EWA

هيئة الكهرباء والماء

Electricity & Water Authority

Kingdom of Bahrain

Technical Expert to develop grid connection guidelines and standards for the Kingdom of Bahrain

Distributed Solar PV Connection Guidelines for Customers and Installers

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1 INTRODUCTION

1.1 Scope

These Guidelines provide information meant for Bahraini Residents, Consultants and Contractors on the essential aspects which have to be taken into consideration in order to connect the Solar Photovoltaic (PV) plants to the Low Voltage or Medium Voltage Distribution Network.

It applies to the planning, execution, operation and modification of these power generating plants that are usually called PV or Solar PV Plants.

The basic principles of this kind of plants, along with the illustration of the connection process are provided for the Bahrain specific conditions.

Thus, this guide shall serve as a basis for EWA and for the Customer or his appointed agent in the planning and decision-making process.

The technical aspects are not treated here, but separately in the “Standards for Solar PV Systems to be connected in parallel with the distribution networks of the Kingdom of Bahrain” (hereafter referred to as “*the Standards*”), which represents the main reference document for the definition of the requirements these generating facilities have to comply with in order to be connected to the Distribution Network.

This document provides additional information on the photovoltaic technology and equipment, and on the process for getting the Solar PV systems connected to the distribution network. The annex provides Applicants with a template of the Application Form and instructions about the Solar PV plant documentation that shall be submitted when applying. The annex also includes a FAQ section: these FAQs provide the reader with additional information and clarifications regarding the different aspects of the photovoltaic technology and the implementation of the Solar PV systems as dispersed generators connected to the distribution network.

1.2 Definitions

The most relevant definitions for the present Guidelines are listed below.

AC module – PV module with an integrated inverter in which the electrical terminals are AC only

Active power (P) – Under periodic conditions, mean value, taken over one period, of the instantaneous product of current and voltage expressed in W. Under sinusoidal conditions, the active power is the real part of the complex power.

Apparent power (S) – Product of the r.m.s. voltage between the terminals of a two-terminal element or two-terminal circuit and the r.m.s. electric current in the element or circuit expressed in VA. Under sinusoidal conditions, the apparent power is the modulus of the complex power.

Application – Is submitted in order to get a Solar PV system connected to the Distribution Network.

Cable type – Description of a cable to enable its rating and suitability for a particular use or environment to be determined (Note: In many countries this is done via a code number e.g. “H07RNF”)

Connection Agreement – Stipulates the terms and conditions for the connection and operation of the Solar PV plant into the Power Distribution System of EWA.

Consultant – Is a Solar PV Consultant certified in order to carry out the design of the Solar PV plants.

Contractor – Is a Solar PV Contractor certified in order to install the grid connected Solar PV plants.

Current – unless stated otherwise, current refers to the root-mean-square value of phase current.

Data sheet – Basic product description and specification (Note: Typically one or two pages, not a full product manual)

Distribution system / network – Is the medium or low voltage electricity grid for supplying electricity to the end consumers; for the scope of the present document and in accordance with international standards:

- A Low Voltage (LV) network is a distribution network with nominal voltage lower than 1kV AC or 1.5 kV DC. The LV network nominal voltage of the Kingdom of Bahrain is 400/230V.
- A Medium Voltage (MV) network is a network with nominal voltage included in the range from 1kV AC (1.5 kV DC) up to 35 kV. The MV network nominal voltage of the Kingdom of Bahrain is 11kV.

Final Authorisation – Is issued by EWA after the Final Inspection of the Solar PV plant.
Generating plant – An indivisible set of installations which can generate electrical energy into the distribution network and is composed of generating units, circuits and auxiliary services.
Global horizontal irradiance (GHI) – Direct plus diffuse irradiance incident on a horizontal surface expressed in W/m^2
Grid Connection – The connection of a Solar PV plant to the electrical grid.
Grid Connection fee – The fee to be paid for the connection of a Solar PV plant to the electrical grid.
$I_{MOD\_MAX\_OCPR}$ – PV module maximum overcurrent protection rating determined by IEC 61730-2 (Note: This is often specified by module manufacturers as the maximum series fuse rating).
In – the nominal rating of an overcurrent protection device
In-plane irradiance (Gi or POA) – The sum of direct, diffuse, and ground-reflected irradiance incident upon an inclined surface parallel to the plane of the modules in the PV array, also known as plane-of-array (POA) irradiance. It is expressed in W/m^2.
Interface Protection (IP) – The electrical protection required to ensure that either the generating plant and/or any generating unit is disconnected for any event that could impair the integrity or degrade the safety and reliability of the distribution network.
Inverter – Electric energy converter that changes direct electric current to single-phase or polyphase alternating current.
Irradiance (G) – Incident flux of radiant power per unit area expressed in W/m^2.
Irradiation (H) – Irradiance integrated over a specified time interval expressed in kWh/m^2.
$I_{SC\ ARRAY}$ – the short circuit current of the PV array at Standard Test Conditions (STC), and is equal to:

$$I_{SC\ ARRAY} = I_{SC\ MOD} \times S_A$$

where S_A is the total number of parallel-connected PV strings in the PV array
$I_{SC\ MOD}$ – the short circuit current of a PV module or PV string at Standard Test Conditions (STC), as specified by the manufacturer in the product specification plate (as PV strings are a group of PV modules connected in series, the short circuit current of a string is equal to $I_{SC\ MOD}$)
$I_{SC\ S\text{-}ARRAY}$ – the short circuit current of a PV sub-array at Standard Test Conditions (STC), and equal to:

$$I_{SC\ S\text{-}ARRAY} = I_{SC\ MOD} \times S_{SA}$$

where S_{SA} is the number of parallel-connected PV strings in the PV sub-array
Main electricity meter – Is the device installed at the POC and which measures the amount of electric energy actually exchanged by the customer with the distribution network.
Network – Plant and apparatus connected together in order to transmit or distribute electrical power, and operated by EWA.
Permit – A permit for the purpose of constructing a Solar PV plant.
Point of Connection or POC – Is the location at which a solar PV generating plant is connected to the distribution network and where the main electricity meter is installed.
PV array – Assembly of electrically interconnected PV modules, PV strings or PV sub-arrays.
PV cell – Most elementary device that exhibits the photovoltaic effect, i.e. the direct non-thermal conversion of radiant energy into electrical energy.
PV module – Smallest complete environmentally protected assembly of interconnected PV cells.

PV generation meter – Is installed at the output point of the Solar PV generating plant in order to measure the total energy produced.
PV string – A circuit of one or more series-connected modules.
PV string combiner box – A box where PV strings are connected which may also contain overcurrent protection devices, switch-disconnectors, monitoring equipment, etc.
PV sub-array – A subset of a PV array formed by parallel-connected PV strings.
Protective earthing – Earthing of a point in equipment or in a system for safety reasons.
Connection Process – The set of tasks (which may be of either administrative or technical nature) necessary to develop and get a Solar PV system connected to the distribution network.
Producer – Any entity authorised to produce electricity be means of the solar PV generating plant.
Reactive Power – Represents the imaginary component of the apparent power, usually expressed in kilovar (kVAr) or Megavar (MVAr).
Residual current device (RCD) – is a sensitive safety device that switches off when the residual current exceeds the operating value of the device
Residual current monitor (RCM) – device or association of devices which monitors the residual current in an electrical installation, and which indicates a fault when the residual current exceeds the operating value of the device or when a defined step change is detected
S_A – total number of parallel connected strings in a PV array
S_{SA} – total number of parallel connected strings in a PV sub-array
Standard test conditions (STC) – The reference conditions used for the testing and rating of photovoltaic cells and modules:

a) PV cell temperature of 25 °C;
b) Irradiance in the plane of the PV cell or module of 1000 W/m^2; and
c) Light spectrum corresponding to an atmospheric air mass of 1,5.

Switch-disconnector – Mechanical switching device capable of making, carrying and breaking currents in normal circuit conditions and, when specified, in given operating overload conditions. In addition, it is able to carry, for a specified time, currents under specified abnormal circuit conditions, such as short-circuit conditions. Moreover, it complies with the requirements for a disconnector (isolator).
Testing – implementation of measures in an electrical installation by means of which its effectiveness is proved (Note: It includes ascertaining values by means of appropriate measuring instruments, said values not being detectable by inspection)
Verification – all measures by means of which compliance of the electrical installation to the relevant
standards is checked
Voltage - Unless stated otherwise, voltage refers to the root-mean-square value of phase-to-phase voltages.

1.3 Reference documents

The following documents can be downloaded from (*EWA or other website to be specified*):

[1] EWA – Standards for Solar PV Systems to be connected in parallel with the distribution networks of the Kingdom of Bahrain
[2] EWA – Regulations for Electrical Installations (Second edition, 2004)
[3] Fire safety recommendations
[4] Safety of People recommendations
[5] Design and operation recommendations
[6] Impact on Aviation
[7] Inspection and Testing Guidelines

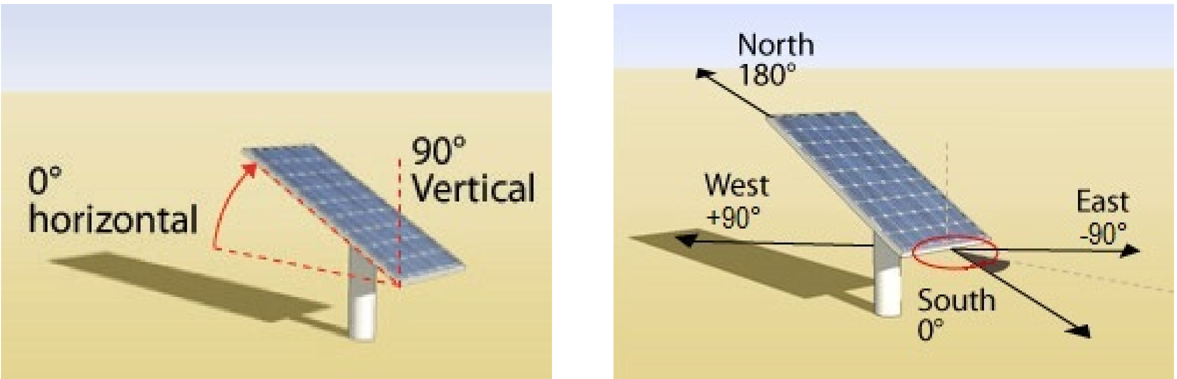
[8] Inspection and Testing Checklists
[9] Eligibility requirements for Solar PV equipment
[10] List of Solar PV eligible equipment
[11] Minimum requirements for the consultants and contractors

2 THE SOLAR PV SYSTEM

2.1 Orientation and Inclination of PV modules

There are several factors to be accounted for when planning to install photovoltaic panels on rooftops. Considering the geometry of the PV array, these factors are (see Figure 1):

- Orientation of PV modules to the sun;
- Inclination (tilt) angle of PV modules; and
- Shadowing from objects or other buildings.



Inclination (tilt) of a PV module *Orientation (azimuth) of a PV module*

Figure 1 – Orientation and inclination of the PV panels

The favourable orientation (azimuth) for fixed solar cells in Bahrain throughout the year is South (0° S) with an inclination (tilt) of about 24° with respect to the horizontal plane. This allows an average annual irradiation on a horizontal plane of about 2100 kWh/m²yr for Bahrain[1] when both the direct and diffused radiation are considered, which means about 1500÷1800 kWh/yr per kWp installed.
Small variations around these values do not significantly affect the production. For instance, an energy reduction not greater than 5% can be noticed by maintaining a South orientation and varying the tilt from 5° (this value to be raised to 10° to allow a better cleaning) to 40°. It is also possible to stay below a 5% loss by varying the azimuth of PV modules from -60° to +60°, if the tilt is maintained at 24°.
It is essential to avoid any shadows on the PV modules, because this can cause a substantial drop in the system performance. In contrast to solar thermal collectors, any shadow on a PV array causes a significant reduction of the power produced. Furthermore, especially in Bahrain, where the beam fraction of the solar radiation is high, partial shadowing on PV modules causes strain on shadowed PV cells which may, in turn, cause local temperature escalation (hot-spots) and may thus compromise the durability and safety of these components.
It is important that PV modules are kept clean and to avoid deposits of dirt and dust, since these reduce the efficiency of these components. Bahrain is in a region prone to dusty desert environments and frequent dust storms, therefore, it is recommended to clean the PV system as to avoid dust, sand and dirt accumulation. A flatter position of PV modules may increase the deposits

[1] Data from the European Joint Research Centre – Photovoltaic Geographical Information System (PVGIS)

on PV modules and render their cleaning and washing more difficult, especially in case of large surfaces. It is therefore recommended to adopt a minimum tilt angle of at least 10°.

