endev

Energising change

Mini Grid PV System Inspection and Commissioning Guideline

2021

Mini Grid PV System Inspection and Commissioning Guideline

Funded by

Implemented by

Imprint

Acknowledgement:
The publisher would like to thank the Government of Indonesia, especially Directorate of New and Renewable Energy and Energy Conservation, Ministry of Energy and Mineral Resources for giving the permission to translate the book into English.

Publisher:
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
Energising Development
Dag-Hammarskjöld-Weg 1-5
65760 Eschborn, Germany
Website: https://endev.info

Writer:
Imam Askolani

Original Contributors:
Physikalisch-Technische Bundesanstalt (PTB)
Bagus Fajar Ramadhani
M. Husni Mubarok

Design and Layout:
Fredy Susanto

Cover:
Shutterstock

Photo, Drawings, and graphs are provided by:
Energising Development (EnDev) Indonesia
Freepik (page 7)

Printed and distributed by EnDev
Eschborn, 2021

endev

Content

List of Figures

List of Table

List of Table

Glossary

alternating current (AC)	An electric current that reverses direction periodically.
air mass (AM)	Defines how many times a ray of sunlight passes the perpendicular thickness of the atmosphere. When the sun is located at a height of 90°, i.e. at noon of the spring or autumn equinox, the AM is equal to 1. Otherwise, the AM increases with the decreasing of the sun's height. As a rule of thumb, and for standard test conditions (STC), an average air mass of AM 1.5 is assumed.
Array	Multiple electrically connected PV modules.
Bypass diode	A diode connected in parallel with a solar cell to provide an alternate current path in case of module shading or failure.
Capacity	Refers to the total installed nominal power of a PV module or array (Wp), as listed on a module's datasheet and determined by a flash test under Standard Test Conditions (STC).
Charge controller	An electronic device in an off-grid PV system, which regulates the voltage applied to the battery system from the PV array, and controls the connection from the PV array to the loads. The primary function of the charge controller is to protect the batteries from deep discharging and overcharging, and it is therefore essential for ensuring that the batteries obtain longest possible life.
Conductor	A material with a low electrical resistance, which allows for the flow of electrical current through it. Opposite of an insulator.
Crystalline silicon (c-Si)	A type of PV cell made from a single crystal or polycrystalline slice of silicon.
Current	The flow of electric charge in a conductor between two points having a difference in potential (voltage). Current is measured in Amperes (A) and is abbreviated with the letter I.
Depth-of-discharge (DoD)	The percentage of 'emptiness' of a battery or bank of batteries. DoD is the opposite of state-of-charge (DoD = 1 – SoC).
Direct current (DC)	Electric current flowing in only one direction.
Distributed PV systems	or decentralised PV systems Many small or medium-scale PV installations of various sizes and connected to an electrical grid in many different locations, usually to the low-voltage grid.
Efficiency	The ratio of output power (or energy) to input power (or energy). Expressed as a percentage, which is always less than 100% due to conversion losses, transmission losses etc.
Energy	The ability of a system to do work. Measured in joules or kilowatt-hours (kWh).
Feed-in meter	A kWh meter in a grid-connected system which measures electricity that has been fed into the grid.
Flash test	A procedure used to evaluate the output characteristics of a PV cell or module under specific Standard Test Conditions (STC).
Frequency	Number of repetitions per unit time of a complete waveform, expressed in Hertz (Hz).

Grid Term used to describe an electrical utility distribution network.

Grid-connected PV System A PV system which feeds energy onto a national electricity grid. Also called a **grid-tied PV system** or a **utility-interactive PV system**.

Grid-tied PV system See **grid-connected PV system** or a **utility-interactive PV system**.

Hot spot Damage caused by heat build-up in a PV solar cell, normally caused by shading. If the heat increase is significant, the cell can be irreversibly damaged.

infrared (IR) light Electromagnetic radiation with longer wavelengths than those of visible light. IR wavelengths range from approximately 700 nm to 300,000 nm. Because of the longer wavelengths, IR light tends to pass through many materials, including may solar cells, and also carries less energy compared with visible light or ultraviolet light. IR light is also emitted by thermal radiation. IR light, in the language of solar cells, is commonly referred to as 'red light'.

insulator A material with a high electrical resistance. Opposite of a conductor.

Inverter In a PV system, an inverter converts DC power from the PV array/battery to DC power compatible with the utility and AC loads.

insolation Another term for **irradiation**.

islanding A situation where a section of an electricity grid is switched off (in order to carry our repairs safely, for example) but a generator (e.g. a PV system) keeps feed-into electricity into the grid. Grid-connect inverters are designed to avoid this happening.

irradiance Solar radiation incident on a surface at any one time, measured in kW/m^2. The solar power incident on a surface. Solar irradiance is literally the power (watts) of the sun incident to a surface. The international unit of scientific measurement of irradiance is W/m^2 per hour, day or year.

irradiation The total solar energy over a set period of time reaching a unit of surface area. Usually expressed in kilowatt-hours per square meter (kWh/m^2). For grid-connected systems the figure needed is the average $kWh/(m^2 \cdot yr)$. For off-grid systems the figure needed is the average $kWh/(m^2 \cdot day)$. for each month of the year. Also called **insolation**.

I-V curve The plot of the characteristic behaviour of a photovoltaic cell, module, or array. Output electrical current is plotted on the vertical-axis versus voltage on the horizontal-axis. Three important points on the I-V curve are the open-circuit voltage (where current is equal to zero), short-circuit current (where voltage is equal to zero), and the peak power operating point (where the product of current and voltage is at a maximum).

joule (J) Unit of energy equal to 1/3,600 kilowatt-hours.

kilowatt (kW) One thousand watts. A unit of power.

kilowatt-hour (kWh) One thousand watt-hours. A unit of energy. Power multiplied by time.

light energy Electromagnetic radiation in the form of energy carrying photons, integrated over time. Although light energy often only refers to the visible spectrum, light energy can be absorbed by solar cells across the whole solar spectrum, from the invisible infrared light to visible light to ultraviolet light.

Load An electrical device or appliance which consumes electrical energy.

Load current (A) The current required by an electrical device.

maximum power point (MPP) That point on an I-V curve that represents the largest area rectangle that can be drawn under the curve. Operating a PV array at that voltage will produce maximum power.

maximum power point tracking (MPPT) Operating the array at the peak power point of the array's I-V curve where maximum power is obtained for a given amount of incident light intensity. A maximum power point tracker (MPPT) uses electronic transistor circuits to simulate a variable electronic load across the PV array. By changing this electronic resistance, the operating point of the PV array will move along the I-V curve. Software algorithms in the MPPT are then used to ensure the array is operating at the maximum possible power.

micro/mini-grid An isolated grid or interconnection a small separately operated grid. The terms micro and mini refer to the maximum nominal power of grid generation. Micro/ mini-grids are often powered by hybrid systems and include energy storage technologies.

multicrystalline Another word for p**olycrystalline**.

nominal operating cell temperature (NOCT) Temperature at which a solar cell operates when producing electricity over time under nearly full sunshine conditions, specifically 800 [W/m^2], 20 °C ambient temperature, and 1 [m/s] of wind speed. More realistic conditions that STC. Figure is given by manufacturers. Typically, 20 °C + upwards of 27 °C = 47 °C for standard modules. Sometimes used in sizing.

open circuit voltage (V_{sc}) The maximum voltage produced by an illuminated photovoltaic cell, module, or array with no load connected.

peak power The amount of electrical power a photovoltaic module will produce at Standard Test Conditions (normally 1,000 W/m^2 and 25 °C cell temperature), expressed in units of watt-peak (Wp) or a related unit such as kilowatt-peak (kWp) or megawatt-peak (MWp).

peak sun hour (PSH): If a location receives an average 1,200 kWh/(m^2·yr), it is said to receive an average 1,200 PSH per day. If a location receives an average 5 kWh/(m^2·day), it is said to receive an average 5 PSH per day. A peak sun hour is equivalent to 1000 watts of solar energy falling on an area of 1 square meter for 1 hour or for example as 500 watts of solar energy falling on an area of 1 square meter for 2 hours.

polycrystalline Another word for **multicrystalline**.

power The rate at which energy is produced or consumed.

radiation Energy from the sun is emitted as electromagnetic radiation, which includes visible light.

semiconductor A material that has the ability to act as either a conductor or an insulator. The electrical conductivity of the material, or its capacity for conducting electricity, can be regulated by changing the material's properties or by applying external influences, such as sunlight, on the material. PV cells are manufactured from a variety of semiconductor materials. Silicon metal, for example, is the most common semiconductor material used to make PV solar cells.

short circuit current (I_{sc}) The current produced by an illuminated PV cell, module, or array when its output terminals are short-circuited.

standard test conditions (STC) The accepted standard for controlled laboratory testing and certification of PV cells and module output. Standard Test Conditions are defined as 1,000 W/m^2 of light intensity with a replicated solar spectrum of AM 1.5 and 25 °C cell (or module) temperature.

state-of-charge (SoC) The amount of energy remaining in a battery, as a percentage of its maximum capacity. SoC is the opposite of depth-of-discharge (SoC = 1 – DoD). For example, a state of charge = 60% means that 40% of the battery has been discharged (they are 40% empty, or the depth-of-discharge = 40%).

tilt angle The angle of inclination of a solar collector measured from the horizontal.

transformer A device that transfers electrical energy from one circuit to another through inductively coupled conductors. Transformers induce either a voltage or current in a secondary circuit, which is proportional to the voltage or current in the primary circuit. The inductively coupled conductors in transformers achieve a galvanic separation between the primary and secondary circuits.

ultraviolet (UV) light Electromagnetic radiation with shorter wavelengths than visible light. Wavelengths of UV light range from approximately 10 nm to 400 nm. Because of the short wavelengths, UV light carries higher levels of energy per photon than infrared light or visible light. When speaking about solar cells, UV light is commonly referred to as 'blue light'.

utility-interactive PV system See **grid-connected PV system**.

visible light Electromagnetic radiation, which is visible to the human eye. The wavelengths of visible light range between 380 nm and 750 nm. Within that range, the different wavelengths are visible as colours, from longer to shorter: red, orange, yellow, green, blue, indigo and violet.

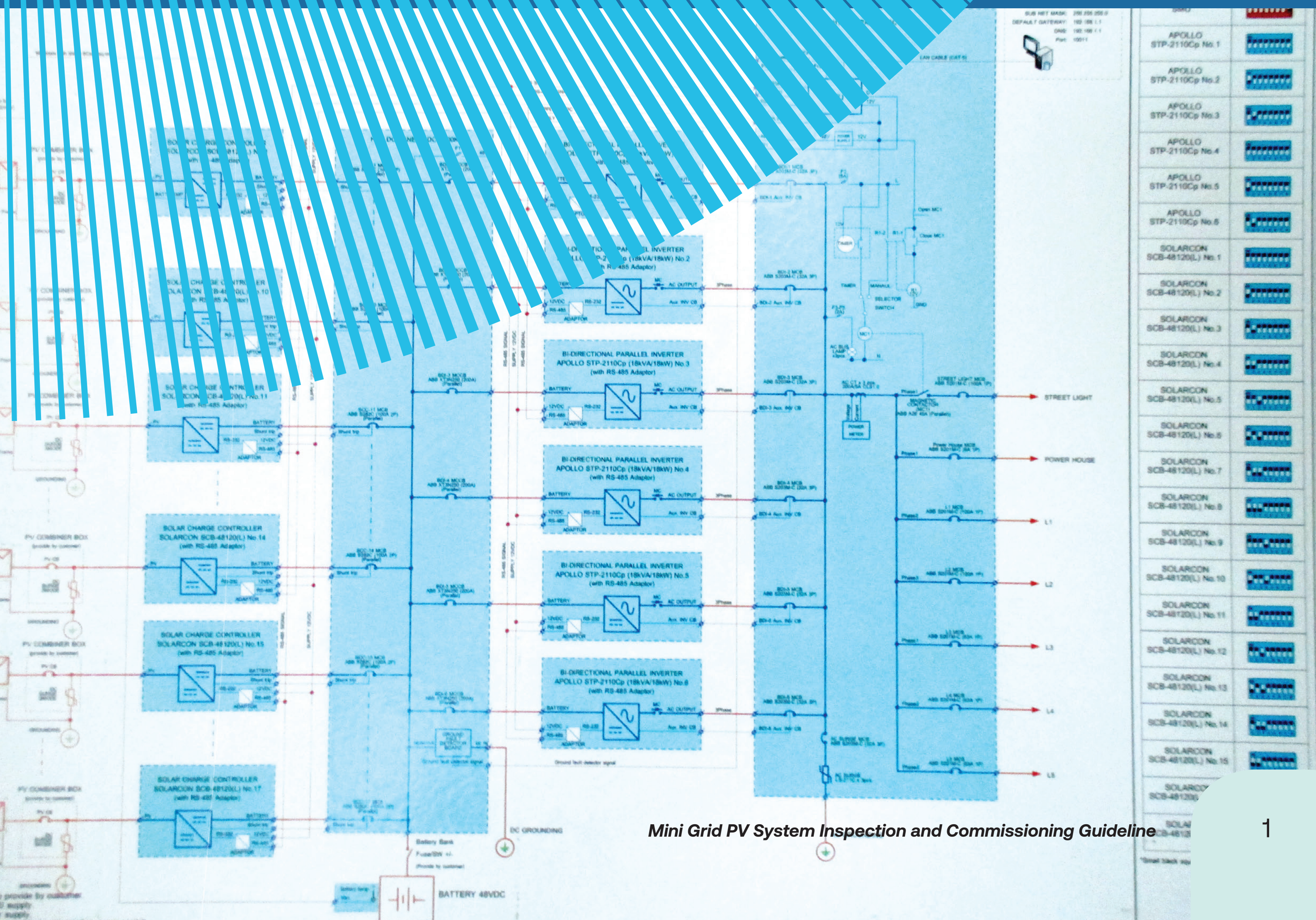
volt (V) The unit of electromotive force that will force a current of one ampere through a resistance of one ohm.

watt-peak (Wp) The amount of electrical power a photovoltaic module will produce at Standard Test Conditions (normally 1,000 W/m^2 and 25° cell temperature). Normally denoted in units of watt-peak (Wp) or a related unit such as kilowatt-peak (kWp) or megawatt-peak (MWp).

yield Amount of electrical energy produced by a PV system. Yield is usually expressed in kilowatt-hours per kilowatt-peak per year or kWh/(kWp·yr) for grid-connected systems, or kilowatt-hours per kilowatt-peak per day or kWh/(kWp·day) for off-grid systems. Yield can also be expressed as a total absolute value, as kilowatt-hours produced over the total lifetime of a system.

zenith angle. The angle between directly overhead and the line intersecting the sun (90°-zenith) is the elevation angle of the sun above the horizon.

1 Introduction



1 Introduction

1.1 OBJECTIVE

Commissioning and testing of a PV mini grid is an important step to ensure reliability, safety and environmentally friendliness of the system. The system must be able to deliver as planned in term of power output and reliability so that it can serves then community (target community) well. The regulation in each country will be different concerning this matter, but they will usually refer to the international standards of electrical installation governed by IEC.

The system must be tested and proved to be reliable so that they can deliver the energy to the community it serves. Reliability of the system is an important aspect for the long-term sustainability of the system that will affect whether the system can influence social and economic impact to the community.

The system must be safe so that operation of the system will not harm both operators and the consumers. Any preventive actions in relation to the operation of the system and the utilization of energy generated by the system must be put properly and according to the design or to the minimum requirements from the local government.

The purpose of this guideline is to provide a general testing procedures and requirements for a PV system so that they become reliable, safe, and environmentally friendly. The checklist and requirements are adopted from Indonesian regulation Ministry of Energy and Mineral Resources No.38 of 2018 and modified based on best practices in Indonesia to meet international requirements.

1.2 NORMATIVE REFERENCE

a) **IEC 60364 (all parts)**, “Low-voltage electrical installations” .

b) **IEC 62446 Ed.1.0 (2009-05)**, “Grid-tied photovoltaic systems - Minimum requirements for system documentation, commissioning tests, and inspection”.

c) **IEC TS 62257-1 Ed 3.0 (2005-10)**, “Recommendations for renewable energy and hybrid systems for rural electrification - Part 1: General introduction to IEC 62257 series and rural electrification”.

1.3 PROJECT DEVELOPMENT STAGES

In general, the development of PV projects follows the following stages

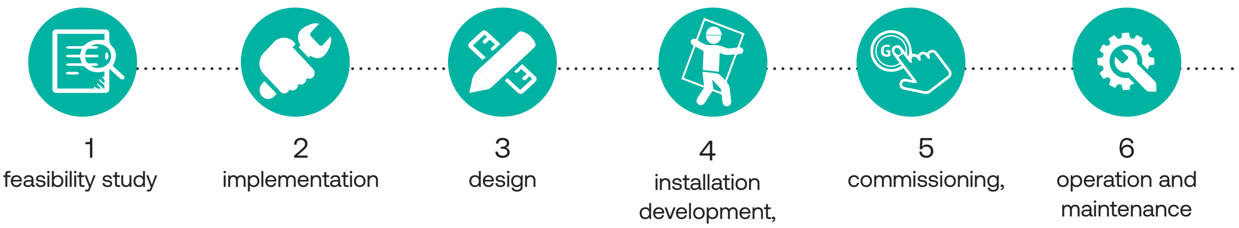


Figure 1 Step of PV Project Development

Inspections can be carried out at various stages of development in accordance with applicable regulations and the needs of the project's owner or developer. As a reference, inspections can be carried out in the following stages:

- **Q1 is an inspection carried out during the preparation**, implementation, and design, before the financial closure;
- **Q2 is an inspection carried out after construction** until commissioning is complete, before handover to the owner takes place;
- **Q3 is an inspection carried out after the system operates.** For example, inspections carried out for regular inspections to determine the performance of the system.

