**Testing and Commissioning Guide for**

**Solar Mini Grid Projects**

# List of Abbreviations

AC: Alternating Current

AEPC: Alternative Energy Promotion Centre

DC: Direct Current

DoD: Depth of Discharge

ESCOs: Energy service companies

Imp: Current at maximum power

Isc: Short circuit current

LED: Light Emitting Diode

kW: Kilo-watt

kWp: Kilo-watt-peak

kWh: Kilo-Watt-Hour

MoEWRI: Ministry of Energy, Water Resource and Irrigation

MPPT: Maximum Power Point Tracker

RE: Renewable Energy

STC: Standard Test Conditions

SMG: Solar Mini-Grid

Vmp: Voltage at maximum power

PV: Photo-voltaic

T&D: Transmission and Distribution

UC: Users Committee

Voc: Open circuit voltage

VRLA: Valve Regulated Lead Acid

# List of Terms and Definitions:

***Array junction box:*** enclosure where all PV strings of any PV array are electrically connected and where protection devices can be located

***Array Mounting System:*** The equipment used to safely secure the PV modules to the mounting surface or ground

***Current at maximum power (Imp):*** the current that results in maximum power under given condition of light and temperature, used as the “rated” current of a device

**Electricity Network**-An electrical system supplied by one or more sources of voltage and comprising all the conductors and other associated electrical equipments used to conduct electricity for the purposes of conveying energy to one or more Customer’s premises, street lights, or other Networks.

***Kilowatts peak (kWp):*** units for defining the rating of a PV module where kW generated at STC

***MPPT Controller:*** A device that provides the interface between PV array and the battery to maximize input power from solar PV array

***Open circuit voltage (Voc):*** It is the maximum voltage produced in a PV module when there is a break in the circuit.

***PV cell:*** Basic Photovoltaic unit which can generate electricity when exposed to sun light

***PV module:*** Smallest environmentally protected assembly of interconnected PV cells

***PV string:*** Circuit in which PV modules are connected in series, in order for a PV array to generate the required output voltage

***PV array:*** mechanically and electrically integrated assembly of PV modules, and other necessary components, to form a DC power supply unit

***PV string cable:*** cable connecting PV modules to form a PV string

***PV DC main cable:*** cable connecting the PV generator junction box to the DC terminals of the PV inverter or MPPT controller

***PV inverter:*** device which converts DC voltage and DC current into AC voltage and AC current

***PV supply cable:*** cable connecting the AC terminals of the PV inverter to a distribution circuit of the electrical installation

***PV installation:*** erected equipment of a solar PV power supply system

***PV Standard test conditions (STC):*** test conditions specified for PV cells and modules (25⁰C, light intensity or irradiance 1000W/m2, air mass 1.5)

***Signage:*** PV system installed requires various signs to ensure safety

***Short circuit current (Isc):*** the maximum current measured in a PV module when its positive and negative terminals are short circuited, and voltage in the circuit is zero.

***System Monitoring:*** shows the system owner exactly how much electricity their system is producing and can be helpful in detecting a problem within the system

***SMG:*** solar mini grid that can operate independently to supply energy for limited number of consumers in a village or a hamlet.

***Voltage at maximum power (Vmp):*** the voltage that results in maximum power under given conditions of the light and temperature

# Objective

The objective of Testing and Commissioning is to verify the proper supply of goods, installation and functioning of mini-grid systems as per the design requirements. As per subsidy delivery mechanism (SDM) 2079 (B.S.), once the vendor sends the project completion report, Employer is required to send the technical team (Centre, Outreach Centre or independent consultant) for testing and commissioning of the systems. Therefore, SDM foresees the testing and commissioning of each system to comply equipment quality and workmanship.

The testing and commissioning guideline aims to achieve the following Objectives:

* All equipment are sized and installed as per design and contract agreement BoQ with correct manufacturer specifications
* Equipment are numbered, labeled and connected correctly
* Equipment have no electrical / ground faults
* Appropriate state of charge of the battery bank
* Load test to verify system functionality
* Equipment ground continuity
* Quality assurance inspection

The guideline’s objectives relate to verification of the design and functioning of components and system, and safety and quality assurance are adequate. The technical experts consider such verifications are according to best practice.

The test methods during commissioning included in the guideline are visual inspection, general measurement and electrical measurement. The inspection and measurements are recorded in a checklist and are defined for each component: solar PV array, charge controller, battery bank, inverter or inverter/charger, interconnection, grounding work and end use loads. The testing and commissioning approach considered in the guideline are according to best practice in off grid solar PV mini grid systems application.

The guideline mentions the requirement but does not consider the test method details and pass criteria for load test and appropriate state of charge of the battery bank. Furthermore, the test and commissioning shall also consider the provision on requirement of complete documentation of project.

# The Stakeholders

The Project Developers or Users Committee, Suppliers or Contractors, and Employer are the core stakeholders involved in Testing and Commissioning of Solar Mini Grid. The roles and responsibilities are briefly indicated here.

