INSTALLATION AND OPERATIONS MANUAL FOR MALDIVES’ GRID-CONNECTED ROOFTOP PHOTOVOLTAIC SYSTEMS

MARCH 2023
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ACKNOWLEDGMENTS

*Installation and Operations Manual for Maldives’ Grid-Connected Rooftop Photovoltaic Systems* was prepared by a team led by Jaimes Kolantharaj, senior energy specialist, South Asia Energy Division of the Asian Development Bank (ADB). The lead author of this manual is Dwipen Boruah, senior technical consultant for the Ministry of Environment, Climate Change and Technology, Republic of Maldives. The team is grateful for the valuable guidance and support of ADB’s Kenichi Yokoyama, director general, South Asia Department; Priyantha Wijayatunga, chief, energy sector group; and Thiam Hee Ng, director, South Asia Regional Cooperation and Operations Coordination Division. The team acknowledges contributions from the following ADB staff: David Morgado, senior energy specialist; Maria Charina Apolo Santos, project analyst; and consultants Sergio Ugarte (SQ Consult), Abdulla Firag, and Marietta L. Marasigan.

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While methods, approach, procedures, and instructions included in this manual are based on the terms and conditions prescribed in the “Regulation for Connecting Renewable Energy Systems to the Electricity Network on a Net Metering Basis 2020,” relevant International Electrotechnical Commission and Institute of Electrical and Electronics Engineers standards and global best practices, the author; the Ministry of Environment, Climate Change and Technology, Republic of Maldives; the Asian Development Bank; and any stakeholder implementing and administering the bank’s Preparing Outer Islands for Sustainable Energy Development project in Maldives do not assume responsibility and expressly disclaim liability for loss, injury, damage, expense or inconvenience sustained by any users of this manual or in relation to any information or data contained in this manual.

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Installation and Operations Manual for Maldives’ Grid-Connected Rooftop Photovoltaic Systems was prepared to support the implementation of grid-connected rooftop photovoltaic (PV) projects in the Republic of Maldives. The methods, approach, procedures, and instructions included in this manual are based on the terms and conditions prescribed in the “Regulation for Connecting Renewable Energy Systems to the Electricity Network on a Net Metering Basis 2020,” relevant International Electrotechnical Commission (IEC), European Standards (EN), and Institute of Electrical and Electronics Engineers standards and global best practices.1

This manual specifically supports utility engineers to verify and approve grid connection applications from eligible consumers for rooftop PV systems under net meter regulation. The manual provides guidelines for the verification of site details, PV system design information, bill of quantity, system documentation, etc. Though this manual is specified as “grid-connected rooftop PV systems,” it can be used and applied as a reference manual for any grid-connected PV system connected to a low-voltage grid network (220 volts [V] to 440 V).

The manual provides detailed checklists for the verification of equipment, system design and planning, electrical and fire safety, mounting structure and system installation, and operation and maintenance practices during the post-installation inspection as per relevant standards, grid code requirements, and best practices. System performance evaluation methods and preventive maintenance advisories included in the manual intend to help utility engineers to monitor and manage rooftop PV systems as well.

Ready-to-use application and connection agreement forms, checklists, and the list of equipment required for inspection will help the end users, supply and installation companies, project managers, and engineers of service providers to take swift and definitive action while implementing rooftop PV projects.

The operations manual includes the following:

(i) application form for the grid connection of rooftop PV systems by eligible consumers;
(ii) verification and approval form by the service provider;
(iii) technical specifications, standards, and installation requirements;
(iv) documentation requirements;
(v) warranty and guarantee terms for different components and quality of works;
(vi) post-installation inspection and verification process and checklists;
(vii) PV system performance evaluation method;
(viii) preventive maintenance advisory;
(ix) grid connection agreement form for rooftop PV systems; and
(x) list of equipment required for inspection.

**Application Form for Eligible Consumers for the Grid Connection of Rooftop Photovoltaic Systems**

Interested eligible consumers may use the following application form to request the grid connection of rooftop PV systems on a net metering basis.

<table>
<thead>
<tr>
<th>1</th>
<th>Consumer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Full name:</td>
</tr>
<tr>
<td>1.2</td>
<td>Address:</td>
</tr>
<tr>
<td>1.3</td>
<td>Atoll/island:</td>
</tr>
<tr>
<td>1.4</td>
<td>Contact phone number:</td>
</tr>
<tr>
<td>1.5</td>
<td>E-mail address:</td>
</tr>
<tr>
<td>1.6</td>
<td>Account number of existing meter in the premises where the photovoltaic (PV) system is to be installed:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2</th>
<th>Installation Agent</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Full name:</td>
</tr>
<tr>
<td>2.2</td>
<td>Address:</td>
</tr>
<tr>
<td>2.3</td>
<td>Contact phone number:</td>
</tr>
<tr>
<td>2.4</td>
<td>E-mail address:</td>
</tr>
<tr>
<td>2.5</td>
<td>License number issued by Utility Regulatory Authority (URA) to carry out electric works:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3</th>
<th>Rooftop PV System Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Manufacturing date:</td>
</tr>
<tr>
<td>3.2</td>
<td>Type of PV technology (mono or poly-crystalline/cadmium telluride [CdTe] or copper indium gallium selenide [CIGS] thin film):</td>
</tr>
<tr>
<td>3.3</td>
<td>Type of inverter based on use of transformer (isolated/non-isolated):</td>
</tr>
</tbody>
</table>

*continued on next page*
3.4 Type of inverter based on interface with PV array (micro/string/optimizer based):

3.5 Power factor:

3.5 Rating (in kilowatt [kW] and kilovolt-ampere [kVA]):

3.6 Voltage (in volt [V]):

3.7 Frequency (in hertz [Hz]):

3.8 Estimated annual total electricity generation (in kilowatt-hour [kWh]):

4. Site Installation Details

4.1 A site plan drawn to scale of the location of installation must be submitted with this form. This plan must include the site boundaries, point of installation, meter location, and the connection point of the system to the service provider’s network.

4.2 A single line drawing with clear indications of the system’s electricity generator (PV inverter), meter, connection point, isolation devices, and safety devices must be submitted with this form.

4.3 Details of the system’s security measures to prevent “unintended islanding” as follows:
- Systems connected to the network shall be able to avoid “unintended islanding,” and in the event of unintended islanding, the system shall contain components able to prevent the service provider’s network from getting energized within 0.5 seconds.
- In the event of an intentional or unintentional disconnection of the service provider’s network, the systems connected to the network shall automatically disconnect within 0.5 seconds.

5. Schedule of Works

5.1 Estimated date of commencement of installation:

5.2 Estimated date of system commissioning and connection to the grid:

6. Declaration

I hereby request the grid connection of the rooftop PV system to the service provider’s network on a net metering basis in accordance with the information provided in this form.

I declare that the rooftop solar PV system to be connected to the grid shall be in compliance with all aspects of the “Regulation for Connecting Renewable Energy Systems to the Electricity Network on a Net Metering Basis 2020” (2020/R-46).

Name:

Address:

Signature:

Date:

* The net metering regulation defines “unintended islanding” as the generation of electricity from the system established by the customer even when there is no electricity in the network.
Service Provider Verification and Approval

The service provider may use the following form to verify and approve applications for grid connection of rooftop PV systems:

### Section 1: Applicant Details

<table>
<thead>
<tr>
<th>No.</th>
<th>Information</th>
<th>Service Provider Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Date of submission of the application</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Name of the consumer as stated in the electricity account</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Consumer’s complete address for communication</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Electricity consumer account number</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Name of contact person (a single point of contact should be provided)</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Telephone number of contact person</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>E-mail address of contact person</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Name and designation of the person authorized to make the financial decision</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Name and designation of the person to whom the service is allocated/granted and is authorized to make the technical decision</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Name and designation of the person to whom the service is allocated/granted and is authorized to make the overall management decision</td>
<td></td>
</tr>
</tbody>
</table>

### Section 2: Site Details

<table>
<thead>
<tr>
<th>No.</th>
<th>Information</th>
<th>Service Provider Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The physical address of the building where the rooftop PV system will be installed</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Geographic coordinates of the building where the rooftop PV system will be installed</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Mark the building roofs on Google earth map where the rooftop PV system will be installed</td>
<td></td>
</tr>
</tbody>
</table>

*continued on next page*
## Section 2: Site Details

<table>
<thead>
<tr>
<th>No.</th>
<th>Information</th>
<th>Service Provider Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>PV plant layout showing the location of PV arrays on the building roof</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Locations in the building where inverters will be installed</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Location in the building where the rooftop PV system will be connected to the grid (point of interconnection)</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Location in the building where the energy meter for the rooftop PV system will be installed</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Shadow analysis done for installation of PV arrays. Shading heat map or shadow analysis report.</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Permits and clearances obtained from local authorities as per building bylaws for installation of PV systems on the building roof as applicable</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Fire safety clearance obtained from the concerned authority for installation of PV systems on the building roof as applicable</td>
<td></td>
</tr>
</tbody>
</table>

PV = photovoltaic.  
* Google earth maps available at https://earth.google.com/web/.