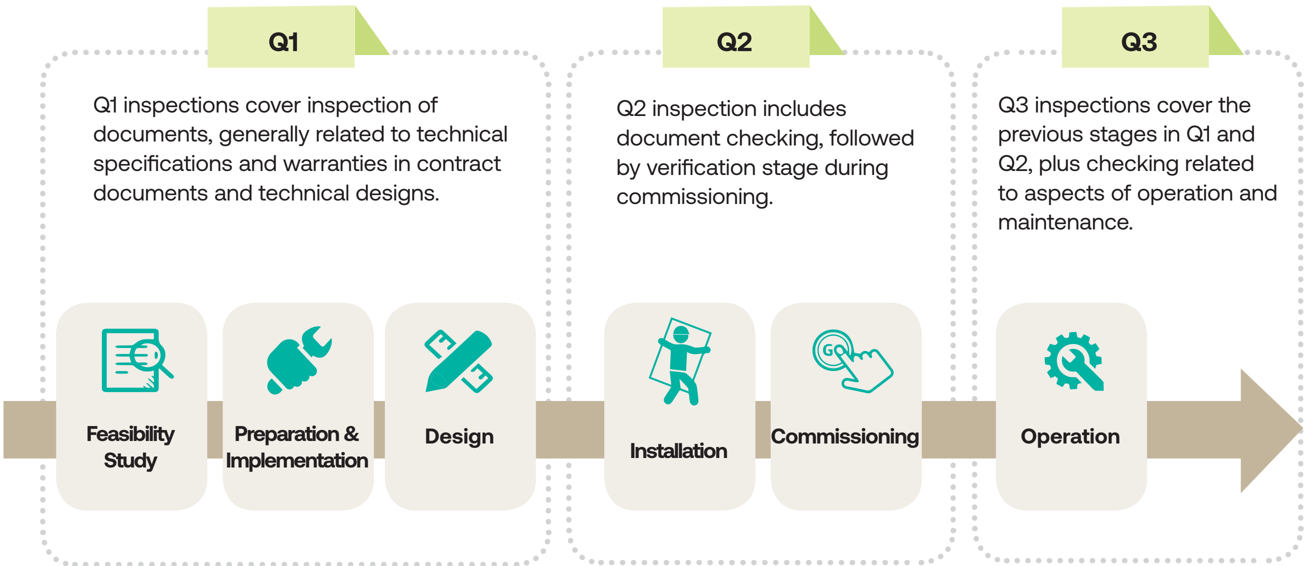


Figure 2 Step of PV Project Inspection

Q1 inspections cover inspection of documents, generally related to technical specifications and warranties in contract documents and technical designs. Q2 inspection includes document checking, followed by verification stage during commissioning. Q3 inspections cover the previous stages in Q1 and Q2, plus checking related to aspects of operation and maintenance. This guidance is primarily intended for Q2 inspections. In Indonesia, Q2 inspections are carried out after the contractor submits the Official Report of Construction Completion.

1.4 USER TARGET

The potential danger contained in the PV System is categorically high since it may cause serious work-related accidents, even death. For this reason, inspection and commissioning must be performed by people with suitable ability and expertise on the basic of electricity, especially PV system. However, as a reference to meet the quality of installation and maintenance, this book may be used as a reference for:

- Supervisor of government project development
- Educational and training institutions
- Electricity supply company
- EPC (Engineering, Procurement, and Construction) Company
- Repair and maintenance service company

1.5 ABOUT THIS BOOK

This book is a guide that can be used by implementers and inspectors of photovoltaic systems in the field. The guidance provided is specific to each component that forms a unified photovoltaic system, including solar modules, inverters, batteries, etc. In addition to containing the guide, this book also provides basic theories that may be required to better understand the components and the overall system.

Communal photovoltaic systems scattered in remote areas generally consist of three parts, namely generation, distribution, and utilization. This book is created as a guide in the examination and testing for sub-field generation in a centralized off-grid PV system.

Anyone with an interest in or a relation to work related to photovoltaic systems can use this book as a reference for proper installation and maintenance. However, in order to understand this book more easily, it is recommended that readers understand the basic concepts of electricity, Electricity Safety, and Occupational Health and Safety.

1.6 PV SYSTEM'S EXAMINATION AND TESTING STAGES

Checks and tests must be adjusted to the stages that can prevent workplace accidents as well as maintaining the quality of the inspected system; for which, we need an appropriate flow of inspection and testing steps. Based on IEC 62446 Ed.1.0 (2009-05), there are 3 stages in order to maintain the safety of inspection officers, namely;

2 Examination of Commisioning Test Documents

2 Examination of Commisioning Test Documents

Examination activities for the completeness of the commissioning test documentation requirements are a way to ensure the availability of all required documentation forms after installation work completes. PV system documentation must be kept properly by the manager and is made available for inspection both in the context of inspection and maintenance. This documentation includes system data and manuals for operation and maintenance.

In inspections, document checking is carried out through the following stages:
1. checking the completeness of the documentation based on the minimum documentation requirements;
2. ensuring that appropriate documentation is available for the installer and the user;
3. maintaining record on each finding;
4. providing recommendations for improvement, if required;
5. creating documentation in the forms of photos or notes.

2.1 GENERAL INFORMATION

Basic information on the PV-VP system which is generally included in the cover page of the system documentation, including:
1. Project identification (if any);
2. System power rating (DC kW or AVC kVA);
3. Information on photovoltaic modules and inverters - manufacturers, models, and quantities;
4. Installation date;
5. Date of commissioning;
6. Customer's Nname;
7. Location address.

2.2 INFORMATION ON SYSTEM DESIGNER

This information concerns information on all agencies/institutions in charge of the design of the PV-VP system. If there is more than one company, the information below must be made available to each company involved, complete with a description of their role in the project:
1. System designer company;
2. Name of contacted person in charge of the company;
3. Postal address, telephone number, and e-mail address.

2.3 INFORMATION ON SYSTEM INSTALLER

This information concerns information on all agencies/institutions in charge of the installation of the PV-VP system. If there is more than one company, the information below must be made available to each company involved, complete with a description of their role in the project:

1. System installation company;
2. Name of contacted person in charge of the company;
3. Postal address, telephone number, and e-mail address.

Photo: Freepik

2.4 WIRING DIAGRAM

A wiring diagram must be provided, accompanied by detailed explanations related to points 1-5 below:

1. **General specifications for photovoltaic arrays**

   The wiring diagram or system specification must include information on the array design which includes:
   - module type,
   - the total number of modules,
   - number of strings,
   - the number of modules in each string,
   - identification of each string connected to which array.

   If an array is divided into sub-arrays, the wiring diagram must show the design of the arrays and include all the information above for each sub-array.

2. **Photovoltaic string information**

   The wiring diagram must include the following photovoltaic string information:
   - string cable specifications - size and type,
   - specifications of string's overcurrent protection equipment - type/voltage/current rating,
   - type of blocking diode (if relevant).

3. **Array electrical details**

   The wiring diagram or system specifications must include the following array's electrical information:
   - Main cable specifications - size and type,
   - combiner box/junction box location,
   - DC breaker switch, location, and rating (current and voltage),
   - array of overcurrent protection equipment - type, location, and rating (voltage/current),
   - other array of protection circuits (such as arc failure detection), if required - type, location, and rating.

4. **AC system**

   The wiring diagram or system specification must include AC system information.
   - Location, type, and rating of AC insulators,
   - Location, type, and rating of the AC current protection equipment,
   - Location, type, and rating of residual current equipment.

5. **Overvoltage and grounding protection**

   The wiring diagram or system specification must include the following grounding and overvoltage information:
   - detailed information on all bonding conductors - sizes and types, including details of equipotential bonding cable to array frame if appropriate,
   - details of all connections in the lightning protection system (LPS),
   - details of installed surge protection equipment (both on AC and DC lines), including location, type, and rating.

2.5 STRING LAYOUT

For systems that have three or more strings, a layout drawing of type photovoltaic system showing how arrays are separated and connected to strings must be provided. This is very useful for finding failures on sufficiently large systems and in arrays installed in certain buildings whose back modules are difficult to access.

2.6 DATA SHEET

Data Sheets must at least be made available for the following system components:

1. **Module data sheets for all types of modules used in the system (refer to IEC 61730-1):**

- type, trade name, or registered trademark of the manufacturer;
- designation or model number;
- "Maximum system voltage" or V_{Sys};
- Class of protection against electric shock;
- "Voltage in open circuits" or V_{Sys}, including manufacturing tolerances;
- "Short-circuit current" or I_{sc}, including manufacturing tolerances;
- "Maximum module power" or "P_{max}" including manufacturing tolerance;
- "Maximum overcurrent protection level" whose suitability is verified by the reverse overcurrent test (MST 26).

Other required documented information:

- maximum serial/parallel configuration of the recommended PV module;
- rated current from overcurrent protection, as specified in MST 26. IEC 60269-6 provides guidelines to determine current values;
- voltage's temperature coefficient in open circuit;
- max power's temperature coefficient; and
- temperature coefficient for short-circuit current.
- electrical and mechanical mounting methods
- module classes as well as constraints for these classes
- environmental conditions whose qualifications have been met by the module(s) (for example temperature, wind load, safety factors).
- minimum cable diameter for PV modules intended for field wiring;
- all restrictions regarding cabling and cable management methods applicable to the junction boxes for PV module;
- size, type, material, and temperature value of the conductor to be used;
- type of wiring terminal in the field;
- model/type of PV connector and specific manufacturer suitable for PV module connector;
- bonding method to be used (if applicable) must be determined. All supplied or specified hardware must be listed in the documentation;
- the type and value of the bypass diode to be used (if applicable).
- All electrical data must be displayed relatively, depending on standard testing conditions (STC) (1,000 W/m2, (25 ± 2) ° C, AM 1.5 according to IEC 60904-3)

Descriptions related to installation (refer to SNI/IEC 61730-1):

- limits regarding installation conditions (e.g. slope, means of installation, cooling);
- a statement indicating the level of fire and the standard applied or a statement that the resistance to an external fire source is not evaluated, as well as restrictions regarding the level (e.g. installation slope, sub-structure or other applicable installation information);
- a statement indicating the minimum mechanical means to secure PV module (as evaluated during mechanical load test (MST 34)); and
- a statement indicating the maximum height intended for PV module.

2. **Inverter data sheets for all types of inverters used in the system.**
3. **Data sheets for other significant components must also be considered.**

2.7 MECHANICAL DESIGN INFORMATION

Data sheets for module support system must be made available.

2.8 EMERGENCY SYSTEM

Documentation for emergency systems related to photovoltaic systems (fire alarms, smoke alarms, etc.).

2.9 OPERATION AND MAINTENANCE INFORMATION

Operation and maintenance information must cover at least the following:

1. Procedure for verifying that the system is operating properly;
2. Checklist of activities when a system failure occurs;
3. System shutdown/isolation in an emergency;
4. Maintenance and cleaning recommendations (mechanical, civil, and electrical);
5. Considerations for any future works that will affect PV array (e.g. roof work);
6. Warranty documents for modules and inverters which include the start date and warranty period;
7. Documentation of any applicable work or guarantee against certain weather effects.

2.10 TEST RESULT AND COMMISSIONING DATA

Copies of all test results and commissioning data must be made available, at least including verification test results.

3 Inspection

3 Inspection

3.1 GENERAL

Inspection must be performed before testing and is usually performed before activating the system. If cables are difficult to access after installation, they can be checked before or during installation work.

3.2 RISK IDENTIFICATION

There are many potential dangers to inspection and testing work of PV systems. All personnel working in the proximity of a PV generation system must be aware of and understand the precautions associated with safety issues such as working at high altitude, exposure to low and high voltage electricity, and other matters related with photovoltaic systems.

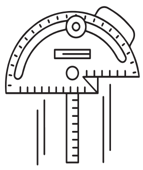
Table 1 Risk Identification

1) Risk of working with photovoltaic system • Solar modules exposed to the Sun and are connected by cables can produce dangerous DC voltage. • Photovoltaic arrays always produce voltage even during interruptions or short circuit conditions. • Disconnecting when the photovoltaic array is connected to the load will trigger sparks that cannot be self-extinguished. • Disturbances on the AC side of the grid-tied system can cause the metal parts of the photovoltaic array structure to receive voltage.
2) Risk of working with low voltage electricity • Cables that are not protected by insulators are very dangerous when they receive voltage which result in workers being exposed to electric shock.
3) Risks of working at height • Working at an altitude above 1.8 meters will pose a potentially serious danger if performed without proper precautions. • Activities below an overhead lifting work has the potential of drop objects. • Workers at height who do not use harnesses have the risk of falling due to tripping or electric shock.
4) Risk of working with batteries • Short connected batteries will produce very high currents and can cause fire and even explosion. • Batteries produce explosive hydrogen gas. • Acid from batteries is corrosive and can cause blindness and damage to skin.
5) Manual lifting • Wrong lifting position will potentially cause injury to limbs. • Objects that are too heavy to lift with inappropriate lifting methods can affect the spine. • Sharp edges of materials such as solar modules or inverters can scratch the limbs.
6) Risks of the surrounding work environment • Prolonged sunlight exposure can cause dehydration and other health problems. • Working on off-grid PV systems, likely to be in remote areas with wild animals and insects and other dangerous animals can cause serious to fatal injuries. • Slippery or rocky work surfaces can cause serious injury when something goes wrong in the work process.

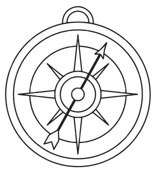
3.3 COMPONENT INSPECTION

3.3.1 Photovoltaic Modules

Required Tools

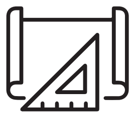


Inclinometer

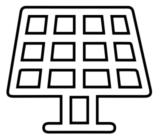


Compass

Prerequisites



Drawings



Installed Photovoltaic Array

There are several important points that must be inspected directly. These points are presented sequentially as follows:

1. GENERAL INFORMATION

a. The steps to perform in carrying out a visual inspection on general information on photovoltaic modules are as follows:

- Checking the list of materials for photovoltaic modules, photovoltaic strings, photovoltaic arrays, and combiner boxes.
- Checking the conformity of the number and configuration of the module, string and photovoltaic array with the system specification sheet.
- Checking the conformity of the number and configuration of the combiner box with the system specification sheet.

b. Explanation of completing forms.

- Record all findings and non-conformities in the provided inspection sheet

Table 2 PV Array Checking Sheet

No	Parameters	Installed Specification	Design Specification	Note
1	Total number of photovoltaic modules	98	100	Mismatch number
2	Number of photovoltaic arrays	5	5	
3	Number of combiner boxes	5	5	

2. TECHNICAL SPECIFICATIONS OF PHOTOVOLTAIC MODULES

a. The steps to perform in carrying out a visual inspection of technical specifications of the module are:

- Checking the photovoltaic module specifications in the data sheet and planning drawing.
- Checking the label/nameplate on the module and note down the data listed. The label or nameplate, displaying the parameter values of the solar module, can be found on the back of the inspected module.

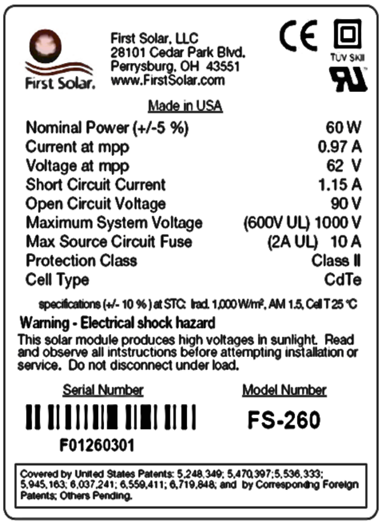


Figure 3 PV Module Specification Label

- Making sure that all photovoltaic modules have the same brand and type.

b. Explanation on completing forms

- Record all findings and discrepancies between the label/nameplate of the photovoltaic module and the data sheet in the provided inspection sheet provided.

Table 3 Technical Specifications of Photovoltaic Modules

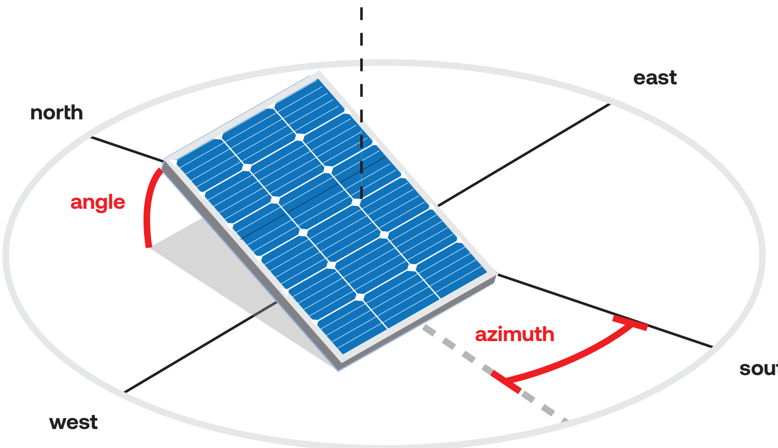
B. Technical Specifications of Photovoltaic Modules				
No	Parameters	Specifications Installed	Design Specification	Note
1	Brand of photovoltaic module	Sunny	Sunny	
2	Type of photovoltaic module	XYZ Series	XYZ Series	

3. ARRAY/FIELD OF PHOTOVOLTAIC AND SUPPORT STRUCTURES

a. *The actions to take in carrying out a visual inspection of the photovoltaic array/ field and support structures:*

1. Provide a compass and angle measuring instrument.
2. Measure and record orientation and slope of the module. Orientation of the array is measured using a compass, while the slope angle of the module is measured using an angle gauge. The reference value of the module orientation is the azimuth, where the value of 0 degree is in a position parallel to the South Pole of the Earth.
3. Comparing the results of the inspection with data on the system specifications.
4. Checking the quality of installation of photovoltaic modules and supports, on aspects of material suitability, corrosion, joints between parts of support construction, and the quality of the support foundation.