In a building, PV modules are usually installed on the roof in order to reduce shadowing and also to exploit surfaces often left unused. When possible, PV modules may be integrated in the building structure as Building Integrated Photovoltaic (BIPV) systems; these are frequently adopted to mitigate the visual impact of PV systems. Although often attractive from the point of view of aesthetics, PV facades (tilt = 90° or similar) are not recommended from an energy efficiency point of view, because their production is approximately 50% less than when optimally positioned.

2.2 Shading

A solar PV plant is composed by a number of PV modules (PV array) placed on a given area. Often, the hemisphere above the PV array is not free of obstructions and therefore in most cases both the direct and the diffuse solar irradiation are affected by constructions, hills, vegetation, walls or other obstacles that one may found in the surroundings. When one of such elements intercepts the direct sun rays a shadow appears on a portion of the PV array and thus a problem related to shading might arise.

We should be aware that in many cases it is difficult to avoid shading, especially in urban areas or also in rural areas with vegetation or uneven ground. However it is important to avoid situations where shading may compromise the energy yield of the solar PV plant or, worse, endanger the integrity of the PV modules.

A qualitative analysis of the shading on a PV array may be done by drawing the solar paths on a diagram where x-axis represents the azimuthal orientation clockwise (0° = North, 90° = East, 180° = south, 270° = West) and the y-axis represents the sun elevation. Sun paths are usually drawn for each month of the year but those symmetric are considered equivalent.

Obstructions are thus inserted in the diagram considering their elevation angle and their azimuthal wideness. All obstructions affect the diffuse radiation, but the most important are those that intercept the direct radiation, namely in the diagram are placed on sun paths.

The Figure 2 shows the monthly sun paths in Bahrain and the two areas where shading is allowed and where it should be avoided.

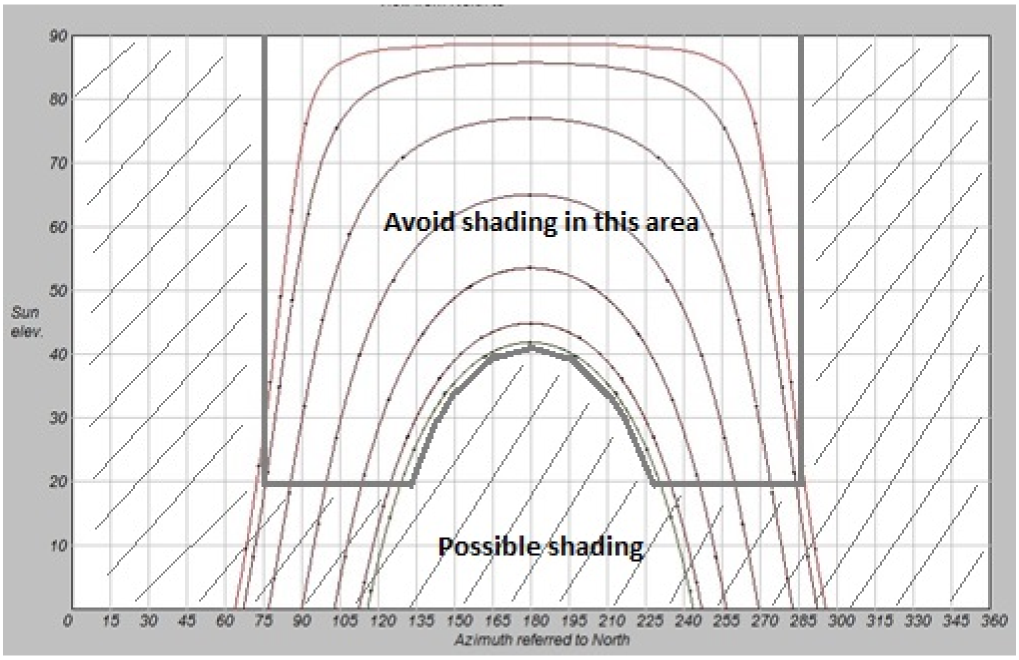


Figure 2 – Solar paths and recommended maximum shading

The Figure 2 shall be strictly followed in case of obstructions that may shade a portion of the PV array because they may compromise the integrity of the PV modules. Conversely, in other cases where the PV array is highly inclined or even vertical (facades) a derogation may be accepted.

2.3 Solar PV Equipment

2.3.1 How a grid-connected Solar PV plant works

A typical solar PV plant producing electricity has to be connected to a sub main distribution board or to the main distribution board and is usually composed of:

- Solar PV modules and their interconnections;
- Inverter(s);
- Metering System;
- Interface Protection; and
- Electrical and mechanical installations (structures, cables, switchgears and controlgear assemblies).

The Figure 3 shows a simplified diagram of a grid connected solar PV plant, where the electric loads are represented by domestic appliances. The same diagram applies alto to larger PV plants installed, for instance, on schools, factories or malls. Most likely, in these cases the PV plant is larger and the electric loads change considerably.

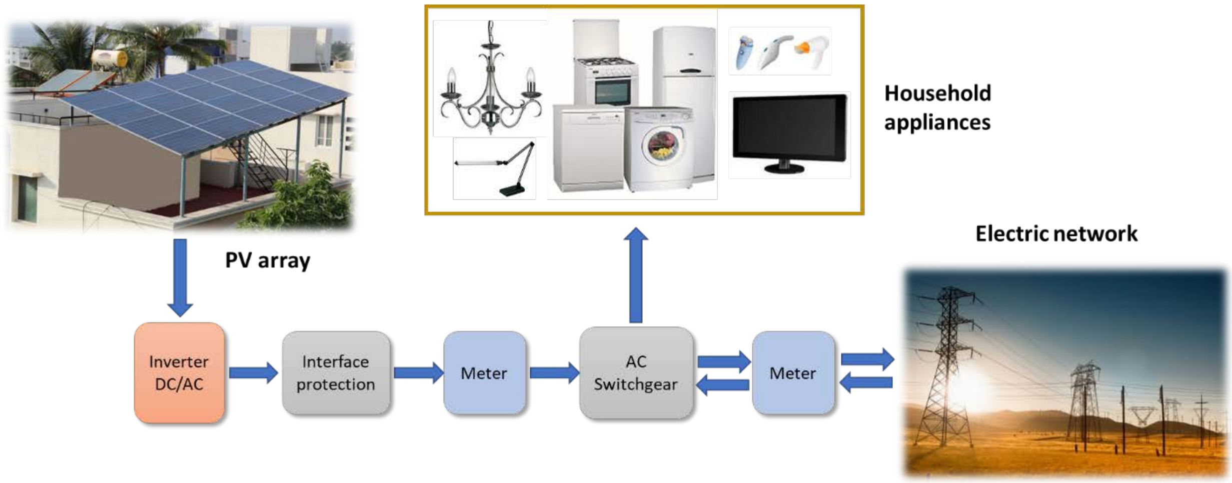


Figure 3 – Block diagram of a grid-connected solar PV plant for a household

In Figure 3 we can see that an exchange of energy from end to the grid is present. When the power from PV is higher than the electric consumption the power in excess is sent to the grid. Conversely, when the power produced by the PV plant is not enough, the difference is taken from the grid.
The way the solar PV plant is connected to the network is explained in the connection schemes shown in the Standards [1].
Standards also specify another important element, the Interface Protection, which prevents the current of the plant from being injected into the network whenever a faulty event is detected on the latter. This IP protection may also be included in the inverter.

The switch on which the Interface Protection acts (Interface Switch) may also be used to disconnect the plant for maintenance purposes, without causing any shortages on the existing loads.
Consultants and contractors shall refer to the detailed instructions and requirements provided by the suppliers that shall be fulfilled during the installation operation and maintenance of the solar PV system.

2.3.2 Solar PV modules

Solar PV modules can consist of PV cells of different technologies. In commercial and non-concentrating applications, single-crystalline and multi-crystalline cells achieve the maximum efficiency while thin-film technologies need more surface to produce the same power than their crystalline counterparts. Most manufacturers often guarantee a life time of 25 years or more, but they seldom take into account harsh conditions like those in Bahrain. Furthermore, manufacturers indicate that PV modules undergo a loss of performance over time and therefore, a guaranteed efficiency is provided (e.g. usually 90 % after 10 years and 80 % after 25 years). However it is advisable to have a workmanship warranty of at least 10 years and, given the harsh conditions in Bahrain, also a third party insurance backing for medium-large size plants (e.g. greater than 1 MW).
In general, bypass diodes should be installed in order to prevent reverse bias in the PV modules and to avoid consequent hot spot heating.

2.3.3 Inverter

The inverter converts the DC current produced by PV modules into AC current that can be used directly in the house/premises and/or injected into the external network. Ideally, the inverter should be located close to the photovoltaic modules to avoid losses, but this cannot always be possible because of the harsh outside conditions. High temperatures and dust in particular, require special caution in order to avoid any damage or performance reduction of the equipment.
It is therefore recommended to verify that the highest temperature to which the inverter can be exposed in summer does not cause any damage to it or reduce its life. Moreover, it is necessary to avoid high temperatures that may trigger any protection system aimed to reduce the internal temperature of the inverter by reducing its power (de-rating protection). If these conditions are not satisfied by mounting the inverter outside it is recommended to install the inverter in a safe room with enough ventilation and air conditioning, if necessary.
The inverters shall be provided with an IP65 enclosure for outdoor application andIP54 enclosure for indoor application. In this latter case, lower protection grades shall only be permitted if the characteristics of the room are properly conceived to protect the equipment (e.g. air conditioned rooms with means to avoid dust penetration). Whatever the case may be, the inverter should be able to withstand the maximum temperatures with effective heating dispersion and without power de-rating for temperatures lower than 50 °C. The efficiency of the Inverter should be greater than 95 % with a general guarantee of at least 10 years.

2.3.4 Metering System

To measure the electricity generated by the renewable generation unit and electricity consumed by the house/ building, two bidirectional energy meters must be installed:

1. The first meter supplied and installed by EWA in the PoC measures the power injected to the Distribution Network and the energy consumed from the Distribution Network. (“Main electricity meter”). This meter is already present in existing installations, however it shall be substituted by a smart meter if this has not already been done.
2. The second meter supplied and installed by EWA measures the electricity generated by the photovoltaic system (PV generation meter).

During the connection process, EWA will inspect the Solar PV system before the metering system can be installed. The inspection aims to ensure that the Solar PV plant complies with the Standards, with the wiring regulations, and with the safety rules.

2.3.5 Other equipment

All the components and equipment used in the PV plant shall comply with applicable standards and laws in force in Bahrain. Any component or equipment that may introduce harmful or hazardous conditions shall be rejected.
All components and equipment is chosen adequately in order to assure its integrity and operation for a long lasting period. All equipment should be of an IP rating suitable for the location and this particularly applies to:

- Cables and connectors exposed to sunrays (UV in particular), external temperature and other weather conditions. This equipment is to be certificated for their application (e.g. solar cables). In DC circuits single-wire cables should be used with different colours for the two poles.
- Switchgears and controlgear assembly shall be properly protected against temperature, sunrays (UV in particular), dust, salinity and all other weather conditions present on the site. Installation in a safe room is recommended. Their compliance to applicable standards shall be properly certificated (IEC 61439 series).
- PV string combiner boxes shall be properly protected against temperature, sunrays (UV in particular), dust, salinity and all other weather conditions present on the site. Their location shall be visible without obstacle to their inspection and replacement of components (e.g. fuses). Their compliance to applicable standards shall be properly certificated (IEC 61439 series where applicable).

2.4 Compliance of the solar PV equipment to the Standards

The equipment of the Solar PV plant that is to be connected to EWA distribution network must comply with the requirements of the Standards.
Particularly, the PV modules, the inverters and the Interface Protections are to be certified according to the compliance requirements defined in [1]. The manufacturers shall provide the Producer with certificates, proving that each equipment complies with these requirements. The eligibility requirements are defined in [9]. A list of the updated certified equipment is made available and regularly updated by EWA [10]. The certification document will be requested by EWA during the connection process.