## Section 3: PV System Details

<table>
<thead>
<tr>
<th>No.</th>
<th>Information</th>
<th>Service Provider Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Proposed PV array capacity (kWp)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Proposed number and capacities of inverters (kW)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Approximate cost of the complete system</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Name of the manufacturer and model number of proposed PV modules (check the PV module data sheet)</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Standards and certification for PV modules (verify the authenticity of test certificates)</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Name of the manufacturer and model number of the proposed inverter (check the inverter data sheet)</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Standards and certification for proposed inverters (verify the authenticity of test certificates)</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Output AC voltage of proposed inverter</td>
<td></td>
</tr>
</tbody>
</table>

*continued on next page*
## Section 3: PV System Details

<table>
<thead>
<tr>
<th>No.</th>
<th>Information</th>
<th>Service Provider Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Frequency tolerance of proposed inverter</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Voltage tolerance of proposed inverter</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Power factor range of proposed inverters</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Type, material, and name of the manufacturer of proposed module mounting structure (check data sheet/design of the module mounting structure)</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Standards and certification for module mounting structure (check certificates)</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Determine the maximum wind speed considered for designing the module mounting structure</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Type, material, and name of the manufacturer of proposed DC and AC combiner boxes</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Standards and certification for combiner boxes (check certificates)</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Make, voltage (current rating), and certification of DC isolators for strings and array cable</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Make, specification, and certification of DC string cables and DC array cable</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Make, voltage (current rating), and certification of DC cable connectors</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Confirm installer agreement to provide all markings and signages as per the international standard IEC 62548 on “Photovoltaic (PV) arrays–Design requirements”</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Confirm installer agreement to provide all documentation as per the international standard IEC 62446 on “Photovoltaic (PV) systems–Requirements for testing, documentation, and maintenance ‘Part 1: Grid connected systems–Documentation, commissioning tests, and inspection’ and ‘Part 2: Grid-connected systems–Maintenance of PV systems’” as mentioned in this manual</td>
<td></td>
</tr>
</tbody>
</table>

AC = alternating current, DC = direct current, IEC = International Electrotechnical Commission, kW = kilowatt, kWp = kilowatt-peak, PV = photovoltaic.
## Section 4: PV System Design Information

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameters</th>
<th>Service Provider Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Does the installer agree to follow the international standard IEC 62548 to meet PV arrays design requirements?</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>What are the safety measures considered in the design to prevent electric shock?</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>What are the safety measures considered to prevent fire hazards from the PV system?</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>What measures are considered for overcurrent protection at string?</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>What measures are considered for overvoltage protection in DC side and AC side?</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Is there a provision for installation of lightning protection system?</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>What measures are taken to protect the DC cables from any mechanical damage?</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Has the applicant considered the load-bearing capacity of the roof to take the combined load of the PV system and wind pressure?</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Check and approve the single line diagram for the DC side</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Check and approve connection diagram of PV modules</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Check and approve the single line diagram for the AC side</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Check and approve detailed connection diagram for grid integration of the PV system, including energy meter and isolation</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Check module mounting structure engineering drawings and accessories showing details of fixing to the roof and attachment of the PV modules</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Check drawings for fixing or grouting of the module mounting structure to prevent leakage in the roof</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Check system earthing electrical diagram</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Check and approve earthing continuity and resistivity test report</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Check detailed diagram of lightning protection system showing protection coverage area</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Verify names and contact details of the persons who designed and approved the design drawings</td>
<td></td>
</tr>
</tbody>
</table>

AC = alternating current, DC = direct current, IEC = International Electrotechnical Commission, PV = photovoltaic.
### Section 5: Bill of Quantity

<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Service Provider Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PV modules</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Grid-tied inverter</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Mounting structure</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Inverter mounting structure</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>String over current protection</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>DC isolator for strings</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>DC isolator for PV array</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>AC isolator for inverter</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>AC isolator for grid disconnection</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>DC surge protection device</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>AC surge protection device</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>DC combiner box</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>AC combiner box</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>DC string cable</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>DC array cable</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>AC cables</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Earthing conductor</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Energy meter</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Monitoring system</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Solar array cleaning arrangement</td>
<td></td>
</tr>
</tbody>
</table>

AC = alternating current, DC = direct current, PV = photovoltaic.
The components used in the distributed grid-connected rooftop PV systems must comply with the specific component standards listed in this manual.

The installation or supply company is required to provide verifiable test certificates confirming that the major components used in the system comply with the relevant specified standards tested by a laboratory accredited to perform the test(s) as per the International Organization for Standardization (ISO)-ISO/IEC 17025.

**Component (Equipment) Standards (Informative)**

Quality system components in the solar energy industry are typically tested and certified against standards developed by the IEC, Underwriters Laboratory (UL), or, in some cases, EN. Many products such as solar modules, batteries, inverters, and controllers are tested and certified to one or more sets of standards. For example, some inverters that are manufactured in the United States (US) are tested against the UL standard for the US versions and also have the Conformité Européenne (CE) marking, meaning that they conform to European requirements. As the industry has been progressing very quickly, there are instances when some of the balance of system equipment used in the industry do not have IEC or UL standards available, but they do meet standards from other organizations like the EN or specific country standards.

**Testing Laboratories and Verification of Certificates**

Testing and verifying that the system components have met the relevant standard(s) shall be undertaken by a testing laboratory accredited to ISO/IEC 17025 General Requirements for the Competence of Testing and Calibration Laboratories.

The test laboratory shall have ISO/IEC 17025 accreditation for the particular standard or test method used.

Copies of all the relevant ISO/IEC 17025 accreditation certificates and/or other supporting documentation from the test laboratory shall be verified by the approving authority. The installation and supply company is required to provide verifiable test certificates to the approving authority confirming that the major components used in the system comply with the relevant specified standards. The approving authority will confirm that the laboratory has ISO/IEC 17025 accreditation and that the test certificates are genuine.
Photovoltaic Modules

Solar modules shall meet either of the following relevant design qualification and type approval standards:

- IEC 61215 Terrestrial PV modules – Design qualification and type approval
  - IEC 61216-1 Part 1: Test requirements
  - IEC 61216-2 Part 2: Test procedures

and

- IEC 61730 PV module safety qualification
  - IEC 61730-1 Part 1: Requirements for construction
  - IEC 61730-2 Part 2: Requirements for testing

and


Only “Class A” modules designed according to IEC 61730-1 and IEC 61730-2 standards are considered. All modules used in one power plant shall be from a single manufacturer with similar wattage and shall be with positive power tolerance only. Negative power tolerance shall not be accepted.

Each module shall be marked with a serial number to provide traceability to the manufacturer’s name, factory, and date of manufacture.

The module label must show the correct certifier mark (logo) corresponding to that on the test certificate supplied at the time of approval.

The following information must be mentioned in each module (this can be inside or outside the laminate but must be able to withstand harsh environmental conditions):

- name of the manufacturer;
- month and year of manufacture;
- country of origin;
- current voltage (I-V) curve for the module;
- wattage, current at maximum power point ($I_m$), voltage at maximum power point ($V_m$), and fill factor for the module;
- unique serial number and model number of the module;
- date and year the IEC PV qualification certificate was obtained; and
- name of the testing lab issuing the IEC certificate.
Inverter, Control, and Remote Monitoring System

Grid-connected inverters that complied with IEC 62109-1:2010 (Safety of power converters for use in photovoltaic power systems – Part 1: General requirements) and IEC 62109-2 (Safety of power converters for use in photovoltaic power systems – Part 2: Particular requirements for inverters) will be used. The inverter system should be provided with surge protection devices. The inverter must be equipped with global system for mobile (GSM)-based data module for uploading performance data.

The inverter must be certified in accordance with the applicable standards and national grid code requirements for grid connectivity to qualify to the following grid parameters.

