هيئة تنظيم الكهرباء - عمان
AUTHORITY FOR ELECTRICITY REGULATION, OMAN

Small Scale Grid-Connected Solar PV Systems

Connection Guidelines

May 2017

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1 INTRODUCTION

1.1 Scope

These "Guidelines for Solar PV generating plants to be connected to MV and LV network", briefly "Connection Guidelines", provide information meant for Residents, Consultants and Contractors of the Sultanate of Oman on the essential aspects which have to be taken into consideration in order to connect a Solar PV plant to the Low (240/415 V) or Medium Voltage (11 or 33 kV) Distribution Network.

It applies to the planning, execution, operation and modification of Photovoltaic (PV) Generating Plants, also called Photovoltaic or Solar PV Plants.

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

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

Furthermore, this guide shall provide information to any Customers about solar PV plants and the process for the building and connection of the same to the Distribution Network.

The technical aspects are not treated here, but separately in the "Small Scale Grid-Connected Solar PV Systems- Technical Guidelines" (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 is to be considered as general information to the Customers on the connection of solar PV systems to the public network in Oman. However it seems necessary that a specific finalization be made by AER, the DISCOs and the other stakeholders in order to maximize its usefulness and completeness.

It is intended that the present Guidelines shall be finalised with the contribution of the DISCOs and any other entity involved in the process. The final version of the present Guidelines shall include at least:

- *Additional information on specific aspects in order to clarify certain provisions of the Standards, in particular the connection schemes.*
- *Application Form for the collection of required data relating to the generating plant. The purpose of this latter document is to provide the DISCOs with the necessary information needed for the feasibility assessment and for network planning*.

1.2 Definitions

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

AC module - A PV module with an inverter mechanically secured to it so that the electrical output is a.c. and no d.c. plug/socket connections are in use between the module and the inverter.

Active Power - Active Power is the real component of the apparent power, expressed in watts or multiples thereof (e.g. kilowatts (kW) or megawatts (MW)). In the text this may be generically referred as P or Pn in case of rated active power of equipment.

Apparent Power - Is the product of voltage (in volts) and current (in amperes). It is usually expressed in kilovolt-amperes (kVA) or megavolt-amperes (MVA) and consists of a real component (Active Power) and

an imaginary component (Reactive Power). In case of inverters, the rated apparent power corresponds to the maximum active power deliverable by the inverter at unity power factor.

Application for Connection – It is filled by an Applicant for a new Solar PV Connection. This application shall be made in a format prescribed and shall contain the required information.

Connection Agreement – The agreement signed between the Customer and the local DISCO, by which the DISCO agrees to allow Customer to connect and operate their Generation Facilities in parallel with DISCO's electric system in accordance with the operating procedures and other conditions to be specified by the DISCO.

Connection Point - Is the location at which the Solar PV Generating Unit is connected to the Network and where the Main Meter is installed. This coincides with the Metering Point defined in the Law. In the connection schemes this is also referred to as POC (Point Of Connection).

Consultant – A company that carries out the design of Electrical facilities of all types including design of Solar PV plants and certified for Solar PV installations.

Contractor – A company with a valid Trade License that carries out Electrical Consulting/Contracting works of all types including Solar PV plants. The Contractor may also perform design, supply equipment and materials or labour, especially for constructing, building and installing Solar PV plants. The Contractor should also be certified for Solar PV installations.

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

DISCO – Distribution Company – Company that manages the electricity network and assures the distribution and supply of electricity to customers, in an authorized area under a license issued by the Authority for Electricity Regulation.

Distribution System / Network - Is the medium (11 or 33 kV) or low voltage (415 V) electricity grid for supplying electricity to the end consumers.

Downstream – For a Solar PV plant, *"Downstream"* means generator bound, e.g. towards the distribution network. *"Upstream"*, instead, means the PV panel for a PV plant.

Generating Unit / Plant - A Generating Unit is an indivisible set of installations which can generate electrical energy. A set of Generating Units, circuits and auxiliary services for the generation of electrical energy forms a Generating Plant.

Interface Protection - The electrical protection required to ensure that either the Generating Plant or the Generating Unit is disconnected for any event that could impair the integrity or degrade the safety of the Distribution Network.

Inverter – Device which converts the direct current produced by the photovoltaic modules to alternating current in order to deliver the output power to the grid. The inverter is also capable of controlling the quality of output power.

Isolated inverter – An inverter with, at least, simple separation between the main power output circuits and PV circuits (usually by means of a transformer) and with leakage currents less than the limits required to be classified as an isolated inverter (IEC 62109-2). The separation/ isolation may be either integral to the inverter or provided externally, e.g. an inverter with an external isolation transformer.