2.5 PV array system configuration

2.5.1 PV system architectures and earthing

The relation of a PV array to earth is determined by whether any earthing of the array for functional reasons is in use, the impedance of that connection and also by the earth status of the circuit. This and the location of the earth connection all affect safety for the PV array. The requirements and recommendations of manufacturers of PV modules and manufacturers of inverters to which the PV array is connected will be taken into account when determining the most appropriate system earthing arrangement.
Protective earthing of any of the conductors of the PV array is not permitted. Earthing of one of the conductors of the PV array for functional reasons is not allowed, unless there is at least simple

separation from mains earth provided, either internally in the inverter or externally via a separate transformer.
Earthing of PV module frames and supporting metallic structures shall be executed according to IEC 62548 and other applicable standards.
All earthing connections in the PV plant (DC and AC sections) shall be part of a unique earthing system, i.e. a proper bonding shall be assured.

2.5.2 Series-parallel configuration of modules and strings

All PV strings within a PV array connected in parallel are to be of the same technology and have the same number of series connected PV modules. In addition, all PV modules in parallel within the PV array shall have similar rated electrical characteristics including short circuit current, open circuit voltage, maximum power current, maximum power voltage and rated power (all at STC).
It is important that the characteristics of any array or sub-array be fully compatible with the input characteristics of the inverter used. This in particular applies to:

- Rated power at STC;
- Minimum and maximum voltage at any operation condition (solar radiation, air temperature); and
- Maximum system voltage.

2.5.3 Use of inverters with single and multiple DC inputs

PV arrays are often connected to inverters with multiple DC inputs. If multiple DC inputs are in use, overcurrent protection and cable sizing within the various sections of the PV array(s) are critically dependent on the limiting of any back-feed currents (i.e. currents from the inverter out into the array) provided by the input circuits of the inverter.
Where an inverter input circuit provides separate maximum power point tracking (MPPT) inputs, the overcurrent protection of the sub-array connected to the inputs shall take into account any back-feed currents. Each PV section connected to an input must be treated as a separate PV sub-array. Each PV array or sub-array shall have a switch-disconnector to provide isolation of the inverter.

2.5.4 DC/AC converters (Microinverters) in combination with PV modules

Microinverters are electrically connected to PV modules through direct wirings and may be used as:

- Permanently mounted close to the PV module but not mounted to or in direct contact with the module backsheet (also called Detached Microinverters). DC wiring are thus accessible to service personnel although is deemed to be not user-accessible.
- Permanently mounted to the PV module’s backsheet for both electrical and mechanical means of connection (AC modules).

Differently from classical PV arrays, in PV systems that use microinverters the connections in the array are made by using one or more AC parallel wiring systems (AC bus).
Instructions of manufacturers shall be applied especially as regards bonding/earthing of microinverters and in order to avoid overloads on AC wiring. In particular, AC cables shall have a proper voltage rate and, unless they are adequately protected, they shall be resistant to high temperatures, UV rays and other possible mechanical stresses.
In case of detached microinverters, attention has to paid to the characteristics of DC connectors when used as a means to disconnect the DC circuit. When not rated to disconnect under load, all the necessary precautions have to be taken before disconnecting them (e.g. covering of the module).

2.5.5 Mechanical design

Support structures and module mounting arrangements shall comply with applicable building codes regulations and standards and module manufacturer's mounting requirements.

Provisions should be taken in the mounting arrangement of PV modules to allow for the maximum expansion/contraction of the modules under expected operating temperatures, according to the manufacturer's recommendations. Similar provisions should be taken for other applicable metallic components, including mounting structures, conduits and cable trays.

The PV array support structures shall comply with local standards, industry standards and regulations with respect to loading characteristics.

PV modules, module mounting frames, and the methods used for attaching frames to buildings or to the ground shall be rated for the maximum expected wind speeds in Bahrain according to local codes.

In assessing this component, the wind speed observed (or known) on site shall be used, with due consideration to wind events (cyclones, tornadoes, hurricanes, etc.). The PV array structure shall be secured in an appropriate manner or in accordance with local building standards.

Wind force applied to the PV array will generate a significant load for building structures. This load should be accounted for in assessing the capability of the building to withstand the resulting forces.

Module mounting frames, and the methods used for attaching modules to frames and frames to buildings or to the ground, shall be made from corrosion resistant materials suitable for the lifetime and duty of the system, e.g. aluminum, galvanized steel, zinc-coated steel, etc.

Aluminum, when used, shall be anodized to a thickness and specification suitable for the location and duty of the system. Corrosive gases such as ammonia, in farming environments also need to be contemplated.

Care shall be taken to prevent electrochemical corrosion between dissimilar metals. This may occur between structures and the building and also between structures, fasteners and PV modules.

Stand-off materials shall be used to reduce electrochemical corrosion between galvanically dissimilar metal surfaces; e.g. nylon washers, rubber insulators, etc. Manufacturer's instructions and local codes should be consulted regarding the design of mounting systems and any other connections such as earthing systems.

3 SAFETY ISSUES

3.1 Preface

The PV plant shall be designed and erected in accordance with the relevant and applicable international standards, in particular IEC 60364 and IEC 62548 as concerns the Low Voltage DC and AC sections.
Technical choices shall not be in contrast with the local technical rules in force in Bahrain.

3.2 Maximum DC voltage

In the case of the maximum PV array voltage, as calculated at the minimum outdoor temperature of 0 °C, exceeds 1,000 Vdc, the entire PV array and associated wiring and protection, shall have access restricted to competent persons only. PV arrays for installation on buildings shall not have maximum voltages greater than 1,000 Vdc.
For protection against electric shock, the requirements of IEC 60364-4-41 shall apply. PV module exposed metal earthing and bonding shall be according to applicable standards.

3.3 Protection against overcurrent in the DC section

Overcurrent within a PV array can result from earth faults in array wiring or from fault currents due to short circuits in modules, in junction boxes, PV array combiner boxes or in module wiring.
PV modules are current limited sources but can be subjected to overcurrents because they can be connected in parallel and also connected to external sources. The overcurrents can be caused by the sum of currents from PV strings, PV sub-arrays and PV arrays with direct functional earth connection.

3.3.1 PV string overcurrent protection

String overcurrent protection shall be used if:

$$((S_A - 1) \times I_{SC\_MOD}) > I_{MOD\_MAX\_OCPR}$$

Where fuses are applied, these fuses need to meet the requirements as described in IEC 60269-6 (Type “gPV”)”.
Where string overcurrent protection is required, either (see Figure 4):

a) each PV string shall be protected with an overcurrent protection device (e.g. fuse or circuit breaker), where the nominal overcurrent protection rating of the string overcurrent protection device shall be I_n where:
$I_n > 1.5 \times I_{SC\_MOD}$ and
$I_n < 2.4 \times I_{SC\_MOD}$ and
$I_n \leq I_{MOD\_MAX\_OCPR}$

Or

b) strings may be grouped in parallel under the protection of one overcurrent device provided:
$I_n > 1.5 \times S_G \times I_{SC\_MOD}$ and
$I_n < I_{MOD\_MAX\_OCPR} - ((S_G - 1) \times I_{SC\_MOD})$

Where

S_G is the number of strings in a group under the protection of the one overcurrent device;

I_n is the nominal overcurrent protection rating of the group overcurrent protection device.

In some PV module technologies I_{SC_MOD} is higher than the nominal rated value during the first weeks or months of operation. This should be taken into account when establishing overcurrent protection and cable ratings.

NOTE 1: Strings can generally only be grouped under one overcurrent protection device if $I_{MOD\_MAX\_OCPR}$ is greater than $4 \times I_{SC\_MOD}$.

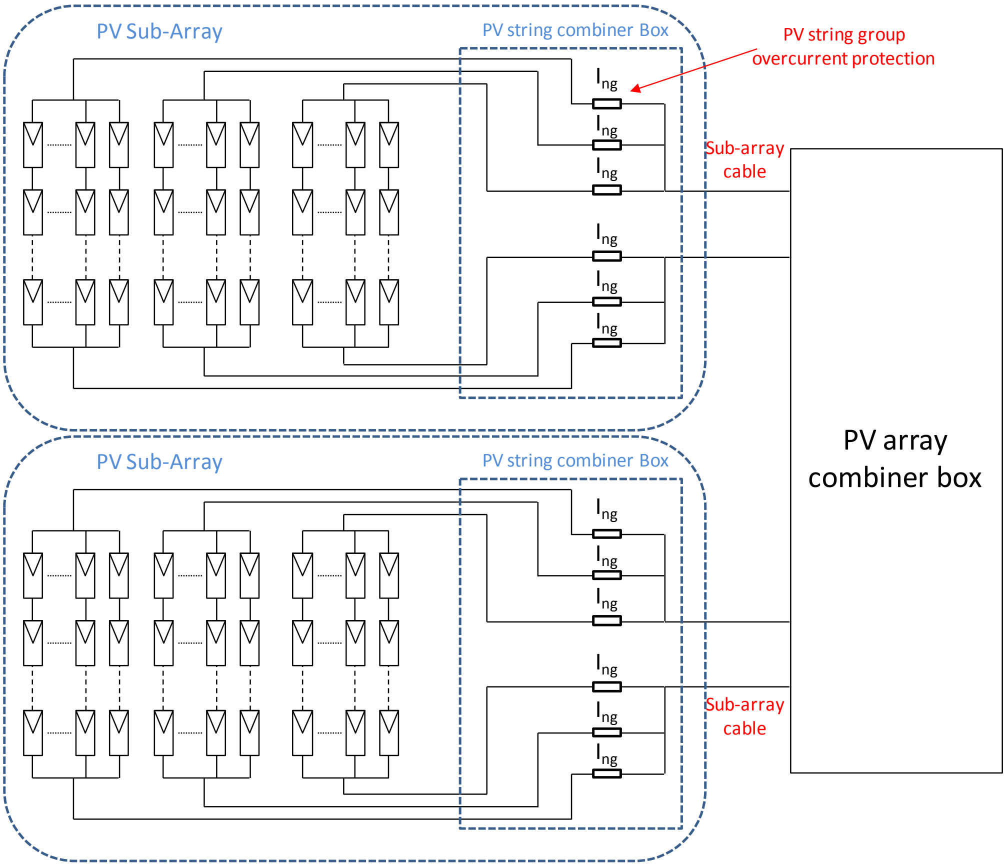


Figure 4 – Example of a PV array diagram where strings are grouped under one overcurrent protection device per group

3.3.2 PV sub-array overcurrent protection

The nominal rated current (I_n) of overcurrent protection devices for PV sub-arrays shall be determined with the following formula:

$I_n > 1.35 \times I_{SC\ S\text{-}ARRAY}$ and

$I_n \leq 2.4 \times I_{SC\ S\text{-}ARRAY}$

The nominal rated current (I_n) of overcurrent protection devices for PV arrays shall be determined with the following formula:

$I_n > 1.35 \times I_{SC\ ARRAY}$ and
$I_n \leq 2.4 \times I_{SC\ ARRAY}$

The 1.35 multiplier used here instead of the 1.5 multiplier used for strings is to allow designer flexibility but also taking into account of the heightened irradiance.

3.3.3 PV arrays with direct functional earth connections

PV arrays that have one conductor directly connected to a functional earth (i.e. not via a resistance) shall be provided with a functional earth fault interrupter which operates to interrupt earth fault current if an earth fault occurs in the PV array. This may be achieved by interruption of the functional earth of the array. The nominal overcurrent rating of the functional earth fault interrupter is shown in Table 1.

The functional earth fault interrupter shall not interrupt the connection of exposed metal parts to earth.

Table 1 – Nominal overcurrent rating of functional earth fault interrupter

Total PV array power rating [kWp]	Rated current [A]
0 – 25	≤ 1
>25 – 50	≤ 2
>50 – 100	≤ 3
>100 – 250	≤ 4

3.4 Earth fault array detection

3.4.1 General

Requirements for detection of earth faults, actions required and alarms depend on the type of system earthing and whether the inverter provides electrical separation of the PV array from the output circuit (e.g. the grid). For PV systems whose DC voltage is higher than 120 V, Table 2 shows the requirements for measurements of PV array earth insulation resistance and PV array RCM as well as the actions and indications required if a fault is detected.