<table>
<thead>
<tr>
<th>Grid Parameters</th>
<th>Typical Requirement or Acceptable Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response to abnormal voltage and frequency</td>
<td>Voltage: 85% to 110%</td>
</tr>
<tr>
<td></td>
<td>Frequency: 47.5 hertz (Hz) to 52.5 Hz</td>
</tr>
<tr>
<td>Synchronization</td>
<td>Voltage: ± 6%; no objectionable flicker</td>
</tr>
<tr>
<td>Unintentional islanding</td>
<td>Disconnection in &lt;2 seconds; reconnection in &gt;60 seconds</td>
</tr>
<tr>
<td>Limitation of direct current (DC) injection</td>
<td>&lt;0.5%</td>
</tr>
<tr>
<td>Harmonics</td>
<td>&lt;5%</td>
</tr>
<tr>
<td>Interface protection device functional</td>
<td>Unintentional islanding, under voltage protection, overvoltage protection, over frequency, under frequency</td>
</tr>
</tbody>
</table>

Remote monitoring of various parameters at inverter level should be made possible on the site by installing the suitable monitoring system. This should be maintained in an hourly logbook for all inverter events, including low performance and faults, and should be stored in the logbook for at least 1 year. The monitoring system shall have features for simultaneous monitoring and recording of various parameters of different subsystems and power supply of the rooftop PV system at the direct current (DC) side and alternating current (AC) side. This will enable monitoring of the status of inverters by gathering information on energy generation. Daily reports of the plant’s energy generation will be provided by the monitoring system. Remote data access will be provided through a GSM-based communication interface.

Energy Meter

The main electricity meter shall be a service provider (utility company)-approved bi-directional energy meter as established under the net metering regulation. A separate energy meter (solar meter) to measure and monitor energy generation from the PV system shall be installed at the AC distribution box/AC combiner box or main distribution panel in the main electrical panel room where inverter power will be injected. Both meters will be of electronic, tri-vector type, suitable for 3-phase 4-wire connections, with initial and sustained accuracy of class 0.2S. The meters shall fully comply with all stipulations in applicable standards with the latest amendments and the relevant provisions of the national grid code.
Photovoltaic Module Mounting Structure

The structural design of module mounting structures must conform to withstand a minimum “basic wind speed” of 180 kilometers/hour. The installer shall ensure that the array frame that they install has applicable engineering certificates verifying that the frame meets wind loadings appropriate for that particular location. The array structures shall be made of hot dipped galvanized iron with minimum 120-micron hot dipped galvanization or extruded aluminum EN-AW-6063 T6 or equivalent. All fasteners shall be of stainless steel-SS 304 or higher grade. Nut and bolts, and supporting structures (including module mounting structures) shall have to be adequately protected against all climatic conditions such as salinity, extreme humidity, high wind loading, etc. High tensile stainless steel deco-coated fasteners are acceptable.

The following instructions should be followed while designing and installing a module mounting structure:

(i) The structure must be designed to allow sufficient space below the array (>50 millimeters [mm] or 2 inches) for cooling of the PV modules by natural ventilation. Insufficient cooling will result in high module operating temperatures and lower outputs from the modules.

(ii) Solar modules should be attached to the array structure using either the mounting holes provided by the manufacturer or clamps that are suitable for the maximum wind at the site. Mounting of the PV modules should allow for the expansion and contraction of the PV modules under expected operating conditions.

(iii) The mid-clamps used for attaching the modules must be longer than 50 mm (2 inches) in length to withstand high wind loading, and it is recommended to use three rails while installing in portrait position. For systems having more than eight modules in a single row, consideration shall be given for using an end clamp for every fourth module so if one does become loose, only a few other modules would be affected, and not necessarily the whole array.

(iv) Any roof penetrations must be suitably sealed and remain waterproof for the expected life of the system. If this is not possible, then this must be detailed in the maintenance timetable.

(v) If the roof uses tiles, tiles shall sit flat after the installation of tile mounting brackets to ensure the tiles maintain their original water ingress protection. There may be a requirement to grind some of the underside of the tile to enable it to sit correctly.

(vi) For metal roofs the array frame structure should be attached to the roof using brackets that are screwed through the ridges of the roof into a purlin or rafter below.

(vii) The installer must follow the array frame supplier’s or manufacturer’s recommendations when mounting the array to the roof support structure to ensure that the array structure still meets the wind loading certification.
Photovoltaic Array and Photovoltaic String Combiner Boxes

PV array and PV string combiner boxes exposed to the environment shall be at least ingress protection code (IP) 65 compliant as per IEC 60529 and shall be ultraviolet (UV)-resistant. Any enclosure IP code rating shall suit the environmental conditions. This IP code rating shall apply to the relevant mounting position and orientation.  

Circuit Breakers

Circuit breakers used for overcurrent protection in PV arrays shall be
(i) certified to either IEC 60898-2 or IEC 60947-2 and not be polarity sensitive;
(ii) rated to interrupt full load and prospective fault currents from the PV array, diesel generators and the grid; and
(iii) rated for overcurrent as per IEC 62548 (footnote 2).

Disconnectors and Switch-Disconnectors

As required, all disconnectors shall
(i) not have exposed live metal parts in connected or disconnected state; and
(ii) have a current rating equal to or greater than the associated overcurrent protection device, or in the absence of such device, have a current rating equal to or greater than the minimum required current carrying capacity of the circuit to which they are fitted (footnote 2).

Switch disconnectors shall be certified to IEC 60947-1 and IEC 60947-3 standards and have mechanisms that have independent manual operation (footnote 2).

As additional compliance, circuit breakers and any other load-breaking switch disconnectors shall
(i) not be polarity sensitive,
(ii) be rated to interrupt full load and prospective fault currents from the PV array and the grid, and
(iii) be rated as per IEC 62548 when overcurrent protection is incorporated (footnote 2).

Direct Current Cables

The DC solar cables must be made of copper with UV protection-type insulation and a minimum voltage rating of 1,000 volts. Cable sizes for PV string cables, PV sub-array cables, and PV array cable shall be determined with regard to overcurrent protection ratings where in use, with the minimum current rating and voltage drop and prospective fault current considerations as specified in IEC 62548:2016 PV arrays – Design requirements. The largest cable size obtained from these criteria shall be applied.

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Cable derating factors shall be considered according to IEC 60364 based on cable location and installation method. Maximum cumulative voltage drop in all cable length should not be more than 2% in the DC side and 1% in the AC side (footnote 2).

Cables used within the PV array shall (i) be suitable for DC application, (ii) have a voltage rating equal to or greater than the PV array maximum voltage at lowest possible temperature, and (iii) have a temperature rating according to the application. Cable insulation of wiring installed in contact or near PV modules shall be rated at 90°C, UV-resistant, water-resistant, double insulated, and flame retardant (footnote 2).

String cables shall be flexible to allow for thermal and wind movement of arrays and modules. Cables shall be supported so that they do not suffer fatigue due to wind and snow affects. They shall also be protected from sharp edges. Cables shall be supported so that their properties and installation requirements are maintained over the stated life of the PV plant. All nonmetallic conduits and ducting exposed to sunlight shall be UV-resistant. Cable ties shall not be used as a primary means of support (footnote 2).

Only bright-annealed 99.97% pure bare copper conductor wires, which offer low resistance, lower heating, and of reputed make shall be used (footnote 2).

The AC cable must be of copper armored XLPE insulation with a minimum voltage rating of 1 kilovolt (kV) (footnote 2). All AC cables shall be electrolytic tinned copper class 2, according to IEC 60228. Insulation shall be as per IEC 60502-1 and IS 1554 standards. Cables shall also confirm to IEC 60189 for test and measuring methods.

### Wiring Loops

Cables need to be laid in parallel and close together to avoid wiring loops, which may cause damaging high-voltage surges to the controller or inverter if there are nearby lightning strikes. Figures 1 to 3 give examples on how a conductive wiring loop can be avoided while Figure 4 shows a wiring arrangement that will cause a conductive loop and should not be used. For minimizing lightning-generated voltage surges, the positive and negative wires should always be run together.

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**Figure 1: Wiring to Avoid Conductive Loops – Example 1**

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PV = photovoltaic.
Source: Produced by Global Sustainable Energy Solutions.
Figure 2: Wiring to Avoid Conductive Loops – Example 2

PV module

PV module

PV module

PV module

PV module

PV module junction box

PV = photovoltaic.
Source: Produced by Global Sustainable Energy Solutions.

Figure 3: Wiring to Avoid Conductive Loops – Example 3

Source: Produced by Global Sustainable Energy Solutions.

Figure 4: Example of Wiring to be Avoided Because it Includes Conductive Loops

PV module

PV module

PV module

PV module

PV module

PV module junction box

PV = photovoltaic.
Source: Produced by Global Sustainable Energy Solutions.
Plugs, Sockets, and Connectors

Plugs and socket connectors (popularly known as the MC4 connector) mated together in a PV system shall be of the same type from the same manufacturer to avoid fire hazards in the PV plant and buildings, i.e., a plug from one manufacturer and a socket from another manufacturer or vice versa shall not be used to make a connection.

Plugs, sockets, and connectors shall (i) comply with the standard EN 50521 Connectors for photovoltaic systems – Safety requirements and tests; (ii) be rated for DC use; (iii) have voltage rating of 1,000 volts; (iv) shall be protected from contact with live parts in connected and disconnected state; and (v) have a current rating equal to or greater than the current carrying capacity for the circuit to which they are fitted. When installed outdoor, plugs, sockets, and connectors shall be UV-resistant and rated for IP 65 or above. Plugs, sockets, and connectors shall be installed to minimize strain on the connectors (e.g., supporting the cable on either side of the connector). Plugs and socket outlets normally used for the connection of household equipment to low-voltage AC power shall not be used in PV arrays.