Non-isolated inverter – An inverter without the minimum separation between the main power output and PV circuits or with leakage currents greater than the requirements for an isolated inverter.

Junction box – Closed or protected connecting device were one or several junctions are performed.

Low Voltage (LV) Network – A Network with nominal voltage lower than 1kV.

Maximum Capacity - The maximum continuous Active Power which a Generating Plant can feed into the Network as agreed between the DISCO and the Plant Producer. This corresponds to the sum of the maximum active power deliverable by the inverters at the AC side, that is also the sum of the rated power of the inverters at unity power factor (to be noted that this latter may also be lower than the sum of the power at STC of the photovoltaic modules). In the text, this maximum capacity will also be indicated as P_{MC}.

Medium Voltage (MV) Network- A Network with nominal voltage included in the range from 1kV up to 33 kV. In the Sultanate of Oman, the voltage levels on the MV distribution network, are 11 and 33 kV.

Main Electricity Meter - The main electricity meter installed at the Connection Point (DISCO side) and will perform the Net Metering of: i) the electricity delivered by the Solar PV plant to the Distribution Network; and ii) the energy absorbed from the Distribution Network on a monthly basis.

Microinverter - An inverter that converts direct current produced by a single PV module to alternating current. The output from several microinverters is combined in order to deliver the output power to the grid.

Solar PV Plant Electricity Meter - Electricity meter installed at the common output point of all the Generating Units, to measure the total energy produced by the Solar PV plant.

Network - Plant and apparatus connected together and operated by the DISCO in order to transmit or distribute electrical power.

Non-Synchronously-Connected Generating Unit – A Generating Unit that is not electromagnetically directly connected to the Network. All types of installations that are fully connected to the Network through Power Electronic Converters, for instance photovoltaic power Generating Units, fall into this category.

Overall duration: Total amount of time needed for project development until PV plant starts operating.

Peak Power (Wp) – The output power achieved by a Photovoltaic Module under Standard Test Conditions (STC). It is measured in Wp (W peak). The sum of the peak power of the photovoltaic modules of either a string or an array determines the peak power of the string and the array respectively (usually measured in kWp). The peak power of a photovoltaic array at STC is conventionally assumed as the rated power of the array.

Permission: A license to carry out an act that, without such licence, would be considered unlawful.

Photovoltaic (PV) cell – The most elementary device that exhibits the photovoltaic effect, i.e. the direct non-thermal conversion of radiant energy into electrical energy.

Photovoltaic (PV) module – Also called Photovoltaic (PV) panel. The smallest, complete, environmentally protected assembly of interconnected cells.

Photovoltaic (PV) string – A circuit of one or more series-connected modules.

Photovoltaic (PV) string combiner box – A junction box where PV strings are connected which may also contain overcurrent protection devices and/or switch-disconnectors.

Photovoltaic (PV) array – Assembly of electrically interconnected PV modules, PV strings or PV sub-arrays.

Photovoltaic (PV) sub-array – An electrical subset of a PV array formed by parallel-connected PV strings.

Power Factor - Is the ratio of Active Power to Apparent Power.

Protective earthing – Earthing of a point in equipment or in a system for safety reasons.

Power Distribution System -The electrical network and its components which are owned and operated by the DISCO with the main purpose of delivering electricity to consumers from the Power Transmission System. The 33kV and below voltage levels are considered a distribution system. The components of a

Power Distribution system include all associated equipment including but not limited to interconnecting lines, electrical substations, pole mounted transformers, analogue electrical elements such as resistors, inductors, capacitors, diodes, switches and transistors.

Power Transmission System - The system belonging to Distribution Company which entirely or mainly comprises of the High-Voltage (> 33 kV) electricity cables, lines and electricity installations and facilities owned and/or operated by the DISCO and used to transmit electricity from a power unit to a power substation or other electricity generation unit.

Process: A Process is one of the necessary functional procedures necessary to develop a PV system. A Process is described by a sequence of Process Steps (which may be of either administrative or technical nature).

Process Duration: The overall time needed to complete a specific process of the PV project lifecycle.

Process Step: A step is one of a sequential succession of actions that need to be executed in order to satisfy the legal-administrative and the other requirements of a process.

Producer: Any entity authorised by the Authority to produce electricity connected to the network in Sultanate of Oman. In other documents the term “Generator” may be used.

PV Project Lifecycle: All the procedures required to authorise, install and finally connect a PV system. The Project Lifecycle is defined as a sequential succession of Processes, each of them described by a sequence of Process Steps (either administrative or technical).

Reactive Power - Reactive Power is the imaginary component of the apparent power, usually expressed in kilovar (kVAr) or Megavar (MVAr).