Table 2 – Requirements for different system types based on inverter isolation and PV array functional earthing

Earth fault detection method	Type of safety measure on fault	Non-isolated inverter	Isolated inverter	
		No functional earth on PV array	No functional earth on PV array	Functionally earthed PV array
PV array earth insulation resistance	Action	Shutdown inverter And Disconnect all poles of the output circuit or all poles of the PV array from the inverter	Connection to the output circuit is allowed (inverter is allowed to operate)	
	Indication	Yes		
PV array residual current monitoring	Action on fault	Shutdown inverter And Disconnect all poles of the output circuit or all poles of the PV array from the inverter	Not required	Functional earth shall be disconnected Connection to the output circuit is allowed. (inverter is allowed to operate)
	Indication	Yes	Not required	Yes

3.4.2 Array insulation resistance detection

These requirements, regarding detection and response to abnormal array insulation resistance to earth are intended to reduce hazards due to degradation of the insulation system.

In a non-isolated inverter connected to an earthed output circuit (e.g. mains), an array earth fault will result in potentially hazardous current flow as soon as the inverter connects to the earthed circuit. E.g. an inverter connected to the mains, due to the earthed neutral on the mains, so the inverter shall not connect to the mains. In an isolated inverter, if an earth fault in a floating or functionally earthed PV array goes undetected, a subsequent earth fault can cause hazardous current to flow. The detection and indication of the original earth fault is required.

A means shall be provided to measure the insulation resistance from the PV array to earth before starting operation and at least once every 24 h.

NOTE: This functionality for insulation resistance measurement may be provided within the inverter.

Minimum threshold values for detection shall be according to Table 3.

Table 3 – Minimum insulation resistance thresholds for detection of failure of insulation to earth

System size [kW]	R limit [kΩ]
≤ 20	30
>20 and ≤ 30	20
>30 and ≤ 50	15
>50 and ≤ 100	10
>100 and ≤ 200	7
>200 and ≤ 400	4
>400 and ≤ 500	2
> 500	1

It is recommended that the threshold of detection for insulation resistance should where possible be set at values greater than the minimum values specified in these calculations. A higher value will increase the safety of the system by detecting potential faults earlier.
The measurement circuit shall be capable of detecting insulation resistance to earth of the PV array below the limit above. It is permitted to remove the PV array functional earth connection during the measurement.
The action on fault required is dependent on the type of inverter in use, as follows:

– for isolated inverters, shall indicate a fault (operation is allowed); the fault indication shall be maintained until the array insulation resistance has recovered to a value higher than the limit above;
– for non-isolated inverters, shall indicate a fault, and shall not connect to any earthed output circuit (e.g. the mains); the device may continue to make the measurement, may stop indicating a fault and may allow connection to the output circuit if the array insulation resistance has recovered to a value higher than the limit above.

3.4.3 Protection by residual current monitoring system

Where required by Table 2, residual current monitoring (RCM) shall be provided that functions whenever the inverter is connected to an earth referenced output circuit with the automatic disconnection means closed. The residual current monitoring means shall measure the total (both AC and DC components) RMS residual current.
If the inverter AC output connects to a circuit that is isolated from earth, and the PV array is not functionally earthed, residual current monitoring is not required.
Detection shall be provided to monitor for excessive continuous residual current, and excessive sudden changes in residual current according to the following limits:

a) Continuous residual current: The RCM system shall cause disconnection within 0,3 s and indicate a fault in accordance with 6.4.2 if the continuous residual current exceeds:
   – maximum 300 mA for inverters with continuous output power rating ≤ 30 kVA;
   – maximum 10 mA per kVA of rated continuous output power for inverters with continuous output power rating > 30 kVA.

   NOTE: It is possible to implement distributed residual current monitoring for example at sub-array level or in smaller subsections of the array. This can be beneficial especially in large arrays as it enables smaller thresholds of detection to be implemented. This can lead to more rapid identification of potential faults and can assist in identifying the section of the array that may be affected.
   The RCM system may attempt to re-connect if the leakage threshold and the array insulation resistance meets the limits specified in corresponding tables.

b) Sudden changes in residual current: The inverter shall disconnect from any earth referenced output circuits (e.g. the mains) within the time specified in Table 4 and indicate a fault if a sudden increase in the RMS residual current is detected exceeding the value in the table.

Table 4 – Response time limits for sudden changes in residual current

Residual current sudden change [mA]	Max time for disconnection from earth referenced circuit [s]
30	0.3
60	0.15
150	0.04

3.4.4 Earth fault alarm

As required in Table 2 an earth fault alarm system shall be installed. When activated the alarm system is to continue its operation until the system is shutdown and/or the earth fault is corrected.

The alarm shall be of a form that ensures that the system operator or owner of the system becomes aware of the fault. For example, the alarm system may be a visible or audible signal placed in an area where operational staff or system owners will be aware of the signal or another form of fault communication like Email, SMS or similar.

A set of operational instructions shall be provided to the system owner which explains the need for immediate action to investigate and to correct the fault.

Many inverters have earth fault detection and indication in the form of indicator lights. However, typical inverter mounting locations mean that this indication may not be noticed. IEC 62109-2 requires that inverters have a local indication and also a means of signalling an earth fault externally.

4 PV PLANT CONNECTION PROCESS

This section describes the steps and the tasks that must be completed to get a PV Plant connected to EWA distribution network. Figure 5 shows the main logical flow for the connection process.

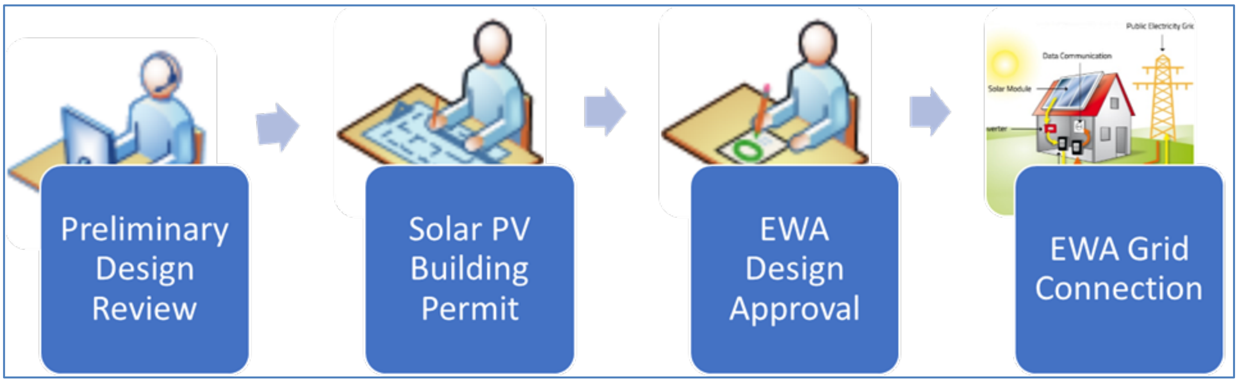


Figure 5 – Connection Process

4.1 Project Preparation

4.1.1 Engaging with Consultants / Contractors

Once the decision is made to invest in a PV plant, it is recommended that the future Producer requests an offer from an Electrical and Solar PV Consultant / Contractor who advises on the best possible solution for the Solar PV system in compliance with EWA regulations. This offer is to be agreed between the Producer and the Consultant / Contractor.

The **Technical** part should contain:

- High level electrical design/ structural drawings of the installation;
- Proposed installed capacity in kW;
- Technology proposed and system working principle;
- Estimation of the electrical production for one year, with a detailed indication of loss diagram;
- Comparison to the expected electricity consumption (based on past consumption);
- Installation monitoring system (if required by the Standards or optional if not); and
- Maintenance plan including costs.

The **Financial** part should contain:

- Price for the equipment;
- Cost of installation;
- Warranties from the Manufacturers and Contractors.

4.1.2 Consultant / Contractor required in order to apply for solar PV connection

The Application for the connection of a Solar PV system must be submitted by an Electrical and Solar PV Consultant / Contractor.

After the Producer has selected the offer he deems most suited in terms of technical performance and financial cost, he selects the Consultant / Contractor who will design and install the solar PV system.

Both the Consultant and the Contractor have to own a standard Trade License issued by the Government of Bahrain.

Moreover, Electrical and Solar PV Consultant / Contractor has to be accredited for the installation of these renewable energy generating plants. The minimum requirements for the accreditation of the consultants and contractors are defined in [11].

4.2 Preliminary Design Review

The Preliminary Design Review request represents the initiation of a Solar PV Application.
The Applicant has to submit through EWA an application in order to obtain the connection approval from EWA.
The Applicant shall submit the Application Form, duly filled and signed, and a number of annexed documents. The template of the form is provided is the Annex B.1 – Solar PV Application Form.
The following information is required in the Application Form:

- Information on the Applicant
- Information on Consultant / Contractor
- Point of Connection details (Contract Account No., ID of the meters);
- Project overview;
- Copy of site setting out plan showing details of proposed works, PV panels layout on the roof, meter location(s), etc.;
- Single Line Diagram showing the PV arrays, the inverters, the interface protection, the interface switch and the meters;
- Short circuit contribution from the plant to the network.

4.2.1 Assessment by EWA

EWA makes a further check of the completeness of the application.
If the check of completeness is passed the New Request can be assessed by EWA/EDD, otherwise the Applicant will be asked for completion. If some information relevant for EWA is missing in the dossier, the Applicant is notified the list of the data he must provide in order EWA can process the Application.

4.2.2 Notification to the Applicant

At the end of the assessment EWA notifies the Applicant the result from the Application assessment finalization:

- In case of non-positive result, a formal notification is sent to the Applicant of no capacity available. The notification includes a short description of the reasons to reject the request.
- If some power capacity can be injected at POC but this is less than that requested, the Applicant is asked to accept a curtailment. The notification includes a short description of the reasons to ask for a curtailment of the requested power capacity.
- In case of positive result, a formal notification is sent to the Applicant of the approval of the Application.

Based on the result of the assessment the Applicant that may decide if go further or give up the project.

4.3 Solar PV Building Permit

After he received EWA's approval, the Applicant has to submit a request for obtaining a Building Permit for the solar PV plant to the Municipality / MOSS.
The procedures, the application form and the documents required are those requested by the Municipality as regards the specific type and mode of installation of the solar PV plant.

This task is under the control of the Municipality / MOSS that processes the request of the Applicant, makes the necessary verifications and coordinates the activities of all involved stakeholders aimed to verify the eligibility of the request.
A Building Permit is eventually granted to the Applicant if the process gives a positive result.

4.3.1 Assessment by the Municipality

The Applicant gives the Municipality sufficient information in order to scrutinise the application (e.g. civil project with drawing, etc., the level of detail depends on the rules issued by the Municipality).
The Municipality will check the availability of EWA's approval before processing the new request.
A first formal check of completeness is made by the Municipality in order to be sure that the Applicant has compiled all the items of the form and all the required annexes have been delivered.
The Municipality activates an assessment procedure in order to evaluate if the proposal is compliant with the existing laws and rules. This evaluation of compliance may require the contribution of other bodies, such as the Civil Defence.
If the project is compliant, the Municipality notifies the Building Permit to the Applicant and to the EWA, otherwise the application is rejected: in the event of rejection the Municipality informs the Applicant by means of a formal communication.

4.4 Get Design Approval and install the solar PV plant

If the Applicant decides to proceed with the Solar PV Plant Project, he submits the final design of the solar PV plant to EWA. The minimum requirements for the solar PV plant design depend on the size of the plant.
The purpose of the Design Approval is to assure the Solar PV design and the electrical installation work comply with the Technical Standards [1], EWA regulation for electrical installations [2], as well as any other provisions issued in order the Solar PV plant can be successfully installed and connected to the distribution network of Bahrain, such as:

- Fire safety recommendations [3]
- Safety of People recommendations [4]
- Design and operation recommendations [5]
- Impact on Aviation [6]
- Inspection and Testing Guidelines [7]
- Inspection and Testing Checklists [8]

In order EWA can assess the final design of the Solar PV project, the Applicant provides the minimum documentation listed in the following paragraphs, according to the renewable capacity to be installed.

4.4.1 Solar PV plants up to 11 kW

As specified in the Inspection and Testing Guidelines [7], the following information shall be provided:

- Basic system information
- System designer information
- System installer information
- Wiring diagram
    - Array – General specifications
    - PV string information
    - PV array electrical details
    - AC system

    - Earthing and overvoltage protection
- Planimetry and String layout
- Datasheets
- Mechanical design information
- Emergency systems
- Esteem of the yearly energy production

4.4.2 Solar PV plants above 11 kW

As specified in the Inspection and Testing Guidelines [7], the following information shall be provided:

- Technical report
    - Front page
    - Chapter 1 – Foreword (or Introductory section, or Preface, …)
    - Chapter 2 – Input data
    - Chapter 3 – Characteristics of the main devices and equipment
    - Chapter 4 – System architecture and dimensioning
    - Chapter 5 – DC section
    - Chapter 6 – AC section
    - Chapter 7 – Civil and mechanical installation
    - Chapter 8 – Performance calculation
- Wiring diagram
    - Array – General specifications
    - PV string information
    - PV array electrical details
    - AC system
    - Earthing and overvoltage protection
- Planimetry and String layout
- Datasheets
- Mechanical design information
- Emergency systems

4.4.3 Assessment of the final design

When EWA terminates the assessment of the final design, the Applicant is notified the result.