Cable Termination

The termination (both end terminations and straight-through joints) of all cables has to be done by a URA registered skilled technician using cable glands, lugs, and ferrules that are properly sized and reputedly made. The cable glands shall be installed by drilling or punching appropriately sized holes on gland plate. All unused holes will be closed using appropriate plugs. The gland plate has to be refitted properly to ensure that the panel seal is vermin proof.

The lugs shall be made of copper and crimped using a compression-type crimping tool, while hydraulic crimping tools shall be used for larger cables. Before crimping, a reputedly made contact enhancement paste has to be applied to the lugs. The termination is then carried out to ensure tightness and proper contact at the point of termination. Every termination has to be ensured for proper tightness of connections after termination.

Earthing System

All exposed, metallic, and conductive parts of the system must be bonded together and earthed in accordance with IEC 62548: 2016: PV array design requirements to avoid uneven potentials across an installation. PV array bonding conductors shall be run as close as possible to the positive and negative PV array and or sub-array conductors to reduce induced voltages due to lightning. The conductor used to earth the PV array’s exposed metallic frames shall have a minimum size of 6 square millimeters (mm²) copper or its equivalent. If the array exposed-conductive part is required to be earthed for lightning protection, the minimum size of the earthing conductor shall be 16 mm². The earthing system must have less than 1-ohm resistance. When required, functional earthing has to be done as per the equipment manufacturer’s instruction. URA’s standards have to be followed in all earthing requirements.
Marking and Danger Signs

Marking and danger signs in English and the local language will be provided for emergency responders with appropriate warning and guidance so that they can work their way around the system and know how to isolate it. This will facilitate identifying energized conductors or wires that connect the solar modules to the inverter. As per IEC 62548: PV arrays – Design requirements, all signs shall be

- indelible,
- legible from at least 0.8 meters (m),
- constructed and affixed to remain legible for the life of the equipment it is attached or related to, and
- understandable by the operators.

Recommended signages and labeling for solar PV system are presented in Figure 5.

**Figure 5: Recommended Signage and Labeling for Solar PV System**

- **SOLAR DC CABLES**
  - Permanently and legibly marked with “SOLAR DC” every 5 meters

- **WARNING MULTIPLE SUPPLIES ISOlate ALL SUPPLIES BEFORE WORKING ON THIS SWITCHBOARD**

- **PV ARRAY D.C. SWITCH-DISCONNECTOR**
  - Sign installed on PV array and PV string combiner boxes with “SOLAR DC” and “Live during daylight”
  - Sign located in a prominent location on the disconnector with “PV array DC disconnector”
  - Sign adjacent to the inverter with “Warning: Multiple DC sources. Turn off all DC isolators to isolate equipment”

- **MAIN SWITCH (INVERTER SUPPLY)**
  - A sign adjacent to the inverter main switch with “Main Switch (Inverter Supply) Inverter Located at _______

- **MAIN SWITCH (GRID SUPPLY)**
  - A sign adjacent to main service switch with “Main adjacent to main service switch with ______”

- **PV**
  - For emergency services, maintenance workers, network operators, etc., a sign indicating the presence of PV at the service connection point/electric meter switchboard to which the inverter is connected

DC = direct current, PV = photovoltaic.
Source: Produced by Global Sustainable Energy Solutions.
On completion of the rooftop PV system installation, system documentation is to be provided in the templates presented in this manual, which follow the requirements of IEC 62446: Part 1: Grid-Connected Photovoltaic Systems – Minimum requirements for system documentation, commissioning tests and inspection; and IEC 62446: PV Systems – Requirements for testing, documentation and maintenance – Part 2 – Grid-connected systems – Maintenance of PV systems. The objective is to ensure that key system data is readily available to a customer, inspector, or maintenance engineer.

The following are documents that must be supplied for each system installed as per IEC 62446: Part 1:

1. **Basic System Information**

   As a minimum, the following “nameplate” information should be presented on the cover page of the system documentation pack:

   (i) project identification reference (where applicable);
   (ii) rated (nameplate) system power (kW DC or kVA AC);
   (iii) PV modules and inverters–manufacturer, model, and quantity;
   (iv) installation date;
   (v) commissioning date;
   (vi) customer name;
   (vii) electrical meter and/or connection number; and
   (viii) site address.

2. **System Designer Information**

   This is a list of all the information that shall be provided, as a minimum, for all parties responsible for the system design. When more than one company is responsible for the design of the system, the following information should be provided for all companies together with a description of their role in the project:

   (i) system designer, company;
   (ii) system designer, contact person;
   (iii) system designer, postal address, telephone number, and e-mail address; and
   (iv) URA licensee number.
3. System Installer Information

This is a list of all the information that shall be provided, as a minimum, for all parties responsible for system installation. When more than one company is responsible for the installation of the system, the following information should be provided for all companies together with a description of their role in the project:

(i) system installer, company;
(ii) system installer, contact person; and
(iii) system installer postal address, telephone number, and e-mail address.

4. Plant Layout Diagram

The plant layout diagram will include the following:

(i) array layout plan (placement of PV modules) with dimensions;
(ii) location of all major electrical components;
(iii) string layout plan showing electrical connection (strings) over physical layout; and
(iv) location of lighting protection system, if any.

5. Direct Current Side Single-Line Diagram

The DC side single-line diagram (SLD) will include the following:

(i) number of modules in each string;
(ii) number of strings;
(iii) strings of array and sub-arrays;
(iv) string cable size and type;
(v) string–inverter connection identification;
(vi) string overcurrent protection device specifications–type and voltage or current rating;
(vii) array main cable specifications–size and type;
(viii) sub-array cable specifications–size and type (if applicable);
(ix) string combiner box;
(x) DC switch disconnector, location, and rating (voltage or current);
(xi) surge protection device (SPD) location and type; and
(xii) earthing conductors for equipotential bonding–location, size, and type.

6. Alternating Current Side Single-Line Diagram

The AC side SLD will have the following information:

(i) connection at inverter;
(ii) the interconnection of inverters (for multiple inverters);
(iii) AC isolator location, type, and rating;
(iv) AC overcurrent protective device location, type, and rating;
(v) residual current device location, type, and rating (if applicable);
(vi) SPD location and type; and
(vii) earthing and overvoltage protection.

7. Datasheets and Component Design Information

The datasheets and design information of the following components shall be included:

(i) PV module datasheet,
(ii) inverter datasheet,
(iii) string combiner box, and
(iv) drawing and design information for module mounting structure and attachment accessories.

8. Test Results and Commissioning Data

Copies of all the following tests and commissioning data shall be provided as a part of the documentation pack, which shall include the results from the pre-commissioning tests and commissioning tests:

(i) string voltage and current,
(ii) string polarity test,
(iii) continuity test,
(iv) earthing continuity and resistivity test,
(v) anti-islanding functionality test of inverter(s),
(vi) Earth-neutral voltage, and
(vii) associated meter reading.

9. Operation and Maintenance Information

Operation and maintenance information shall include the following items:

(i) procedures for verifying correct system operation;
(ii) a process checklist in case of a system failure;
(iii) emergency shutdown and isolation procedures;
(iv) maintenance and cleaning recommendations for PV modules, including water quality;
(v) considerations for any future building work related to the PV array;
(vi) warranty documentation for PV modules and inverters;
(vii) documentation on any applicable quality or weather-tightness warranties; and
(viii) documentation of any emergency systems associated with the PV system.
## Warranty and Guarantee

