Small Scale Grid-Connected Solar PV Systems

Additional Document on

Health and Safety criteria to be adopted on construction sites

May 2017

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1 INTRODUCTION

1.1 Scope

The present document outlines the main issues that have to be taken into account in terms of health and safety in construction sites when installing and connecting to the network a new PV plant. The topics are mainly related to low and medium voltage range and, mainly rooftop mounted.

Although PV systems provide many benefits to the environment, there are hazards associated with them especially when installed onto rooftops. The installation of PV systems on roofs may create electrical, fire, structural, and weather-related hazards that need to be adequately addressed by codes, standards and guidance documents. Significant progress has been made in the past years in many countries where PV systems are already installed in large number, but there are still gaps that need to be pointed out.

The purpose of this document review is to compile information on a wide variety of hazards concerning the safety of people working on the installation of photovoltaic (PV) systems on roof structures.

The report summarizes basic performance categories associated with PV panel installation practice and identifies specific hazards to be taken into account. These include safety of workers both in construction and operation phases (as well during the future decommissioning): safety in solar installation is normally related to electrical hazards, and installing PV plants on rooftops add the hazards typical of construction performed in elevation.

The reliable installation requires compliance with relevant health and safety regulations. This report thus reviews existing information in the literature related to best practices for risks assessment to address the above issues. A comprehensive reference section is provided.

Finally, is attached a table of reference of the main issues and the relative stakeholder with recommendations on specific issues that should be taken into account. Different safety issues can be highlighted during the lifetime of a PV plant:

- Permitting – is the stage of design and evaluation of risks related to the new PV Plant and the environment where it will be installed;
- Construction and Connection – is the stage when workers with different skills install the PV Plant equipment and connect it to the electrical network;
- Inspection – is the stage when checks and tests are performed.
- Operation and Maintenance – is the phase of generating electricity, which shall require regular and occasional maintenance operations;
- Decommissioning – when at end of life the plant shall be dismantled and all components disposed or recycled, and the site correctly remediated; disposal and recycling of PV modules at end of life is discussed in a dedicated report.

A summary of the recommendations described of the present document is reported in Annex A.

1.2 Important notice

This document includes a number of safety measures specifically applied to the erection of PV systems. These measures take into account the specific characteristics of PV components and shall be observed carefully.

However, one should always consider these measures as additional to the existing ones; therefore, both the local Omani laws and these additional rules must be always applied. Fore sake of safety, in case of conflict the strictest measure shall prevail.

1.3 Definitions

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

AFDDs – Arc Fault Detection Devices: devices that protect specifically against arc faults. They automatically trip a circuit when they detect dangerous electric arcs. In US market are also known as arc fault circuit interrupters: AFCIs.

BIPV – Building integrated photovoltaics – photovoltaic materials that are used to replace conventional building materials in parts of the building envelope such as the roof, skylights, or facades.

BAPV – Building applied photovoltaics – photovoltaic materials that are used to substitute conventional building materials in parts of the building envelope such as the roof, skylights, or facades.

DMM – Digital Multi Meter, a tool which can measure voltage, amperage, and resistance used for testing PV systems

DISCO –Distribution Company. DISCOs operate the distribution network to bring electricity from the transmission network to Customers.

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.

CPE – Collective Protection Equipment. They are aimed to move personnel away from the source of danger, physically or in time and are always implemented in precedence over PPE.

Grid Connection: The connection of a PV Plant to the electrical grid

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 this output power.

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

Medium Voltage (MV) Network – a Network with nominal voltage included in the range from 1kV up to 33 kV. In Oman two voltage levels may be found on MV distribution network, namely 11 and 33 kV. The 11 kV voltage level is the most used and spread one.

Network – plant and apparatus connected together in order to transmit or distribute electrical power, and operated by the OETC and DISCOs

OETC – Oman Electricity Transmission Company

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

Permission – A license to carry out an act that; without such licence would have been unlawful

PPE – Personal Protection Equipment. They are defined as any device or means intended to be worn or held by one person to protect itself against one or several risks liable to threaten its safety or its security.

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

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

Photovoltaic (PV) Modules – also called Photovoltaic (or PV) panels. Set of elementary photovoltaic cells for the conversion of the solar radiation into electric current.

Photovoltaic Array – A frame containing different Photovoltaic Panels usually grouped in a "String" for the conversion of the solar radiation into electric current.

PV Plant – A plant that produces power from the conversion of the solar radiation into energy.

Surge Protective Device (SPD) – device intended to limit transient overvoltages and divert surge currents; contains at least one non-linear component.

WEEE – Waste Electrical and Electronic Equipment as defined in 2012/19/EU Directive

1.4 Reference documents

The following documents are here quoted as a reference:

[1] IEC/TS 60479-1 – Effects of current on human beings and livestock. Part 1: General aspects

[2] IEC/TS 60479-2 – Effects of current on human beings and livestock. Part 2: Special aspects

[3] IEC/TS 60479-5 – Effects of current on human beings and livestock. Part 5: Touch voltage threshold values for physiological aspects

[4] IEC 61440 – Protection against electric shocks. Common aspects for installations and equipment

[5] European Agency for safety and health at work, "Hazard identification checklist: OSH risks associated with small-scale solar energy applications", E-Facts 69, 2012

[6] Good Company, "Health and Safety Concerns of Photovoltaic Solar Panels", Eugene, 2010

[7] NFPA, "Fire Fighter Safety and Emergency Response for Solar Power Systems", Quincy, May 2010.