## Project Developer or Users Committee

The Developer or Users Committee of solar mini-grid projects as envisaged by Renewable Energy (RE) subsidy policy B.S. 2078 could be community, cooperative, private, or public-private partnership entities. The project Developer or its representative and plant Operators should participate in the testing and commission process and shall:

* Ensure this activity conducted by the supplier or contractor in coordination with Employer
* Conditionally accept site delivered equipments after inspection and check
* Accept fully or conditionally, if so, after system starts energy production

## Supplier or Contractor

The responsibility of Supplier or Contractor is to demonstrate that all equipment supplied/civil structures they constructed are functional, complying technical standards stipulated in the contract agreement between employer and the Supplier or Contractor. They shall,

* Ensure that all SMG or SWMG item components comply technical specifications
* Demonstrate that all installed SMG or SWMG equipment are functional.
* Manage equipment and test kits for field testing and commissioning.
* Document and submit testing and commissioning report to AEPC and Developer.

# Testing and Commissioning Preparation

## Team Composition

The field testing and commissioning task shall be carried out by or in the presence of representatives from at least following stakeholders.

|  |  |  |  |
| --- | --- | --- | --- |
| **S.N.** | **Name** | **Institution** | **Signature** |
| 1 | XXX | Supplier/Installer Company Representative |  |
| 2 | XXX | Developer or UC Representative |  |
| 3 | XXX | Employers Representative (Technical) |  |
| 4 | XXX | [Others] |  |

## List of Testing Equipments and Tools

It is the responsibility of employee or contractor/supplier to ensure tools and equipments are in place for field testing and commissioning purpose. Following measuring tools and equipments are suggested while conducting field level testing and verification by the technical team.

1. Digital Multi-meter
2. Clamp-on Power Analyzer
3. Three Phase Electrical Power Quality Analyzer
4. Ground Resistance Tester or Earth Tester and Megger
5. Measuring Tape
6. GPS meter
7. Magnetic Compass
8. Safety shoes, gloves and goggles

## Review of Documents

The scope of works under the contract agreement made between employer (AEPC) and employee (Private Company or ESCO) shall be reviewed prior to conduct inspection and testing of goods and services at the respective project sites. The quantity of goods and services under ‘schedule of supply’ of the contract agreement must fully comply in terms of their technical standards, specifications, quality test certificates, approved design/drawings and quantities. The field level testing and commissioning job is required to be conducted with the detailed understanding of equipments, design (goods and services) implemented at the site that are supposed to be reviewed through the available documents. The reference documents of the respective solar mini-grids are as follows.

* + Contract Agreement between employer and employee
  + Installation completion report submitted by the employee
  + Factory or Warehouse inspection report of goods
  + Salient Features of the implemented project

## System Commissioning Knowhow

The testing and commissioning team is supposed to do final installation checkout of mini-grid power generation and distribution system components. Component-wise warranty check, warranty claim procedures shall be understood and oriented to the system operator as well as local stakeholders. Inspection of outdoor and indoor wiring or electrical installation works to be thoroughly conducted. The generation system outdoor wiring behind Solar PV Module shall be well inspected, as with the junction boxes, combiner boxes, AC/DC disconnects, service panel, earthing and other items. The visual Inspection (Labels and Markings) including visually checking of PV modules, batteries, controllers, inverters and accessories, against cracks and other damages.

## Technical Loss Factors of Solar Mini-grid

The maximum theoretical energy output from solar mini-grid (name plate rating x peak sun hours) will never be produced in the field due to inefficiencies of and losses in the PV system, known as de-rating factors. Those losses in a solar PV system arise from weather factors, site constraints and voltage drop. Estimated loss for a solar mini-grid system depends on system design, component selection and site operating temperature and normally total loss is around 30%. Actual loss will be as per site conditions but typical losses are tabulate as follows.

| **Cause of Loss** | **Estimated Loss (%)** | **De-rating Factor** |
| --- | --- | --- |
| Temperature | 10% | 0.90 |
| Dirt | 3% | 0.97 |
| Manufacturer’s Tolerance | 3% | 0.97 |
| Shading | 2% | 0.98 |
| Orientation | 0% | 1.00 |
| Tilt Angle | 1% | 0.99 |
| Voltage Drop | 2% | 0.98 |
| Inverter and Power Conditioning | 5% | 0.95 |
| Loss due to irradiance level | 3% | 0.97 |
| Distribution & Transmission | 5% | 0.95 |
| **Total De-rating Factor** |  | **0.7** |

˭ x x

**Total De-rating Factor**

**Module Rated Power**

**Peak Sun Hour**

**Energy Yield**

# Testing and Commissioning Process

Testing and commissioning of solar mini-grid can be done by physical inspection, physical counting, name plate ratings, test certificates, real time or historical data stored in the installed power conditioning devices (MPPT controllers and Inverters) display, and measurement through electrical multi-meter, clamp-on power analyzer and power quality analyzer. Testing and commissioning of power generation station as well as power transmission and distribution system shall be carried out through available tools/equipments and visual inspection of implemented technologies. In addition to technical measurement and testing, it is also advisable to do observation of local environmental and social factors, system operation and management components of respective solar mini-grid project.

## Observation of General Site Condition

The general site conditions shall be observed also by referring to previously generated reports and through direct consultation with the local stakeholders.

* Access to the site for regular operation and maintenance
* Security of supplied and installed equipments and project ownership
* Site upkeep to ensure system maintaining in good working order
* Safety signage for its safe operation
* Fencing to protect from outside disturbances
* Water and waste management within or around power plant
* Environmental and social safeguard compliance
* Orientation provided to the energy users and operator for smooth operation

## Visual Inspection and observations

Observation shall be carried out whether the power generation system components installed and their configuration comply with the specifications offered. This includes name of the manufacturer, model, type, serial number, no. of components installed, labels & markings etc. for each component.