Figure 4 Illustration of Angle and Orientation of PV Module Installation.



b. *Explanation on completing forms*

1. Record all findings and non-conformities in the provided inspection sheet.

Table 4 PV Array

C. Photovoltaic Array					
No	Parameters	Array field			
		1	2	3	Note
1	Number of photovoltaic modules	20	20	20	
2	Number of photovoltaic strings	4	4	4	
3	Array orientation (Azimuth). North = 0°, East = 90°, South = 180°, West = 270°	0°	0°	0°	
4	Tilting [°]	15°	15°	15°	

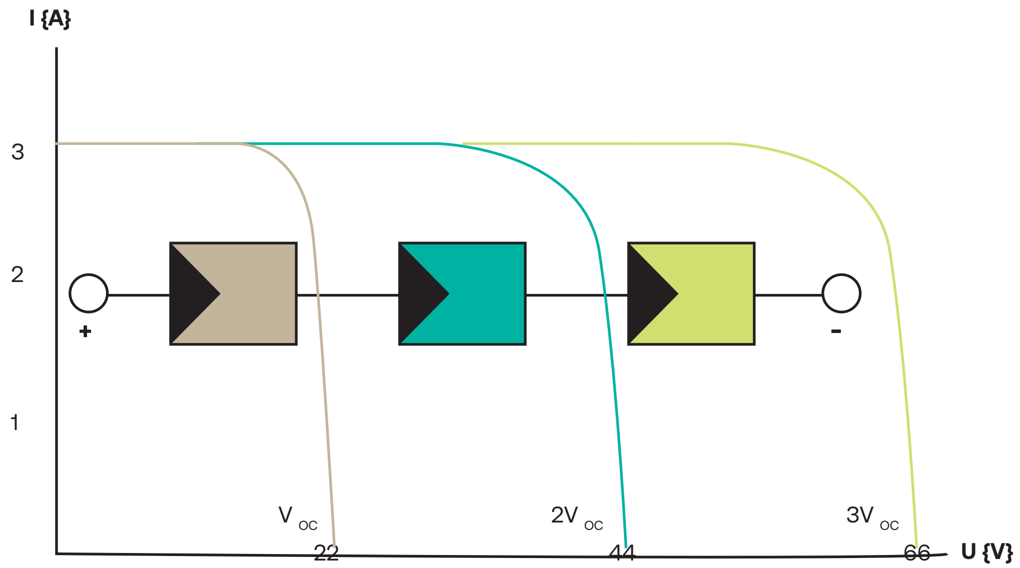
4. PHOTOVOLTAIC STRING

a. The actions to take in carrying out a visual inspection of the photovoltaic string are:

1. Ensuring that the DC disconnector at the combiner box output is off.
2. Verifying the existence of blocking diodes. On some systems, sometimes there are blocking diodes on each photovoltaic string.
3. Checking and collecting photovoltaic string data according to the inspection sheet.
4. Comparing inspection results with system specifications.

b. Explanation on completing forms

1. V_{oc} string value is obtained from the number of modules arranged in series multiplied by V_{oc} nameplate.



$$V_{string}=V_1+V_2+V_3+...$$

Figure 5 PV Series Installation Illustration

2. (Record all findings and non-conformities in the provided inspection sheet.

Table 5 PV String

D. Photovoltaic String (the table may be adjusted in accordance with number of strings)								
No	Parameters	*String*						
		1	2	3	4	5	6	Note
1	Position on which array number?	1	1	2	2	3	3	
2	Number of photovoltaic modules	10	10	10	10	10	10	
3	Open circuit voltage during STC	456	456	456	456	456	456	
4	Short circuit during STC	5,422	5,422	5,422	5,422	5,422	5,422	
Protection specifications and cabling of photovoltaic strings								
5	Type of overcurrent protection (for example fuses and/ or circuit breakers or others)	Fuse	Fuse	Fuse	Fuse	Fuse	Fuse	
6	The number of overcurrent protection instrument type	FD-gPV 10A	FD-gPV 10A	FD-gPV 10A	FD-gPV 10A	FD-gPV 10A	FD-gPV 10A	
7	Types of string cables	XLPE Insulated Single Core	XLPE Insulated Single Core	XLPE Insulated Single Core	XLPE Insulated Single Core	XLPE Insulated Single Core	XLPE Insulated Single Core	
8	Cross-section of the string cable [mm^2], according to the installed specifications	4mm	4mm	4mm	4mm	4mm	4mm	
9	Types of grounding cables	BC 50	BC 50	BC 50	BC 50	BC 50	BC 50	
10	Cross-section of the grounding cable [mm^2], according to the installed specifications	50mm	50mm	50mm	50mm	50mm	50mm	
11	Type of blocking diode (if installed)	-	-	-	-	-	-	
12	Rated current [A] of blocking diode	-	-	-	-	-	-	
13	Rated voltage [A] of blocking diode	-	-	-	-	-	-	

5. COMBINER BOX

a. The actions to take in carrying out a visual inspection of the combiner box are:

1. Making sure that DC disconnector at the combiner box output is off.
2. Checking the overcurrent protection rating value.
3. Inspecting and recording the inspection results according to the inspection sheet instructions.
4. Checking that the state of the surge arrester is in good condition, which can generally be seen from the green indicator.
5. Making sure that all combiner boxes have good groundings. Non-metal combiner boxes have class 2 protection specification (Class 2 is a double insulation level where no grounding is needed).

b. Explanation on completing forms

1. Record all findings and non-conformities in the provided inspection sheet.
2. If the manufacturer does not provide information on the overcurrent protection rating of the string,

$$\textbf{Protection rating} = 1{,}5 \times I_{sc} \leq I_{trip} < 2{,}4 \times I_{sc}.I_{sc}$$

Table 6 Combiner Box

E. *Combiner Box* (the table may be adjusted in accordance with the number of combiner boxes)					
No	Parameters	combiner box			
		1	2	3	Note
1	IP Standard	IP 67	IP 67	IP 67	
2	Type of Fuse	DC Fuse	DC Fuse	DC Fuse	
3	Fuse operational voltage rating [V]	1000 VDC	1000 VDC	1000 VDC	
4	Fuse operational current rating [A]	10A	10A	10A	
5	Number of fuses	5	5	5	
6	Type of disconnector	MCB DC	MCB DC	MCB DC	
7	Disconnector voltage rating [V]	1000 VDC	1000 VDC	1000 VDC	
8	Disconnector current rating [A]	63A	63A	63A	
9	Type of surge protection	SPD	SPD	SPD	
10	Operational voltage rating [V]	2000V	2000V	2000V	
11	Lightning impulse current rating [A]	20 kA	20 kA	20 kA	
12	Type of output cable	BC 6	BC 6	BC 6	
13	Cross-section of output cable [mm^2]	6mm	6mm	6mm	
14	Types of grounding cables	BC 6	BC 6	BC 6	
15	Cross-section of grounding cable [mm^2]	6mm	6mm	6mm	

Table 7 Verification of the Suitability and Quality of Combiner Box

I. Verification of the Suitability and Quality of Combiner Box			
No	**Parameters**	**Check [√]**	**Note**
1	Combiner box is not exposed to direct sunlight and is placed under the photovoltaic module with a safe distance from the module.	√	
2	IP rating for used combiner box is not less than IP65.	√	
3	Combiner box is equipped with air ventilation to avoid excess heat and a breather.	√	
4	Cable gland is tightly installed in the combiner box cable hole.	√	
5	Unused cable gland must be closed at DC distribution panel and AC distribution panel.	√	
6	No gaps are allowed on combiner box which may allow animals to get inside.	√	
7	For combiner box made of metal, it must be connected to grounding cable made of copper with at least 6mm2 of cable type.	√	

6. INSPECTION OF INSTALLATION QUALITY

a. Activities to perform during the inspection of installation quality are:

3. Ensuring that all DC connectors between the combiner box and the inverter are in the off position.
4. Checking the quality of installation of photovoltaic modules and supports, on the aspects of material suitability, corrosion, joints between parts of support construction, and the quality of the support foundation.
5. Noting down the following during the installation quality inspection:
    - Shadow on the photovoltaic module. In identifying the shadows on the photovoltaic module, the inspection officer needs to check several times during sunlight in order to identify the source of the shadow, or use a Solar Pathfinder tool.
    - Cable systems and DC components. During quality checks of cable systems and DC components, the actions that need to be taken are:
        a. Making sure that the cable used is double insulated.
        b. Verifying the component resistance to UV light.
        c. Checking the connection density of DC cables to avoid arcing danger.
        d. Making sure that large amounts of parallel cables are fastened properly;
        e. Checking DC voltage rating used.
        f. Making sure that the cable is not scratched, blistered, nor sliced due to friction with sharp objects.

- Grounding connection. During grounding connection check, actions that need to take are:

  a. Making sure the grounding system comply with the system design.
  b. Making sure grounding connection is fastened properly.
  c. Making sure the grounding cable's cross section is of the correct size.
  d. Making sure that the cable is not scratched, blistered, nor sliced due to friction with sharp objects.
  e. Making sure that all modules are connected to the bonding of the grounding system.

b. Explanation on completing forms

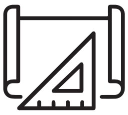
1. Record all findings and non-conformities in the provided inspection sheet

Table 8 Installation Quality of PV Array

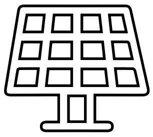
F. Installation Quality of PV Array			
No	**Parameters**	**Check [√]**	**Note**
1	The specifications and number of photovoltaic modules comply with the proposal (terms of reference document).	√	
2	The number and configuration of installed photovoltaic modules, strings, and arrays according to technical drawings (as built).	√	
3	The photovoltaic module frame is installed correctly and stable. All bolts and clamps are installed properly and are not lose or rusty.	√	
4	All photovoltaic modules are in good condition; no cracks, bent frames, air bubbles, white spots, delamination, broken wires, and/or loose or un-enclosed junction boxes.	√	
5	Photovoltaic modules in the same array are installed at the same level or height.	√	
6	The installed photovoltaic modules have the same type, brand, and characteristics.	√	
7	The interconnection between modules is well connected and uses a closed and secure connector (MC4 connector).	√	
8	There are no shadows on the photovoltaic modules throughout the day from either the photovoltaic array, buildings, trees, and wild plants.	√	

3.3.2 Grid-Tied Inverter

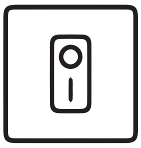
Prerequisites



Drawings



Installed Photovoltaic Array



The Following Main Switches are in the "Open" Position Before Visual Inspection.
1. DC or AC Switch on the Inverter
2.DC Breaker in Combiner Box

During the visual inspection stage of a grid-tied inverter, there are nine points to consider. They are:

1. GENERAL INFORMATION OF GRID-TIED INVERTER

a. Actions to perform in visual inspection of general information on grid-tied inverters are:

1. (Checking the label/nameplate for the type of inverter (1 phase or 3 phases), number of inverter units, power capacity per unit of inverter, and total capacity of grid-tied inverters.
2. Comparing the field data with the specifications
3. Calculating the total capacity of all installed inverters and make the necessary records.

b. Explanation on completing forms

1. Ensure that all findings and non-conformities are recorded in the provided inspection sheet.

Table 9 General Information of Grid-Tied Inverter

A. General Information				
No	**Parameters**	**Installed Specification**	**Design Specification**	**Note**
1	Number of grid-tied inverters (unit)	3	3	
2	Total capacity of grid-tied inverters (kW)	30	30	

2. SPECIFICATION OF GRID-TIED INVERTER

a. The actions to performed in a visual inspection of the specifications of grid-tied inverter are:

1. Making sure that the inverter has ground-fault protection and residual current monitoring.
2. Checking the inverter nameplate and record all the listed data according to the required parameters on the inspection data sheet.
3. Checking the number and labeling of the photovoltaic string connected to the inverter.
4. Comparing the inspection results with the specifications on the data sheet and record all irregularities and discrepancies that exist.

b. Explanation on completing forms

1. Ensure that all findings and non-conformities are recorded in the provided inspection sheet

Table 10 Specification of Grid-Tied Inverter

B. Specification					
No	**Parameters**	**1**	**2**	**3**	**Note**
1	Brand	XYZ	XYZ	XYZ	
2	Type	XYZ Series	XYZ Series	XYZ Series	
3	Serial number	xxxxxx	xxxxxx	xxxxxx	

3. SPECIFICATION OF GRID-TIED INVERTER'S PROTECTION AND CABLING

a. The actions to perform in visual inspection of the protection and cabling specifications of the inverter are:

1. Make sure that the DC switch on the inverter and DC disconnector on the combiner box are in the off position.
2. Check AC main switch and record all necessary data.
3. Check all AC power cords and note the cable type along with the cross-section area of the cable.

b. Explanation on completing forms

1. Ensure that all findings and non-conformities are recorded on the provided inspection sheet.

Table 11 Specification of Grid-Tied Inverter's Protection and Cabling

C. Specification of Grid-Tied Inverter's Protection and Cabling					
No	**Parameter**	**1**	**2**	**3**	**Note**
1	Type of overcurrent protection	MCB AC	MCB AC	MCB AC	
2	Operational overcurrent protection	25A	25A	25A	
3	Operational overcurrent protection	25A	25A	25A	
4	Capacity of overcurrent protection	4.5	4.5	4.5	
5	AC-side cable type	NYY 4x6	NYY 4x6	NYY 4x6	
6	AC-side cable size [mm^2]	6mm	6mm	6mm	

4. INSTALLATION QUALITY OF INVERTER

a. The actions to perform in visual inspection of the quality of the inverter installation are:

1. Making sure that the DC switch on the inverter and the DC disconnector on the combiner box are in the off position.
2. Evaluating the specifications of the inverter and ensure compliance with the type and amount installed.
3. Checking that the inverter is correctly installed according to the instructions in the manual and follow the installation instructions written on the inspection sheet.
4. Checking the quality of the cable installation and protection as specified specifications. The power cable must be separated from the communication signal cable.
5. Making sure that unused cable glands are closed.

b. Explanation on completing forms

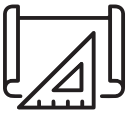
1. Ensure that all findings and non-conformities are recorded on the provided inspection sheet.

Table 12 Installation Quality of Inverter

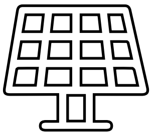
D. Installation Quality			
No	**Parameters**	**Check [√]**	**Note**
1	The specifications and number of inverters comply with the proposal (terms of reference document, TOR).	√	
2	The inverter is installed according to the manufacturer's instructions and in accordance with the tender document. It is recommended that the distance between inverters is not less than 30 cm vertically or horizontally.	√	
3	Inverters are installed properly and there are no loose bolts	√	
4	The inverter is placed in a shaded area and not directly under exposure of sunlight	√	
5	The inverter is placed in an area that is easily accessible by emergency or fire teams	√	
6	The inverter ventilation is not blocked by any objects	√	
7	The output cable, input cable, and inverter communication cable are protected from exposure to solar radiation and are embedded which is protected by conduits or pipes	√	
8	The power cable and the communication cable connected to the inverter are not close together and are not in the same conduit	√	
9	The conduit is properly installed in the module frame or on the wall	√	
10	Each inverter must be equipped with overcurrent protection with a rating of not less than 1.25x the maximum output current of the inverter	√	
11	Cable size and type comply with manufacturer's recommendations and are no less than the nominal rating of overcurrent protection	√	
12	Cable glands are firmly attached to the hole of the inverter cable and the empty opening for cable is closed	√	
13	The voltage and current of the photovoltaic array is no more than the grid-tied inverter's input specification	√	
14	A grid-tied inverter matches the photovoltaic array capacity. It is recommended that the capacity of the inverter is in the range 0.9 ... 1.2x the capacity of the connected photovoltaic array	√	
15	The inverter is equipped with internal or external ground fault protection devices.	√	
16	The inverter is connected with a grounding cable with a copper-cable type and with recommended cable size of not less than 10 mm^2	√	

3.3.3 Battery Bank

Prerequisites



Drawings



Installed photovoltaic modules

In the implementation stage, there are five points that must be considered. The five points are presented sequentially as follows:

1. GENERAL INFORMATION OF BATTERY BANK

a. Actions to perform in visual inspection of battery bank general information are:

1. Checking the following information:
   - The total number of battery cells.
   - Number of battery banks.
   - The capacity of each battery bank.
   - The overall capacity of the battery banks.
2. Taking photos during inspection and when special findings occur.

b. Explanation on completing forms

1. Ensure that all findings and non-conformities are recorded on the provided inspection sheet.

Table 13 General Information of Battery Bank

A. General Information battery Test				
No	**Parameters**	**Actual**	**Design Specification**	**Note**
1	Total number of battery cells	48	48	
2	Total number of battery strings	2	2	
3	Capacity of battery string (Ah)	2000	2000	
4	Total number of battery banks	2	2	
5	Capacity of battery bank (Ah)	4000	4000	
6	Total battery capacity (Ah)	4000	40000	

2. TECHNICAL SPECIFICATIONS OF BATTERY CELL

1. Checking the following information:
    - Brand, type and dimensions of the battery cell.
    - Weight of each battery cell, voltage per battery cell, float charging voltage, and the capacity of each battery cell.
2. Taking photos during inspection and when special findings occur.

b. Explanation on completing forms

1. Ensure that all findings and non-conformities are recorded on the provided inspection sheet.

Table 14 Battery Cell Technical Specifications

B. Battery Cell Technical Specifications					
No	**Parameters**	**Actual**	**Design Specification**	**Note**
1	Brand	XYZ	XYZ	
2	Type	OPzV 2-1000	OPzV 2-1000	

3. INFORMATION OF BATTERY BANK

a. Actions to take in visual inspection of battery bank information are:

1. Checking the following information:
    - Number of battery cells connected in series and in parallel.
    - Battery bank voltage and float charging.
    - Battery bank capacity.
    - C10 Rating
2. Taking photos during the inspection and when special findings occur.

b. Explanation on completing forms

1. Ensure that all findings and non-conformities are recorded on the provided inspection sheet.

Table 15 Battery Bank Information

C. Battery Bank Information (table can be adjusted according to the location of the battery bank)				
No	**Parameters**	**Battery bank**		
		1	**2**	**Note**
1	Number of battery strings connected in parallel	2	-	
2	Number of battery banks	1	-	
3	Capacity of battery bank (Ah)	4000	-	
4	Total capacity of battery bank (Ah)	4000	-	

4. INSTALLATION QUALITY OF BATTERY BANK

a. The actions to perform in visual inspection of the quality of the battery bank installation are:

1. Making sure that the completeness of battery's overcurrent protection.
2. Making sure that the determination cable is installed properly.
3. Making sure that the battery terminals are protected.
4. Making sure that the cable type and size comply with manufacturer's instructions.
5. Making sure that the installation and configuration of the battery bank comply with manufacturer's instructions.
6. Making sure that the cables leading to the distribution panel are protected.
7. Making sure that the battery is in good condition.
8. Making sure that the temperature of battery bank room is not higher than 2^{0}C of outside temperature.
9. Making sure that the ventilation in the battery bank room complies with the manufacturer's instructions.
10. Checking the condition of the battery mounting.
11. Making sure that the battery cells are not dusty and are not in a condition that may cause short-circuit.
12. Taking photos during inspection and when special findings occur.

b. Explanation of completing forms.