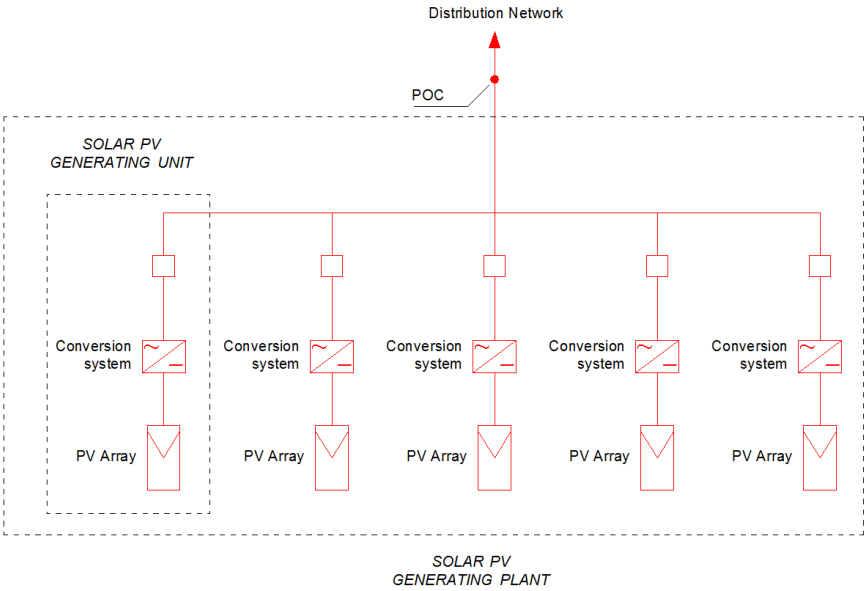
Representative - Any person representing or mandated to represent a party, including, but not limited to its directors, members of management, officers, employees, or professional advisors.

Solar PV Application fee - The fee to be paid when applying for the connection of a Solar PV plant. When the Producer receives the Design Approval and the estimation of the Grid Connection fee, this Application fee will be reimbursed and/or compensated with reference to payment of the Solar PV Connection fee.

Solar PV Connection fee - The fee to be paid for the connection of a Solar PV generating plant to the grid.

Solar PV Generating Plant - Is a set of Solar PV Generating Units.

Solar PV Generating Unit - Is a Generating Unit that produces power exclusively from the Solar PV renewable primary resource. This Solar PV Generating Unit can be part of a Generating Plant that includes non-renewable resources. In this latter situation, the Solar PV Generating Unit mentioned in the Standards is the part of the Plant that is able to produce energy without input from non-renewable resource. The Photovoltaic Generating Plant is illustrated below:



Solar PV Plant Voltage - Unless stated otherwise, voltage refers to the root-mean-square value of phase-to-phase voltages.

Solar PV Initial Enquiry – An application for the purpose of constructing a Solar PV generating plant.

Standard test conditions (STC) – A standard set of reference conditions used for the testing and rating of photovoltaic cells and modules. The standard test conditions are:

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).

Test Engineer – A Contractor or a Consultant or a Licensed Engineer who is skilled and qualified for testing photovoltaic installations as certified by the Distribution Company.

Upstream – See: *Downstream*

1.3 Reference documents

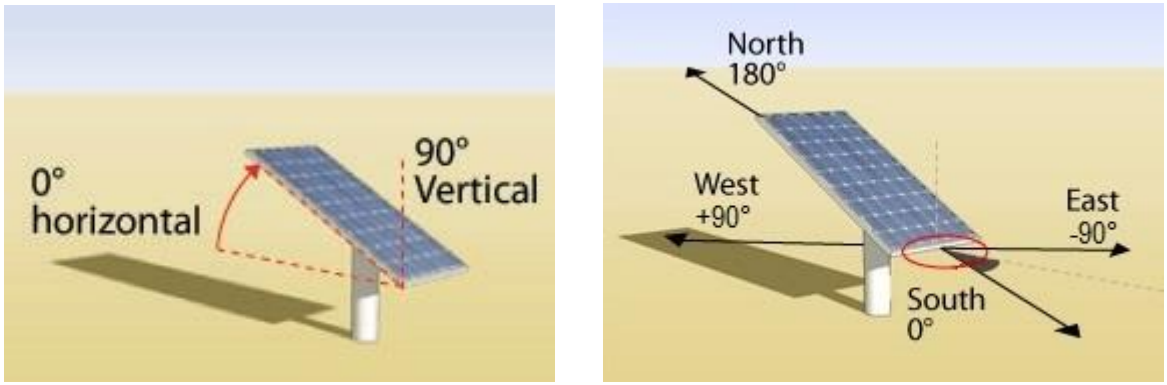
[1] M. Pudlik, C. Reise; “Advisory Services on Renewable Energy Promotion in Oman”; GIZ (Berlin), 2014
[2] “Small Scale Grid-Connected Solar PV Systems- Technical Guidelines”, 1st edition