<table>
<thead>
<tr>
<th>No.</th>
<th>Items</th>
<th>Type of Warranty or Guarantee</th>
<th>Coverage under Warranty or Guarantee</th>
<th>Minimum Coverage Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Photovoltaic (PV) modules</td>
<td>Material warranty</td>
<td>Defects and/or failures due to manufacturing and/or materials, including potential-induced degradation (PID) defect and nonconformity to specifications due to faulty manufacturing and/or inspection processes</td>
<td>Until 10 years from the date of installation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Performance warranty</td>
<td>Minimum 95% power output at standard test conditions</td>
<td>At the end of 5 years from the date of installation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Minimum 80% power output at standard test conditions</td>
<td>At the end of 25 years from the date of installation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Maximum 1% degradation</td>
<td>Over a period of 1 year during 25 years of life</td>
</tr>
<tr>
<td>2</td>
<td>Grid-connected inverters</td>
<td>Material warranty</td>
<td>Defects and/or failures due to manufacturing and/or materials, and nonconformity to specifications and national grid codes due to faulty manufacturing and/or inspection processes</td>
<td>5 years from date of commissioning with provision for extension of warranty period</td>
</tr>
<tr>
<td>3</td>
<td>PV array mounting structure and accessories</td>
<td>Design, materials, fabrication, assembly, and installation fault</td>
<td>Defects and/or failures due to design fault and/or failures due to materials, fabrication, assembly, and installation; and nonconformity to specifications due to faulty manufacturing and/or inspection processes</td>
<td>10 years from date of commissioning</td>
</tr>
<tr>
<td>4</td>
<td>All electrical and mechanical components and accessories used in the system</td>
<td>Design, materials, fabrication, assembly, and installation fault</td>
<td>Defects and/or failures due to design fault and/or failures due to materials, manufacturing, fabrication, assembly, and installation; and nonconformity to specifications and national grid codes due to faulty manufacturing, design, installation, and/or inspection processes</td>
<td>2 years from date of commissioning</td>
</tr>
<tr>
<td>5</td>
<td>Electrical, mechanical, and civil works</td>
<td>Quality warranty on electrical and fire safety</td>
<td>Quality on safe installation of equipment, fittings, and accessories; laying of cables, conduits, and cable tray adequately protected from any mechanical damage</td>
<td>2 years from the accepted date of commissioning of the project</td>
</tr>
<tr>
<td>6</td>
<td>Troubleshooting and maintenance</td>
<td>Operation and maintenance</td>
<td>Attend to and rectify fault, malfunctioning or unexpected low performance within 60 hours of reporting</td>
<td>2 years from the accepted date of commissioning of the project</td>
</tr>
</tbody>
</table>

PID = potential-induced degradation, PV = photovoltaic.
# General Information

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameters</th>
<th>Method/Tools to Use</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Name of the system owner</td>
<td>Record</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>System location</td>
<td>Record</td>
<td>Physical address</td>
</tr>
<tr>
<td>3</td>
<td>Geographic coordinates</td>
<td>Record by GPS at site</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Type of consumer</td>
<td>Residential/business/institutional/government, etc.</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Sanctioned load (kW or kVA)</td>
<td>As per the electricity bill</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Implementing agency</td>
<td>Record</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>EPC company/installer</td>
<td>Record</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Date of installation</td>
<td>Record</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Date and time of PV inspection</td>
<td>Record</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Total energy generated until the time of inspection (kWh)</td>
<td>Check and record from inverters</td>
<td>Check the inverter data. If there are multiple inverters, check all inverters and add to the total.</td>
</tr>
<tr>
<td>11</td>
<td>Inverter power at the time of inspection (kW)</td>
<td>Check and record</td>
<td>Check the inverter data. If there are multiple inverters, check all inverters and add to the total.</td>
</tr>
<tr>
<td>12</td>
<td>Irradiance at the time of inspection (kW/m²)</td>
<td>Use solar irradiance meter to record</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Temperature of inverter at the time of inspection (in degrees C)</td>
<td>Use infrared temperature meter or camera and record</td>
<td>Check the operating temperature of the inverter and check if the cooling fan is working or ventilation is blocked for each inverter. Check all inverters.</td>
</tr>
<tr>
<td>14</td>
<td>Name of the inspector</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

C = Celsius; EPC = engineering, procurement, and construction; GPS = Global Positioning System; kVA = kilovolt-ampere; kW = kilowatt; kWh = kilowatt-hour; m² = square meter; PV = photovoltaic.
## PV Module Information

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameters</th>
<th>Method/ Tools to Use</th>
<th>Description of Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Make and model number</td>
<td>Visual</td>
<td>Take photo</td>
</tr>
<tr>
<td>2</td>
<td>Type of cell</td>
<td>Visual</td>
<td>Take photo</td>
</tr>
<tr>
<td>3</td>
<td>Module name plate information</td>
<td>Read and collect information</td>
<td>Take photo</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>P&lt;sub&gt;mp&lt;/sub&gt;:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Tolerance:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>V&lt;sub&gt;oc&lt;/sub&gt;:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>I&lt;sub&gt;sc&lt;/sub&gt;:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>V&lt;sub&gt;mp&lt;/sub&gt;:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>I&lt;sub&gt;mp&lt;/sub&gt;:</td>
</tr>
<tr>
<td>4</td>
<td>Temperature coefficients (C)</td>
<td>Use datasheet of PV module</td>
<td>T&lt;sub&gt;c&lt;/sub&gt; (α) for I&lt;sub&gt;sc&lt;/sub&gt;:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>T&lt;sub&gt;c&lt;/sub&gt; (β) for V&lt;sub&gt;oc&lt;/sub&gt;:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>T&lt;sub&gt;c&lt;/sub&gt; (γ) for P&lt;sub&gt;mp&lt;/sub&gt;:</td>
</tr>
<tr>
<td>5</td>
<td>Total number of modules</td>
<td>Count and record</td>
<td></td>
</tr>
</tbody>
</table>

C = Celsius, I = current, mp = maximum power, oc = open circuit, P = power, PV = photovoltaic, sc = short circuit, T = temperature, V = voltage.

## Inverter Information

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameters</th>
<th>Method/ Tools to Use</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Make and model number</td>
<td>Read and record or take photo</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Type of inverter</td>
<td>Visual</td>
<td>Micro, string, optimizer, semi central</td>
</tr>
<tr>
<td>3</td>
<td>Name plate information</td>
<td>Read nameplate</td>
<td>Maximum DC capacity:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Take photo</td>
<td>Maximum DC input voltage:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Use inverter datasheet</td>
<td>Nominal AC capacity:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nominal AC voltage and phase:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Maximum AC output current:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Number of MPPT:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>MPPT voltage range:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Number of inputs per MPPT:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Maximum input DC current:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>IP rating:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Certification:</td>
</tr>
<tr>
<td>4</td>
<td>Total number of inverters installed</td>
<td>Count and record</td>
<td></td>
</tr>
</tbody>
</table>

AC = alternating current, DC = direct current, IP = ingress protection code, MPPT = maximum power point tracker.
# Checklist for Verification of Design and Planning

## a. Orientation

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameters</th>
<th>Method/ Tools to Use</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Orientation and tilt of the PV array</td>
<td>Inclinometer (mobile app) compass</td>
<td>Tilt: Orientation:</td>
</tr>
<tr>
<td>2</td>
<td>Is the PV array free from shadow?</td>
<td>Solar pathfinder and camera</td>
<td>Location affected by shadow: Object creating shadow: Months of shadow: Time of shadow:</td>
</tr>
<tr>
<td>3</td>
<td>Measure inter-row spacing</td>
<td>Measuring tape</td>
<td>Distance between closest point between two rows: Dimension of row: H (min), H (max)</td>
</tr>
<tr>
<td>4</td>
<td>Any object close to the array that creates shadow</td>
<td>Measuring tape, distance meter, or camera</td>
<td>Type of object: Location of the object: Height of the object: Distance from nearest point on PV array:</td>
</tr>
</tbody>
</table>

H = height, PV = photovoltaic.

## b. String Information

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameters</th>
<th>Method/ Tools to Use</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Number of modules in one string</td>
<td>Count and record</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Total number of strings connected to one inverter</td>
<td>Count at DCCB or inverter</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Number of optimizers connected to one inverter (if applicable)</td>
<td>Count and record</td>
<td>Applicable optimizer-based inverter</td>
</tr>
<tr>
<td>4</td>
<td>Remote monitoring system</td>
<td>Observe and record</td>
<td>Make and model: Type of communication port: Medium of communication:</td>
</tr>
</tbody>
</table>

DCCB = direct current combiner box.
### c. Direct Current and Alternate Current Cable Sizing

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameters</th>
<th>Method/ Tools to Use</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DC and AC SLD</td>
<td>Collect SLD</td>
<td>Use separate sheet to draw DC and AC SLD</td>
</tr>
<tr>
<td>2</td>
<td>String cable size (mm²)</td>
<td>Read and record</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Array cables size (DCCB to inverter) (mm²)</td>
<td>Read and record</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>DC cable route length (from array to inverter, m)</td>
<td>Measure</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>AC cable size (inverter to ACDB/ACCB, mm²)</td>
<td>Read and record</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Placement of strings according to shadow profile and orientation of plan</td>
<td>Observe and record</td>
<td>If the array is affected by shadow, confirm whether strings are arranged to minimize shadow loss</td>
</tr>
</tbody>
</table>

AC = alternating current, ACCB = AC combiner box, ACDB = AC distribution box, DC = direct current, DCCB = DC combiner box, m = meter, mm² = square millimeter, SLD = single line diagram.