1. Ensure that all findings and non-conformities are recorded on the provided inspection sheet.

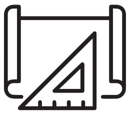
Table 16 Installation Quality of Battery Bank

D. Installation Quality			
No	**Parameters**	**Check ✓**	**Note**
1	There is a number for string and battery bank	x	No string numbering
2	There is danger sign on battery bank	✓	
3	Cable color matches voltage polarity	✓	
4	The specifications and number of batteries, battery strings, and battery banks match with the proposal (terms of reference document, TOR).	✓	

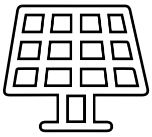
D. Installation Quality			
No	**Parameters**	**Check ✓**	**Note**
5	The battery is in good condition: no physical damage to the battery, vent valve; no sign of leakage; and the terminal is clean from sulfide flakes the surface of the fluid is at normal level (wet battery type)	✓	
6	Each battery bank is equipped with overcurrent protection adjusted to 1.25x of the maximum charging and discharging current from the charge controller or stand-alone inverter	✓	
7	Cables are properly terminated and firmly attached to the battery cell terminals	✓	
8	Battery terminals are protected with proper insulating material and no active conductors are exposed	✓	
9	The type and size of the cable comply with the possibility of charging and discharging currents and with the manufacturer's instructions for stand-alone charge controller and inverter. The strength of cable current and interconnection between battery cells is greater than overcurrent protection.	✓	
10	The cable from battery bank to DC distribution panel is protected using cable rack/conduit/other special protections	✓	
11	Installation and configuration of battery bank comply with manufacturer's instructions. It is recommended that there are no more than 4 parallel battery strings in a battery bank.	✓	
12	The distance between battery cells is not less than 1 cm; the distance between battery strings is not less than 50 cm; and the distance between battery strings and powerhouse wall is not less than 50 cm	✓	
13	Batteries are not exposed to sunlight and the ventilation of the battery room is not blocked	✓	
14	The temperature of battery bank room is not higher than 2°C than outside ambient temperature. It is recommended that ambient temperature is not higher than battery's operational temperature.	✓	
15	The ventilation of the battery bank room is sufficient and comply with battery manufacturer's instructions and room temperature requirements	✓	
16	Battery mounting has corrosion resistant coating, is stable, is able to support the battery weight, and is not at risk of falling	✓	
17	All battery cells are clean (not dusty) and there are no objects across the surface of the battery cells	✓	

3.3.4 Charge Controller

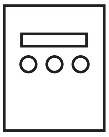
Prerequisites:



Drawings



Installed photovoltaic modules



Solar Charge Controller (SCC) is installed

In the implementation stage, there are four points that must be considered. The four points are presented sequentially as follows:

1. GENERAL INFORMATION OF CHARGE CONTROLLER

a. Actions to visually inspect charge controller general information cover:

1. Inspect the charge controller's label or data sheet.
2. Count the required number of charge controllers to determine the total charge controller installed capacity.

b. Explanation on completing forms

1. Record all findings, discrepancies, and irregularities on the provided inspection sheet.

Table 17 General Information of Charge Controller

A. General Information				
No	**Parameters**	**Installed Specification**	**Design Specification**	**Note**
1	The number of the components of solar charge controller (unit)	10	9	Mismatch number
2	Total capacity of the solar charge controller	20 kW	18 kW	Low power due to insufficient number of SCC

2. SPECIFICATION OF SOLAR CHARGE CONTROLLER

Actions to take ini visual inspection of the Solar Charge Controller specifications include:

a. Inspect the following aspects:

1. Brand and type.
2. Max output power.

b. Explanation on completing forms

1. Record all findings, discrepancies, and irregularities on the provided inspection sheet.

Table 18 Specification of Solar Charge Controller

B. Specification *(the table may be adjusted with the number of SCC)*				
No	**Parameters**	**1**	**Design Specification**	**Note**
1	Brand	XYZ	XYZ	
2	Type	XYZ Series	XYZ Series	
3	Max output power (W)	3500	3500	

3. SPECIFICATION OF PROTECTION AND CABLING OF SOLAR CHARGE CONTROLLER

Actions to take in visual inspection of the protection and cabling specifications of the Solar Charge Controller include:

a.Inspect the followings:

1. Overcurrent protection type and capacity.
2. Overcurrent protection rating and overcurrent protection voltage.
3. Type and size of the battery cable.

b. Explanation on completing forms

1. Record all findings, discrepancies, and irregularities on the provided inspection sheet.

Table 19 Specification of Protection and Cabling Solar Charge Controller

C. Specification of protection and cabling of solar charge controller				
No	**Parameters**	**1**	**Design Specification**	**Note**
1	Overcurrent protection type	NH Fuse	NH Fuse	
2	Overcurrent protection current rating [A]	63	63	
3	Overcurrent protection voltage rating (A)	500	500	
4	Overcurrent protection capacity	120 kA	120 kA	
5	Type of battery cable	NYAF	NYAF	
6	Size of battery cable [mm^2]	16	16	

3. INSTALLATION QUALITY OF SOLAR CHARGE CONTROLLER

Actions to take in visual inspection on the quality of the installation are:

a. Inspect the quality of the charge controller installation for the following:

1. Making sure that the results of the open voltage calculation (V_{oc}) and short-circuit current (I_{sc}) of the photovoltaic string are smaller than the input specification of charge controller.
2. Making sure that the charge controller is installed in compliance with manufacturer's guidelines and that there are no loose bolts.
3. Making sure that the charge controller is placed at a distance complying with manufacturer's instructions so that the cooling system can work properly. It is recommended to be no less than 20 cm vertically or horizontally, making sure that the ventilation of charge controller is not blocked by any objects.
4. Making sure that the cables from photovoltaic array to charge controller are protected from exposure to solar radiation and are embedded in the ground and protected by conduit/pipes.
5. Making sure that the cable size and type match the terminal size, making sure that the cable conductivity is not less than overcurrent protection rating. (overcurrent protection rating of not less than 1.25x max charging current).
6. Making sure that the cable installation is safe and that there is no potential for short circuiting or safety hazards.
7. Making sure that the power and communication cables are separated, i.e. not in the same conduit to avoid interference with data communication system due to the induction in the power cable.
8. Making sure that the gland cable is properly installed in the charge controller cable hole to prevent the entry of objects that can affect the performance of the charge controller.
9. If Lithium-Ion or Zinc-air batteries are used in the PV system, make sure that charge controller can communicate with Battery Management System (BMS).
10. If the PV system uses Lead-Acid batteries, make sure that charge controller has three stages, namely bulk (constant current), absorption (constant voltage), and float.
11. For parallel-mounted charge controllers, make sure that there is no differences in parameter configuration.
12. Making sure that the battery temperature sensor is installed on the battery and the charge controller may read it.
13. Making sure that the charge controller is equipped with a ground fault protection device. Only a device is installed if solar charge controller is connected in parallel.

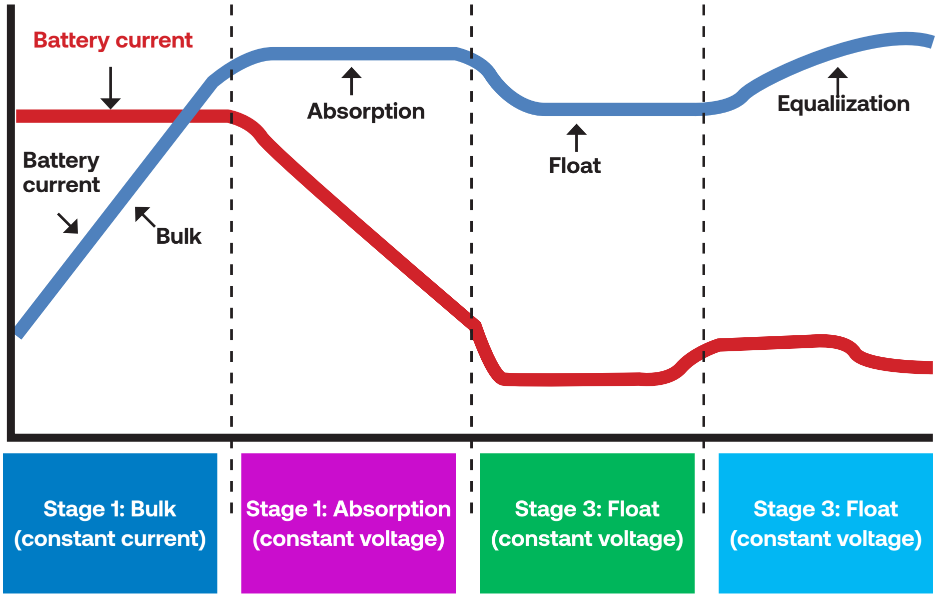


Figure 6 Battery Charging Stages

b. Explanation on completing forms

1. Record all findings, discrepancies, and irregularities on the provided inspection sheet.

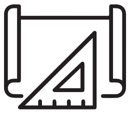
Table 20 Installation Quality of Solar Charge Controller

D. Installation Quality			
No	**Parameters**	**Check [√]**	**Note**
1	Open circuit voltage (V_{oc}) and short-circuit current (I_{sc}) of photovoltaic strings are less than the specification of solar charge controller input	√	
2	Solar charge controllers are installed properly and there are no loose bolts	√	
3	The solar charge controller is placed at a distance complying with manufacturer's instructions. It is recommended to be no less than 20cm vertically or horizontally.	√	
4	Solar charge controller ventilation is not blocked by any objects	√	
5	The cable from photovoltaic array to solar charge controller is protected from exposure of solar radiation and is embedded and protected by pipes	√	

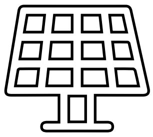
D. Installation Quality			
No	**Parameters**	**Check [√]**	**Note**
6	The size and type of the cable comply with the size of the terminal and the current conductivity is not less than the nominal current and nominal rating of the overcurrent protection	√	
7	Cabling is securely installed and does not potentially cause a short circuit or jeopardize safety	√	
8	The power and communication cables connected to the solar charge controller are not placed close together and are not in the same conduit	√	
9	The cable gland is firmly attached to the solar charge controller cable hole and empty cable opening is closed	√	
10	The solar charge controller matches the photovoltaic array capacity and nominal battery voltage	√	
11	The solar charge controller can communicate with the battery management system (BMS) if lithium-ion or zinc-air battery is used	√	
12	Battery charging for lead acid technology uses a three-stage method, namely bulk (constant current), absorption (constant voltage), and float.	√	
13	There is no difference in the configuration parameters of each solar charge controller connected in parallel	√	
14	The battery temperature sensor is mounted on the battery and is read on the solar charge controller	√	
15	Each solar charge controller must be equipped with overcurrent protection with a rating of not less than 1.25x maximum charging current	√	
16	The solar charge controller is equipped with a ground fault protection device. Only one device is installed if the solar charge controller is connected in parallel.	√	
17	The solar charge controller is connected to a grounding cable with a copper cable type and the cable size is not less than 6 mm^2	√	

3.3.5 Battery Inverter

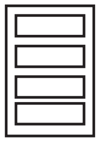
Prerequisites



Drawings



Installed photovoltaic



Battery and inverter are installed

In the implementation stage, there are five points that must be considered. The five points are presented sequentially as follows:

1. GENERAL INFORMATION OF BATTERY INVERTER

a. Actions to visually inspect battery inverter general information cover:

1. Inspect the battery inverter's label or data sheet.
2. Count the required number of battery inverters to determine the total capacity of the installed battery inverters.
3. Perform network configuration inspection (single phase/three phases)
4. Count the number of clusters, if any.

b. Explanation on completing forms

1. Record all findings, discrepancies, and irregularities on the provided inspection sheet.

Table 21 General Information of Battery Inverter

A. General Information				
No	**Parameters**	**Finding**	**Design Specification**	**Note**
1	Number of battery inverters [unit]	6	6	
2	Total capacity of battery inverters (kW)	48	48	
3	Network configuration (single phase/three phases)	3	3	
4	Number of clusters [unit]	2	2	

12. SPECIFICATION OF BATTERY INVERTER

a. Inspect the following aspects:

1. Brand and type.
2. Nominal AC output power.
3. AC voltage output range.

b. Explanation on completing forms

1. Record all findings, discrepancies, and irregularities on the provided inspection sheet.

Table 22 Specification of Battery Inverter

B. Specification (the table may be adjusted with the number of inverters)				
No	**Parameters**	**Actual**	**Design Specification**	**Note**
1	Brand	XYZ	XYZ	
2	Type	XYZ Series	XYZ Series	

3.SPECIFICATION OF MULTICLUSTER (IF ANY)

a. Inspect the following aspects:

1. Multicluster brand.
2. Multicluster type.
3. Maximum number of batter inverters
4. Nominal power

b. Explanation on completing forms

1. Record all findings, discrepancies, and irregularities on the provided inspection sheet.

Table 23 Specification of Multicluster

D. Specification of Multicluster				
No	**Parameters**	**Actual**	**Design Specification**	**Note**
1	Brand	XYZ	XYZ	
2	Type	XYZ Series	XYZ Series	
3	Maximum number of battery inverters [unit]	6	6	
4	Nominal power [kW]	55 kW	55 kW	

4. INSTALLATION QUALITY

a. Actions to take in visual inspection on the quality of the installation are:

1. Making sure that the battery inverters are installed properly and there are no loose bolts
2. Making sure that the battery inverters are placed at a distance complying with manufacturer's instructions. It is recommended to be no less than 30 cm vertically or horizontally.

b. Explanation on completing forms

1. Record all findings, discrepancies, and irregularities on the provided inspection sheet.

Table 24 Installation Quality of Battery Inverter

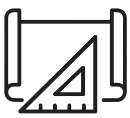
E. Installation Quality			
No	**Parameters**	**Check [√]**	**Note**
1	Battery inverters are installed properly and there are no loose bolts	√	
2	The battery inverters are placed at a distance complying with manufacturer's instructions. It is recommended to be no less than 30 cm vertically or horizontally.	√	
3	The battery inverter's ventilation is not blocked by any objects	√	
4	Cables connected to the inverter are placed inside a cable conduit. The power cable and the communication cable may not be put in the same conduit	√	
5	The size and type of cables according to the terminal and the current conductivity are adjusted in compliance with the nominal charging and/or discharging current and the nominal rating of overcurrent protection. This is performed while taking into account the correction factor.	√	
6	Cabling is securely installed and does not potentially cause a short circuit or jeopardize safety	√	
7	Communication monitoring and synchronization cabling (if available) is tightly attached	√	
8	Cable from the inverter to the battery connected in one cluster has the same length	√	
9	Cable glands are firmly attached to the hole of the inverter cable and the empty opening for cable is closed	√	
10	Battery inverter can communicate with the battery management system (BMS) if lithium-ion or zinc-air battery is used	√	

E. Installation Quality			
No	**Parameters**	**Check [√]**	**Note**
11	Battery charging for lead-acid technology uses bulk, absorption, and float methods.	√	
12	There is no difference in the configuration parameters of each battery inverter connected in parallel	√	
13	The battery temperature sensor is mounted on the battery and is read on battery converter or monitoring system	√	
14	Each battery inverter must be equipped with overcurrent protection on the DC and AC sides with a rating of not less than 1.25 x the maximum charging or discharging current. This is performed while taking into account the correction factor.	√	
15	There is a battery inverter distribution panel (multi-cluster box) if the inverter consists of several clusters.	√	
16	Battery inverters are connected by copper grounding cables and a minimum recommended cable size of 10 mm^2	√	

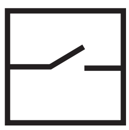
3.3.6 AC/DC Distribution Panel

Prerequisites

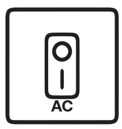
The following components are in "off" condition.



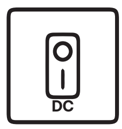
Drawing



DC disconnector on combiner box.



AC switch



DC switch on distribution panel.

Visual inspection on the distribution panel is performed on the following three components:

1. DC DISTRIBUTION PANEL

a. The actions to perform in visual inspection of DC distribution panel are:

1. Checking the number of connected battery strings and battery banks.
2. Checking the number of connected charge controllers for systems with DC-coupling.