2 PHOTOVOLTAIC INSTALLATION

2.1 Orientation and Inclination of PV modules

There are several factors to be accounted for when planning to install photovoltaic panels. 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 the Sultanate of Oman throughout the year is South (0° S) with an inclination (tilt) approximately ranging from 20° (Salalah) to 24° (Muscat) with respect to the horizontal plane. This allows an average annual irradiation on a horizontal plane of about 2060÷2390 kWh/m²yr (average 2225 kWh/m²yr) for Oman [1] when both the direct and diffused radiation are considered, which means about 1650÷1900 kWh/yr (average 1780 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 the Middle East, 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. The Sultanate of Oman is in a region prone to dusty desert environments and 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 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 Equipment

A typical renewable generation unit 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; and
- Electrical and mechanical installations (structures, cables, switchgears and controlgear assemblies).

The way this is connected to the network is explained in the connection schemes shown in the "Technical Guidelines" [2], according to the voltage level of the network itself.

The connection schemes also show another important element, namely 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 protection may also be included in the inverter as specified in the Standards. The required protection functions are also specified in the Standards.

If the Interface Protection acts by means of a switch-disconnector, this may also be used to disconnect the plant for maintenance purposes, without causing any shortages on the existing loads. On the contrary, if the Interface device is a contactor it is necessary to disconnect all live conductors before maintenance.

2.2.1 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 The Sultanate of Oman. 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 The Sultanate of Oman, 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.

PV modules are to be certified according to the compliance requirements defined in the Standards. The manufacturer shall then provide the Producer with certificates, proving that the PV modules are compliant with these requirements. The Applicant will be required to submit the certification document during the connection process. A list of the updated certified equipment is available at AER and or DISCO on request.

2.2.2 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.

As specified in the Standards, the inverters shall be provided with an IP65 enclosure for outdoor application and IP54 enclosure for indoor application. In this latter case, lower protection grades shall only be permitted if the characteristics of the room will be properly conceived to protect the equipment (e.g. air conditioned rooms with means to avoid dust penetration). Whatever the case may be, the inverter shall be able to withstand the maximum temperatures with effective heating dispersion and with a power derating smaller than or equal to 25 % of its rated power as determined for an ambient temperature of 50 °C at the DC design voltage. This temperature is to be considered the maximum outdoor value at which all equipment, apparatus, materials and accessories used in electrical installations must be capable of operating with satisfactory performance in the climatic conditions of the Sultanate of Oman. In addition, provisions which prevent the increase of the internal heating of the inverters shall be taken for outdoor installation (e.g. protections against direct exposition to the sun). For those inverters which do not comply with the above set rule, a placement in cooled room or enclosures with effective ventilation shall be required, inside which the ambient temperature will be kept below the value which determines a power derating equal to 25 % of the inverter rated power at the DC design voltage.

The efficiency of the Inverter should be greater than 95 % with a general guarantee of at least 10 years.

The Inverter shall be certified according to the compliance requirements defined in the Standards. The manufacturer shall then provide the Producer with a certificate, proving that its equipment is compliant with these requirements. The Applicant will be required to submit the certification document during the connection process. A list of the certified equipment is available at AER or DISCO on request.

2.2.3 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 the DISCO in the Connection Point 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 the DISCO measures the electricity generated by the photovoltaic system (Solar PV Plant Electricity Meter).

During the connection process, the Solar PV Plant will be inspected by the DISCO before the metering system can be installed. The inspection aims to ensure that the Solar PV Plant complies with the Standards and with safety rules.

2.2.4 Other equipment

All the components and equipment used in the PV plant shall be compliant to the applicable International standards and, in addition, they shall comply with applicable standards and laws in force in the Sultanate of Oman. 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 its application (e.g. solar cables). In DC circuits single-wire cables shall be used with different colours for the two poles: red for positive (+) and black or blue for negative (-). In order to avoid misunderstandings, the cables used in the AC sections of the solar PV systems shall have colours different from black and red. It is also recommended that all other AC cables used in the structures where the solar PV systems are located have colours different from black and red.
- 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).

2.3 PV array system configuration

2.3.1 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.

2.3.2 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 operating condition (solar radiation, air temperature); and

- Maximum system voltage.

2.3.3 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.

2.3.4 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 be 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).

2.3.5 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 the Sultanate of Oman 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.

2.4 Safety issues

In case 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.