### d. System Protection for Over Current and Over Voltage

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameters</th>
<th>Method/Tools to Use</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fuse ratings (A)</td>
<td>Read and record</td>
<td>□ Type and ratings</td>
</tr>
<tr>
<td>2</td>
<td>SPD type (T-1 or T-2)</td>
<td>Read and record</td>
<td>□ Type and ratings</td>
</tr>
<tr>
<td>3</td>
<td>DC isolator rating (A)</td>
<td>Read and record</td>
<td>□ Type and ratings</td>
</tr>
</tbody>
</table>
| 4   | Lightning protection system     | Observe and record take photo | □ Check if an LPS is installed  
|     |                                 |                     | □ If yes, check the type of LPS               |

Comments on design and planning:

A = ampere, DC = direct current, LPS = lightning protection system, SPD = surge protection device.
# Checklist for Verification of Electrical and Fire Safety

## a. Electrical Safety

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameters</th>
<th>Method/Tools to Use</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Earthing continuity for equipotential bonding</td>
<td>Multimeter</td>
<td>☐ Check continuity of each segment of conductor connecting the earth pit</td>
</tr>
<tr>
<td>2</td>
<td>Type and size of earthing cable/strip</td>
<td>Observe and record</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Condition of earthing conductor</td>
<td>Observe and record</td>
<td>☐ Observe if there is rust and poor connection/joints on the earth conductor that can potentially disrupt the continuity</td>
</tr>
<tr>
<td>4</td>
<td>Separate earthing for DC side, AC side, and LPS</td>
<td>Observe and record</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>System isolation</td>
<td>Observe and record</td>
<td>☐ Check if DC isolators are used for string cable</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>☐ Check if DC isolators are used for array cable</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>☐ Isolation between inverter and main panel</td>
</tr>
<tr>
<td>6</td>
<td>Signage and warnings</td>
<td>Observe and record</td>
<td>☐ Confirm presence of warning signs for DC cables, isolators, inverters, and shutdown procedure</td>
</tr>
<tr>
<td>7</td>
<td>Location of lightning protection system</td>
<td>Observe and record</td>
<td>Take photo</td>
</tr>
</tbody>
</table>

**Comments on electrical safety:**

AC = alternating current, DC = direct current, LPS = lightning protection system.
## b. Fire Safety

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameters</th>
<th>Method/Tools to Use</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Access, pathways, and smoke ventilation</td>
<td>Observe and record</td>
<td>Check if the system blocks any fire exit, fire protection equipment, pathways, or smoke ventilation</td>
</tr>
<tr>
<td>2</td>
<td>Protection of long DC cables</td>
<td>Observe and record</td>
<td>If DC cables are longer than 50 meters, or terminals of the cable are not at the site, check if disconnectors are installed on both ends</td>
</tr>
</tbody>
</table>
| 3   | Protection of DC cable (string and array cable) | Observe and record | - Confirm if string cables are tied properly  
- Check for any string cable hanging  
- Check if DC cable from PV array is protected by conduit or cable tray  
- For conduit, check if it is UV-stabilized  
- Check if the cable tray is covered  
- Check if cable tray has sharp edges  
- Check for any cable lying exposed on the floor |
| 4   | Exposed DC conductor | Observe and record  
Take photo | - Look for cable damage and record  
- Look for cable exposed to sharp metallic objects and record  
- Look for exposure of cables that may be damaged by rodents or squirrels |
| 5   | Loose connections in cable joints | Infrared camera or infrared gun | Check the temperature of the joints and record |
| 6   | Cable glands | Observe and record  
Take photo | Observe for loose or open cable glands |
| 7   | Signage and warnings | Observe and record | Confirm presence of warning signs for DC cables, isolators, inverters, and shutdown procedure |

**Comments on fire safety:**

DC = direct current, PV = photovoltaic, UV = ultraviolet.
## Checklist for Verification of Installation

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameters</th>
<th>Method/Tools to Use</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Distance from PV array to inverter (m)</td>
<td>Measure</td>
<td>□ Check if inverter is installed outdoor or indoor</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>□ Check if the inverter is accessible</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>□ Check inverter installation height</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>□ Confirm gap between inverter and walls</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>□ Check if inverter is well-ventilated</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>□ Check if the inverter gets direct sunlight</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>□ Check if the inverter is installed in a corner or under a staircase</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>□ Check if the inverter is protected by a cover or box, and the make of the cover or box</td>
</tr>
<tr>
<td>2</td>
<td>Location of inverter</td>
<td>Check and verify</td>
<td>□ Check if inverter is installed outdoor or indoor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Take photo</td>
<td>□ Check if the inverter is accessible</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>□ Check inverter installation height</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>□ Confirm gap between inverter and walls</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>□ Check if inverter is well-ventilated</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>□ Check if the inverter gets direct sunlight</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>□ Check if the inverter is installed in a corner or under a staircase</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>□ Check if the inverter is protected by a cover or box, and the make of the cover or box</td>
</tr>
<tr>
<td>3</td>
<td>Inverter operating temperature (C)</td>
<td>Measure and record</td>
<td>□ Check operating temperature of the inverter and record; if there is more than one inverter record operating temperature of all inverters</td>
</tr>
<tr>
<td>4</td>
<td>DC string combiner box</td>
<td>Check and verify</td>
<td>□ Check distance from the PV array</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Take photo</td>
<td>□ Check distance from the inverter</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>□ Confirm location (outdoor or indoor)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>□ Check height from the floor or ground</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>□ Confirm protection from rain</td>
</tr>
<tr>
<td>5</td>
<td>AC combiner box</td>
<td>Check and verify</td>
<td>□ Check distance from the inverter</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Take photo</td>
<td>□ Check distance from main grid panel</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>□ Confirm location (outdoor or indoor)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>□ Check height from the floor or ground</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>□ Confirm protection from rain</td>
</tr>
<tr>
<td>6</td>
<td>Cable routing and conduit</td>
<td>Observe and record</td>
<td>□ Check if conduits or cable tray are intact and UV-protected</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>□ Check if there is any cable not protected by conduit or cable tray</td>
</tr>
<tr>
<td>7</td>
<td>Grid instability and set points of inverters</td>
<td>Interview the owner</td>
<td>□ Ask owner if there is unstable (very low and very high) grid voltage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Use stopwatch</td>
<td>□ Perform anti islanding and functionality test</td>
</tr>
</tbody>
</table>

*continued on next page*
### Checklist for Verification of Module Mounting Structure

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameters</th>
<th>Method/Tools to Use</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Height of building (m)</td>
<td>Estimate</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Type of mounting structure</td>
<td>Observe and record</td>
<td>Check mounting structure (e.g., ballast type, racking, flush mount, carport type raised structure, etc.)</td>
</tr>
<tr>
<td>3</td>
<td>Type of module attachment to the mounting structure</td>
<td>Observe and record</td>
<td>Check the type of fixing accessories used to fix modules (e.g., clamps, nut and bolt, clip)</td>
</tr>
<tr>
<td>4</td>
<td>Size of the modules table (L [m] x W [m])</td>
<td>Count and record</td>
<td>Check the size of the modules table and its layout (e.g., landscape/portrait)</td>
</tr>
<tr>
<td>5</td>
<td>Height of PV array from the base (m)</td>
<td>Measure</td>
<td>□ Maximum height from the base:  □ Minimum height from the base:</td>
</tr>
<tr>
<td>6</td>
<td>Surrounding terrain of the plant side</td>
<td>Observe</td>
<td>Check whether the surrounding area is open or obstructed by other buildings or structures</td>
</tr>
<tr>
<td>7</td>
<td>Effective wind area (L [m] x H [m])</td>
<td>Calculate</td>
<td>Check the exposed area vertical to the wind flow (measure length of the table exposed to wind and multiply by the height from the base where structure is installed)</td>
</tr>
<tr>
<td>8</td>
<td>Material of mounting structure</td>
<td>Observe and record</td>
<td>Check material used (e.g., galvanized iron or aluminum)</td>
</tr>
</tbody>
</table>

*AC = alternating current, C = Celsius, DC = direct current, m = meter, PV = photovoltaic, UV = ultraviolet.*
### Comments on the mounting structure:

- H = height, L = length, m = meter, mm = millimeter, µm = micron, PV = photovoltaic, W = width.