3. Checking the number of connected stand-alone battery inverters.
4. Checking the compatibility of cross-section and cable type and grounding quality on the panel.
5. Checking IP class description on the nameplate panel.
6. (Inspecting supporting components according to the table on the inspection sheet.

b. Explanation on completing forms

1. Record all findings, discrepancies, and irregularities on the provided inspection sheet.
2. Take photos during the inspection and when special findings occur.

Table 25 General Information of Distribution Panel

A. General Information				
No	**Parameters**	**Actual**	**Design Specification**	**Note**
1	Number of DC distribution panel	1	1	
2	Number of AC distribution panel	1	1	

Table 26 General Information of DC Distribution Panel

B. General Information (table may be adjusted with the number of distribution panels in a location)					
No	**Parameters**	**1**	**2**	**3**	**Note**
1	Number of connected battery strings	2	-		
2	Number of connected charge controllers	10	10		
3	Number of connected battery inverters	2	2		
4	Number of overcurrent protections	2	2		
5	Material of DC distribution panel	Metal	Metal		
6	IP standard for DC distribution panel	45	45		
7	Type of grounding cable	NYA	NYA		
8	Cross-section of grounding cable [mm^2]	10	10		

2.Battery Bank Protection and Cabling

a. The actions to perform in visual inspection of battery bank's protection and cabling are:

1. Checking the following information:
   - Protection type and rating and overcurrent protection capacity.
   - The type and size of the connection material between the battery cells.
   - The type and size of the connection cable.
2. Taking photos during the inspection and when special findings occur.

b. Explanation on completing forms

1. Ensure that all findings and non-conformities are recorded in the provided inspection sheet.

Table 27 Specification of Battery String Protection and Cabling

C. Specification					
No	**Parameters**	**1**	**2**	**3**	**Note**
1	Overcurrent protection type	FUSE	FUSE		
2	Overcurrent protection current rating [A]	63	53		
3	Overcurrent protection voltage rating (V)	200	200		
4	Overcurrent protection capacity [kA]	1	1		
5	Fully-loaded DC breaker switch	x	x		
6	The type of material between the battery cells	Copper	Copper		
7	Size of connection material (p x l x t) cm, or (mm^2)	50	50		
8	Type of connection cable from battery block to battery panel	NYY	NYY		
9	Cable size [mm^2]	50	50		

3. SPECIFICATION OF STAND ALONE INVERTER PROTECTION AND CABLING

a. Inspect the following aspects:

1. Type of overcurrent protection installed on the DC side.
2. DC overcurrent protection current rating.
3. DC overcurrent protection voltage rating.
4. DC overcurrent Breaking Capacity.
5. Type of DC cable.
6. Size of DC cable.

7. Type of overcurrent protection installed on the AC side.
8. AC overcurrent protection current rating.
9. AC overcurrent protection voltage rating.
10. AC overcurrent Breaking Capacity.
11. Type of AC cable.
12. Size of AC cable.

b. Explanation on completing forms

1. Record all findings, discrepancies, and irregularities on the provided inspection sheet.

Table 28 Specification of Stand-Alone Inverter Protection and Cabling

C. Specification					
No	**Parameters**	**1**	**2**	**3**	**Note**
1	Type of DC overcurrent protection	MCB DC	MCB DC		
2	DC overcurrent protection current rating [A]	200	200		
3	DC overcurrent protection voltage rating [V]	100	100		
4	DC overcurrent protection capacity [kA]	2.5	2.5		
5	Type of DC cable	NYY	NYY		
6	Size of DC cable [mm^2]	50	50		
7	Type of AC overcurrent protection	MCB	MCB		
8	AC overcurrent protection current rating [A]	50	50		
9	AC overcurrent protection voltage rating [V]	400	400		
10	AC overcurrent protection capacity [A]	3	3		
11	Type of AC cable	NYM	NYM		
12	Size of cable to AC distribution panel [mm^2]	6	6		


SMA
AWAS TEGANGAN
TINGGI DC
COMBINER BOX

4. AC DISTRIBUTION PANEL

a. The actions to perform in visual inspection of AC distribution panel are:

1. Checking the number of connected stand-alone battery inverters.
2. Checking the number of connected grid-tied inverters.
3. Checking 3-phase or 1-phase connections to distribution networks with feeder protection, overcurrent protection and surge protection.
4. Verifying the overcurrent and surge protection specifications with information on the component nameplate.
5. Checking the compatibility of cross-section and type of feeder cable and grounding quality on the panel.

b. Explanation on completing forms

1. Record all findings, discrepancies, and irregularities on the provided inspection sheet.
2. Take photos during the inspection and when special findings occur.

Table 29 AC Distribution Panel

C. AC distribution panel (table may be adjusted with the number of distribution panels in a location)				
No	**Parameters**	**Actual**	**Design Specification**	**Note**
1	Network configuration (single phase/three phases)	1	1	
2	Material of AC distribution panel	Metal	Metal	
3	Number of connected battery inverters	3	3	
4	Number of feeders	5	5	
5	Number of overcurrent protections	5	5	
6	Overcurrent protection current rating [A]	10	10	
7	Overcurrent protection voltage rating (V)	250	250	
8	Type of feeder cable	NYM	NYM	
9	Size of feeder cable [mm^2]	35	35	
10	Type of surge protection device	Type 2	Type 2	
11	Surge voltage protection voltage rating (V)	240	140	
12	Surge voltage lightning impulse protection current rating [kA]	25	25	
13	Type of grounding cable	NYY	NYY	
14	Cross-section of grounding cable [mm^2]	6	6	

5. INSTALLATION QUALITY

a. The actions to perform during the inspection of installation quality are:

1. Ensuring the compatibility of the cross section and the color of the grounding cable.
2. Make sure that no gaps are too large on the gland for the cable.
3. The relation to the current breaker between the overcurrent breaking rating and related nominal current value.
4. Make sure that the cross-sectional area and cable type are suitable

.

b. Explanation on completing forms

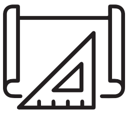
1. Record all findings, discrepancies, and irregularities on the provided inspection sheet.
2. Take photos during the inspection and when special findings occur.

Table 30 Installation Quality of AC Distribution Panel

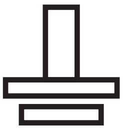
D. Installation Quality			
No	**Parameters**	**Check [√]**	**Note**
1	DC distribution panel is located indoors and has a minimum protection grade of IP4x	√	
2	AC distribution panel is located indoors and has a minimum protection grade of IP4x	√	
3	DC distribution panel box, if made of metal, is connected with a copper grounding cable with recommended minimum cable size of 6 mm^2	√	
4	AC distribution panel box, if made of metal, is connected with a copper grounding cable with recommended minimum cable size of 6 mm^2	√	
5	The cross-section of grounding cable on AC distribution panel must be the same as the phase cable if the size of the phase cable is less than 16 mm^2	√	
6	Cable glands are firmly attached to the holes of DC and AC distribution panels	√	
7	Unused mounted cable glands in DC and AC distribution panels are in closed condition	√	
8	There are no gaps for animals to enter the combiner box, DC distribution panel, and AC distribution panel	√	
9	Cabling inside the panel is neatly mounted, no loose cables, and no potential for short-circuiting or danger to operator	√	
10	Each feeder must be equipped with a current protection with a rating of not less than 1.25x the peak load or the number of customers installed. This is performed while taking into account the correction factor.	√	
11	Cable size and type comply with manufacturer's recommendations and are no less than the nominal rating of overcurrent protection	√	
12	**Temperature measurement:** Temperature of the cable, terminal, and overcurrent protection are normal or recommended to be below 50^{o}C during operation	√	
13	**Temperature measurement:** Ambient temperature in the distribution panel is recommended to be no more than 45^{o}C during operation	√	
14	The energy meter is installed and functioning on the AC distribution panel and the voltage measurement is equipped with overcurrent protection.	√	

3.3.7 Grounding and Lightning Protection

Prerequisites



Drawings



Grounding system is installed

1. GROUNDING SYSTEM

a. The actions to performed in a visual inspection of grounding and lightning protection are as follows:

1. Performing an inspection of the type of grounding used on the system.
2. Inspecting the conformity of the number of points and the grounding control tub as per design.
3. Inspecting the compatibility of the ground cable cross-section as per design.
4. Taking photos during the inspection and when special findings occur.

b. Explanation on completing forms

1. Record all findings, discrepancies, and irregularities on the provided inspection sheet.

Table 31 Specification of Grounding System

A. Specification				
No	**Parameters**	**Installed Specification**	**Design Specification**	**Note**
1	Product type and cross-sectional area of grounding cable for photovoltaic module frames [mm^2]	NYA 6	NYA 6	
2	Product type and cross-sectional area of grounding cable supporting photovoltaic module [mm^2]	BC 10	BC 10	
3	Product type and cross-sectional area of combiner box grounding cable [mm^2]	NYA 6	NYA 6	
4	Product type and cross-sectional area of solar charge controller grounding cable [mm^2]	NYA 6	NYA 6	
5	Product type and cross-sectional area of grid-tied inverter grounding cable [mm^2]	NYA 6	NYA 6	
6	Product type and cross-sectional area of battery inverter grounding cable [mm^2]	NYA 6	NYA 6	

7	Product type and cross-sectional area of DC distribution panel grounding cable [mm^2]	NYA 10	NYA 10	
8	Product type and cross-sectional area of AC distribution panel grounding cable [mm^2]	NYA 10	NYA 10	
9	Product type and cross-sectional area of lightning pole grounding cable [mm^2]	BC 70	BC 70	
10	Product type and cross-sectional area of DC voltage surge protection grounding cable [mm^2]	NYA 6	NYA 6	
11	Product type and cross-sectional area of AC voltage surge protection grounding cable [mm^2]	NYA 6	NYA 6	
12	Product type and cross-sectional area of powerhouse grounding cables [mm^2]	BC 35	BC 35	
13	Product type and cross-sectional area of the grounding cable on the guardrail of the generator area [mm^2]	BC 35	BC 35	
14	Number of equipotential grounding rails	2	2	
15	Cross-sectional area of equipotential grounding rails [mm^2]	50	50	
16	Total number of rod-type grounding electrodes (rods)	6	6	
17	Length of grounding electrode [m]	2	2	
18	Cross-sectional area of grounding electrode [mm^2]	25	25	
19	Number of grounding box	2	2	
20	Type of grounding system (TN-C, TN-C-S, TN-S, TT)	TN-C	TN-C	
21	Number of grounding at distribution network	10	10	
22	Pole interval for grounding of distribution network	5	5	
23	Cross-sectional area of the distribution network pole grounding cable [mm^2]	35	35	

2. LIGHTNING PROTECTION SYSTEM

a. The actions to performed in a visual inspection of lightning protection system are as follows:

1. Inspecting all parameters of the lightning protection system stated on the inspection sheet.
2. Recording all findings, discrepancies, and irregularities on the provided inspection sheet.
3. Taking photos during the inspection and when special findings occur.

b. Explanation on completing forms

1. Record all findings, discrepancies, and irregularities on the provided inspection sheet.

Table 32 Specification of Lightning Protection System

B. Specification				
No	**Parameters**	**Installed Specification**	**Design Specification**	**Note**
1	Type of DC voltage surge protection	Type 1	Type 1	
2	Operation voltage rating at DC surge protection [V]	100	100	
3	Lightning impulse current rating at DC surge protection [kA]	25	25	
4	Type of AC voltage surge protection	Type 2	Type 2	
5	Operation voltage rating at AC surge protection [V]	400	400	
6	Lightning impulse current rating at AC surge protection [kA]	25	25	
7	Lightning protection system (air terminal) used (passive/early streamer)	passive	passive	
8	Product type for lightning strike counter	n/a	n/a	
9	Material type and cross-sectional area of down conductor from	Copper	Copper	
10	Materials and types of grounding electrodes in lightning protection	Copper	Copper	
11	Length (m) and cross-sectional area (mm^2) of grounding	2, 25	2, 25	
12	Number of lightning protection poles	1	1	
13	Height of lightning protection pole (m)	10	10	

3 INSTALLATION QUALITY OF GROUNDING AND LIGHTING

a. The actions to perform in visual inspection of the quality of the installation are:

1. Inspecting all parameters of the lightning protection system stated on the inspection sheet.
2. Recording all findings, discrepancies, and irregularities on the provided inspection sheet.
3. Taking photos during the inspection and when special findings occur.

b. Explanation on completing forms

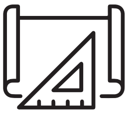
1. Record all findings, discrepancies, and irregularities on the provided inspection sheet.

Table 33 Installation Quality of Grounding and Lighting

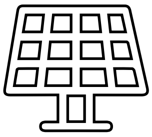
C. Installation Quality			
No	**Parameters**	**Check [√]**	**Note**
1	The cross-sectional area of the grounding cable for the main equipotential bonding and which is connected to the main grounding terminal is not less than 6mm^2 (copper), 50mm^2 (steel), or according to the manufacturer's recommendations.	√	
2	The cross sectional area of the conductor cable of the equipotential bonding is not less than 16mm^2	√	
3	Grounding size for type 1 voltage surge protection is recommended to not less than 10mm^2 and not less than 6mm^2 for type 2	√	
4	The cross-sectional area of grounding electrode is not less than 25mm^2 planted at a depth of not less than 2 meters	√	
5	The cross-sectional area of *down conductor* of the lightning protection pole is not less than 25mm^2	√	
6	Grounding from the powerhouse (inclusive of all electrical and electronic equipment in the powerhouse), the solar module supporting structure and lightning protection may only have one common meeting point at a single main grounding terminal (to avoid galvanic and inductive influences during voltage surges or lightning strikes from one area to another)	√	
7	Grounding cables are installed properly and there are no loose bolts	√	
8	The lightning pole is stable with a height of not less than 17 meters. For lightning pole with a height of less than 20 meters, the distance between the lightning pole and the powerhouse is no more than 6 meters.	√	
9	Lightning pole and its accessories have stainless steel or galvanized iron coating	√	
10	Surge protection for DC is mounted on each combiner box and is connected to the positive and negative terminals of the photovoltaic module and is connected to the grounding terminal	√	
11	Surge protection on the AC side is mounted on the AC distribution panel and is connected to each line, neutral cable (if any), and the grounding terminal	√	
12	Surge protection is in good condition and shows a green indicator or still functioning	√	
13	Lightning counter is installed and functioning	√	
14	Grounding in the distribution network is installed on the first, the last pole, and every 200 meters from the first pole (± every 5 poles); the shortest distance is selected	√	

3.3.8 Monitoring, Instrumentation & Control

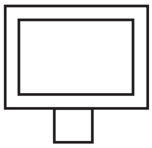
Prerequisites



Drawings



Installed photovoltaic modules



Monitoring system is installed

Visual inspection covers two parts, namely:

1. MONITORING AND PYRANOMETER SYSTEMS

a. The actions to perform in this inspection are:

1. Making sure that the files from the vendor are stored safely and easily accessed, namely data sheets, installation manuals, application notes, etc.
2. Making sure that there is sufficient internal and external memory to store data in compliance with the instructions on the inspection sheet.
3. Making sure that the power and communication monitoring system cabling is completely and properly installed mechanically and electrically so that it can operate properly afterwards.
4. Making sure that the wiring method follows all instructions and guidelines found in the installation book and manual of the vendor's monitoring system.
5. Making sure that the connection of the pyranometer takes into account the data transfer from the pyranometer to the monitoring system so that it can run well in the long-term therefore the risk of data loss can be minimized.
6. Making sure to mechanically install the pyranometer and its position must be free of shadows at all times during daylight.
7. Making sure that the monitoring system connection to the nearest BTS system is properly configured so that wireless cellular data transmission does not experience obstacles when the monitoring system collects and sends data.
8. Making sure that the all parameter configurations software and hardware settings in the monitoring system are properly recorded (in the form of photos, sketches, or prints) in special reports on construction results stored safely (softcopy or hardcopy), and are easily accessed.
9. Making sure that the operation and maintenance guidelines are securely stored (softcopy and hardcopy) and easily accessible by local plant operators and management.

b. Explanation on completing forms

1. Recording all findings, discrepancies, and irregularities on the provided inspection sheet.

Table 34 Specification of Sistem Monitoring dan Pyranometer

A. Specification				
No	**Parameters**	**Installed Specification**	**Design Specification**	**Note**
1	Brand of monitoring system	ReMo XX	ReMo XX	
2	Type of monitoring system	ReMo 123	ReMo 123	
3	Data logging capability (yes/no)	Yes	Yes	
4	Internal/external storage device	Yes	Yes	
5	Capacity of internal/external storage device [MB]	1024	1024	
6	Monitoring system communication user interface	N/A	N/A	
7	Long-distance communication capability (yes/no)	Yes	Yes	
8	Long-distance communication system (cellular, satellite)	Cellular	Cellular	
8	Total monitoring system	1	1	
9	Brand of pyranometer	KX	KX	
10	Type of pyranometer	KX 123	KX 123	
11	Type of temperature sensor connected to the pyranometer	KX 456	KX 456	
12	Pyranometer communication interface	Serial	Serial	

2. INSTALLATION QUALITY

a. The actions to perform during the visual inspection of installation quality are:

1. Performing a visual inspection in accordance with the inspection sheet.
2. Recording all findings, discrepancies, and irregularities on the provided inspection sheet.
3. Taking photos during inspection and when special findings occur.
4. Verification of the performance of the monitoring system is performed to make sure that the system records all measurements. It should be noted that testing on the monitoring system can be carried out simultaneously with the PV system.

b. Explanation on completing forms

1. Recording all findings, discrepancies, and irregularities on the provided inspection sheet.

3 Inspection

Table 35 Installation Quality of Sistem Monitoring dan Pyranometer

B. Installation Quality			
No	**Parameters**	**Check [√]**	**Note**
1	Monitoring system specification complies with the proposed specification	√	
2	Monitoring system is able to perform long-distance communication.	√	
3	Installed external storage device has sufficient capacity to store data for at least 5 years with an interval of 10 minutes. Recommended minimum storage capacity 8 GB.	√	
4	Data reading (time diagram) of the remote monitoring system may be performed on standard Windows PC/laptops	√	
5	Power supply is available and connected to power remote monitoring system	√	
6	Communication interface cable is installed on the components and between components	√	
7	Communication cable used complies with the manufacturer's recommendation, no slagging, and equipped with strain relief	√	
8	Pyranometer is properly installed and connected to the monitoring system	√	
9	Irradiation and temperature values may be read through measurement using pyranometer	√	
10	There are no shadows on the pyranometer. It is recommended to install the pyranometer parallel in height and angle with the photovoltaic module	√	
11	Modem on the remote monitoring system has been configured and ready to operate	√	
12	Communication and power cables are not placed in the same conduit	√	
13	Configuration and settings for PV system parameter monitored by RMS system are available	√	
14	If signal is transmitted through a BTS system: configuration list is available for communication through cellular system	√	

4 Testing

4 Testing

4.1 GENERAL

Testing is performed when inspection concludes and it is declared to be safe.