Similarly installation workmanship refers to whether the installations are done according to recently adopted standard quality practice or not. For instance this includes, if cabling is properly done or not, PV array installed free of any shadowing, optimum tilt and orientation, identical component used, avoid the use of long cables, accessible for cleaning, use of copper cable shoes, protection components etc.

## Component Compliance

**Major System Components Compliance and their Technical features:**

|  |  |  |  |
| --- | --- | --- | --- |
| **Major Parameters** | **Agreed Capacity/Size** | **Tested, Observed and Verified Results** | **Remarks** |
| Solar PV Array Size (kWp) | - | - | - |
| Battery Bank size (kWh) | - | - | - |
| PV Inverter Size (kW or kVA) | - | - | - |
| Battery Inverter Size (kW or kVA) | - | - | - |
| Inverter/Charger Size (kW or kVA) | - | - | - |
| Powerhouse size (m2) | - | - | - |
| Length of 3-Phase T&D Line | - | - | - |
| Length of 1-Phase T&D Line | - | - | - |
| Number of Size of Transformers | - | - | - |
| Numbers of Connected Households (HH) | - | - | - |
| Number of Connected Enterprise Loads | - | - | - |
| Number of Connected Public Institutions | - | - | - |
| Number of Street Lights | - | - | - |

## Technology and Workmanship Inspection

## Inspection of Solar PV Array

The installed PV modules and array shall be visually checked if there are any visual defects. At least following items should be evaluated during testing and commissioning phase:

* Conduct physical counting of installed PV modules and PV array installation arrangement
* Whether individual PV module’s glasses are broken
* No sharp objects are in contact with the PV module surfaces
* PV modules are not shaded by unwanted obstacles and; or foreign material
* Is corrosion along the cells’ bus-bar seen? The corrosion is caused by moisture intrusion thought the module back sheet.
* Hotspots testing (leading to back skin burning and safety issue or power loss higher than warranty limit)
* Check whether the back sheet is burn out
* Check if screws and mounting brackets are tight, adjust and tighten as necessary
* Inspection of Connector and Cables
* PV Module mounting structure and civil work foundation
* DC junction box or string monitoring box
* Lightening Arrestor and Surge Protection proper grounding arrangement
* Cable identification an cable routine inspection

## Inspection of MPPT Controller and Inverters

* Conduct physical counting of installed MPPT and Inverters
* Check physical condition of individual MPT controller and inverter
* Check whether the name plate ratings are in place or not
* Check the compliance of major electrical parameters of the installed devices
* Check whether the devices are installed as per manufacturers’ guideline
* Check for sufficient ventilation available around installed devices
* Check incoming/outgoing cables of the devices are properly tagged
* Check connection for phase sequence R, Y, B are in proper order (for 3-phase inverter)
* Check whether the auxiliary power cables are connected properly
* Check whether all cable terminations are done properly

## Inspection of Battery Bank

* Conduct physical counting of installed Batteries
* Check physical condition of individual Batteries
* Check whether the nameplate ratings are in place or not
* Check parallel strings for all connected power conditioning devices
* Check battery series and parallel cables, including battery fuse as per the design
* Check if screws, cable shoe and battery rack are in place or not
* Cable identification an cable routine inspection
* Check whether the auxiliary power cables are connected properly
* Check whether all cable terminations are done properly
* Check for sufficient ventilation available inside the installed battery room
* In case of vented lead acid batteries, sufficient ventilation is needed to remove battery gases as hydrogen is given off during charging and a concentration of more than 4% creates an explosion hazard. Ventilation also prevents excessive heat build up

## Inspection of Cable Size and connections

During system testing and commissioning it has to be ensured that the design and installation standard shall have considered following factors.

* Cables used in solar mini grid system should be sized such that overall voltage drop at STC between generation unit and power conditioning devices shall be <3%.
* The cables used for wiring DC section need to be selected to ensure that they can withstand the environmental, voltage and current conditions at which they may be expected to operate.
* Cable identification colors need to be implemented for all Positive, Negative and Ground conductors.
* The PV string cables need to be suitably rated such that they may safely carry the maximum possible fault current.

## DC Junction Box and Combiner Box

The testing and commissioning team shall visually inspect and conduct test as required to the following sections.

* If there is more than one string, the DC junction box is normally the point at which they are connected together in parallel.
* Junctions need to be made using high quality connectors, typically screw terminals. The box may also contain string fuses and test points.
* The DC junction box must be labeled as ‘PV array DC junction box’ and also labeled with ‘Danger’ contains live parts during daylight’. All labels must be clear, legible, located so as to be easily visible, and durably constructed and affixed to last.
* A readily accessible disconnection device shall be provided to isolate individual strings. Isolation shall be provided in both positive and negative string cables.
* Fabrication of the enclosure that are installed shall be from non-conductive material. All the metal casings must be earthed as per design document
* Positive and negative bus bars inside PV combiner box are adequately separated and segregated within the enclosure and/or by a suitably sized insulating plate, or separate positive and negative junction boxes.
* Cable and terminal layout such that short-circuits during installation and subsequent maintenance are extremely unlikely.
* String fuses or DC circuit breakers shall be used
* Surge protection devices (SPDs) shall be available inside the box as per design document

## System Earthing

The system earthing location shall be chosen as per the installation drawing approved by the employer. The earth conductors need to be properly connected to metal parts of all structures. All array frames, battery rack and structure shall be earthed as well as bonded properly as per the design. The testing and observation of earthing of exposed conductive parts (e.g. PV array frame) as well as electrical system earths shall be carried out.