- If the design of the solar PV plant is not approved, the notification contains the reasons of the rejection and could also contain the suggestion that the Applicant may adopt in order to make the project eligible for a further review.
    - The Applicant may amend the design of the solar PV plant in order to send it again to EWA and obtain approval.
- The design of the solar PV plant is approved, the Applicant is notified the positive result.

4.4.4 Payment

The Applicant receives from EWA the estimate of the PV connection fees based on the approved drawings and the comments (the remarks shall indicate whether a substation is needed or not).
The Applicant then pays the connection fees and EWA will carry out all the necessary interventions on the network, in order to make the connection feasible.

4.4.5 Execution

Once the connection fee is paid, the Applicant can commission the construction of the plant.

4.4.6 Declaration of Conformity

After the construction of the solar PV plant, the Consultant/Contractor issues and signs a Declaration of Conformity, where he declares the following:

- Under his responsibility the plant has been made in a workmanlike manner.
- The plant has been made according the design approved by EWA/EDD and minor changes (if any) do not worsen the grid compatibility, the performances and the safety. Any minor changes is duly reported in an as-built design attached to the Declaration of Conformity.
- All the materials, components and equipment used in the solar PV plant have been chosen according to the design and to the laws and rules in force in Bahrain.

4.5 Grid Connection

The fulfillment of the requirements set forth by the Kingdom of Bahrain must be verified before EWA can install the meter and connect the Solar PV system to the distribution network.
The Figure 6 shows the tasks envisaged during the Grid Connection stage with regards to the capacity Pn of the PV plant. The sequence of inspections and tests is based on best practice and international standards. The Applicant shall appoint a Test Engineer to make the below inspections and tests.

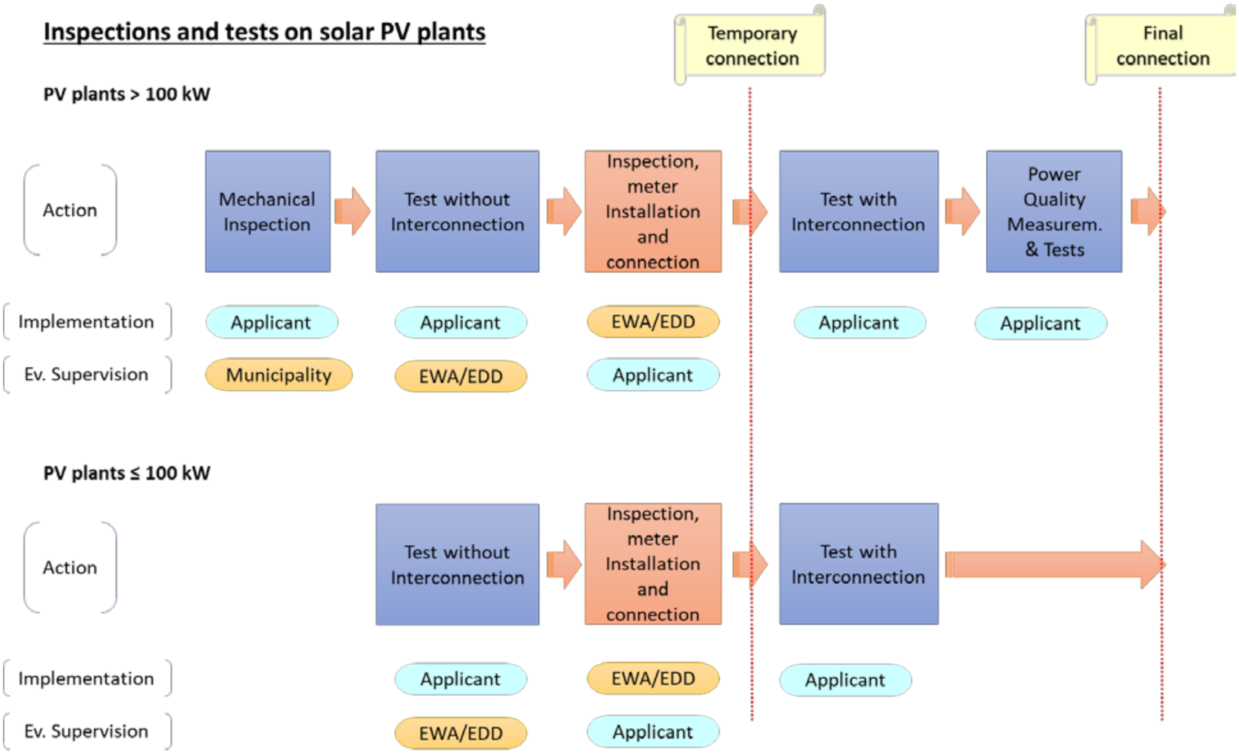


Figure 6 – Sequence of the testing activities for solar PV plants

4.5.1 Inspection of the solar PV plant by the Municipality and EWA/EDD inspector

EWA/EDD decides the available periods for the Applicant to make the Mechanical Inspection (only if Pn > 100 kW) and the Test Without Interconnection (all plants). During this period the EDD inspector will perform the EWA inspection, according to EWA Electrical Wiring Regulations, as required before the meter can be installed. If the Municipality wants to be present at the Mechanical Inspection, the available periods for the Applicant to make the Mechanical Inspection shall take into account also the needs of the Municipality. After the suitable periods are agreed, the Applicant will proceed with the implementation of the required test sequence.

4.5.2 Solar PV plant documentation

Prior to initiating the inspections and tests, the Applicant prepares the documentation of the solar PV plant, that is listed in the "Inspection and Testing Guidelines". This documentation will ensure key system data are readily available to the Producer, to EWA and Municipality Inspectors, as well as to the maintenance engineer. The documentation includes basic system data and the information expected to be provided in the operation and maintenance manual.
The list is based on the IEC 62446-1 standard, but depending on the size of the PV plant, up to 11 kW or above, the design documentation required and its organization may be different. The documentation on Operation and Maintenance is specified separately.
The results of the inspections and tests performed by the Test Engineer appointed by the Applicant are described in one or more "Inspection and Test Reports": the Applicant deliver these reports for evaluation and approval to the Municipality (in case of Mechanical Inspection) and to EWA (Test without and with interconnection).
The submission of the Solar PV plant documentation is a necessary condition before EWA issues the Final Authorization that allows the Applicant to begin the power production with the solar PV plant.

4.5.3 Mechanical Inspection

The Mechanical Inspection applies to all solar PV plants whose capacity is above 100 kW, regardless their voltage connection.
As a rule, this test begins after the completion of the solar PV plant, although the Test Engineer may initiate the inspection on those sections that have been erected and fully completed. In this case, the results of these tests shall be duly reported and completed with date and time.
Although the separate Mechanical Inspection applies to all solar PV plants whose Pn is above 100 kW, a verification of the mechanical installation is required regardless the capacity of the PV plants. As a result, for the PV plants whose Pn is up to 100 kW, this verification has to be done during "Testing Without Interconnection".

4.5.4 Test without Interconnection

The Test without Interconnection applies to all solar PV plants regardless their nominal power and voltage connection. This test is composed by an inspection and a set of tests made by the Test Engineer appointed by the Applicant.
As a rule, this test begins after the completion of the solar PV plant, although for large PV plants with Pn above 100 kW for safety reason the Test Engineer may initiate the tests on strings during installation in order to prevent parallel of strings with different length or reversed polarity. In this case, the results of these tests shall be duly reported and completed with date and time.
In all the cases where tests are initiated and completed in a single day it is sufficient to add the date of the day and the times of initiation and completion.

4.5.5 Installation of the meter(s)

In case of a positive result of the site inspection, EWA installs the meter(s). During this inspection, EWA also tests the installation protection system and the earthing in case of LV connected facilities or supervises the measurements made by the Applicant in case of MV connected facilities.

In case of construction of a new EWA substation, the Substation Inspection Request is also sent through EWA website by the Applicant after completing the civil works of the proposed substation as per the Trench Layout drawing.
After the meters have been installed, the RE-G can be energized. For plants connected to the Medium Voltage distribution network, it is particularly important that this operation be supervised by EWA Engineers. The same Engineers will take care of all the necessary provisions for the energization of the ring to which the plant is connected (manoeuvres to be made on the EWA Distribution Network), and eventually witness the closure of the RE-G main circuit breaker.

4.5.6 Testing with Interconnection to the grid

After the plant has been connected to the network, a number of tests with the aim of verifying the correct behaviour of inverters, protections as well as the electrical checks on the installation, need to be carried out.
For all the plants, these tests shall be carried out by certified Test Engineer. The results of these tests will be collected into a Technical Dossier to be submitted to EWA for approval. In case of plants with Pn > 100 kW or connected to MV network, this approval is a prerequisite to the execution of the Performance Tests. For plants up to 100 kW, no further tests or inspections are required, so the Final Inspection Report will be prepared by EWA and Connection Agreement issued (see below). No EWA supervision is needed during this testing stage.

4.5.7 Power Quality measurements

The Power Quality measurements and tests applies to all solar PV plants whose Pn is above 100 kW, regardless their voltage connection.
The harmonic emissions generating from the solar PV plant shall be measured to allow EWA/EDD to verify that network power quality is actually in line with the requirements reported in the *Standards for Solar PV Systems to be connected in parallel with the distribution networks of the Kingdom of Bahrain* and in EN 50160. The solar PV plant shall not generate disturbances to other customers.
In principle, the tests are made for the whole power plant at POC. If the solar PV plant has different POCs, the tests must be performed at each POC.

4.5.8 Additional Tests

Additional tests are defined in the Inspection and Testing Guidelines.

4.5.9 Final steps: O&M Contract, Insurance and Connection Agreement

A regular Operation and Maintenance (O&M) Contract has to be provided by the Applicant. The Contractor and/or Consultant will inform the Producer about the requirements of the plant in terms of O&M. An O&M manual shall be made available to the Producer, in order for the Producer to correctly and safely operate the plant, if adequately skilled, or to transfer the operating obligations to an appointed Contractor. As stated above, the Contractor services are required for the Maintenance[2]. EWA will verify the availability of this manual in the inspections.
The Producer also needs to provide EWA with a statement stipulating that he is aware of the O&M needs of the plant, indicating who will be responsible for the O&M.
It is also strongly recommended to have an insurance for the PV system as specified in Section 5 (the system can be included in the Building insurance or a specific insurance may be stipulated for the PV system).
Once the Final Inspection Report has been issued, the Connection Agreement will be signed and submitted to EWA by the Producer.

[2] This may also be different from whom has erected the plant.

The Connection Agreement encompasses both the technical and commercial aspects of the connection, addresses the Standards and Minimum Technical Requirements and specifies the Terms and Conditions including the constraints on quality of supply, in accordance with the defined rules.
The official production start date and time that will be utilized for Net Metering purposes, is thus the date of the Connection Agreement.

4.5.10 Renewable Generation: Start of Production

After the official start of the electricity production, EWA will read the production meter on a monthly basis monitoring how much electricity the system has produced, as well as the main electricity meter monitoring the net electricity flows (Metering Process), calculate the economic amount of electric energy supplied based on the defined price rules (Settlement Process, see also General Terms and Conditions regarding net metering) and prepare the bill (Billing Process).

5 DEFINITION OF THE RESPONSIBILITIES

The purpose of this Section is to define a list of obligations and entitlements that each one of the parties involved in the building and in the network connection of the Solar PV plant has to comply with.

The limits of responsibility of the below are outlined:

- EWA;
- the Customer/Producer (as owner of the plant);
- the Consultant / Contractor (as appointed by the Producer); and
- the Manufacturers of Solar PV equipment.