The reader is addressed to the Standards where there is a detail of:

- Protection against electric shock and overcurrent:
    - Protection against electric shocks
    - Protection against overcurrent
    - PV string overcurrent protection
    - PV sub-array overcurrent protection
    - PV arrays with direct functional earth connections
- Array insulation resistance detection
- Protection by residual current monitoring system
- Earth fault protection on AC side
- Protection against effects of lightning and overvoltage
- Equipment marking and labeling

3 PV PLANT CONNECTION PROCESS

The procedure described in this section represents the steps that an Applicant must complete to get a PV Plant connected to the Distribution Network.

The whole process could be performed through the web-service which allows consumers to apply for passive connection to the Distribution Network of the licensed DISCOs.

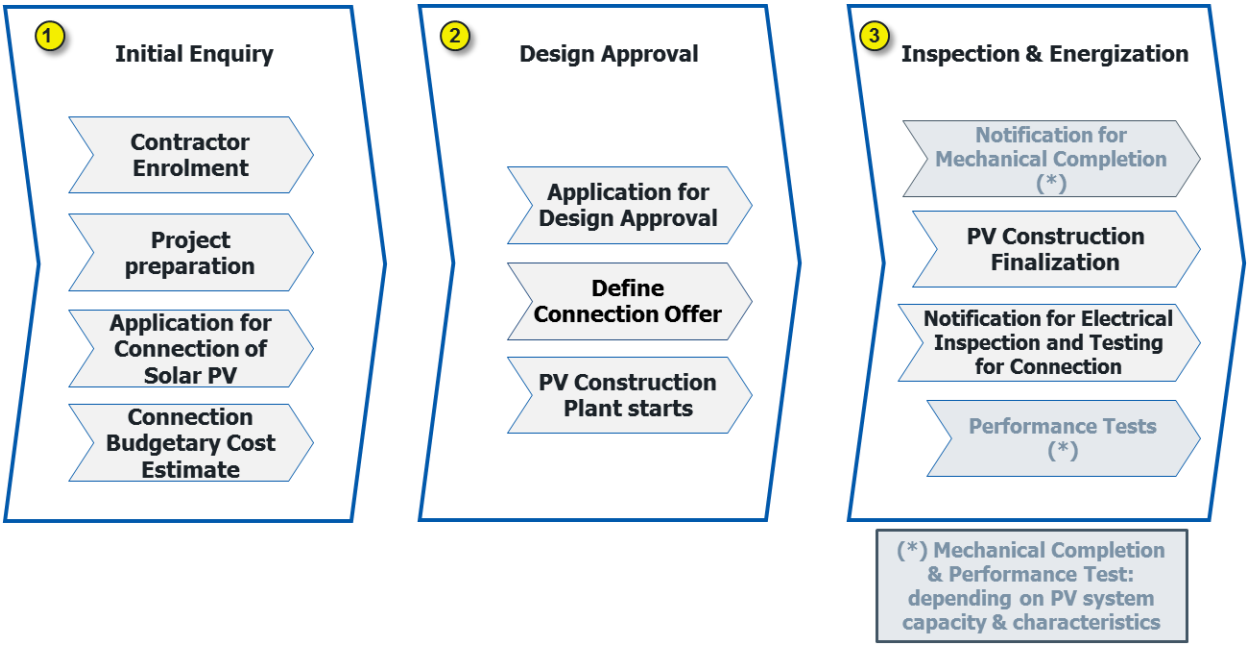


Figure 2 – Connection Process

3.1 Solar PV Initial Enquiry

3.1.1 Enrolment

An **Electrical Consultant / Contractor** has to be accredited for the installation of Solar PV Plants.

A new Electrical Consultant / Contractor will have to register through the appropriate service or website exclusively designed to apply and track the application online.

The accredited Electrical Consultant / Contractor will have in his sponsorship the technical staff possessing the required certification (Junior or Senior Solar PV expert).

Both the Electrical Consultant and the Contractor have to own a proper Trade License.

3.1.2 Project Preparation

Once the decision is made to invest in a PV plant, it is recommended that the future Producer requests an offer from an accredited Electrical Consultant / Contractor.

The **Technical** part should contain:

- High level electrical design/ structural drawings of the installation;
- Proposed installed capacity in kWp;
- 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); and
- Warranties from the Manufacturers and Contractors.

The **Financial** part should contain:

- Price for the equipment;
- Cost of installation;
- Installation monitoring system (if required by the Standards or optional if not); and
- Maintenance plan.

3.1.3 Solar PV Initial Enquiry

The Applicant has to submit an Application Form for Solar PV Connection in order to construct the Solar PV generating plant, and connect this plant to the distribution network.

The Applicant could be required the payment of a Solar PV Application Fee when he submits an application for the connection of a Solar PV Plant.