## Checklist for Verification of Operation and Maintenance

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameters</th>
<th>Method/Tools to Use</th>
<th>Findings</th>
</tr>
</thead>
</table>
| 1   | Cleaning practice                       | Ask the owner                        | □ Method of cleaning: Dry or wet  
□ Frequency of cleaning:  
□ Tools used for cleaning:  
□ Cleaning practices (e.g., stepping on the module, using detergent, removing bird droppings) |
| 2   | Source of cleaning water                | Ask the owner                        | Source:                                                                  |
| 3   | Hardness of water used for module cleaning (ppm) | Use TDS meter to measure              | Hardness in ppm:                                                         |
| 4   | Type and quality of scrubber used       | Observe and record                    |                                                                          |
### Post-Installation Inspection and Verification Process

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameters</th>
<th>Method/Tools to Use</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Appearance of PV modules</td>
<td>Observe and record</td>
<td>☐ Check if the module glass looks dull</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>☐ Observe any arc damage</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>☐ Check for deposits of dirt on the edges and corners of the modules</td>
</tr>
<tr>
<td>6</td>
<td>Ventilation of inverter</td>
<td>Observe and record</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Operating temperature of inverter (in degrees C)</td>
<td>Infrared camera or infrared gun</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Availability of O&amp;M manuals</td>
<td>Ask the owner and verify</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Availability of remote monitoring system</td>
<td>Observe and record</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>System maintenance work</td>
<td>Ask the owner</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Reports of any major breakdown of the system since its installation</td>
<td>Ask the owner</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Warranty for PV modules</td>
<td>Warranty documents</td>
<td>Review document and confirm</td>
</tr>
<tr>
<td>13</td>
<td>Warranty for inverter</td>
<td>Warranty documents</td>
<td>Review document and confirm</td>
</tr>
<tr>
<td>14</td>
<td>Warranty for structure</td>
<td>Warranty documents</td>
<td>Review document and confirm</td>
</tr>
<tr>
<td>15</td>
<td>Warranty for electrical items</td>
<td>Warranty documents</td>
<td>Review document and confirm</td>
</tr>
</tbody>
</table>

**Comments on operation and maintenance:**

C = Celsius, O&M = operation and maintenance, ppm = parts per million, PV = photovoltaic, TDS = total dissolved solids.
## System-Level Performance Evaluation

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameters</th>
<th>Method/Tools to Use</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Instantaneous PR measurement</td>
<td>([Power output from inverter in kW ÷ DC capacity of plant in kW] x [1,000 Watt/m² ÷ Measured solar irradiance in Watt/m²]). Both inverter power and solar irradiance should be measured at the same instance</td>
<td>Record calculation as per the formula</td>
</tr>
<tr>
<td>2</td>
<td>Long duration PR estimation</td>
<td>(Energy delivered by the inverter for # number of days ÷ [# number of days x average daily PSH for those days x DC capacity of plant])</td>
<td>Record calculation as per the formula</td>
</tr>
<tr>
<td>3</td>
<td>Specific yield (kWh/kWp/day)</td>
<td>(Energy delivered by the inverter for # number of days ÷ [# number of days x DC capacity of plant])</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Capacity utilization factor (CUF) for AC capacity</td>
<td>(Specific yield [kWh/kWp/day] ÷ [24 x AC capacity of plant])</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Loss of performance due to grid outage</td>
<td>Ask the owner and estimate</td>
<td></td>
</tr>
</tbody>
</table>

**Comments on system performance:**

AC = alternating current, DC = direct current, kW = kilowatt, kWh = kilowatt-hour, kWp = kilowatt-peak, m² = square meter, PR = performance ratio, PSH = peak sun-hours.
## Diagnostic Performance Evaluation

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameters</th>
<th>Method/Tools to Use</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Appearance of PV modules</td>
<td>Observe and record</td>
<td>□ Check for any change in color or browning of modules (partial or full)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>□ Check for any snail trails</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>□ Check for any visible cracks or marks on the module</td>
</tr>
<tr>
<td>2</td>
<td>Broken module</td>
<td>Count and record</td>
<td>Check for any broken modules in the system</td>
</tr>
<tr>
<td>3</td>
<td>Module back sheet quality</td>
<td>Observe and record, Infrared camera</td>
<td>□ Observe if there are any bubbles or uneven surfaces on the back sheet</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>□ Observe if there is uneven temperature on the back sheet</td>
</tr>
<tr>
<td>4</td>
<td>Installation practice</td>
<td>Interview with the owner</td>
<td>Check if the installer stepped on the modules while installing them</td>
</tr>
<tr>
<td>5</td>
<td>Infrared imaging</td>
<td>Infrared camera, Take photo</td>
<td>Take infrared image of modules when any one of the issues mentioned in</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>items 1, 2, 3, and 4 above is confirmed</td>
</tr>
<tr>
<td>6</td>
<td>String level performance</td>
<td>Use a current voltage curve (I-V) tracer to measure</td>
<td>Use string level I-V curve tracing to confirm for defects in one or more</td>
</tr>
<tr>
<td></td>
<td></td>
<td>string level performance</td>
<td>modules in the string</td>
</tr>
<tr>
<td>7</td>
<td>Module level performance</td>
<td>Use an I-V tracer to measure module level performance</td>
<td>Use module level I-V curve tracing to confirm for defects in the tested</td>
</tr>
<tr>
<td>8</td>
<td>Electroluminescence (EL) testing</td>
<td>EL camera</td>
<td>□ Identify modules with hotspot</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>□ Conduct EL test for one or two modules that are having severe hotspot</td>
</tr>
</tbody>
</table>

**Comments on system diagnostic performance evaluation:**

I-V = current-voltage, PV = photovoltaic.
The following table provides frequency and advisory for preventive maintenance work of rooftop PV plant.

<table>
<thead>
<tr>
<th>Maintenance Work</th>
<th>Frequency</th>
<th>Advisory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Securing the power plant</td>
<td>Day-to-day</td>
<td>Owner shall keep the site secured and debar trespassing of unauthorized persons on the roof or terrace where solar arrays and inverters are installed</td>
</tr>
<tr>
<td>Cleaning the solar PV panels</td>
<td>Bi-weekly or monthly</td>
<td>Pressurized water supply and cleaning tools (e.g., flexible pipes, nozzle) shall be made available at the required points on the roof. Trained personnel shall be deployed for cleaning the solar arrays regularly</td>
</tr>
<tr>
<td>Monitoring power generation and export</td>
<td>Daily or weekly (can be done remotely)</td>
<td>Owner shall be trained and encouraged to monitor system output and performance regularly.</td>
</tr>
<tr>
<td>Keeping the inverters clean</td>
<td>Quarterly</td>
<td>Only qualified technicians shall conduct the following inspection of inverters every 3 months:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>□ Check cooling fans</td>
</tr>
<tr>
<td></td>
<td></td>
<td>□ Clean dust and blockage in filters</td>
</tr>
<tr>
<td></td>
<td></td>
<td>□ Check fuses</td>
</tr>
<tr>
<td></td>
<td></td>
<td>□ Check surge protection</td>
</tr>
<tr>
<td></td>
<td></td>
<td>□ Thermography inspection</td>
</tr>
<tr>
<td>Ensuring all electrical connections are kept clean and tight</td>
<td>Bi-annually</td>
<td>Only qualified technicians shall carry out inspection and tidying up of cables every 6 months</td>
</tr>
<tr>
<td>Checking mechanical integrity of the array structure</td>
<td>Annually</td>
<td>Only competent personnel shall carry out inspection and take remedial action as and when needed</td>
</tr>
<tr>
<td>Checking all cabling for mechanical damage</td>
<td>Annually</td>
<td>Only competent technicians shall carry out inspection and take remedial action as and when needed</td>
</tr>
</tbody>
</table>

*continued on next page*
<table>
<thead>
<tr>
<th>Maintenance Work</th>
<th>Frequency</th>
<th>Advisory</th>
</tr>
</thead>
</table>
| Monitoring module performance (e.g., checking output voltage and current of each string of the array and comparing with the expected output under existing conditions) | Annually  | Only qualified personnel shall carry out the following tests and take remedial action as and when needed:  
- Visual inspection  
- IR imaging  
- I-V curve tracing  
- EL test if required |
| Checking the operation of the PV array DC isolator electrical switchboards (DCCB and ACCB) | Annually  | Only qualified personnel shall carry out the following inspection and take remedial action as and when needed:  
- Integrity check and cleaning  
- Check fuse status  
- Check surge protection status  
- Check integrity of cables and state of terminals  
- Thermography inspection |
| Cables DC, AC, Communication                                                     | Annually  | Only qualified personnel shall carry out the following inspection and take remedial action as and when needed:  
- Thermography inspection  
- Integrity or damage inspection  
- Cable terminal inspection |
| Module mounting structure                                                          | Annually  | Only qualified personnel shall carry out the following inspection and take remedial action as and when needed:  
- Check tightening of clamps and nuts and bolts  
- Check for rusting or other damage to anti rust coating |

AC = alternating current, ACCB = AC combiner box, DC = direct current, DCCB = DC combiner box, EL = electroluminescence, I-V = current-voltage, IR = infrared, PV = photovoltaic.

Source: Produced by the author.
This agreement is signed between the Service Provider and Consumer according to Article 10(d) of the “Regulation for connecting renewable energy systems to the electricity network on a net metering basis 2020,” Regulation Number 2020/R-46.