5.1 EWA

EWA shall be responsible for:

- operating and maintaining a secure, reliable and efficient electricity distribution network, in order to be able to receive the power produced by the solar PV plants;
- granting the connection to the network to the Producers, by any possible and economical means of network reinforcement.
- conducting the site and plant inspections as defined above;
- undertaking any possible provisions to clear a fault in the distribution network in the shortest time, EWA shall not be liable for the loss of production that the solar PV plants connected to the Distribution Network will undergo in case of disconnection following the intervention of the Interface Protection [3].

Ownership Boundaries:

- the boundary between EWA and the Producer is the Connection Point as indicated in the connection schemes in Annex A;
- the respective ownership of Plant or Apparatus shall be recorded in the Connection Agreement between EWA and the Producer in the form of a diagram.

5.2 Customer/Producer

- The Producer must enter into a Connection Agreement with EWA. The Connection Agreement encompasses both the technical and commercial aspects of the connection, addresses the Standards and Minimum Technical requirements and specifies the terms and conditions including the connection fee, net metering criteria, use of system and quality of supply in accordance with the EWA Standards.
- The Producer shall indemnify EWA and accept liability for safety and supply quality issues that occur when the PV Plant is operating.

The Producer shall be responsible for:

- the choice of any of the PV Plant equipment;
- the installation, operation and maintenance of all the PV Plant equipment;

[3] In order to allow the automatic re-connection of the Solar PV plant to the distribution network once the disturbance in the network has been cleared, proper automatic re-closure devices and functions shall be installed .

- ensuring that there is a safe system of work for all representatives that are involved in the PV Plant construction, in compliance with all applicable standards and statutory requirements;
- the protection and safety of the generating facility or the generating units, respectively;
- the reliable protection of the plants (e.g. short-circuit, earth-fault and overload protection);
- the PV Plant insurance against damages by storm, hail, lightning, over voltage, theft, fire or any other external hazards.

5.3 Consultant

Consultant's responsibility and liability are defined by the laws in force.
In particular, the Consultant shall be responsible for:

- carrying out the application process on behalf of the Producer as described above;
- the correct choice of equipment;
- correct consulting of the producer regarding all technical aspects.

5.4 Contractor

Contractor's responsibility and liability are defined by the laws in force.
In particular, the Contractor shall be responsible for:

- applying a safe system of work in the PV Plant construction, in compliance with all applicable standards, regulations and statutory requirements;
- proposing to the Producer adequate and certified PV equipment;
- building the installation in accordance with the design and its correct interpretation;
- building the installation in accordance with best practice and in compliance with all applicable technical standards[4];
- appointing a Test Engineer to perform inspection and testing on the plant;
- providing O&M services.

As stated above, the limits of liability as specified for the Consultants apply also for the Contractors when their services extend to include consultancy services and the design of the plant.

5.5 Manufacturers

Manufacturers' responsibility and liability are defined by the laws in force.
The manufacturers shall in particular be liable in case of delivery of false certificates of compliance for the PV products (PV modules, inverters, cables, protections, and so forth).

[4] The Contractor will have to deliver a Declaration of Conformity of the plant to these standards.

ANNEX A: FREQUENTLY ASKED QUESTIONS

In this section some FAQs are provided regarding the design installation and operation of the Solar PV plants.

Question #1 – What are photovoltaic (solar) systems or "PV"?
A photovoltaic system (PV system) uses photovoltaic cells (PV) to convert sunlight into electricity. PV cells are made of semiconductors and are used to assembly PV modules that are the components used in PV systems. A great advantage of PV systems is that they are fully scalable and may vary in size according to the local energy needs, thus they can be used for residential, commercial and industrial electricity supply.
There are two main types of PV systems: grid-connected and stand-alone.

- A grid-connected PV system is connected to the existing electricity grid. The electricity produced by the system can be used to feed local loads and the surplus is delivered to the electricity grid. This type of system is our main focus, as EWA Distributed Solar Program deals with PV systems connected to EWA electricity grid.
- Off-Grid PV systems are not connected to the grid and are designed to use the electricity produced by the PV exclusively in your own residence or facility.

NOTE: In all cases the energy produced by the PV modules is converted from DC to AC by an Inverter, either for your own use or for export to the EWA network.

Question #2 – What are the benefits of installing a solar PV system for home and business owners?
(Preliminary remark: from here forward only grid-connected PV systems will be considered).
Using solar energy produces no air or water pollution and no greenhouse gas emissions.
Solar power offers benefits to both homeowners and businesses:

- Reduce electricity bills - installing a solar PV system requires you to undertake an initial investment, but – due to the electricity generated locally – allows you to reduce your electricity bills over lifetime of the system (25 years and beyond for a well maintained installation);
- Increase the value of your propriety – should you decide one day to sell or rent your propriety, it will attract a higher price or rent in the market if a PV system is installed. In fact, the new owner will enjoy lower electricity bills due to the electricity generated by the PV system;
- Reduce your carbon footprint - Your carbon dioxide footprint is a measure of how much carbon dioxide you are releasing into the environment based on your energy-consuming habits. By using solar energy, you will be able to reduce or even erase your carbon footprint;
- Supports Bahrain’s economy and ensure its sustainable future - Solar power is locally produced, and every kWh of solar energy that we produce in Bahrain, reduces our demand for electricity.

Question #3 – How does our society collectively benefit from this?
Solar energy is a full renewable energy, which is clean, secure, and limitless. It produces no emissions and does not negatively affect the environment.
Using renewable energy reduces our reliance on the diminishing traditional sources of energy such as gas, oil and coal, ensuring sustainability for future generations.
Renewable energy is a key factor in Bahrain’s efforts to foster economic, and social growth while preserving the environment.

Question #4 – How high is the investment cost (equipment, installation, connection, maintenance)?
Cost depends on a number of factors, such as whether the system is building-applied on building (BAPV), building-integrated on building (BIPV), ground-mounted or different. Moreover, the size, the technology and other minor factors actually affect the investment cost.
It can be roughly said that the PV modules make up between 30-50% of the total installation costs. Annual maintenance fees are in the range of 0.5-1% of the installation costs. Connection fees are typically a small share of the total cost.

Question #5 – Are any incentives being provided?
The Kingdom of Bahrain is applying a so-called Net Metering scheme. In this case you can produce your own electricity and consume it directly. If more electricity is produced than consumed, it can be injected into the EWA distribution network. This surplus energy will be credited and used to offset future consumption of electricity. The incentive is therefore the savings on the electricity bill, as you will be purchasing less electricity from EWA in order to meet your needs

Question #6 – What is the estimated return on investments and savings for a residential property/ commercial and/or industrial premises?
If the solar PV system is well dimensioned according to consumptions, the return on investment depends mainly on the followings:

- the electricity tariff you are paying;
- how much electricity the photovoltaic system will produce (with respect to its capacity);
- the cost of the PV system (with respect to its capacity).

Savings are normally related to the scale of the investment: the bigger the solar PV plant, the higher the savings. Furthermore, in spite of their full technical scalability, solar PV systems are affected by scale economy, that is their cost increases less than proportionally to their size.
In order to dimension correctly the solar PV system, you can ask your provider how much your new system will produce on an annual basis and compare that number to your annual electricity demand to get an idea of how much you will save.

Question #7 – Who is involved in the different steps needed to connect a Solar PV system?
The followings are always present:

- EWA
- Municipality and other public bodies involved in the Building Permit
- Customer or Applicant
- Consultant / Contractor

Question #8 – Can I install a solar PV system in my home/ business premises/ production facility?
Solar PV systems can be installed in your home and in your commercial or industrial premises provided there are suitable conditions for the installation. Solar PV systems can be blended into a wide range of residential, commercial and industrial building structures.
PV can be used to power your premise's electrical systems, including lights, electrical cooling systems, and appliances.

Question #9 – How big a photovoltaic system do I need?
The size of solar PV system you need depends on several factors such as how much electricity you use, the size of your roof, or anyway the surface you wish to cover with PV modules, and how much

you're willing to invest. Also, you need to consider whether you want the system to supply your complete electricity usage, or only a part of that. In order to optimize the financial benefits of the net metering scheme, you should install a system that during its lifetime, produces at the most, the amount of electricity that you will be consuming over the same period.
You can contact a Certified Consultant that will help you determine what size and type of system would suit your needs.

Question #10 – What equipment is needed?
A PV system is made up of different components. These include:

- Solar PV Modules (also called Solar Panels) – Solar PV modules are the electricity generating units of a PV system. Normally, the specific nominal power of a PV modules at full sunlight (Standard Test Conditions) is 200-300 W, but its actual yield depends from several factors, first of all the solar irradiance. The power produced by PV modules may be hardly used as it is and requires a Power Conversion Equipment or inverter in order to fit grid parameters.
- Inverter - The Inverter converts the DC power produced by the solar PV modules into AC power that is perfectly compatible with the EWA supply. This AC power feeds internal electric loads and, when production exceeds consumption, is delivered to the Bahrain's electric network.
- Metering System – To measure the electricity generated by the renewable generation plant and electricity consumed in the premises, two energy meters must be installed:
    - The first meter, supplied and installed by EWA, measures the power generated by the PV system.
    - The second meter, supplied and installed by EWA, measures the power imported and exported from/to the electric network.
- AC panel and Interface protection – In addition, an automatic decoupling device (also called Interface Protection) shall be installed between the inverter and the network connection point (if it is not yet incorporated in the inverter). This decoupling device stops the PV plant when a problem is detected on the network or when there is a network outage.

Question #11 – Who will be responsible for maintaining the solar panels and related equipment once it is installed?
The maintenance of the system is under the responsibility of the customer, who is required to have a maintenance contract with a Certified Consultant/ Contractor. During the connection process, the Applicant will be required to present a signed Maintenance and Service Contract.

Question #12 – What happens to my current electricity meter if I install a PV system?
Your current meter will be replaced by a smart meter measuring not only the electricity that you will import from the EWA electricity grid, but also the electricity that you will export to EWA grid. Moreover, a second smart meter measuring the electricity generated by your PV system will be installed.

Question #13 – Where are the solar PV modules usually installed?
In urban environments such, the solar panels are typically placed in buildings or canopies rather than mounted on the ground. Installations are preferable on rooftops rather than on the building façade, to optimize the power production (vertical tilted PV modules produce about a half than those optimally tilted). Access for cleaning and maintenance shall also be taken into account. However, PV systems can be blended into almost any imaginable structure. As an example, you might find PV systems being used outdoors in parking lot rooftops and bus station shelters.

Question #14 – Is there a limit as to how much solar electricity a EWA customer can produce?
As per the Connection Conditions, the power capacity installed cannot exceed the maximum load allowed at your premises. Moreover, EWA could impose a lower threshold should it be justified by technical limitations related to the integration of your PV system into the power distribution grid.
In order to optimize the financial benefits of the net metering scheme, you should dimension the solar PV system that during its lifetime, produces at the most, the electricity that you will be consuming over the same period.

Question #15 – What happens to the energy produced? Is it automatically available for my personal use or is it fed back into the grid?
The electricity produced by the solar panel system is available for your own use and any excess is fed back into the grid. The quantities exported to EWA grid are carefully monitored by the meter so that you can be credited on your future electricity bills.

Question #16 – In case of a network outage, can I use my solar PV system as a power supply?
Unfortunately not. For many technical reasons a grid connected solar PV system can work properly only if the network is on and its parameters (voltage and frequency) are in their correct range.
Just for sake of clarity and information, different PV systems are normally used in Countries where the network is unreliable. These systems are more expensive because need an energy storage and redundancy equipment.

ANNEX B - DOCUMENTATION DETAILS

B.1 – Solar PV Application Form

The following form is used by the Applicant for a new request.