The following information is required in the Solar PV Application Form:

- Identification of existing electricity connection (Contract Account No., ID of the meters at the Points of Connection);
- Project Details;
- Electricity Demand Details (information related to captive consumption);
- Electricity Production Details (information related to solar generation);
- Copy of Municipality approved affection plan/site original scale;
- 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;
- Foreseen date for completion of the plant and connection to the network.

The DISCO will notify the Applicant the acceptance of Solar PV Initial Enquiry, the maximum PV capacity that will be connected to the distribution network, and the PV connection budget estimation.

This acceptance of the Solar PV Initial Enquiry is mandatory prior to obtaining a Building Permit from the Municipality and to start construction activities at site.

Additionally, the acceptance of the Solar PV Initial Enquiry may have a 6 month validity from the date of issue.

3.2 Design Approval

If the Applicant decides to proceed with the Solar PV Plant Project, the Design Approval Application Form must be submitted.

The purpose of obtaining the **Design Approval** is to carry out the electrical installation work complying with the Distributor regulation for electrical installations:

- OES 4 Electrical Installations in Buildings, Second Edition, May 1989;
- OES 11 General Specifications for Electrical Materials and Equipment, Second Edition, January 1995;
- “Small Scale Grid-Connected Solar PV Systems- Technical Guidelines”, 1st edition.

The following documents and information is required (Application Assessment):

- Solar PV Initial Enquiry acceptance;
- Building Permit from the Municipality;
- Detailed plan of project electricity connection points;
- Connected load & maximum demand schedules at each connection point (*this information can be significant for the larger consumers and/or Solar PV plants of very high capacity*);
- Production details (kWp and kWh per annum);
- Single line diagram, with details of metering and protection system (relays, CTs and VTs when adopted, e.g. for MV network connections);
- Site setting out plan showing details of proposed works, PV panels layout, meter location(s), etc.;
- Details on PV modules, for each kind used in the plant (Manufacturer, model reference, efficiency, warranty years for manufacturing defects, peak capacity per single PV module [Wp], surface per single PV module [m²], orientation (South= 0°, East= -90°, West=90°), tilt angle (inclination with respect to horizontal), number of modules of this type);
- Compliance (to applicable Standard) certificate of the modules;
- Details on Inverters, for each kind employed in the plant (number of inverters of each type, manufacturer, model reference, compliance with the Inverters approved by AER and/or DISCO, warranty years, rated AC power, nominal power factor and adjustable range, maximum DC input voltage, AC output voltage, connection phases, Total Current Harmonic Distortion, synchronization method with the DISCO network, environmental protection rating (IP), means to avoid dust penetration in the installation room (if any));
- Compliance to AER and/or DISCO and International Standard certificate of the inverters (if not in the list of the already approved ones);
- Details of Interface Protections (number, manufacturer, model reference, compliance with the protections approved by AER and/or DISCO;
- Compliance to AER and/or DISCO and International Standard Certificate of the interface protection (if not in the list of the already approved ones);
- Plan of substation location (if requirement of substation is indicated in the DISCO's Solar PV Initial Enquiry acceptance or if a MV connection is needed);
- Ground Floor and / or Typical Floor Layout indicating Location of Electrical rooms, Switchgears, Inverters, etc.;
- Dimensional layout of electrical RMU rooms, LV switch rooms with arrangement of the panels, metering rooms or enclosures;
- Wiring layouts;
- Load distribution schedules;
- Harmonic currents generated by the Generating Units[1];
- Structural drawings[2];

[1] For low voltage connections it shall be specified if these currents are in accordance with the requirements specified in the Standards.

- Other drawings/technical specification as applicable;
- Explicit acceptance and agreement to the terms and Conditions of the Connection Agreement; and
- Operation and Maintenance criteria and main planned actions.

In some cases, particularly when the new Solar PV Plant has a relevant power capacity, this may be connected to the MV Distribution network or to a LV feeder, if possible. If the capacity of the new Solar PV plant exceeds the feeder technically acceptable limits, **a new substation** might be envisaged by the DISCO.

The following situations may then be possible:

- PV plant with Maximum Capacity $P_{MC} \leq 400$ kW to be connected to an LV feeder, but where a new MV/LV substation of the DISCO is required in Customer's premises (e.g. inside a compound).
- PV plant with Maximum Capacity $P_{MC} > 400$ kW to be connected to a new MV/LV substation of the DISCO.
- PV plant with Maximum Capacity $P_{MC} > 400$ kW to be connected to a private MV substation and then to a new MV RMU substation of the DISCO.

If the requirement of one or more substations is indicated in the DISCO's Solar PV Initial Enquiry acceptance and, if a connection to the MV network is needed (Maximum Capacity of the PV plant > 400 kW), the Applicant shall submit all the information for the approval of each of the substations, providing the information required by the DISCO.