This agreement is made between ____________________ (herein after referred to as the “Consumer”) and ____________________________ (herein after referred to as the “Service Provider”) to connect the renewable energy system installed in ____________________________ to the Service Provider’s network in accordance with the terms and conditions of this agreement.

1.0 System installed by the Consumer
   1.1 Account number assigned to the Consumer by the Service Provider:
   1.2 Identification number assigned to the system by Service Provider:
   1.3 Address where the system is installed (including GPS coordinates):
   1.4 System technology type:
   1.5 Rated capacity of installed system:
   1.6 Estimated annual total of maximum electricity generating capacity of the system:
   1.7 Date of completion of installation and connection to the Service Provider’s network:

2.0 Technical specifications of the photovoltaic (PV) system
   2.1 The system installed must be designed, installed, commissioned, and operated in compliance with the Maldives Utility Regulatory Authority’s “Regulation for connecting renewable energy systems to the electricity network on a net metering basis 2020.”
   2.2 Any modification to the registered system or increase in the registered rated capacity of the system shall be allowed upon obtaining a written approval from the Service Provider.

3.0 Metering and billing
   The electricity generated from the installed system and the electricity used in the premises where the System is installed must be metered and billed according to the Maldives Utility Regulatory Authority’s “Regulation for connecting renewable energy systems to the electricity network on a net metering basis 2020.”
4.0 Reduction or temporary suspension of electricity generation

4.1 The service provider may, under the following circumstances, request to reduce or temporarily suspend electricity generation from the installed system.

4.2 During installation, maintenance, modification, removal, and troubleshooting of the Service Provider’s electricity network, OR

4.3 During an emergency, or to prevent any damage to the Consumer and other parties using the services of the Service Provider resulting from a disaster, OR

4.4 In the event of service degradation to the Service Provider’s customers, inconvenience to the general public, goods and other amenities, and the stability of Service Provider’s electricity network resulting from parallel operation, the Service Provider may request the Consumer to immediately disconnect the service. Reconnection of the service shall be allowed by the Service Provider once the situation improves.

4.5 If the Service Provider requires suspension of the system operations in accordance with this article, a prior notice should be given to the Consumer to provide sufficient time for action. The Consumer must also be informed of the duration of suspension or the reduction of electricity generation of the system if such information is available beforehand.

5.0 Permission of entry to the premises where the system is installed

5.1 The Service Provider may, without prior notice, enter the premises where the PV system is installed during socially acceptable hours under the following circumstances.

5.1.1 To test and verify the system’s safety or take meter readings or test any other system components OR

5.1.2 To take any immediate action necessary to ensure the safety of the persons or to prevent any damage caused to the Consumer or the Service Provider’s network due to malfunctions in the safety components of the installed system.

6.0 Entire agreement

This agreement supersedes any and all other prior understandings and agreements, either oral or in writing, between the parties with respect to the subject matter hereof and constitutes the sole and only agreement between the parties with respect to the said subject matter.

7.0 Term of agreement

This agreement shall remain in force unless terminated by the agreement of the parties.

8.0 Termination of agreement

8.1 This agreement will be terminated upon termination of the service agreement between the Service Provider and the Consumer.

8.2 This agreement will be terminated if the Consumer fails to comply with the final notice issued by the Service Provider in the event the Consumer breaches an article of this agreement.

8.3 The Consumer shall relocate the installed system upon signing of a new agreement with the Service Provider.

8.4 This contract will be terminated should the Consumer wish to decommission the installed system.
9.0 Revisions to the agreement

9.1 Should the Service Provider wish to revise any article of this agreement, they may submit a request to the Maldives Utility Regulatory Authority with appropriate justification(s) for such change.

9.2 The Service Provider and the Consumer shall agree to any revision issued by the Maldives Utility Regulatory Authority Pursuant to Article 9.1 of this agreement, on the day of issuance of the revision, which thereupon shall form part of this agreement.

10.0 Notices

10.0 Any notice, document, request or announcement required or permitted to be given under this agreement shall be in Dhivehi language, and is deemed duly given and sufficient if either delivered in person, or sent by registered mail, or sent by facsimile to a registered facsimile number of the received that has been published in public.

10.1 All written notices required by this agreement under Article 10.1 shall consider the addresses indicated below or to such addresses that the parties may subsequently give such notice of under Article 10.1 of this agreement.

Address of the Service Provider:

Address of the Consumer:

11.0 Transfer of ownership

The Consumer shall transfer the ownership of the permit issued by the Service Provider upon obtaining a written approval from the Service Provider and in accordance with an agreement between the Service Provider and the Consumer to transfer the ownership.

12.0 Severability of articles

If an article in this agreement is declared by a competent court of jurisdiction to be illegal, invalid, or incapable of being enforced under the jurisdiction of Maldives, it shall in no way affect the validity or enforceability of other articles of this agreement, and the remaining articles shall be deemed legal, valid, and enforceable under the jurisdiction of Maldives.

13.0 Signing of agreement

IN WITNESS HEREOF, this agreement is signed between the Service Provider and the Consumer, upon the terms and subject to the conditions set forth herein, on the date hereof, to fulfil the obligations of this agreement.

Service Provider:

Consumer:

**APPENDIX 2**  
**EQUIPMENT REQUIRED FOR INSPECTION**

<table>
<thead>
<tr>
<th>No.</th>
<th>Name of Equipment, Tools, and/or Software</th>
<th>Purpose of Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Solar pathfinder</td>
<td>Provides shadow analysis on site</td>
</tr>
<tr>
<td>2</td>
<td>Infrared camera</td>
<td>Provides thermal imaging of PV modules, electrical contacts</td>
</tr>
<tr>
<td>3</td>
<td>Electroluminescence tester (camera)</td>
<td>Provides electroluminescent image of module to detect microcracks, snail trail, and PID loss on sample modules after preliminary test of thermal image and I-V tracing</td>
</tr>
<tr>
<td></td>
<td>[only for qualified trained personnel]</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>I-V Tracer</td>
<td>Traces I-V curve of PV modules for degradation test</td>
</tr>
<tr>
<td></td>
<td>[only for qualified trained personnel]</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Ordinary camera</td>
<td>Captures images of visual inspection</td>
</tr>
<tr>
<td>6</td>
<td>Earth resistance tester</td>
<td>Measures resistance with earth for equipotential bonding and functional earthing</td>
</tr>
<tr>
<td>7</td>
<td>Insulation tester</td>
<td>Checks insulation of cables</td>
</tr>
<tr>
<td>8</td>
<td>Irradiance meter</td>
<td>Measures solar irradiance (watt/m²)</td>
</tr>
<tr>
<td>9</td>
<td>Multimeter</td>
<td>Checks continuity and voltage</td>
</tr>
<tr>
<td>10</td>
<td>DC clamp meter</td>
<td>Measures voltage and current</td>
</tr>
<tr>
<td>11</td>
<td>Stopwatch</td>
<td>Tests anti island functionality</td>
</tr>
<tr>
<td>12</td>
<td>Ultrasonic thickness gauge</td>
<td>Measures thickness of protective coating</td>
</tr>
<tr>
<td>13</td>
<td>Torque tester or wrench</td>
<td>Measures integrity of structure</td>
</tr>
<tr>
<td>14</td>
<td>Digital distance meter</td>
<td>Measures distance without touching surfaces</td>
</tr>
<tr>
<td>15</td>
<td>Total dissolved solids meter</td>
<td>Tests water hardness at site</td>
</tr>
</tbody>
</table>

DC = direct current, I-V = current voltage, m² = square meters, PID = potential-induced degradation, PV = photovoltaic.

Source: Produced by the author.
A TYPICAL CONNECTION DIAGRAM FOR GRID-CONNECTED PHOTOVOLTAIC SYSTEM WITH STRING INVERTER

**AC** = alternating current, **ACDB** = AC distribution board, **DC** = direct current, **MC4** = multi-contact 4 millimeters, **MCB** = miniature circuit breaker, **PV** = photovoltaic, **SPD** = surge protection device.

Source: Produced by the Global Sustainable Energy Solutions (GSES) according to the regulations of Maldives.
A TYPICAL CONNECTION DIAGRAM FOR GRID-CONNECTED PHOTOVOLTAIC SYSTEM WITH MICRO INVERTER

AC = alternating current.

Source: Produced by the Global Sustainable Energy Solutions (GSES) according to the regulations of Maldives.
Installation and Operations Manual for Maldives’ Grid-Connected Rooftop Photovoltaic Systems

This manual aims to support the implementation of grid-connected rooftop photovoltaic (PV) projects in the Republic of Maldives. It provides information to assist utility engineers and rooftop solar service providers with the installation, operation, and maintenance of grid-connected solar PV systems, and reflects the latest industry best practices. It highlights the importance of observing safety requirements when dealing with all the elements of a new PV system.

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