## Lightning and Surge Protection

The lightning protection system can’t stop occurrence of lightning in the particular site, rather it will control the path of the lightning after it hits. If solar mini-grid systems are poorly grounded and poorly protected without surge protection device arrangements, the majority of operational stage technical problems will be seen because of lightning strikes. Lightning can cause damage either from a direct strike or from surges due to a nearby strike, for example, some section of power distribution network. Due to lightning strike, surges may be induced on both the PV array conductors and the AC cables leading to the powerhouse and control room. The inspection of equipment ground and electrical ground shall be carried thoroughly during system testing and commissioning phase.

## Set up for Remote System Monitoring

* Conduct physical counting and rating of devices provisioned for remote monitoring
* Check physical condition of remote monitoring devices including Wifi router, if available
* Check whether the name plate ratings are in place or not
* Check if screws and mounting brackets are tight, adjust and tighten as necessary
* Inspection of Connector and Cables for power and communication devices
* Check availability of Mobile Data or Internet Service Provider (ISP) nearby the powerhouse location
* Check the type of technology that has been installed for technical monitoring, for example: Web-portal of installed inverter/power conditioning devices or any other topology

## Verification of Documents

While conducting testing and commissioning the technical team has to ensure following document verifications but not limited to:

* Technical data sheet of the major system components, respective certificates, warranty documents. The major system components are solar PV module, MPPT controller, PV inverter, battery inverter, inverter/charger, energy storage battery, distribution transformer, energy meters, system controller or synchronizing devices etc.
* In case of system components tested by Renewable Energy Test Station (RETS) Nepal, of which Product Introductory Test (PIT) certificates submitted during bidding stage, the Random Sampling Test (RST) test certificate issued by RETs shall be checked.
* Project as built design, Layout and Single line diagram
* Installation and operation manual for major components of solar mini grid systems
* Operation and maintenance manual for the system with clear information on preventive maintenance, frequency of maintenance and procedure of maintenance
* Safety manual, emergency shutdown procedure of installed technology
* Training manual both in English and Nepali language to be provide at powerhouse for operator’s reference
* Spare parts availability and list of spare parts

## Electrical Measurement

Electrical measurement shall be carried with the help of clamp-on power analyzer or multi-meter, at the different components input & output sides. In order to conduct overall power generation system’s energy and power balance testing, it is suggested to log at least 2/3 days testing with the help of 3-phase power analyzer. During testing and commissioning phase, electrical parameters monitoring and verification shall be carried out for minimum of the following sections:

* PV Array voltage and current
* PV MPPT controller instantaneous voltage and current
* Battery and Battery bank instantaneous voltage/current
* Inverter instantaneous Input and output voltage/current
* System loading during peak, off-peak and normal hours
* Interconnection continuity
* Interconnection polarity
* Grounding connection
* Cable insulation
* Voltage drop measurement
* Grounding Resistance
* Load and load type etc.

AEPC technical expert considers the above-mentioned types of measurements during commissioning for solar mini-grid projects as are according to best practice. The measurement of these parameters ensures the proper functioning of components and ensures the safety approaches considered in the design. However, the current guideline only mentions the electrical measurements but does not specify the pass/fail criteria for the measurement. The technical expert understands that some of the parameters mentioned above shall be verified against the designed value in line with the Schedule of Supply, being specific to the project. The technical expert will investigate further and include verification criteria for the relevant measurements during tender preparation of mini-grid projects.

## Mini-grid System Performance Verification

Once the electrical measurement has been successfully completed, solar mini-grid system performance check must be performed, at given weather condition, to verify whether the complete system is working as per the design condition and project output requirements. This will also include testing and monitoring of daily energy yield and overall system efficiency. A trial run and commissioning of the system shall be conducted for 2-3 days to evaluate system performance during both day (charging cycle) and night (discharging cycle). The analysis of the day time business, enterprise and public power/energy demands as well as evening peak and night time energy consumption pattern shall be monitored.

## Mini-grid System Protection and Safety

The protection system incorporated in the solar and solar power generation system as well as power distribution system shall be thoroughly inspected and monitored. From the beginning, the designer and installer team must consider the potential hazards carefully, and systematically devise methods to minimize the risk. This will include mitigating potential hazards present during and after the installation phase

## Inspection and Testing of Solar PV DC Section or Circuit

Inspection and testing of DC circuits, particularly testing of PV array circuits requires special considerations. The following table will cover the inspection and testing of PV array circuits and documentation to be provided.