Solar PV Application – New request	
Information on the Applicant	
Type of Applicant	☐ Individual ☐ Organization
Organization (if applicable)	
First name	
Last name	
P.O. Box	
Street number	
Street name	
Location / Area	
City	
Nationality	
Telephone	
Mobile telephone	
Fax	
e-mail	
Notes	
Information on Consultant / Contractor	
Organization (if applicable)	
Name or the accountable	
P.O. Box	
Street number	
Street name	
Location / Area	
City	
Nationality	
Telephone	
Mobile telephone	
Fax	
e-mail	
Notes	
Point of Connection details	
Connection (POC) owner	
P.O. Box	
Street number	
Street name	
Location / Area	
City	

EWA
هيئة الكهرباء والماء
Electricity & Water Authority
Kingdom of Bahrain

Solar PV Application – New request	
Voltage delivery	☐ 230V (1 phase) ☐ 400 V (3 phases) ☐ 11 kV
Total connected load	
Proposed load (if different)	
Project overview	
PV capacity [kW]	
Inverter AC capacity [kW]	
Short circuit contribution from the plant to the network [A]	
PV module installation	☐ On building ☐ Other structure (e.g. canopy) ☐ Ground
Building installation (if applicable)	☐ Flat rooftop ☐ Roof flap ☐ Façade ☐ Other
Building type (if applicable)	☐ Villa or small household ☐ Apartment block ☐ Offices ☐ School/University ☐ Healthcare/Hospital ☐ Industrial ☐ Hotel/Restaurant ☐ Entertainment ☐ Agricultural/Stable ☐ Detention/Correctional ☐ Other . . . .
Area of the PV array [m^2]	
PV technology	☐ Mono-crystalline silicon ☐ Multi-crystalline silicon ☐ Thin-film (specify) . . . . ☐ Other (specify) . . . .
Tracking system if any	☐ No tracking ☐ Single-axis tracking ☐ Two-axes tracking
List of annexes	
Planimetrics	
Single-line diagram	
Annex 1	
Annex 2	
Annex 3	
Annex 4	
Annex 5	
Annex 6	
Annex 7	
Annex 8	
Annex 9	
Annex 10	

ANNEX C – SOLAR PV DESIGN REQUIREMENTS

1 PREFACE

In this section the minimum documentation that should be provided in the frame of the process for the installation of a grid connected PV system is listed. This information will ensure key system data is readily available also to a customer, inspector or maintenance engineer. The documentation includes basic system data and the information expected to be provided in the operation and maintenance manual.
The list reported hereafter is based on the IEC 62446-1, but depending on the size of the PV plant, that is up to 11 kW or above, the design documentation required and its organization is different. Check lists are also provided in the paragraphs 1.4.1 (Solar PV plant up to 11 kW) and 1.4.2 (Solar PV plants above 11 kW) to assure all the required documentation is shared during the process.
The documentation on Operation and Maintenance is listed separately in the paragraph 1.4.3.

1.1 All Solar PV plants

1.1.1 Basic system information

As a minimum, the following basic system information shall be provided. This "nameplate" information shall be presented on the cover page of the system documentation pack:

a) Project identification reference (where applicable)
b) Rated (nameplate) system power (kW DC and kVA AC)
c) PV modules and inverters – manufacturer, model and quantity
d) Installation date
e) Commissioning date
f) Customer name
g) Site address

1.1.2 System designer information

As a minimum, the following information shall be provided for all bodies responsible for the design of the system. Where more than one company has responsibility for the design of the system, the following information should be provided for all companies together with a description of their role in the project.

a) System designer, company.
b) System designer, contact person.
c) System designer, postal address, telephone number and e-mail address.

1.1.3 System installer information

As a minimum, the following information shall be provided for all bodies responsible for the installation of the system. Where more than one company has responsibility for the installation of the system, the following information should be provided for all companies together with a description of their role in the project.

a) System installer, company.
b) System installer, contact person.
c) System installer, postal address, telephone number and e-mail address.

1.2 Solar PV plants up to 11 kW

1.2.1 Wiring diagram

As a minimum, a single line wiring diagram in a suitable and readable format shall be provided.
In general, it is expected that this information will be presented as annotations to the single line wiring diagram. In some circumstances, typically for larger systems where space on the diagram may be limited, this information may be presented in table form.

1.2.1.1 Array – General specifications

The wiring diagram or system specification shall include the following array design information.

a) PV module type(s).
b) Total number of PV modules.
c) Number of strings.
d) Number of PV modules per string.
e) Identify which strings connect to which inverter.

Where an array is split into sub-arrays, the wiring diagram shall show the array – sub-array design and include all of the above information for each sub-array.

1.2.1.2 PV string information

The wiring diagram or system specification shall include the following PV string information.

a) String cable specifications – size and type.
b) String overcurrent protective device specifications (where fitted) – type and voltage/current ratings.
c) Blocking diode type (if relevant).

1.2.1.3 PV array electrical details

The wiring diagram or system specification shall include the following array electrical information (where fitted).

a) Array main cable specifications: Size, type manufacturer and model.
b) Array junction boxes / combiner boxes: Locations, manufacturer, model and internal electric diagram.
c) DC switch disconnector: Location and rating (voltage / current), manufacturer and model.
d) Array overcurrent protective devices: Type, location, rating (voltage / current), manufacturer and model.
e) Other array electronic protective circuitry (such as arc fault detection), if applicable: Type, location, rating, manufacturers and models.

1.2.1.4 AC system

The wiring diagram or system specification shall include the following AC system information.

a) AC isolator location: Type, rating, manufacturer and model.
b) AC overcurrent protective device: Location, type, rating, manufacturer and model.
c) Residual current (where fitted): Device location, type and rating.
d) Interface protection: Type, manufacturing and model
e) Interface switch (and backup switch if applicable): Location, type, rating, manufacturer and model.

1.2.1.5 Earthing and overvoltage protection

The wiring diagram or system specification shall include the following earthing and overvoltage protection information.

a) Details of all earth / bonding conductors – size and type. Including details of array frame equipotential bonding cable where fitted.
b) Details of any connections to an existing Lightning Protection System (LPS).
c) Details of any surge protection device installed (both on AC and DC lines) to include location, type and rating.

1.2.2 Planimetry and String layout

Planimetry of the PV array with the indication of tilt and orientation. Possible sources of shading shall be clearly indicated.

For systems with three or more strings, a layout drawing of the PV system showing how the array is split and connected into strings shall be provided.

This is particularly useful for finding faults in larger systems and on building mounted arrays where access to the rear of the modules is difficult.

1.2.3 Datasheets

As a minimum, datasheets shall be provided for the following system components:

a) PV module datasheet for all types of modules used in system
b) Inverter datasheet for all types of inverters used in system.
c) Interface protection datasheet

The provision of datasheets for other significant system components should also be considered.

1.2.4 Mechanical design information

A data sheet for the array mounting system shall be provided. If the mounting structure was custom engineered, include the relevant documentation.

1.2.5 Emergency systems

Documentation of any emergency systems associated with the PV system (fire alarms, smoke alarms, etc.). This information shall include both operation and design details.

1.2.6 Esteem of the yearly energy production

An esteem of the yearly energy production, based on data from literature, shall be calculated.

1.3 Solar PV plants above 11 kW

1.3.1 Technical report

Here below the structure of the Technical report is described along with a list of the minimum information to be included. Further information might be required, depending on the type and size of the PV system, and the document might be organized differently. For example, in case of MV connection, a further section dedicated to MV shall be included.

Although the organization of the Technical report as described below is recommended, one may adopt a different structure, provided the general criteria be fulfilled (e.g. separation of the input data from the information elaborated during the design) and no information are missing.

1.3.1.1 Preliminary information

As a minimum, the following basic system information shall be provided. This "nameplate" information preferably shall be presented on the cover page of the system documentation pack:

a) Project identification reference or name
b) Rated (nameplate) system power (kW DC and kVA AC)
c) PV modules and inverters – manufacturer, model and quantity
d) Installation date
e) Commissioning date
f) Customer name
g) Site address

1.3.1.2 Chapter 1 – Foreword (or Introductory section, or Preface, …)

As a minimum, the following information shall be provided:

- Type of solar system (rooftop, ground mounted, façade, …), integration if relevant (BAPV, BIPV, …), fixed mounting or tracking, technology (monocrystalline, polycrystalline, thin-film, …)
- A short description of the purpose of the project, also referring to the benefits for the client, for the environment, for the electric system, for the Nation, etc…
- System designer information for all bodies responsible for the design of the system. Where more than one company has responsibility for the design of the system, the following information should be provided for all companies together with a description of their role in the project.
    a. System designer, company.
    b. System designer, contact person.
    c. System designer, postal address, telephone number and e-mail address.
- System installer information for all bodies responsible for the installation of the system. Where more than one company has responsibility for the installation of the system, the following information should be provided for all companies together with a description of their role in the project.
    a. System installer, company.
    b. System installer, contact person.
    c. System installer, postal address, telephone number and e-mail address.

1.3.1.3 Chapter 2 – Input data

It is important to separate the input data for the design (environment, local laws and rules, constraints, relevant grid characteristics, etc.) listed here below from the information elaborated at design stage that will be detailed in further chapters.

As a minimum, the following information shall be provided:

- Definitions (recommended)
- Laws and standards applicable (the most relevant ones)
- Solar and environmental data on the site (monthly averages of direct and diffuse solar radiation, wind speed, average and maximum temperatures, …)
- Geological and environmental constraints (if any) as type of soil, inclination, need of stabilization or other treatment, shading, presence of vegetation, animals, etc…
- Characteristics of the grid at POC: voltage, frequency, No. of phases, type of earthing system (TT, TN, IT, etc…), short circuit current, any further available information on power supply.

1.3.1.4 Chapter 3 – Characteristics of the main devices and equipment

As a minimum, the following information shall be provided:

- PV modules (Manufacturer, model, technology, type of PV cells, Pn, Vm, Im, Voc, Isc, Temperature coefficients α β γ, NOCT, dimensions and weight, certifications, etc…)
- Inverters (manufacturer, model, Pn, Max input current, Max input voltage, MPPT range, output voltage and frequency range, Max temperature, IP enclosure, dimensions, weight, certifications, etc…)
- DC combiner boxes – if present – (Manufacturer, model, No. of inputs, protection on inputs, switch/disconnector, PV string monitoring if any, IP enclosure, dimensions, weight, certifications, etc…)
- Interface protection – if external to the inverters – (Manufacturer, model, functions, standards compliance, certifications, etc…)
- Monitoring system – if present – (manufacturer, model, solar and meteorological inputs, DC inputs, AC inputs, data line exchange, storage, data display, certifications if any, etc…)

1.3.1.5 Chapter 4 – System architecture and dimensioning

As a minimum, the following information shall be provided:

- DC and AC capacity and how is obtained from PV modules and inverters
- General architecture of the system from PV modules to the POC (this should include a very simple block diagram with PV modules, inverters, main switches and protections, meters, POC, energy flows, etc…)
- Characteristics of the PV strings and PV array(s) (Vm, Im, Voc, Isc, inclination(s), orientation(s))
- Verification of compliance for PV strings/array(s) and inverters (MPPT range, max volt ages, max currents, etc…)
- Description of the grid connection and power delivery (protection, grid services, capability, etc…)

1.3.1.6 Chapter 5 – DC section

As a minimum, the following information shall be provided:

- Verification of compliance for DC cables (current, voltage drops)
- Measures to prevent overcurrent in parallel PV strings

1.3.1.7 Chapter 6 – AC section

As a minimum, the following information shall be provided:

- Measures to prevent electric shocks from direct contacts (class II insulations, tubes and channels, etc…)
- Measures to prevent electric shocks from indirect contacts (earthing, RCDs, etc…)
- Characteristics of the main AC devices (Manufacturer, model, type of device, No. of poles, aux contacts, nominal current, short-circuit current, characteristics of the protection, etc…)
- AC calculations (verification of compliance for AC devices and cables)

1.3.1.8 Chapter 7 – Civil and mechanical installation

As a minimum, the following information shall be provided:

- Description of the mounting structures
- Structural calculations (if necessary)

1.3.1.9 Chapter 8 – Performance calculation

As a minimum, the following information shall be provided:

- Calculation of the solar radiation on the PV system
- Energy Yield (monthly and yearly)
- CO_2 saved

1.3.2 Wiring diagram

As a minimum, a multiple line wiring diagram in a suitable and readable format shall be provided. If necessary, the diagram may be distributed in more than one sheet.

In addition, a single line diagram, which contains the most relevant information and gives an overview of the PV plant is recommended, especially in case of large plants.

The information listed below are also required. In general, it is expected that this information will be presented as annotations to the single line wiring diagram. In some circumstances, typically for larger systems where space on the diagram may be limited, this information may be presented in table form.

1.3.2.1 Array – General specifications

The wiring diagram or system specification shall include the following array design information.

a) PV module type(s).
b) Total number of PV modules.
c) Number of strings.
d) Number of PV modules per string.
e) Identify which strings connect to which inverter.

Where an array is split into sub-arrays, the wiring diagram shall show the array – sub-array design and include all of the above information for each sub-array.

1.3.2.2 PV string information

The wiring diagram or system specification shall include the following PV string information.

a) String cable specifications – size and type.
b) String overcurrent protective device specifications (where fitted) – type and voltage/current ratings.
c) Blocking diode type (if relevant).

