
| | 4, 6 and 8 Modules | 139 OD | 1500 | 1 |
| | 10 Modules | 165 OD | 1500 | 1 |
| 2. | **TOP PLATE (Common for all)** | 300 OD | -- | 1 |
| 3. | **CLAMP WITH BLADE** | | | |
| | 4, 6 and 8 Modules (for 139 OD pole) | 75X8 | 380 | 2 |
| | 10 Modules (for 165 OD pole) | 75X8 | 380 | 2 |
| 4. | **SUPPORTING PIPES** | | | |
| | 4, 6 and 8 Modules | 41 OD & 33 OD | -- | 6 |
| | 10 Modules | 41 OD & 33 OD | -- | 8 |
| 5. | **MAIN TUBE** | | | |
| | 4 and 6 Modules | 60X60X3.6 | 3300 | 1 |
| | 8 and 10 Modules | 122X61X3.6 | 3300 | 1 |
| 6. | **SIDE TUBE** | | | |
| | 4 and 6 Modules | 50X50X3.6 | 3300 | 2 |
| | 8 and 10 Modules | 80X40X3.2 | 3300 | 2 |
| 7. | **MOUNTING PURLIN** | | | |
| | 4 Modules | 80X50X15X2 | 2050 | 4 |
| | 6 Modules | 80X50X15X2 | 3100 | 4 |
| | 8 Modules | 80X50X15X2 | 4150 | 4 |
| | 10 Modules | 100X50X15X2 | 5200 | 4 |

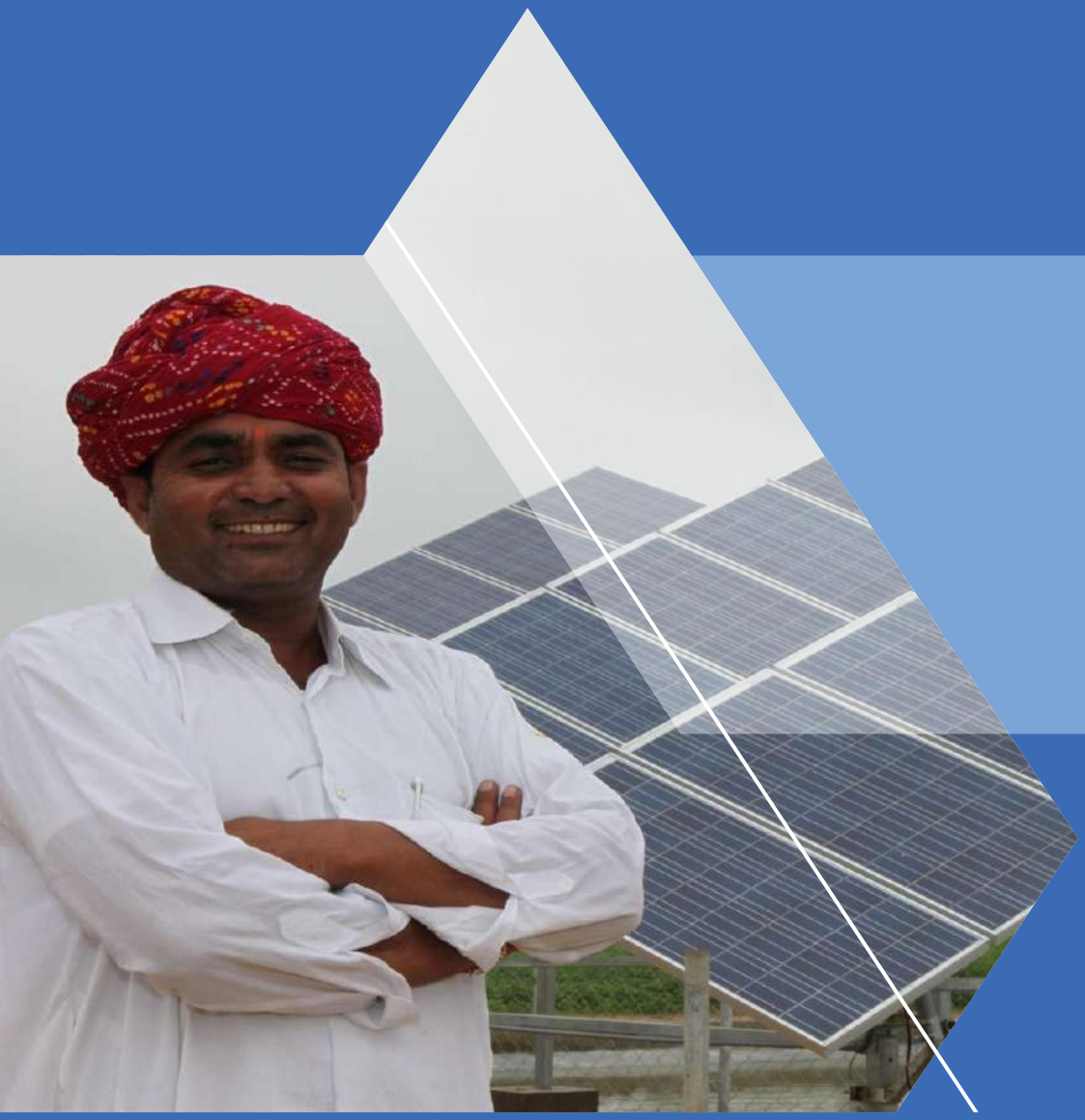
# Annexure IV

## Foundation design




FOUNDATION DESIGN FOR 8 MMS
BOM
TMT BAR | LENGTH | WEIGHT | QUANTITY | TOTAL WEIGHT
16 MM | 1300 MM | 2.05 KG | 8 PCS | 16.4 KG
8 MM | 2400 MM | 0.950 KG | 6 PCS | 5.7 KG
8 MM | 1250 MM | 0.500 KG | 6 PCS | 3 KG
BOM
BLOCK | WIDTH | LENGTH | HEIGHT | VOLUME
RCC COLUMN | 0.600 M | 0.600 M | 1.20 M | 0.432 CU.M
PCC | 0.900 M | 0.900 M | 0.200 M | 0.162 CU.M
600.00
REINFORCING STEEL 16MM DIA.
(MAIN VERTICAL BAR )
REINFORCING STEEL 8MM DIA.
(HORIZONTAL TIE BAR )
1200.00
FOUNDATION 600X1200MM
RCC FOUNDATION GRADE (M-20)
PCC 900X200MM
200.00
900.00
20.00
1025.00
100.00
75.00
20X1200
Note:-All dimensions are critical & in mm. Please maintain the dimensions. Welding dimension should be maintained 5 mm.





Ministry of New & Renewable Energy
Government of India