| **PART- 1: PV Array Installation Checklist** | | |
| --- | --- | --- |
| Contractor/Supplier Name and Address: |  | |
| Signature: |  | |
| Project Site Address: |  | |
| Testing & Commissioning Date: |  | |
| Reference, if any: |  | |
| **General Installation (Electrical)** | | **Tick (🗸)** |
| Equipment comply with standards, correctly selected and not damaged | |  |
| Equipment accessible for operation, inspection and maintenance | |  |
| Equipment and accessories correctly connected | |  |
| Particular protective measures for special location | |  |
| Conductors connected and identified | |  |
| Conductors selected for current carrying capacity and voltage drop | |  |
| Conductors routed in safe zone or protected against mechanical damage | |  |
| **General Installation (Mechanical)** | | **Tick (🗸)** |
| Ventilation provided behind array to prevent overheating / fire risk | |  |
| Array frame and material corrosion proof | |  |
| Array Structure and frame correctly fixed and stable | |  |
| Cable entry weatherproof | |  |
| **Protection against Overvoltage / Electric shock** | | **Tick (🗸)** |
| Live parts insulated, protected by barrier / enclosure, placed out of reach | |  |
| Array frame equi-potential bonding present (only relevant if required) | |  |
| Surge protection devices present | |  |
| Frame correctly integrated with existing lightning protection system (LPS) installation | |  |
| **DC System** | | **Tick (🗸)** |
| Physical separation of AC and DC cables | |  |
| DC switch disconnect fitted | |  |
| DC cables - protective and reinforced insulation (only relevant if required) | |  |
| All DC components rated for operation at max DC system voltage (STC Voc x 1.25) | |  |
| PV strings fused or blocking diodes fitted | |  |
| **Labeling and Identification** | | **Tick (🗸)** |
| General labeling of circuits, protective devices, switches and terminals | |  |
| PV system schematic displayed on site | |  |
| Protection setting and installer details displayed on site | |  |
| Emergency shutdown procedure displayed on site | |  |
| DC Isolator / Junction boxes suitably labeled | |  |
| Signs and labels suitably affixed and durable | |  |

| **PART- 2: PV Array Commissioning Test Sheet** | | | | | | |
| --- | --- | --- | --- | --- | --- | --- |
| Contractor/Supplier Name and Address: | |  | | | | |
| Signature | |  | | | | |
| Installation Address: | |  | | | | |
| Test Date: | |  | | | | |
| Description of work under test: | |  | | | | |
| **String** |  | **1** | **2** | **3** | **4** | **5** |
| PV Array | PV Module |  |  |  |  |  |
| Quantity |  |  |  |  |  |
| Array Parameter | Voc (STC) |  |  |  |  |  |
| Isc (STC) |  |  |  |  |  |
| Protective Device | Type |  |  |  |  |  |
| Rating (A) |  |  |  |  |  |
| DC Rating (V) |  |  |  |  |  |
| Capacity (kA) |  |  |  |  |  |
| Wiring | Type |  |  |  |  |  |
| Phase (mm2) |  |  |  |  |  |
| Earth (mm2) |  |  |  |  |  |
| String Test | Voc (V) |  |  |  |  |  |
| Isc (A) |  |  |  |  |  |
| Sun |  |  |  |  |  |
| Polarity Check |  |  |  |  |  |  |
| Earth continuity (where fitted) |  |  |  |  |  |  |
| Comments: | | | | | | |

## Operation and Maintenance

The testing and commissioning team shall understand and provide guiding inputs to the post installation plan of implemented solar mini-grid project. One of the important aspects is keeping critical spare parts in stock (For example: fuses, connectors, cables, inverter parts such as circuit board etc) and analyze the maintenance provision suitable for the site. Likewise, the operation and maintenance manual (in English and Nepali) shall be kept in the powerhouse and shall be available to the system Operator. In order to act quickly in the emergency situation, all the labels must be clear, easily visible, constructed and affixed to last and remain legible for the lifetime of the system. Observation and inspection of following information and documents shall be conducted.

1. Copy of the basis system information
2. Single line diagram of electrical schematic
3. A checklist of what to do in case of system failure
4. Shutdown/isolation and startup procedures
5. Maintenance and cleaning recommendations (if any)
6. Copy of the manual and data sheets for the major system components
7. Table of inverter protection settings (under/over voltage, under/over frequency, etc)
8. Procedure for verifying correct system operation
9. Warranty Information

In addition to above listed information and plan for system operation and maintenance, the following types of maintenance activities shall be referred for the various types of maintenance.

* *Preventative Maintenance:* Solar PV Module cleaning, Prevention from animals (upkeep data acquisition & monitoring), Upkeep power generation system (site maintenance)
* *Corrective Maintenance:* On-site Monitoring, Critical reactive repair etc.
* *Condition-based Maintenance:* Active monitoring (remote/onsite options), Warranty enforcement, equipment replacement

# APPENDICES

# Appendix- 1: Information About solar mini-grid project

|  |  |
| --- | --- |
| Project Name: |  |
| Province: |  |
| District: |  |
| Rural Municipality: |  |
| Ward No and Tole: |  |
| GPS Coordinates (Latitude, Longitude): |  |
| Users’ Committee (UC) Chairperson Name: |  |
| UC Chairperson Address: |  |
| UC Chairperson Telephone: |  |
| Email ID (if any): |  |
| Supplier/Contractor/Employee Name: |  |
| Installation Completion Date: |  |
| Date of Testing and Commissioning: |  |
| Testing and Commissioning Team Members Name and Contact Number: | * + - 1. ………………………. …………………………….       2. ………………………. …………………………….       3. ………………………. ……………………………. |
| Remarks: | |