1.3.2.3 PV array electrical details

The wiring diagram or system specification shall include the following array electrical information (where fitted).

a) Array main cable specifications: Size, type manufacturer and model.
b) Array junction boxes / combiner boxes: Locations, manufacturer, model and internal electric diagram.
c) DC switch disconnector: Location and rating (voltage / current), manufacturer and model.

d) Array overcurrent protective devices: Type, location, rating (voltage / current), manufacturer and model.
e) Other array electronic protective circuitry (such as arc fault detection), if applicable: Type, location, rating, manufacturers and models.

1.3.2.4 AC system

The wiring diagram or system specification shall include the following AC system information.

a) AC isolator location: Type, rating, manufacturer and model.
b) AC overcurrent protective device: Location, type, rating, manufacturer and model.
c) Residual current (where fitted): Device location, type and rating.
d) Interface protection: Type, manufacturing and model
e) Interface switch (and backup switch if applicable): Location, type, rating, manufacturer and model.

1.3.2.5 Earthing and overvoltage protection

The wiring diagram or system specification shall include the following earthing and overvoltage protection information.

a) Details of all earth / bonding conductors – size and type. Including details of array frame equipotential bonding cable where fitted.
b) Details of any connections to an existing Lightning Protection System (LPS).
c) Details of any surge protection device installed (both on AC and DC lines) to include location, type and rating.

1.3.3 Planimetry and String layout

Planimetry of the PV array with the indication of tilt and orientation. Possible sources of shading shall be clearly indicated.
For systems with three or more strings, a layout drawing of the PV system showing how the array is split and connected into strings shall be provided.
This is particularly useful for finding faults in larger systems and on building mounted arrays where access to the rear of the modules is difficult.

1.3.4 Datasheets

As a minimum, datasheets shall be provided for the following system components:

a) PV module datasheet for all types of modules used in system
b) Inverter datasheet for all types of inverters used in system.
c) Interface protection datasheet

The provision of datasheets for other significant system components should also be considered.

1.3.5 Mechanical design information

A data sheet for the array mounting system shall be provided. If the mounting structure was custom engineered, include the relevant documentation.

1.3.6 Emergency systems

Documentation of any emergency systems associated with the PV system (fire alarms, smoke alarms, etc.). This information shall include both operation and design details.

1.4 Solar PV Design Check-list

The following forms contain the check list used to validate the documentation at design Approval stage. The Applicant can use this form in order to check the completeness of documents and information required at the stage of Design Approval.

1.4.1 Up to 11 kW

Solar PV Design Check-list – Pn ≤ 11 kW

Basic system information

Project identification reference (if applicable)	
Rated (nameplate) system power (kW DC and kVA AC)	
PV modules – manufacturer, model and quantity	
Inverters – manufacturer, model and quantity	
Installation date	
Commissioning date (if available)	
Customer name	
POC	
P.O. Box	
Street name and number	
Location / Area	
City	

System designer information

Company	
Contact person	
Postal address	
Telephone and e-mail	

System installer information

Company	
Contact person	
Postal address	
Telephone and e-mail	

Wiring diagram

Field	Result / Value	Notes
Type of PV modules	☐ Yes ☐ No	
Tot. number of PV modules	☐ Yes ☐ No	
Number of strings	☐ Yes ☐ No	
Number of PV modules per string	☐ Yes ☐ No	
Connection strings / inverters	☐ Yes ☐ Not applicable ☐ No	
String cable size and type		
String overcurrent protective device – type and voltage/current ratings	☐ Yes ☐ Not applicable ☐ No	
Blocking diode type	☐ Yes ☐ Not applicable ☐ No	
Array main cable: Size, type manufacturer and model	☐ Yes ☐ Not applicable ☐ No	
Combiner boxes: Locations,	☐ Yes ☐ Not applicable ☐ No	

manufacturer, model and internal electric diagram		
DC switch disconnector: Location and rating (V/A), manufacturer and model	☐ Yes ☐ Not applicable ☐ No	
Other array electronic protective circuitry: Type, location, rating, manufacturers and models	☐ Yes ☐ Not applicable ☐ No	
AC isolator location: Type, rating, manufacturer and model	☐ Yes ☐ No	
AC overcurrent protective device: Location, type, rating, manufacturer and model	☐ Yes ☐ No	
Residual current (where fitted): Device location, type and rating	☐ Yes ☐ Not applicable ☐ No	
Interface protection: Type, manufacturing and model	☐ Yes ☐ Internal ☐ No	
Interface switch: Location, type, rating, manufacturer and model	☐ Yes ☐ Internal ☐ No	
Backup switch: Location, type, rating, manufacturer and model	☐ Yes ☐ Not applicable ☐ No	
Details of all earth/bonding conductors – size and type	☐ Yes ☐ No	
Details of array frame equipotential bonding cable	☐ Yes ☐ Not applicable ☐ No	
Details of any connections to an existing LPS	☐ Yes ☐ Not applicable ☐ No	
Details of any surge protection device installed	☐ Yes ☐ No	
Planimetry and String layout		
Indication of tilt and orientation	☐ Yes ☐ No	
Sources of shading are clearly indicated	☐ Yes ☐ Not applicable ☐ No	
Layout drawing showing how the array is split and connected into strings	☐ Yes ☐ Not applicable ☐ No	
Datasheets		
Datasheet for all types of PV modules used	☐ Yes ☐ No	
Datasheet for all types of inverters used	☐ Yes ☐ No	
Interface protection datasheet	☐ Yes ☐ Not applicable ☐ No	
Miscellaneous		
Array mounting system documentation	☐ Yes ☐ No	
Documentation of any emergency systems	☐ Yes ☐ Not applicable ☐ No	
Esteem of the yearly energy production	☐ Yes ☐ No	
Final result	☐ Passed ☐ Not passed	

1.4.2 Above 11 kW

Solar PV Design Check-list – Pn > 11 kW

Basic system information

Project identification reference (if applicable)	
Rated (nameplate) system power (kW DC and kVA AC)	
PV modules – manufacturer, model and quantity	
Inverters – manufacturer, model and quantity	
Installation date	
Commissioning date (if available)	
Customer name	
POC	
P.O. Box	
Street name and number	
Location / Area	
City	

System designer information

Company	
Contact person	
Postal address	
Telephone and e-mail	

System installer information

Company	
Contact person	
Postal address	
Telephone and e-mail	

Technical report – Preliminary information

Field	Result / Value	Notes
Project identification reference or name	☐ Yes ☐ No	
Rated (nameplate) system power (kW DC and kVA AC)	☐ Yes ☐ No	
PV modules and inverters – manufacturer, model and quantity	☐ Yes ☐ No	
Installation date	☐ Yes ☐ No	
Commissioning date	☐ Yes ☐ Not available ☐ No	
Customer name	☐ Yes ☐ No	
Site address	☐ Yes ☐ No	

Technical report – Foreword

Type of solar system, integration if relevant, fixed mounting or tracking, technology	☐ Yes ☐ No	
Short description of the purpose of the project	☐ Yes ☐ No	
information for all bodies responsible of the design	☐ Yes ☐ No	
information for all bodies responsible	☐ Yes ☐ No	

of the installation		
Technical report – Input data		
Definitions	☐ Yes ☐ Not available ☐ No	
Most relevant laws and standards applicable	☐ Yes ☐ No	
Solar and environmental data of the site	☐ Yes ☐ No	
Geological and environmental constraints	☐ Yes ☐ Not applicable ☐ No	
Characteristics of the grid at POC	☐ Yes ☐ No	
Technical report – Characteristics of the main devices and equipment		
PV modules	☐ Yes ☐ No	
Inverters	☐ Yes ☐ No	
DC combiner boxes	☐ Yes ☐ Not applicable ☐ No	
Interface protection	☐ Yes ☐ Not applicable ☐ No	
Monitoring system	☐ Yes ☐ Not applicable ☐ No	
Technical report – System architecture and dimensioning		
DC and AC capacity and how is obtained	☐ Yes ☐ No	
General architecture of the system	☐ Yes ☐ No	
Characteristics of the PV strings and PV array(s)	☐ Yes ☐ Not applicable ☐ No	
Verification of compliance for PV strings/array(s) and inverters	☐ Yes ☐ Not applicable ☐ No	
Description of the grid connection and power delivery	☐ Yes ☐ No	
Technical report – DC section		
Verification of compliance for DC cables	☐ Yes ☐ Not applicable ☐ No	
Measures to prevent overcurrent in parallel PV strings	☐ Yes ☐ Not applicable ☐ No	
Technical report – AC section		
Description of measures to prevent electric shocks from direct contacts	☐ Yes ☐ No	
Description of measures to prevent electric shocks from indirect contacts	☐ Yes ☐ No	
Characteristics of the main AC devices	☐ Yes ☐ No	
AC calculations (verification of compliance for AC devices and cables)	☐ Yes ☐ No	
Technical report – Civil and mechanical installation		
Description of the mounting structures	☐ Yes ☐ No	
Structural calculations	☐ Yes ☐ Not applicable ☐ No	
Technical report – Performance calculations		
Calculation of the solar radiation on the PV system	☐ Yes ☐ No	
Energy Yield (monthly and yearly)	☐ Yes ☐ No	
CO2 saved	☐ Yes ☐ No	

Wiring diagram		
Type of PV modules	☐ Yes ☐ No	
Tot. number of PV modules	☐ Yes ☐ No	
Number of strings	☐ Yes ☐ No	
Number of PV modules per string	☐ Yes ☐ No	
Connection strings / inverters	☐ Yes ☐ Not applicable ☐ No	
String cable size and type		
String overcurrent protective device – type and voltage/current ratings	☐ Yes ☐ Not applicable ☐ No	
Blocking diode type	☐ Yes ☐ Not applicable ☐ No	
Array main cable: Size, type manufacturer and model	☐ Yes ☐ Not applicable ☐ No	
Combiner boxes: Locations, manufacturer, model and internal electric diagram	☐ Yes ☐ Not applicable ☐ No	
DC switch disconnector: Location and rating (V/A), manufacturer and model	☐ Yes ☐ Not applicable ☐ No	
Other array electronic protective circuitry: Type, location, rating, manufacturers and models	☐ Yes ☐ Not applicable ☐ No	
AC isolator location: Type, rating, manufacturer and model	☐ Yes ☐ No	
AC overcurrent protective device: Location, type, rating, manufacturer and model	☐ Yes ☐ No	
Residual current (where fitted): Device location, type and rating	☐ Yes ☐ Not applicable ☐ No	
Interface protection: Type, manufacturing and model	☐ Yes ☐ Internal ☐ No	
Interface switch: Location, type, rating, manufacturer and model	☐ Yes ☐ Internal ☐ No	
Backup switch: Location, type, rating, manufacturer and model	☐ Yes ☐ Not applicable ☐ No	
Details of all earth/bonding conductors – size and type	☐ Yes ☐ No	
Details of array frame equipotential bonding cable	☐ Yes ☐ Not applicable ☐ No	
Details of any connections to an existing LPS	☐ Yes ☐ Not applicable ☐ No	
Details of any surge protection device installed	☐ Yes ☐ No	
Planimetry and String layout		
Indication of tilt and orientation	☐ Yes ☐ No	
Sources of shading are clearly indicated	☐ Yes ☐ Not applicable ☐ No	
Layout drawing showing how the array is split and connected into strings	☐ Yes ☐ No	
Datasheets		
Datasheet for all types of PV modules used	☐ Yes ☐ No	
Datasheet for all types of inverters used	☐ Yes ☐ No	
Interface protection datasheet	☐ Yes ☐ No	

Miscellaneous		
Array mounting system documentation	☐ Yes ☐ No	
Documentation of any emergency systems	☐ Yes ☐ Not applicable ☐ No	
Esteem of the yearly energy production	☐ Yes ☐ No	
Final result	☐ Passed ☐ Not passed	

1.4.3 Operation and Maintenance Information

The Applicant deliver to EWA/EDD a document that includes at least minimum information set on Operation and Maintenance as listed below:

a) Procedures for verifying correct system operation.
b) A checklist of what to do in case of a system failure.
c) Emergency shutdown / isolation procedures.
d) Maintenance and cleaning recommendations (mechanical, civil & electrical) – if any.
e) Considerations for any future building works related to the PV array (e.g. roof works).
f) Warranty documentation for PV modules and inverters – to include starting date of warranty and period of warranty.
g) Documentation on any applicable workmanship or weather-tightness warranties.