4.2 SAFETY PREREQUISITE

Avoid performing tests when during rain and thunderstorm. Always wear personal protective equipment (PPE) and follow work's safety standards.

4.3 COMPONENT TESTING

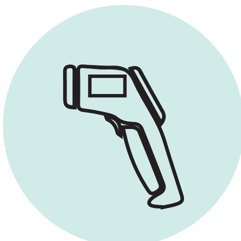
4.3.1 Photovoltaic Array

Required Tools

Irradiance meter

Multimeter

Ampere meter / Clamp meter



Thermal Gun

Prerequisites

a. Irradiance is measured using irradiance meter with the minimum of 500 $W.m^{-2}$

b. Record the temperature measurement on the back of the solar panel when measuring the voltage and the current of the solar panel

1. CONTINUITY OF GROUNDING AND EQUIPOTENTIAL BONDING CONDUCTOR

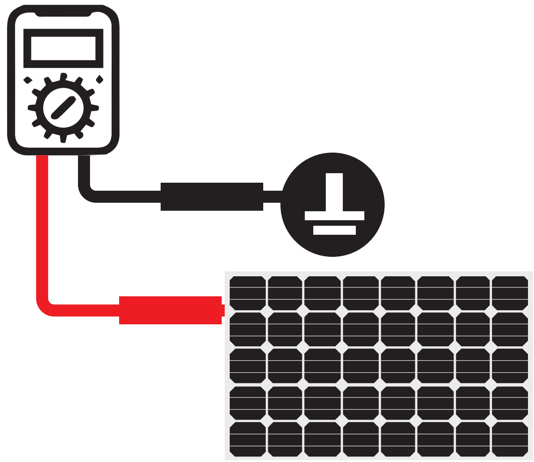


Figure 7 Continuity Measurement Illustration

a. Testing steps

1. Make sure that the entire circuit is no active
2. Set multimeter to continuity test mode
3. Set the position of the multimeter probes; red probe is connected to V Ω and black probe on COM
4. Connect one of the probe heads to grounding cable running to the ground and the other probe head to the conductor side connected to the grounding
5. Observe the measurement results

b. Explanation on completing forms

1. If the multimeter beeps and the resistance value is below 1Ω, the line has continuity.
2. When the condition as stated above is not satisfied, continuity does not occur.
3. When continuity does not occur, checking and fixing must be performed to ensure that all equipotential bonding lines are grounded

Table 36 Continuity Testing of Grounding and Equipotential Bonding

A. Continuity Testing				
No	**Module Frame / Mounting / Other Metal Part**	**Grounding**	**Connected**	**Disconnected**
1	PV Array Frame	point 1	√	
2	Cable Tray	point 1	√	
3	Mounting Array	point 2		√

2. POLARITY, OPEN-CIRCUIT VOLTAGE, AND SHORT-CIRCUIT CURRENT

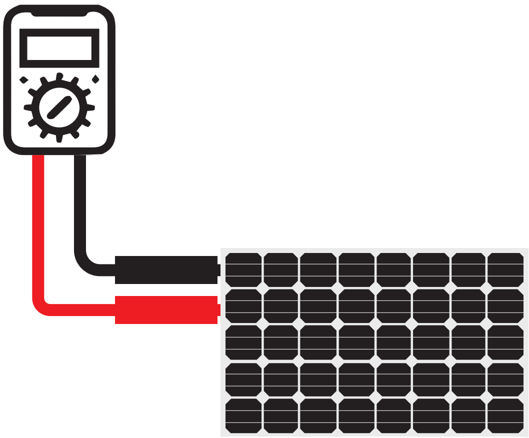


Figure 8 Open-Circuit Voltage Measurement Illustration

2.1 Polarity Test

a. Measuring/testing steps

1. Make sure that all connections between modules on one string are properly and correctly installed.
2. Make sure that the circuit breaker is disconnected
3. The multimeter setting on the DC voltage measurement corresponds to the maximum voltage to be measured
4. Connect the multimeter negative probe to the negative pole on the string and the positive multimeter probe to the positive pole on the string.
5. Observe the results of multimeter measurements.

b. Explanation on completing forms

1. Correct if the measurement results read positively (OK)
2. Incorrect if the measurement results read negatively (NOT OK)
3. Do not proceed to the next process if the polarity test results are not confirmed OK.

2.2 Testing for String's Open-Circuit Voltage

a. Measuring/testing steps

1. Make sure that all between-module connections on one string are properly and correctly connected and connected to the fuse housing
2. Make sure that the circuit breaker is disconnected
3. The multimeter setting on the DC voltage measurement corresponds to the maximum voltage to be measured

4. Connect the multimeter negative probe to the negative pole on the string and the positive multimeter probe to the positive pole on the string.

b. Explanation on completing forms

1. The value of the open-circuit voltage of each string is the sum of the values of the module's open voltage in series.
2. If the voltage value is much lower than the calculated value (more than 5%), check the cabling and the connection.
3. If the open-circuit voltage is still far from expectation after inspection of cables and connections, the solar module is very likely to be in damaged condition and consult the manufacturer.

2.3 Testing the short-circuit current on a photovoltaic string

a. Measuring/testing steps

1. Connect the negative and positive terminals of the photovoltaic string
2. Measure the current with a clampmeter
3. Reopen the negative and positive connections of the photovoltaic string

b. Explanation on completing forms

1. Record the measured current value on the provided form
2. The value of the short-circuit current of the photovoltaic string is the value of the short-circuit current of the individual solar module.
3. If the short-circuit current is not measured, check the cabling of the string or solar module.
4. If the measured current value is too far from the expected (difference of more than 5%), the module is very likely to be damaged and consult the solar module's manufacturer.

TABLE 37 Testing of Polarity, open-circuit voltage, and short-circuit current

B. Testing									
No. String	No. Array	Irradiation [W/m²]	Temp. [°C]	Polarity [OK/ NOT OK]	V_{oc} Measurement [V]	I_{sc} Measurement [A]	V_{oc} Count [V]	I_{sc} Count [A]	Check mark [ü]
1	1	500	28	OK	384	8.5	386.4	9.5	√
2	1	500	28	OK	384	8.5	386.4	9.5	√
3	2	500	28	OK	384	8.5	386.4	9.5	√

3. CABLE INSULATION ON EACH STRING

a. Measuring/testing steps

1. Method 1
   - Make sure that the positive and negative cables are not connected to other materials
   - Insulation tester voltage settings: 250V for Strings with a voltage of less than 120V, 500V for strings between 120 to 500V, and 1000V for strings above 500V.
   - Measure the insulation resistance between the ground and the negative cable with an insulation tester
   - Measure the insulation resistance between the ground and the positive cable with an insulation tester
2. Method 2
   - Short-circuit the positive and negative strings, then measure the ground insulation resistance against the string's short circuit

b. Explanation on completing forms

1. Record the results of measurement.

Table 38 Testing of Cable Insulation

C. Testing				
No. Array	No. String	Method - 1		Method - 2
		POS - GND insulation resistance [MΩ]	NEG - GND insulation resistance [MΩ]	
1	1	0.8	0.7	0.6
1	2	0.7	0.6	0.6
2	3	1.2	1.1	1.1
2	4	1.4	1.3	1.3

2. Use Table 39 for Insulation Testing Reference Value.

Table 39 Reference Value of Insulation Testing

	System Voltage (Voc STC x 1.25)	TestingVoltage (V)	Minimum Resistence Value (MΩ)
Method 1	<120	250	0.5
	120-500	500	1
	>500	1,000	1
	<120	250	0.5
Method 2	120-500	500	1
	>500	1,000	1

a. Verification steps

1. Perform a protection check (Fuse or MCB), make sure that it is in good condition
2. Pay attention to the comparison of the recorded voltage and current from measurement results and calculation results
3. Do a thermal scanning to observe the temperature conditions on the photovoltaic array, cables, and their connections.

b. Explanation on completing forms

1. Protection device is functioning properly if the voltage is not detected when the tool is open (OFF) and the voltage is detected when the tool is closed (ON)
2. The difference in measurement results and calculation of open-circuit voltage and short-circuit current is not more than 5%
3. The recommended module temperature is not more than 70°C and the temperature difference is not more than 10°C.
4. Cable, terminal, and overcurrent protection temperatures are normal or recommended to be less than 40°C.

TABLE 40 Functional Verification of Photovoltaic Array

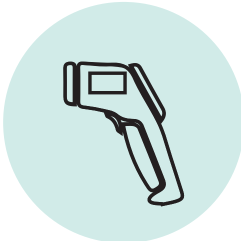
D. Functional Verification		
No	**Parameters**	**Check [✓]**
1	The difference between the measurement and the expected voltage of the open circuit is less than 5%.	✓
2	The difference in measurement and expectation of the short-circuit current for a photovoltaic strings is less than 5%.	✓
3	The difference in the voltage of an open circuit string in the same array (parallel string) is less than 5%.	✓
4	There are no hot-spots on the photovoltaic module by measuring the temperature using an infrared camera. The recommended module temperature is not more than 70°C and the temperature difference is not more than 10°C.	✓
5	Cable, terminal, and overcurrent protection temperatures are normal or recommended to be less than 40°C.	✓
6	Make sure that there is no voltage on the array busbar (parallel string) when all overcurrent protections are open (OFF) and the disconnect switch is in the ON position.	✓
7	Make sure that there is voltage on the array busbar (parallel string) when all overcurrent protection is installed (ON) and the disconnect switch is in the OFF position.	✓
8	Make sure that there is no voltage at the output of the disconnect switch when all string's overcurrent protections are attached (ON) and the disconnect switch is in the OFF position.	✓
9	Make sure that there is no voltage at the output of the disconnect switch when all string's overcurrent protections are attached (ON) and the disconnect switch is in the ON position.	✓

4.3.2 Grid-Tied Inverter

Required tools:

Multimeter

Clampmeter



Thermal Gun

Prerequisites:

- Before carrying out tests, check the inverter specifications to make sure that they comply with the electricity grid at the location
- Make sure that the input's voltage polarity is correct. Input voltage's reverse polarity may damage the inverter.

1 FUNCTIONAL AND INVERTER'S EFFICIENCY

a. Testing steps

1. Switch on fuse/MCB/disconnect photovoltaic array switch
2. Set multimeter to DC voltage mode
3. Measure the voltage at the output point of the photovoltaic array
4. Switch on protection on the Inverter distribution panel
5. Set multimeter in AC voltage mode
6. Measure the inverter output voltage on the Inverter distribution panel
7. Set multimeter in frequency mode (Hz)
8. Measure the frequency of the Inverter output voltage on the Inverter distribution panel
9. Measure the Inverter's input current; Set the clamp meter to DC position, then measure the current from the photovoltaic array
10. Measure the Inverter's output current; Set the clamp meter to AC position, then measure the output current from the inverter

b. Explanation on completing forms

1. The value of inverter's efficiency is a percentage of the ratio of input power to output power.
2. In some types of inverters, the values of voltage, current and input power, voltage, current, power and output frequency are on the provided display interface. Note that there is a significant difference (more than 5%) between the data provided by the inverter's manufacturer and the measurement results.

Table 41 Testing of Functional and Inverter's Efficiency

A. Testing								
No. Inverter	DC input voltage (V)	AC output voltage (V)	Frequency [Hz]	DC Input Current (A)	AC Output Current (A)	DC input Power [W]	AC output Power [W]	Efficiency [%]
1	481	222	50	7.5	15.4	3607	3418	94
2	486	221	50	6	12.3	2916	2718	93
3	483	222	50	7	14.3	3381	3175	93

2. VOLTAGE DROP ON THE CABLE FROM THE COMBINER BOX TO THE GRID-TIED INVERTER

a. Testing Steps

1. Measure the voltage on the combiner box
2. Measure the voltage on inverter input

b. Explanation on completing forms

1. Calculate the difference between the measured voltage at the output of the grid-tied inverter and the measured voltage in the combiner box.
2. The smaller the voltage percentage loss, the less power is lost. Reduced voltage is recommended to no more than 5%

Table 42 Measurement of Voltage Drop on the Cable from the Combiner Box to the Grid-Tied Inverter

B. Measurement			
No. Inverter	Voltage on the combiner box [V]	Inverter's input voltage [V]	Voltage drop [%]
1	485	483	0.41%
2	500	475	5.00%

3. VOLTAGE DROP ON THE CABLES FROM THE GRID-TIED INVERTER TO THE INVERTER'S DISTRIBUTION PANEL

a. Testing Steps

1. Measure the Inverter's output voltage
2. Measure the voltage on the Inverter's distribution panel

b. Explanation on completing forms

1. Calculate the difference between the measured voltage at the output of the grid-tied inverter and the measured voltage on the Inverter's Distribution Panel.
2. The smaller the voltage percentage loss, the less power is lost. Reduced voltage is recommended to no more than 5%

Table 43 Testing of Voltage drop on the Cables from the Grid-Tied Inverter to the Inverter's Distribution Panel

C. Testing			
No. Inverter	**Inverter's output voltage [V]**	**Voltage on distribution panel [V]**	**Voltage drop [%]**
1	220	217	1.36%
2	220	219	0.45%

4. FUNCTIONAL VERIFICATION

a. Verification Steps

1. Compare the measured power, voltage, and frequency values with the inverter's design and data sheet.
2. Perform temperature measurements on cables, cable connection points on the switch, and protection.
3. Check the display on the inverter whether it gives a display complying with the manual provided by the manufacturer
4. Switch off protection of the inverter's output, pay attention to whether the inverter stops operating or not (anti-islanding).
5. Switch on inverter's protection output, pay attention to whether the inverter starts the operation or otherwise.

b. Explanation on Completing Forms

1. Check the cable size and termination tightness if temperatures over 50° C are found.
2. When the switch and the protection output of the inverter are switched off, the inverter must automatically shut down (anti-islanding function), and when the switch is on, the inverter must be automatically active again (ON).

Table 44 Functional Verification

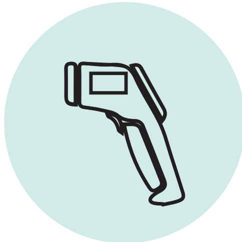
D. Functional Verification		
No	**Parameters**	**Check [√]**
1	Power, voltage, and frequency comply with the system design and inverter data	✓
2	The voltage drop on the cable from the combiner box to the inverter is not more than 1%	✓
3	The voltage drop on the cable from the inverter to the distribution panel is not more than 1%	✓
4	Measurement of the efficiency of the inverter complying with the values listed on the specification data sheet and the difference with specifications is not more than 5%	✓
5	Temperature of all cables, terminals, and overcurrent protection, both input and output under normal conditions or recommended are more than 50^{o}C	✓
6	The inverter's temperature is normal or recommended to not to be higher than the upper limit allowed by the inverter manufacturer	✓
7	The display and indicator lights are functioning and give an indication that the system runs without problems complying with the manual published by the inverter's manufacturer	✓
8	Make sure that grid-tied inverter stops operating when the stand-alone inverter is turned off (anti-islanding)	✓

4.3.3 Battery Inverter

Required Tools:

Multimeter

Clampmeter



Thermal Gun

Prerequisites

- Inverter battery is connected to a load

1. FUNCTIONAL AND INVERTER EFFICIENCY WHEN DISCHARGING

a. Testing steps

1. Switch on fuse/MCB/disconnect the Inverter Battery input switch
2. Switch on fuse/MCB/ disconnect switch Inverter output and switch on MCB/ Disconnect connected to the electricity load
3. Switch off fuse/MCB/disconnect the output switch from the battery charging device (can be a solar charge controller or an inverter connected to the grid)
4. Set the multimeter to DC voltage mode, then measure the Inverter's input voltage
5. Set the clamp meter to DC current mode, then measure the Inverter Battery's Input Current using the Clamp meter
6. Set the multimeter to AC voltage mode, then measure the Inverter's input voltage
7. Set the multimeter to AC voltage mode, then measure the Inverter's input voltage
8. Set multimeter in frequency mode (Hz)
9. Record the temperature recorded on the inverter

b. Explanation on completing forms

1. Enter the measured values on the multimeter on to the provided form.
2. Input power is the multiplication between the input voltage and the input current
3. Output power is the multiplication value of the output and the output current
4. The value of inverter's efficiency is a percentage of the ratio of input power to output power.
5. In some types of inverters, the values of voltage, current and input power, voltage, current, power and output frequency are on the provided display interface. Take note if there is a significant difference between what is read on the inverter display and the measurement results.
6. Perform measurements with several scenarios of the changed load level (output power) and also the different SOC battery (input voltage) level.