# Appendix- 2: System Component Checklist

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **S.N.** | **Component Descriptions** | **Size** | **Quantities as per BoQ** | **Quantities Verified** |
| 1 | Solar PV Modules | ….. Wp | - | - |
| 2 | Solar Batteries | …... AH, ……V | - | - |
| 3 | MPPT Controllers | …..Amp,……V | - | - |
| 4 | Solar Inverters, 1-Phase | ……kW or kVA | - | - |
| 5 | Solar Inverters, 3-Phase | ……kW or kVA | - | - |
| 8 | Controlling/Synchronizing unit | …… | - | - |
| 9 | Distribution Transformers | ……kVA | - | - |
| 10 | Energy Meters, 1-Phase | …… Amp, ….V | - | - |
| 11 | Energy Meters, 3-Phase | …… Amp, ….V | - | - |
| 12 | Street Lights | ……Watt | - | - |
| 13 | Household LED Lights Small | …… Watt | - | - |
| 14 | Household LED Lights Large | …… Watt | - | - |
| 15 | MCBs | ….. Amp,…..V | - | - |
| 16 | MCCBs | …...Amp,…..V | - | - |
| 17 | Distribution Poles | 8 meter | - | - |
| 18 | Distribution Poles | 9 meter | - | - |
| 19 | Transmission Poles | 11 meter | - | - |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
| **NOTE:** Please include all the major system components in order to do field verification and testing. | | | | |

# Appendix- 3: Site Observation and Commissioning Checklist

Following checklist is prepared to conduct site inspection and commissioning of Solar Mini-grid systems.

1. **Solar PV Power Plant:**

| **Solar PV Module/Array** | | |
| --- | --- | --- |
| Brand/Model/Make: |  | |
| Size of Individual Solar PV Module (Watt-Peak): |  | |
| Total Number of PV Modules: |  | |
| Total Size of Installed Solar PV Plant (kW): |  | |
| Are all the installed PV Modules are in good physical condition (no broken glass or cell, no discoloration, frame not damaged) | Yes ( ) No ( ) | |
| Technical Specifications of Individual PV Modules | Mono Crystalline ( ) Poly Crystalline ( )  Mono Perc ( ) Thin-film ( )  Number of Cells/Module: ……  Nominal Power: ……. Wp  Module Efficiency: ……. %  Open Circuit Voltage (Voc): ………Volt  Short Circuit Current (Isc): ……….. Amp  Maximum Power Voltage: ……….. Volt  Maximum Power Current: ………… Amp | |
| Type of Solar PV Module Installation | Ground Mounted ( )  ……….. kWp | Roof Mounted ( )  ……….. kWp |
| Gap between two consecutive Installed PV Modules? | Yes ( ) …..… mm | No Gap ( ) |
| Orientation of PV array and Tilt Angle | Orientation (……..…………) Tilt Angle (…….) | |
| Observe Shading on the Solar PV Array, if any | Yes ( ) | No ( ) |
| Tightening of Cable Glands and Connectors | Good ( ) Satisfactory ( ) Poor ( ) | |
| Positioning and fixation of string combiner boxes for connection of PV strings | Good ( ) Satisfactory ( ) Poor ( ) | |
| Are Cables neatly and professionally held in place? | Yes ( ) Partly ( ) No ( ) | |
| Are all the electrical boxes accessible and placed in the appropriate locations? | Yes ( ) Partly ( ) No ( ) | |
| Are all the hardware and PV support structures Galvanized? | Yes ( ) No ( ) Indicate Non-GI Items | |
| Status of Solar PV Array Grounding? | Good ( ) Satisfactory ( ) Poor ( ) | |
| Proper grounding of all other metallic surfaces that might possibly become energized (conduit, combiner boxes, disconnect enclosures, etc.) | Yes ( ) No ( ) | |
| Are appropriate sign/label posted on Equipments? | Yes ( ) No ( ) | |
| Is the protective fencing installed and will not shade PV array/modules? | Yes ( ) No ( ) | |
| **Document:** Please mention Product Technical Specification, User's Manual, Drawing if exist at the site  (Technical document is important for the operation of the plant, particularly for the system operator)  ………………………………………………………………………………………………………  ……………………………………………………………………………………………………… | | |

1. **Energy Storage Battery System:**

| **Solar Battery and Battery Bank** | | |
| --- | --- | --- |
| Brand/Model/Make and Type of Batteries: |  | |
| Size of Individual Batteries (Amp-hour, Voltage): |  | |
| Total Number of Batteries installed: |  | |
| System Voltage of the installed Battery Bank (Volt): |  | |
| Total Size of Installed Battery Bank (kWh): |  | |
| Type of Batteries | Lead Acid ( ) | Li-Ion ( ) |
| Number of Parallel Strings Connected: |  | |
| Total Size (kWh) of each string, if it is string type: |  | |
| Technical Specifications of Individual Batteries | Brand/Model: ………………………………….  VRLA Gel ( ) AGM ( )  Flooded LA ( ) Li-Ion ( )  No of Cycles @ 80% DoD: ………………… | |
| Are all the batteries tied with Battery Rack or Stand? | Yes ( ) No ( ) | |
| How are batteries connected in Series & Parallel? | Battery Cable Shoe ( ) No Battery Cable Shoe ( )  Standard cable & shoe from Manufacturer ( ) | |
| Are all the battery ratings installed at the site meets the required specification? | Yes ( ) No ( ) | |
| Spot measured battery voltage (sample),  *may need to disconnect from the system* | B1: ….Volt B2: ….Volt  B3: ….Volt B4: ….Volt | |
| **Document:** Please mention Product Technical Specification, User's Manual, Drawing if exist at the site  (Technical document is important for the operation of the plant, particularly for the system operator)  ………………………………………………………………………………………………………….  …………………………………………………………………………………………………………. | | |