In cases where the electrical equipment of the substation (MV and LV panels, meters and so forth) will be the property and responsibility of the DISCO, then the DISCO will take care of the installation either with own technicians or appointed accredited Contractors. The Applicant will be required to complete the Civil works, including the substation building and the cable trenching.

For the construction of **MV private substations**, the Applicant has to be aware of the following:

- the DISCO makes use of 3x240 or 300 mm^2 XLPE/PVC/SWA/PE aluminium/Cu cables complying with IEC 502 for supplying power to 11kV panels incomer.
- The Customer incomers should be suitable for termination of the above mentioned cables with heat shrinkable type cable terminations. The terminations should be carried out by a qualified/approved jointer (name and details to be submitted along with other relevant documents). The termination kits for the same should be provided and installed by the Contractor.
- The Electric supply shall be released by the DISCO at Customer's circuit breaker/s point i.e. the DISCO ownership of point of supply will be at the incomer of the breaker/s.
- The Contractor must obtain written acceptance from the Producer to carry out the maintenance of the MV switchgear and downstream equipment, which will be procured by the Contractor himself, shall be done by the Producer in the future. This declaration shall be forwarded by the Contractor to the DISCO before commencement of works for the project.

The duly approved drawings may then be collected by the Applicant and the construction of the PV plant can begin (Civil and Electrical works).

[2] Only for information purposes. These drawings must be accompanied by a declaration signed by the civil designer on the compliance of the structures to the in force laws and rules.

3.2.1 Customer pays Solar PV Connection Fee

The Applicant receives from the DISCO the estimate of the connection fees based on the approved drawings and the comments in the Solar PV NOC (the remarks shall indicate whether a substation is needed or not). The Solar PV Application Fee will be deducted from these connection fees.

The Applicant then pays the resulting Solar PV Connection Fee and the DISCO will carry out all the necessary interventions on the network, in order to make the connection feasible.

3.2.2 Construction of Solar PV generating plant

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

3.3 Inspection and Energization

3.3.1 Application for Mechanical Inspection

For LV connected Solar PV plants of P ≥100 kW, and for all MV connected PV plants, an application to request a Site Inspection from the DISCO technicians has to be submitted by the Applicant. This Application needs to be submitted once the laying of the PV modules is completed (mechanical completion) and before initiating the electrical works.

This will assure that the modules, layout and fixation comply with the AER and/or DISCO standards and safety rules.

The Contractor will make the As-Built drawings available for the inspection.

In case of a positive result, the PV construction can proceed with the electrical works.

3.3.2 Application for Inspection and Energization, and Post-Connection steps

Application for Inspection

When the PV is installed and all civil and electrical works are completed, the Applicant submits an Inspection Application. This application has to be submitted for all plant sizes.

Before the application, it is mandatory to have the following documents prepared:

- Municipality approved affection Plan/other utilities affection plan;
- Building Completion Certificate from Municipality;
- Owner’s Passport copy/Trade License copy;
- Authorization letter from the owner to his representative;
- A copy of the DISCO approved Design and Shop Drawings;
- A copy of the As-Built Drawings;
- A copy of the DISCO approved Connected Load/Max ;
- Demand Details;
- Inverter Compliance Certification;
- Interface Protection Compliance Certification;
- Module Certification;
- Owner’s No Objection Letter (if tenant application); and

- Solar PV Initial Enquiry acceptance (6 month validity from the date of issue) with submission of:
    - Approved Substation location and size; and
    - Setting out Key Plan showing the Electricity Metering Location.

For MV connections with private substations, the following additional information is required:

- Revised/updated copy of a single line diagram with details on metering and protection system;
- Undertaking letter stating that the load on each feeder shall not exceed 3MW (175A) in normal operation and 6MW (350A) in case of contingency if the adjacent feeder fails;
- Real measurement of harmonics shall be conducted after full commissioning of the equipment and to be submitted to the DISCO for verification to ensure that the values are within prescribed limits;
- Step by step relay setting calculations. The relay co-ordination shall be made on maximum fault current and the grading margin shall be kept at 0.300 seconds between the DISCO ends to private party's panel end;
- Owner's undertaking stating "Our equipment are suitable to energize in line with the Distribution Service Company network system " and confirm that the relays are set as per the DISCO approved setting;
- HV cable Jointer's list in details (approved by the DISCO);
- Names and telephone numbers of contact person for the project who should be available to contact on a 24 hour basis;
- Name of technical staff, competent in the switchgear operation and issuing of permit stating that cable is safe for work. and also ensure no one, will operate during test & repairing time.
- Factory & Site test report for the transformer/breaker, MV cable, etc. and test result for the transformer inrush unbalance current to be forwarded for verification;
- Operation philosophy (interlocking details) -to be incorporated in the single line diagram; and
- All catalogues for CT, VT, relay & motor.