Table 45 Testing of Functional and Efficiency

A. Testing										
No. Inv	**DC input voltage [V]**	**DC Input current [A]**	**AC output**	**AC output**	**Frequency [Hz]**	**Inverter's Temperature**	**Input power [W]**	**Output power [W]**	**Efficiency [%]**	**Check [ü]**
1	52.2	70	222	15.1	50	35.2	3654	3352	92	✓
2	52.2	78	223	16.8	50	34.6	4072	3746	92	✓
3	52.2	75	222	16.7	50	35.6	3915	3707	95	✓

2. LOW VOLTAGE DISCONNECT PROTECTION TEST

a. Testing steps

1. Measurements are made when the input voltage approaches the low voltage disconnect setting value on the inverter (a) or also by increasing the voltage to a value close to the time when the testing process will be carried out (b).
2. For (a) Activate the battery inverter and also activate the load supplied by the Inverter.
3. Measure the voltage on the input side of the inverter, then pay attention until the measurement results approaches the LVD setting of the inverter.
4. For (b), change the LVD setting to close to the measured input voltage.

b. Explanation on completing forms

1. When the battery voltage reaches the LVD setting value, the inverter must give out an alarm and disconnect the load/switch off.
2. LVD settings depend on the type of battery, following the manufacturers' recommendations to maintain the battery's warranty.

Table 46 Parameter Tests of Low Voltage Disconnect Protection

B. Parameter Test			
No. Inv	Alarm level [V]	Protection voltage [V]	Suitable SoC's indicators [√]
1	46	45	√
2	46	45	√
3	46	45	√

3. FUNCTIONAL VERIFICATION OF BATTERY INVERTER

a. Verification Steps

1. Observe the value of the output voltage and output frequency, compare them with the inverter's battery nameplate
2. Perform voltage measurements from the Inverter's input source with the voltage at the Inverter's termination point, then calculate the voltage loss
3. For systems with multiple battery inverter units, make sure that the parameter settings match the system design and configuration
4. Pay attention to the results of measurements of efficiency, temperature, as well as the indicators/display on the inverter.

b. Explanation on Completing Forms

1. Please provide a note if the output voltage of the inverter has a difference of ±10% and the frequency has a difference of ± 2Hz from the specifications listed on the nameplate.
2. Reduce battery voltage to the recommended inverter to no more than 1%
3. Efficiency measurements with those listed on the nameplate are recommended to not more than 5%.

Table 47 Functional Verification of Battery Inverter

C. Functional Verification		
No	Parameters	Check [√]
1	Output voltage and frequency in each condition are in the range complying with the specifications. It is recommended that the output voltage is not more/less than ± 10% and the frequency is not more/less than ± 2Hz	√
2	The voltage drop on the cable from the battery to the battery inverter is not more than 1% during charging and discharging	√
3	Parameter settings comply with the design and configuration	√
4	Measurement of the system's efficiency complies with the specifications and the difference with specifications is not more than 5%	✓

C. Functional Verification		
No	Parameters	Check [√]
5	Cable, terminal, and overcurrent protection temperatures are normal or recommended not to exceed $50^{o}C$ during charging and discharging	✓
6	The inverter temperature is normal or recommended below $40^{o}C$ during charging (bulk or constant current phase) and discharging	✓
7	Temperature deviation between inverters, cables, terminals, and overcurrent protection for the same current is not more than $10^{o}C$ during charging	✓
8	The display and indicator lights are functioning and give out indications that the system is problem-free	✓

4.3.4 Charge Controller

Required Tools:

Irradiance meter

Multimeter

Ampere meter / Clamp meter

Thermal Gun

Prerequisites:

- Irradiation 500W/m2
- Charge Controller is connected to the battery

1. FUNCTIONAL AND EFFICIENCY TEST OF CHARGE CONTROLLER

a. Testing steps

1. Switch on fuse/MCB/disconnect Charge Controller output switch.
2. Set the multimeter to DC voltage mode, then measure the Charge Controller's output voltage.
3. Measure the voltage at the output point of the photovoltaic array's combiner box. Make a measurement before the input protection in the direction of the charge controller is activated. If the measured voltage is still within the charge controller's specification range, the testing process can be carried out; however, if it is higher or lower than the specifications required by the charge controller, the test step must be stopped and the photovoltaic array is reconfigured.

4. Switch on fuse/MCB/disconnect photovoltaic array combiner box output switch
5. Set the multimeter to DC voltage mode, then measure the Charge Controller's input voltage.
6. Set the clamp meter to DC current mode, then measure the input and output currents using the Clamp meter

b. Explanation on completing forms

1. Enter the measured values on the multimeter on to the provided form.
2. Input power is the multiplication between the input voltage and the input current
3. Output power is the multiplication value of the output and the output current
4. The value of charge controller's efficiency is a percentage of the ratio of input power to output power.
5. In some types of inverters, the values of voltage, current and input power, voltage, current, and output power are on the provided display interface. Take note if there is a significant difference between what is read on the inverter display and the measurement results.

Table 48 Functional Test of Charge Controller's

A. Functional Test								
No. SCC	**DC input voltage [V]**	**DC Input current [A]**	**Input power [W]**	**DC output voltage [V]**	**DC output current [A]**	**Output power [W]**	**Efficiency [%]**	**Check [√]**
1	252	8.2	2066	52.2	37.3	1945	94	√
2	261	7.5	1958	52.4	36	1888	96	√
3	258	6.2	1599	52.2	28.4	1482	93	√

2. VOLTAGE DROP OF CABLE BETWEEN COMBINER BOX TO SOLAR CHARGE CONTROLLER

a. Testing steps

1. Measure the DC voltage on the output cable of the photovoltaic array's combiner box, followed by voltage measurement at the input of cable connection point on the charge controller.

b. Explanation on completing forms

1. Calculate the difference between the measured voltage at the photovoltaic array's combiner box and the measured voltage on the charge controller's input.
2. Voltage reduce on the recommended DC system is not more than 1%

Table 49 Voltage Drop of Cable Between Combiner Box to Solar Charge Controller

B. Voltage Drop Combiner Box to SCC				
No. SCC	Voltage on the combiner box [V]	Voltage of solar charge controller [V]	Voltage Drop [%]	Check [✓]
1	261	258	1.1	x
2	265	263	0.7	✓
3	261	260	0.4	✓

3. VOLTAGE DROP OF CABLE BETWEEN SOLAR CHARGE CONTROLLER TO BATTERY BANK

a. *Testing steps*

1. Measure the DC voltage at the charge controller's output cable connection point, followed by voltage measurement at the input cable connection point of the battery bank's combiner box.

b. *Explanation on completing forms*

1. Calculate the difference between the measured voltage on the charge controller and the measured voltage at the input of the battery bank's combiner box.
2. Voltage reduce on the recommended DC system is not more than 1%.

Table 50 Voltage Drop of Cable Between Solar Charge Controller To Battery Bank

C. Voltage Drop SCC to Battery Bank				
No. SCC	Voltage on solar charge controller [V]	Voltage of battery bank [V]	Voltage drop [%]	Check [√]
1	53.2	52.9	0.6	√
2	53.2	53.1	0.2	√
3	53.2	50	6.01	x

4. FUNCTIONAL VERIFICATION

a. *Verification Steps*

1. Observe the value of the charge controller's input voltage, verify that the input voltage is within the range allowed by the charge controller in compliance with the nameplate.
2. Verify that the voltage drop from the photovoltaic array's combiner box to the solar charge controller and from the solar charge controller to the battery's combiner box is not more than 1%.

3. Take temperature measurements on the cable and its connection points.
4. Pay attention to the temperature and the indicator on the solar charge controller. Make sure that the charge controller parameter settings comply with the battery manufacturer's design and recommendations.

b. Explanation on Completing Forms

1. Recommended voltage drop is not more than 1%
2. Efficiency measurements with those listed on the nameplate are recommended to not more than 5%.
3. Provide a note for installation repair if the temperature on cable, terminal, and current protection is found to be more than 50^{0}C.

Table 51. Example of Filling Functional Verification Form

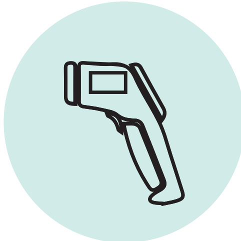
D. Functional Verification Filling Example		
No	**Parameters**	**Check [√]**
1	The DC input voltage corresponds to the MPPT input voltage range	✓
2	The voltage drop on the cable from the combiner box to the solar charge controller is not more than 1%	✓
3	The voltage drop on the cable from the solar charge controller to the battery bank is not more than 1%	✓
4	Measurement of the system's efficiency complies with the specifications and the difference with specifications is not more than 5%	✓
5	Cable, terminal, and overcurrent protection temperatures are normal or to be less than 50 C	✓
6	The temperature of the solar charge controller is normal or recommended to be not more than 40 C during operation	✓
7	The display and indicator lights are functioning and give out indications that the system is problem-free	✓
8	Battery's charge stage voltage parameters comply with the manufacturer's configuration and recommendations. Recommendations for Lead acid OPzV are 2.35 - 2.4 V for the bulk and absorption stages, and 2.25 - 2.3 V for float charging.	✓

4.3.5 Battery Bank

Tools used:

Multimeter

Ampere meter / Clamp meter



Temperature sensor

Prerequisites:

- Battery banks are of same type and capacity.

1. NO-LOAD BATTERY BANK CELL VOLTAGE

Condition: Battery bank circuit is open (no connection between batteries)

a. Testing/measurement steps

1. Set multimeter to DC voltage mode
2. Measure the voltage of each battery
3. Measure the temperature of each battery block

b. Explanation on completing forms

1. Enter the measured values on the multimeter on to the provided form.
2. The battery bank's V_{oc} voltage depends on the bank configuration; for example, on a 48-Volt DC system and the batteries use 2V per block, to form 1 battery bank, as many as 24 battery blocks are arranged in series.
3. Use the manufacturer's recommended value to see whether the battery cell is in good condition or otherwise.

Table 52. Example of Filling No-Load Battery Cell Voltage Measurement form

A. No-Load Battery Cell Voltage Measurement (table can be adjusted according to the number of battery banks on site)											
Battery bank 1			Battery bank 2			Battery bank 3			Battery bank 4		
Cell	V_{oc}	Temperature	Cell	V_{oc}	Temperature	Cell	V_{oc}	Temperature	Cell	Temp	Temperature
1	2.1	30	1	2.2	30	1	2.15	30	1	2.21	29
2	2.1	30	2	2.2	30	2	2.15	30	2	2.21	29
3	2.1	30	3	2.2	30	3	2.15	30	3	2.21	29
4	2.1	30	4	2.2	30	4	2.15	30	4	2.21	29
5	2.1	30	5	2.2	30	5	2.15	30	5	2.21	29
6	2.1	30	6	2.2	30	6	2.15	30	6	2.21	29
7	2.1	30	7	2.2	30	7	2.15	30	7	2.21	29
8	2.1	30	8	2.2	30	8	2.15	30	8	2.21	29
9	2.1	30	9	2.2	30	9	2.15	30	9	2.21	29
10	2.1	30	10	2.2	30	10	2.15	30	10	2.21	29
11	2.1	30	11	2.2	30	11	2.15	30	11	2.21	29
12	2.1	30	12	2.2	30	12	2.15	30	12	2.21	29
Bank 1 V_{oc} [V]		25.2	Bank 2 V_{oc} [V]		26.4	Bank 2 V_{oc} [V]		25.8	Bank 4 V_{oc} [V]		26.52

2. BATTERY BANK'S VOLTAGE DURING CHARGING

Condition: Battery bank is connected to charging source

a. Measuring/testing steps

1. Set multimeter to DC voltage mode
2. Measure the voltage of each battery
3. Measure the temperature of each battery block
4. Set clamp meter on DC current measurement mode
5. Measure input current from each battery bank

b. Explanation on completing forms

1. Enter the values indicated on the multimeter on to the provided form.
2. The battery bank's V_{chg} voltage depends on the bank configuration; for example, on a 48-Volt DC system and the batteries use 2V per block, to form 1 battery bank, as many as 24 battery blocks are arranged in series.
3. Use the manufacturer's recommended value to see whether the battery cell is in good condition or otherwise.

Table 53. Example of Filling Battery Cell Voltage Measurement During Charging Form

B. Battery Cell Voltage Measurement During Charging (table can be adjusted according to the number of battery banks on site)											
Battery bank 1			Battery bank 2			Battery bank 3			Battery bank 4		
Cell	V_{cc}	Temperature	Cell	V_{cc}	Temperature	Cell	V_{cc}	Temperature	Cell	V_{cc}	Temperature
1	2.25	32	1	2.25	32	1	2.25	32	1	2.25	32
2	2.25	32	2	2.25	32	2	2.25	32	2	2.25	32
3	2.25	32	3	2.25	32	3	2.25	32	3	2.25	32
4	2.25	32	4	2.25	32	4	2.25	32	4	2.25	32
5	2.25	32	5	2.25	32	5	2.25	32	5	2.25	32
6	2.25	32	6	2.25	32	6	2.25	32	6	2.25	32
7	2.25	32	7	2.25	32	7	2.25	32	7	2.25	32
8	2.25	32	8	2.25	32	8	2.25	32	8	2.25	32
9	2.25	32	9	2.25	32	9	2.25	32	9	2.25	32
10	2.25	32	10	2.25	32	10	2.25	32	10	2.25	32
11	2.25	32	11	2.25	32	11	2.25	32	11	2.25	32
12	2.25	32	12	2.25	32	12	2.25	32	12	2.25	32
Bank 1 V_{chg} [V]		27	Bank 2 V_{chg} [V]		27	Bank 3 V_{chg} [V]		27	Bank 4 V_{chg} [V]		27
Bank 1 I_{chg} [V]		30	Bank 2 I_{chg} [V]		31	Bank 3 I_{chg} [V]		30	Bank 4 I_{chg} [V]		30

3. BATTERY BANK'S VOLTAGE DURING DISCHARGING

Condition: Battery bank is connected to charging source

a. *Measuring/testing steps*

1. Set multimeter to DC voltage mode
2. Measure the voltage of each battery
3. Measure the temperature of each battery block
4. Set clamp meter on DC current measurement mode
5. Measure output current from each battery bank

b. *Explanation on completing forms*

1. Enter the values indicated on the multimeter on to the provided form.
2. The battery bank's V_{disc} voltage depends on the bank configuration; for example, on a 48-Volt DC system and the batteries use 2V per block, to form 1 battery bank, as many as 24 battery blocks are arranged in series.
3. Use the manufacturer's recommended value to see whether the battery cell is in good condition or otherwise.

Table 54 **Battery Cell Voltage Measurement During Discharging**

C. Battery Cell Voltage Measurement During Discharging (table can be adjusted according to the number of battery banks on site)											
Battery bank 1			Battery bank 2			Battery bank 3			Battery bank 4		
Cell	V_{cc}	Tem-perature	Cell	V_{cc}	Tem-perature	Cell	V_{cc}	Tem-perature	Cell	V_{cc}	Tem-perature
1	2.23	30	1	2.23	30	1	2.23	30	1	2.23	30
2	2.23	30	2	2.23	30	2	2.23	30	2	2.23	30
3	2.23	30	3	2.23	30	3	2.23	30	3	2.23	30
4	2.23	30	4	2.23	30	4	2.23	30	4	2.23	30
5	2.23	30	5	2.23	30	5	2.23	30	5	2.23	30
6	2.23	30	6	2.23	30	6	2.23	30	6	2.23	30
7	2.23	30	7	2.23	30	7	2.23	30	7	2.23	30
8	2.23	30	8	2.23	30	8	2.23	30	8	2.23	30
9	2.23	30	9	2.23	30	9	2.23	30	9	2.23	30
10	2.23	30	10	2.23	30	10	2.23	30	10	2.23	30
11	2.23	30	11	2.23	30	11	2.23	30	11	2.23	30
12	2.23	30	12	2.23	30	12	2.23	30	12	2.23	30
Bank 1 V_{disc} [V]		26.76	Bank 2 V_{disc} [V]		26.76	Bank 3 V_{disc} [V]		26.76	Bank 4 V_{disc} [V]		26.76
Bank 1 I_{dis} [V]		15	Bank 2 I_{dis} [V]		15	Bank 3 I_{dis} [V]		15	Bank 4 I_{dis} [V]		15

4. FUNCTIONAL VERIFICATION OF BATTERY BANK

a. Verification Steps

1. Pay attention to the voltage value of the battery block when the battery circuit is not connected to the charging source and the recommended voltage difference between the battery blocks is not more than $0.03V_{DC}$. When the battery is connected to a charging source (absorption phase) or load, the recommended voltage difference between the battery blocks is not more than $0.05V_{DC}$.
2. During charging and discharging, pay attention to the current deviation between each battery bank. Recommended deviation is not more than 10%.
3. Observe the current value at the time of bulk charge or when given a peak load.
4. Observe the temperature at the battery's connection points and its protection.
5. Verify the battery bank's connection and protection.

b. Explanation on Completing Forms

1. Provide a note for when the battery block's voltage deviation values exceed the recommended values
2. Provide a note for when the current deviation of each bank, during charging/discharging, exceeds 10%
3. Pay attention to the battery manual, make sure that the battery's input/output current does not exceed the rating permitted by the manufacturer.
4. Provide a note for installation repair if the temperature on cable, terminal, and current protection is found to be more than 50^{o}C.
5. Make sure that if the battery protection is open, no voltage is detected in the junction box's DC busbar of the battery (battery bank's combiner panel). Also make sure that the voltage is detected on the DC busbar when the battery is closed.