1. **Solar Charge Controller/MPPT Controller:**

| **MPPT Solar Charge Controller** | |
| --- | --- |
| *If the MPPT Solar Charge Controllers are In-built in the PV Inverter, this section is not required to fill out.* | |
| Are MPPT Controllers In-built in the PV Inverter? | Yes ( ) No ( ) |
| Size of Individual MPPT Controller (Ampere/kW): |  |
| Total Number of MPPT Controllers installed at the Site: |  |
| System Voltage of MPPT Controller (Volt): |  |
| Total Size of Installed MPPT Controller (kW): |  |
| Total energy Yield (kWh), if display facilitates/records: |  |
| Technical Specifications of Individual Charge Controller/MPPT | Brand/Model/Make: …………………….  Charger Peak Efficiency: …….. %  Operating Voltage: 12, 24, 48, 60, 120, 240  Rated Charge Current: ………  Status Display: ………………….. |
| No of days Data Logging in the controller | ……….. Days |
| **Document:** Please mention Product Technical Specification, User's Manual, Drawing if exist at the site  (Technical document is important for the operation of the plant, particularly for the system operator)  ………………………………………………………………………………………………………….  …………………………………………………………………………………………………………. | |

1. **Solar Inverters and Power Conditioning Units:**

| **Solar Inverter (s)** | |
| --- | --- |
| Type of Installed Inverter or Power Conditioning: | ( ) Solar Inverter/Chargers  ( ) String Inverters having PV & Battery Inverters |
| 1. **Solar Inverter/Charger Type Configuration** | |
| Inverter-Charger Brand/ Model/Make: | …………….. |
| Size of Individual Inverters (kW or kVA): | …………….. |
| Rated AC Output Voltage | 3-Phase AC ( ) 1-Phase AC ( ) |
| Inverter Peak Efficiency indicated in the Nameplate | …………..% |
| DC disconnect installed and in accessible place? | Yes ( ) No ( ) |
| AC disconnect installed and in accessible place? | Yes ( ) No ( ) |
| Are all the inverter ratings installed at the site meets the required specification? | Yes ( ) No ( ) |
| Are all the Inverters connected according to the Manufacturer Installation Guidelines? | Yes ( ) No ( ) |
| Is the Internet connection operational for Remote System Monitoring Purpose? | Yes ( ) No ( ) |
| All equipment and parts are labeled as required? | Yes ( ) No ( ) |
| Operation and maintenance instructions available? | Yes ( ) No ( ) |
| 1. **String Inverters Type Configuration (having PV Inverters & Battery Inverters)** | |
| **Type of Inverter Inspected** | **PV Inverter ( )** |
| Brand/ Model of Inverter | …………….. |
| Size of Individual Inverters (kW or kVA) | …………….. |
| AC Output Voltage | 3-Phase AC ( ) 1-Phase AC ( ) |
| Inverter Efficiency indicated in the Nameplate | …………..% |
| DC disconnect installed and in accessible place? | Yes ( ) No ( ) |
| AC disconnect installed and in accessible place? | Yes ( ) No ( ) |
| Are all the inverter ratings installed at the site meets the required specification? | Yes ( ) No ( ) |
| Are all the Inverters connected according to the manufacturer Installation Guidelines? | Yes ( ) No ( ) |
| Is the Internet connection operational for Remote System Monitoring Purpose? | Yes ( ) No ( ) |
| All equipment and parts are labeled as required? | Yes ( ) No ( ) |
| Operation and maintenance instructions available? | Yes ( ) No ( ) |
| **Type of Inverter Inspected** | **Battery Inverter ( )** |
| Brand/ Model of Inverter | …………….. |
| Size of Individual Inverters (kW or kVA) | …………….. |
| AC Output Voltage of Individual Inverter(s) | 3-Phase AC ( ) 1-Phase AC ( ) |
| Output Voltage of Overall System | 3-Phase AC ( ) 1-Phase AC ( ) |
| Inverter Efficiency indicated in the Nameplate | …………..% |
| DC disconnect installed and in accessible place? | Yes ( ) No ( ) |
| AC disconnect installed and in accessible place? | Yes ( ) No ( ) |
| Are all the inverter ratings installed at the site meets the required specification? | Yes ( ) No ( ) |
| Are all the Inverters connected according to the manufacturer Installation Guidelines? | Yes ( ) No ( ) |
| Is the Internet connection operational for Remote System Monitoring Purpose? | Yes ( ) No ( ) |
| All equipment and parts are labeled as required? | Yes ( ) No ( ) |
| Operation and maintenance instructions available? | Yes ( ) No ( ) |
| *Elaborate system controlling unit installed at site for power conditioning (Name/Brand/Size/Model)* |  |