Inspection and installation of the meter(s)

In case of a positive result of the site inspection, the DISCO installs the meter(s).

During this inspection, the DISCO supervises the tests and the measurements on the installation (Inspection and testing without Interconnection to the grid) made by a Test Engineer appointed by the Contractor.

In case of construction of a new substation of the DISCO, the Substation Inspection Request is also sent through the DISCO 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 Solar PV plant can be energized. For plants connected to the Medium Voltage distribution network, it is particularly important that this operation be supervised by Engineers from the Distribution Operations Department. 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 Distribution Network of the DISCO), and possibly witness the closure of the Solar PV plant main circuit breaker.

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 a certified Test Engineer. The results of these tests will be collected into a Technical Dossier to be submitted to the DISCO for approval. In case of plants with $P_{MC} \geq$ 100 kW or connected to MV network, this approval is a prerequisite to the execution of the Performance Tests. For plants below 100 kW, no further tests or inspections are required, so the Final Inspection Report will be prepared by the DISCO and Connection Agreement issued (see below).

No supervision from the DISCO is needed during this testing stage.

Performance Tests and Post Connection Inspection

For PV plants of Maximum Capacity larger than or equal to 100 kW, performance tests are required as indicated in the Technical Guidelines. The tests will be carried out by a Test Engineer or by an appointed system integrator engineer who has to be commissioned by the Applicant. Upon the finalization of the tests, the Applicant submits a copy of the testing documents (As-Built Drawings and the Technical Dossier) and applies to request the Post-Connection Inspection.

The DISCO executes the final site inspection in order to:

- make the final checks on the installation, if necessary;
- verify the correct behaviour of the meters; and
- supervise the performance tests as carried out by the Applicant, in order to verify the efficiency of the plant.

In case of positive result of the inspection, the DISCO Connection Services Department issues the Final Inspection Report, which certifies that the installation is compliant with the DISCO rules and that the electricity production can start (after the signing of the Connection Agreement).

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[3]. The Distribution Company will verify the availability of this manual in the inspections.

The Producer also needs to provide the DISCO with a statement stipulating that he is aware of the Operation and Maintenance 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 chapter 4 (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 between the parties (Producer and the DISCO).

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.

[3] This may also be different from whom has constructed the plant

The DISCO Connection Services Department signs two copies; sends them to the customer; and the Producer returns one signed copy which is filed by the DISCO Connection Services Department. The Solar PV Plant Generator Terms and Conditions apply. The official production start date and time that will be utilized for Net Metering purposes, is thus the date of the Connection Agreement.

Start of Production

After the official start of the electricity production, the Distribution Company will read the production meter on a monthly basis. The Distribution Company will thus monitor how much electricity the system has produced (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).

4 DEFINITION OF THE RESPONSIBILITIES

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

The limits of responsibility of:

- the DISCO;
- the Producer (as owner of the plant);
- the Consultant of the Producer;
- the Contractor (as appointed by the Producer); and
- the Manufacturers of PV products and equipment.

are outlined hereinafter.

Please note that the limits of liability, as specified for the Consultants, may then apply also for the Contractors, if they are also involved in the design of the Solar PV plant.

4.1 The Distribution Service Company

The DISCO 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. The DISCO 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 [4].

Ownership Boundaries:

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

4.2 Producer

- The Producer must enter into a Connection Agreement with the DISCO. 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 Standards.
- The Producer shall indemnify the DISCO and accept liability for safety and supply quality issues that occur when the Solar PV Plant is operating.

The Producer shall be responsible for:

[4] In order to allow the automatic re-connection of the plant to the Distribution Network once the disturbance in the network has been cleared, information regarding the automatic re-closure is provided in the Standards.

- the choice of any of the Solar PV plant equipment;
- the installation, operation and maintenance of all the Solar PV Plant equipment;
- ensuring that there is a safe system of work for all representatives that are involved in the Solar 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 his/her plants (e.g. short-circuit, earth-fault and overload protection);
- the Solar PV Plant insurance against damages by storm, hail, lightning, over voltage, theft, fire or any other external hazards.

4.3 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 (if a Producer so requires);
- the correct choice of equipment;
- correct consulting of the producer regarding all technical aspects.

4.4 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 Solar PV Plant construction, in compliance with all applicable standards, regulations and statutory requirements;
- proposing to the Producer adequate and certified Solar PV equipment;
- building the installation in compliance with all applicable Technical Guidelines[5];
- appointing a Test Engineer to perform tests on the plant.

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.

4.5 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 (modules, inverters, cables, protections, and so forth).

[5] The Contractor will have to deliver a declaration of compliance of the plant to these standards.