Table 55 Functional Verification of Battery Bank

D. Functional Verification		
No	**Parameters**	**Check [√]**
1	Battery's voltage deviation of each battery cell in one battery bank is recommended to be not more than 0.03 V_{DC} without load	√
2	Battery's voltage deviation of each cell in one battery bank is recommended to be not more than 0.05 V_{DC} in absorption or constant voltage charging phase	√
3	Battery's voltage deviation of each cell in one battery bank is recommended to be not more than 0.05 V_{DC} during discharging	√
4	The deviation of the charging current during the bulk or constant current phase in each battery bank is not more than 10%	√
5	Discharging current during peak load is not more than I_{10}-rate	√
6	Temperature deviation between battery cells in one battery bank is recommended to be not more than 3 C during charging	√
7	Cable, terminal, and overcurrent protection temperatures are normal or recommended not to exceed 50 C during charging and discharging	√
8	Temperature deviation between cables, terminals, and overcurrent protection for the same current is not more than 10 during charging	√
9	Make sure that there is no voltage on the DC busbar (parallel battery) when all overcurrent protections are open (OFF)	√

4.3.6 AC and DC Distribution Panels

Required Tools:

Multimeter

Mega Ohm Meter/Insulation meter

Prerequisites:

- The air is in dry condition
- Component is in Off condition

1. DC PANEL INSULATION TEST

a. Testing steps

1. Make sure that DC panel is not connected to the input and output cables
2. Measure the isolation resistance between positive, negative, and ground

b. Explanation on completing forms.

1. The minimum isolation resistance is 1000x the working voltage

Table 56 DC Panel Insulation Test

A. Insulation Test			
No	**Description/parameter**	**Test Voltage (V_{DC})**	**Isolation Value (MΩ)Note**
1	Positive to Negative	1000	50
2	Positive to Ground	1000	60
3	Negative to Ground	1000	50

2. AC PANEL INSULATION TEST

a. Testing steps

1. Make sure that the AC panel is not connected to the input and output cables
2. Measure the isolation resistance between phase, neutral, and ground

b. Explanation on completing forms.

1. The minimum isolation resistance is 1000x the working voltage

Table 57 AC Panel Insulation Test

B. Insulation Test			
No	**Description/parameter**	**Test Voltage (V_{DC})**	**Isolation Value (MΩ)**
1	L1-L2	500	20
2	L1-L3	500	25
3	L2-L3	500	20
4	L1-N	500	30
5	L1-G	500	30
6	L2-N	500	30
7	L2-G	500	30

3. DC PANEL FUNCTIONAL VERIFICATION

a. Testing steps

1. Make sure that the DC panel is not connected to the input and output cables
2. Enable (switch on) MCB/Fuse, set multimeter in continuity test mode
3. Check whether MCB/Fuse input and output terminal points are connected using a multimeter
4. Disable (switch off) MCB/Fuse
5. Check whether MCB/Fuse input and output terminal points are not connected using a multimeter

b. Explanation on Completing Forms

1. When MCB/Fuse is activated, multimeter measurement must show continuity
2. When MCB/Fuse is deactivated, multimeter measurement must show non-continuity

Table 58 **DC Panel Functional Verification**

C. DC Panel Functional Verification			
No	**Description**	**Continuity**	**Non-Continuity**
1	Enable Protection/Current Breaker	√	
2	Disable Protection/Current Breaker		√

4. AC PANEL FUNCTIONAL VERIFICATION

a. Testing steps

1. Make sure that the AC panel is not connected to the input and output cables
2. Enable (switch on) MCB/Fuse, set multimeter in continuity test mode
3. Check whether MCB/Fuse input and output terminal points are connected using a multimeter
4. Disable (switch off) MCB/Fuse
5. Check whether MCB/Fuse input and output terminal points are not connected using a multimeter

b. Explanation on Completing Forms

1. When MCB/Fuse is activated, multimeter measurement must show continuity
2. When MCB/Fuse is deactivated, multimeter measurement must show non-continuity

Table 59 **AC Panel Functional Verification**

D. AC Panel Functional Verification			
No	**Description**	**Continuity**	**Non-Continuity**
1	Enable Protection/Current Breaker	√	
2	Disable Protection/Current Breaker		√

4.3.7 Grounding and Lightning Protection

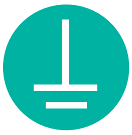
Required Tools:

Multimeter

Grounding Tester

Prerequisites:

- The air is in dry condition
- Grounding system has passed visual inspection



1 GROUNDING CONTINUITY TEST

a. Testing Steps

1. Set multimeter to continuity test mode
2. Set the position of the multimeter probes; red probe is connected to V Ω and black probe on COM
3. Connect probe heads to test points

b. Explanation on Completing Forms

1. If the multimeter beeps, the line has continuity
2. If the multimeter does not beep, the line has no continuity
3. If it has no continuity, checking and repair on the binding's continuity element must be performed

Table 60 Continuity Test of Grounding and Lightning Protection

A. Continuity Test			
No	**Parameters**	**Value**	**Check [√]**
1	"Photovoltaic module frame - Photovoltaic module support structure" connectivity	OK	
2	"Photovoltaic module support structure - Main grounding terminal" connectivity	OK	
3	"Lightning protection - Main grounding terminal" connectivity	OK	

A. Continuity Test			
No	**Parameters**	**Value**	**Check [√]**
4	"Combiner box - Photovoltaic module support structure" connectivity	OK	
5	"Charge controller - Powerhouse's grounding" connectivity	OK	
6	"Grid inverter - powerhouse's grounding" or "grid inverter - photovoltaic module support structure" connectivity	OK	
7	"Stand-alone inverter - powerhouse's grounding" connectivity	OK	
8	"DC distribution panel - powerhouse's grounding" connectivity	OK	
9	"AC distribution panel - powerhouse's grounding" connectivity	OK	
10	"Open conductive area - main grounding terminal" connectivity (one of the examples is metal cable tray)	OK	
11	"Extra conductive part - main grounding terminal" (one of the examples is the fence)	OK	
12	"Powerhouse's grounding - main grounding terminal" connectivity	OK	

2. GROUNDING RESISTANCE TEST

a. Testing Steps *(Analog Grounding Tester)*

4. The red (C) and yellow (P) wires are connected to the provided iron rod which is plugged into the ground. The distance between iron rods is 5m - 10m
5. The green wire (E) is connected to the grounding point whose resistive value will be measured
6. Rotate the measurement scale selector to the highest value, then press the test button. If the measuring needle does not move or moves very small, lower the scale value and do the test again.

b. Explanation on completing forms

1. If needle shows 2 on 1Ω measuring scale, the measurement result is 2 x 1Ω = 2Ω
2. If needle shows 4 on 110Ω measuring scale, the measurement result is 4 x 10Ω = 40Ω
3. Grounding resistance is recommended to be less than 1Ω

Table 61 Grounding Resistance Test

B. Grounding Resistance Test			
No	**Parameters**	**Value (Ω)**	**Check [√]**
1	PV System' grounding resistance (Ω)	2	√
2	Lightning protection's grounding resistance (Ω)	3	√
3	Distribution pole's grounding resistance (Ω)	8	√

3. GROUNDING FUNCTIONAL VERIFICATION

Functional verification is carried out to ensure that the measured values of grounding and lightning pole tests meet the safety and security standards of PV system installation. Provide notes and recommendations for anything which fails to meet the required minimum standards

Table 62 Functional Verification

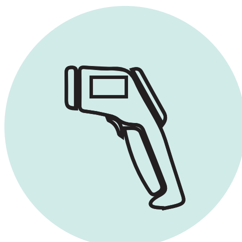
C. Functional Verification		
No	**Parameters**	**Check [√]**
1	All groundings are connected grounding electrodes through continuity test.	✓
2	The grounding resistance of the photovoltaic module support structure and the grounding for each component in the powerhouse (combiner box, SCC, inverter, distribution panel) is maximum 5Ω	✓
3	The grounding resistance of the lightning protection system is maximum 1Ω	✓
4	Grounding resistance on the grid distribution pole is not more than 10Ω	✓

4.3.8 Monitoring System Verification

Required Tools:

Multimeter

Ampere meter / Clamp meter



Thermal Gun

Prerequisites:

- Grounding system has passed visual inspection
- System has been operating for 1 hour

1. VERIFY THE ACCUMULATION MEASUREMENT OF STORAGE DEVICE

Verify the measurement and accumulation of storage devices to ensure that the measurement results and storage devices functions properly. Make notes according to the display of the monitoring system. Verify that the monitoring system has at least the recording function for items as stated on the table below.

Tabel 63. Data of Accumulation Measurement of Storage Device

A. Data of Accumulation Measurement								
Day	Irradiation [Wh/m^2]	Total energy from photovoltaic module [Wh]	Total battery charging energy [Wh]	Total battery discharging energy [Wh]	Total load energy [Wh]	Sample of voltage and current at AC busbar [V; A]	Sample of voltage and current at DC busbar [V; A]	Temperature Sample [°C]
1	600	15000	10000	5000	4800	220 V / 5 A	52 V / 25 A	38°
2	600	18000	12000	6000	5900	219 V / 8 A	51.5 V / 22 A	36°
3	600	17000	13000	4000	3950	222 V / 7 A	51.5 V / 23 A	35°

2. MONITORING SYSTEM FUNCTIONAL VERIFICATION

a. Verification Steps

4. Pay attention to the indicators of the monitoring system. Make sure that the indicators provide signals complying with the function of the indicator's description. Simulation for indicator's functions may be performed to verify the functions.
5. Make sure that the monitoring system records all data of each system component. Monitoring data must be stored and transferred to external storage. Stored raw file is submitted to verificator for checking.
6. Compare the monitoring result with the one measured with owned devices. Make sure that the there are no differences between measurement with external measuring tools and measurement displayed on the monitoring system.
7. Record the interval and data-storage capacity of the monitoring system, perform calculation to verify that the storage capacity of monitoring data is sufficient for 5-year operation.

b. Explanation on completing forms

1. Provide check mark when functional verification complies with the verification steps. If otherwise, provide cross and give note/recommendation.

Table 64. Functional Verification of Grounding System

B. Functional Verification		
No	**Parameter**	**Cek [√]**
1	The monitoring system is operating properly and the indicator lights are on	√
2	The monitoring system records all data from each component and is stored in an external storage device. Raw files are saved and submitted.	√
3	The measurement data passed verification and there was no significant difference between input and output	√
4	Recorded measurements have a minimum interval of 10 minutes for each measured data and can be ascertained by estimating that sufficient storage capacity is available for a minimum of 5 years	x

4.3.9 System Reliability

To determine the overall system performance, it is necessary to test the system reliability for a certain period of time. In a mini-grid PV system, the system reliability test includes observations of the performance of solar panels, charge controllers, inverters and batteries, and other supporting components.

Tests are carried out through simultaneous observation when the system operates. Reliability analysis can be done after all data has been obtained.

Required Tools:

Multimeter

Clamp meter

Prerequisites:

- Battery is fully charged.
- The system is OFF
- Provide a constant load during testing. The load given must be calculated in such a way that the system can still operate for 24 hours.

1. BATTERY RUN-UP, PV MODULE, AND DISTRIBUTION PANEL TESTS (TESTS ARE DONE SIMULTANEOUSLY)

a . Testing steps:

1. Activate the DC system (Battery, PV module, and Charge controller), then activate the AC system (inverter and Distribution Panel as well as the electrical load)
2. Measure sequential voltage and current according to the test time

b. Explanation on completing forms

1. Record the voltage and current on the battery, PV module, dan AC Distribution Panel

Table 65 Battery Condition on 0-8h Charging Time

Battery Table, 0-8h (Start time: ....)

t = 0h to 8h	Current [A]			Voltage [V]								
Battery string	**t = 0**	**t = 4h**	**t = 8h**	**t = 0**	**t = 1h**	**t = 2h**	**t = 3h**	**t = 4h**	**t = 5h**	**t = 6h**	**t = 7h**	**t = 8h**
Battery bank 1 – String 1												
Battery bank 1 – String 2												
Battery bank 1 – String ...												

Table 66 PV Output Measurement on 0-8h Charging Time

PV Table, 0-8h (Start time: ....)

t = 0h to 8h	Current [A]			Voltage [V]								
PV String	**t = 0**	**t = 4h**	**t = 8h**	**t = 0**	**t = 1h**	**t = 2h**	**t = 3h**	**t = 4h**	**t= 5h**	**t= 6h**	**t= 7h**	**t= 8h**
PV 1 Array – String 1												
PV 1 Array – String 2												
PV 1 Array – String ...												

Table 67 AC Voltage Measurement on 0-8h Charging Time

AC Voltage Table, 0-8h (Start time: ....)

t = 0h to 8h	RMS current [A]			RMS voltage [V]								
Distribution phase	**t = 0**	**t = 4h**	**t = 8h**	**t = 0**	**t = 1h**	**t = 2h**	**t = 3h**	**t = 4h**	**t = 5h**	**t = 6h**	**t= 7h**	**t = 8h**
R phase on distribution panel.												
S phase on distribution panel.												
T phase on distribution panel.												

If the reading on the measurement of the battery current is negative (-), it means that the battery is in a state of discharging, whereas if it reads positive (+), it means that the battery is in a charging condition. Charging conditions are possible if the load is less than the power generated by the PV module.*module.*

1. BATTERY DISCHARGE RATE TEST

After the run-up test is complete, continue the testing with the battery discharge test

a. Testing steps:

1. Disable the system by turning off the electricity load first, then turn off the battery inverter, and the grid-tied solar charge controller or inverter.
2. Activate the switch between the battery and the battery inverter, then activate the battery inverter and the distribution panel as well as the load. PV module, solar charge controller, or grid-tied inverter are left in off condition.
3. Perform current and voltage measurements during the test time.
4. After testing completes, turn off the load and battery inverter. Then, wait for at least 30 minutes and take a battery's voltage measurement.

b. Explanation on Completing Forms

1. Measure voltage and current according to the test time. Compare discharge characteristics on battery data sheet.

Table 68 Battery Inverter Condition on 0-2.5h Charging Time

Battery-Inverter Table, 0h - 2.5h

t = 0h to 2.5h	*t* = 0		*t* = 0.5h		*t* = 1h		*t* = 1.5h		*t* = 2h		*t* = 2.5h	
Battery-inverter	*I* [A]	*V* [V]	*I* [A]	*V* [V]	*I* [A]	*V* [V]	*I* [A]	*V* [V]	*I* [A]	*V* [V]	*I* [A]	*V* [V]
Batt-Inverter 1												
Batt-Inverter 2												
Batt-Inverter ...												

Table 69 Battery Inverter Condition on 3-5.5h Charging Time

Battery-Inverter Table, 3h - 5.5h

t = 3h to 5.5h	*t* = 3h		*t* = 3.5h		*t* = 4h		*t* = 4.5h		*t* = 5h		*t* = 5.5h	
Battery string	*I* [A]	*V* [V]	*I* [A]	*V* [V]	*I* [A]	*V* [V]	*I* [A]	*V* [V]	*I* [A]	*V* [V]	*I* [A]	*V* [V]
Batt-Inverter 1												
Batt-Inverter 2												
Batt-Inverter ...												

Table 70 Battery Inverter Condition on 6-8.5h Charging Time

Battery-Inverter Table, 6h - 8.5h

t = 6h to 8.5h	*t* = 6h		*t* = 6.5h		*t* = 7h		*t* = 7.5h		*t* = 8h		*t* = 8.5h	
Battery string	*I* [A]	*V* [V]	*I* [A]	*V* [V]	*I* [A]	*V* [V]	*I* [A]	*V* [V]	*I* [A]	*V* [V]	*I* [A]	*V* [V]
Batt-Inverter 1												
Batt-Inverter 2												
Batt-Inverter ...												

Example of battery discharge characteristics

Table 71 Constant Current Discharge Characteristics

Constant current discharge characteristics (A, 25^0 C)

F.V/TIME	30 Mins	60 mins	2 Hr	3 Hr	4 Hr	5 Hr	6 Hr	8 Hr	10 Hr	20 Hr	24 Hr	48 Hr	72 Hr	100 Hr	120 Hr
1.65 V	833	561	343	264	213	182	156	123	102	53.8	46.4	-	-	-	-
1.70V	808	547	340	262	211	180	155	122	101	53.7	46.1	24.5	-	-	-
1.75V	788	536	335	260	210	179	154	121	101	53.4	46.0	24.4	16.6	-	-
1.80V	759	520	326	252	204	174	149	117	100	53.0	45.8	24.2	16.5	-	-
1.85V	721	494	310	239	194	165	142	111	95.0	5.04	43.5	23.7	16.2	12.1	10.2

Table 72 Constant Power Discharge Characteristics

Constant current discharge characteristics (Watt, 25^0 C)

F.V/TIME	30 Mins	60 mins	2 Hr	3 Hr	4 Hr	5 Hr	6 Hr	8 Hr	10 Hr	20 Hr	24 Hr	48 Hr	72 Hr	100 Hr	120 Hr
1.65 V	1558	1067	662	517	417	358	308	243	202	108	93.3	-	-	-	-
1.70V	1510	1040	656	513	414	355	306	241	202	107	92.6	49.5	-	-	-
1.75V	1473	1019	646	510	412	353	303	240	200	107	92.4	49.2	33.9	-	-
1.80V	1419	988	630	494	399	342	294	232	199	106	92.1	48.9	33.7	-	-
1.85V	1348	939	599	496	379	325	279	220	189.1	100.7	87.5	47.9	33.0	24.4	20.8

Table 73 Residual Capacity of Battery

t = ...hour Residual Capacity:	
Battery	**V [V]**
Battery-bank 1	
Battery-bank 1	
Battery-bank ...	

Table 74 Determine SOC Voltage on Battery

The followings are examples of SOC battery (use data from battery's manufacturer to determine SOC voltage on battery)

State of charge (%)	12V	24V	48V
100	12.83	25.66	51.32
90	12.72	25.44	50.88
80	12.60	25.20	50.4
70	12.47	24.94	49.88
60	12.34	24.68	49.36
50	12.20	24.40	48.80
40	12.06	24.12	48.24
30	11.91	23.82	47.64
20	11.76	23.52	47.04
10	11.61	23.22	46.44

endev