1. **Inspection of Powerhouse and Toilet/Rest Room:**

| **Powerhouse and Toilet** | |
| --- | --- |
| Location of Powerhouse |  |
| External Dimension of Powerhouse  (Length, Breadth, Area) | L: … ….. meter, B: … ….. meter  Area: ……………….. m2 |
| Powerhouse Wall Thickness | ……………….. mm |
| Construction material of Powerhouse | Brick Masonry ( ) Stone Masonry ( ) |
| Type of Powerhouse Roof | Metal Sheet ( ) RCC Flat ( ) |
| Type of powerhouse roof Ceiling | False ceiling ( ) No False Ceiling ( ) |
| Numbers and sizes of Rooms inside Powerhouse |  |
| Number, type and size of Doors used in Powerhouse |  |
| Number, type and size of Windows used in Powerhouse |  |
| Number and size of Ventilations used in Powerhouse |  |
| Color of Powerhouse external plaster and quality |  |
| Color of Powerhouse internal plaster and quality |  |
| Color of All Wood works paint and quality |  |
| Is Fire Extinguisher Mounted inside powerhouse? | Yes ( ) No ( ) |
| Number, type and size of Fire Extinguisher |  |
| Are Safety Signs such as electric shock, acid burn, no smoking area, explosion visible inside Powerhouse? | Yes ( ) No ( ) |
| Is the Toilet or Rest room attached to PH or Separate? | Attached inside PH ( ) Separate ( ) |
| Toilet construction size (Length, Width and Height) | L: … ….. Meter, B: … ….. meter, H:…. |
| Number and Size of Toilet Door |  |
|  |  |
|  |  |
| Water supply pipes & tank fitted | Yes ( ) No ( ) |
| **Remarks:** | |

1. **Inspection of Transmission and Distribution Line:**

|  |  |  |  |
| --- | --- | --- | --- |
| Total Number of electricity distribution poles | …..meter  (…..…) | …. meter (….…...) | ….. meter (….…..) |
| Are all MS Poles Galvanized? |  |  |  |
| Quantity of ACSR Conductors in Distribution Line | Weasel  (…..…Km) | Rabbit  (…..…Km) | Dog  (…..…Km) |
| Indicate other types of conductors (ABC) if so | …. Sq Km  (total..…Km) | …. Sq Km  (total..…Km) | …. Sq Km  (total..…Km) |
| Total distance of 3-phase distribution line, one-way | ………………… Km | | |
| Total distance of 1-phase distribution line, one-way | ………………… Km | | |
| What is the observed minimum ground clearance of conductor in various T&D routes? | …………………. meter | | |
| Transformer Ratings, if exist within T&D line | ………….. kVA, ………..Phase, ……/….Voltage | | |
| Number and Location of Transformers | ……………………………………….. | | |
| Transformer Connections | Primary ……………., Secondary…..…….. | | |
| Transformer Standard (IEC or Other national) | ……………………………………….. | | |
| Transformer Cooling System | ……………………………………….. | | |
| Percentage Impedance | …………………. % | | |
| Are the Transformer Neutral, LA, Body separately Earthed? | Yes (…..…) No (…..…)  Observation of Transformer Earthing: ……………………………………………………………………………………………………………… | | |
| Any Trees or Conductors found touching to the line? |  | | |
| Number and Location of Lightening Arrestors |  | | |
| Are all LA Grounded as per norms and standard? |  | | |
| Number and Location of Stay Sets |  | | |
| Number of Street Lights within the service area, if any |  | | |
| Brand and Wattage of each street lights |  | | |
| **Remarks:** | | | |

1. **Inspection of End Users Premises:**

|  |  |
| --- | --- |
| **Observation and Monitoring at End Users Premises** | |
| No of Households connected to the Mini-grid System |  |
| Brand and Nameplate Rating of Energy Meters Installed |  |
| Type of Energy Meters in stalled at end use premises | Static Meter ( ) Pre-paid Meter ( ) |
| Brand and Nameplate Rating of MCBs |  |
| Average length of service wires for Households | ...…… meter |
| Brand and Nameplate Rating of small LED Light |  |
| Brand and Nameplate Rating of large LED Light |  |
| Number of Small LED Lights for Households |  |
| Number of Large LED Lights for Households |  |
| Number and Type of 1-Phase Business Loads  (connected or planned) | a)  b)  c) |
| Number and Type of 3-Phase Industrial Loads  (connected or planned) | a)  b)  c) |
| Mention Anchor Customer of the Mini-grid, if any |  |
| Mention Public Institution demand or connections, if any | a)  b)  c) |
| **Remarks:** | |

1. **Performance Testing:**
   1. The power and energy output of solar PV array and shall be measured. Alternatively, site observations can be made in the controlling devices or inverters that are integrated in the system.
   2. Record or observe daily energy production and energy consumption pattern of the system by using 3-phase data logger.
   3. Conduct power distribution system voltage drops at any line end which shall not exceed 10% of nominal value.
2. **Final Notes**

Brief notes and observations made at different stages of inspection and testing shall be summarized.

| **Notes and Observations** |
| --- |
| 1. Component compliance |
| 1. Performance verification |
| 1. Workmanship Performance |
| 1. Site cleanup works |
| 1. Others, if any |