[8] OSFM, "Fire Operations for Photovoltaic Emergencies", Sacramento, November 2010

[9] HSE Management System, "Electrical Safety Rules Procedure", 2014

[10] Oman Ministerial decree no 286/2008

[11] ARWA – Omani Environmental Regulations. International Reference Documents. SEU Guidance Notes

[12] BS7671:2008. Requirements for Electrical Installations - IET Wiring Regulations 17th Edition

[13] UK ECA, Guide to the Installation of Photovoltaic Systems, 2012

[14] BS 5499-1:2002. Graphical symbols and signs. Safety signs, including fire safety signs. Specification for geometric shapes, colours and layout

[15] BS 5499-5:2002. Graphical symbols and signs. Safety signs, including fire safety signs. Signs with specific safety meanings

[16] BS 7671:2008. Requirement for electrical installations

2 CONVENTIONAL HAZARDS

The present section analyses, from a general point of view (e.g. installer, inspector, maintenance operator) the most common hazards and the related preventive practices and measures.
Consultants or Contactors, in order to become accredited and apply also for the connection of a Solar PV plants, shall have in their team a minimum number of Certified Solar PV Installers, so as to assure that their personnel possesses the knowledge required to design and construct a Solar PV plant.

2.1 Risks analysis

According to international best practises and to the Omani legislation, in particular the Ministerial decree no 286/2008 [10], each party willing to perform installations shall conduct a Preliminary Hazard Analysis (PHA) to identify HS hazards, analyse environmental aspects and impacts, and estimate any potential HSE risk.
The activities of installation as well as those of operation and maintenance should be submitted thus to a Risk Assessment. In the case of a PV plant this shall mean:

- Identify foreseeable hazards, assess their risks and take action to eliminate or control these risks at the site you will be working at. Analyse the photovoltaic installation activities, to know and to evaluate the risks of every task inside every activity
- Assess the condition of the roof and the types of roofing material, such as colour bond material and glazed tiles. Also ensure that the roof is dry before performing tasks
- Train the staff on the risks depending on their job and specific tasks
- Install the collective protection equipment (CPE) applicable to the specific installation, always considering that CPE are always implemented in precedence over PPE.
- Safely access and work safely on the roof and control the risk of workers falling
- Control the risk of falling objects
- Safely move the material from the ground to the rooftop
- Distribute the equipment of individual protection adapted to every workstation
- Safely mount the solar panels to the rooftop by:
    - following safe work procedures for installing solar panels (these should include the manufacturer's instructions)
    - ensuring other persons who are not involved in the work area are kept away from the work area by utilising barricades or similar control systems
    - checking that tools and personal protection equipment (PPE) are compliant with the standard requested to perform each tasks and that they are properly maintained
    - perform a pre-work risk assessment of the roof and roof cavity and implementing control measures

When the installation is to be started, it shall be the responsibility of the Applicant in accordance to the Omani law:

- To designate a person in charge of checking the correct execution of the prevention plans
- To develop an emergency and evacuation plan

The risk assessment has to be performed for all workers on the rooftop. Workers and personnel of all the stakeholders: Applicant (Consultant or Contractor), EPC contractor, O&M supplier, and DISCOs, workers ought to be aware of risks according to the said assessment.
All personnel working with different designation need to have technical qualification and background and having suitable experience/knowledge & competency to do the work safely.
Each time a worker is introduced to the working site, he shall have to attend H&S induction training and "Tool Box Talk" regularly and prior to start an activity. He should be suitably trained to do the

activities and have knowledge & experience so that as a competent worker he can perform activities on roof and high elevation from ground level.

Recommendation

Perform HSE risk assessment

Use HS induction training and "Tool Box Talk" for prevention of hazards in all operations required for the installation of PV Plant.

2.2 Principal hazards for safety criteria on construction sites

2.2.1 Electric shocks

The working place shall be managed according to the Ministerial Decree no 286/2008 and all related legal requirements.

There are many sources of electric shocks when working on PV systems but only those aspects related to the DC current that takes origin from photovoltaic components are here considered, because they are specific of PV systems and differ considerably from those related to AC applications.

Whether activities are in a household or an industrial facility, people that work with electrical live parts must be aware of the related hazards and it is important that they adopt all the safety measures aimed to minimize the risks.

A common mistake when considering electrical hazards is the undervaluation of the risk related to the electrical shock, especially if the subject is an adult and healthy. On the contrary, one should always consider that electric shocks, further that being directly harmful, might cause further physiological effects related to the current flowing through a human body. These situations are inconvenient or hazardous (such as results of startle reaction) and may concern threshold of perception or threshold of pain or heat sensation. For example, Electricity can cause muscle contraction, which in turns can lead to falls. Depending on the working conditions and environment, the consequences of falls can be far worse than the original shock (severe injuries or death).

The Figure 1 shows the four zones of current-magnitude/time-duration, in each of which the pathophysiological effects may occur as listed below (The chart refers to the ascending hand-to-feet DC current):

1. Imperceptible
2. Perceptible
3. Reversible effects: muscular contraction
4. Possibility of cardiac ventricular fibrillation. In this zone further pathophysiological effects may occur, for instance severe burns. The curves c_2 and c_3 correspond to a probability of respectively 5% and 50%.

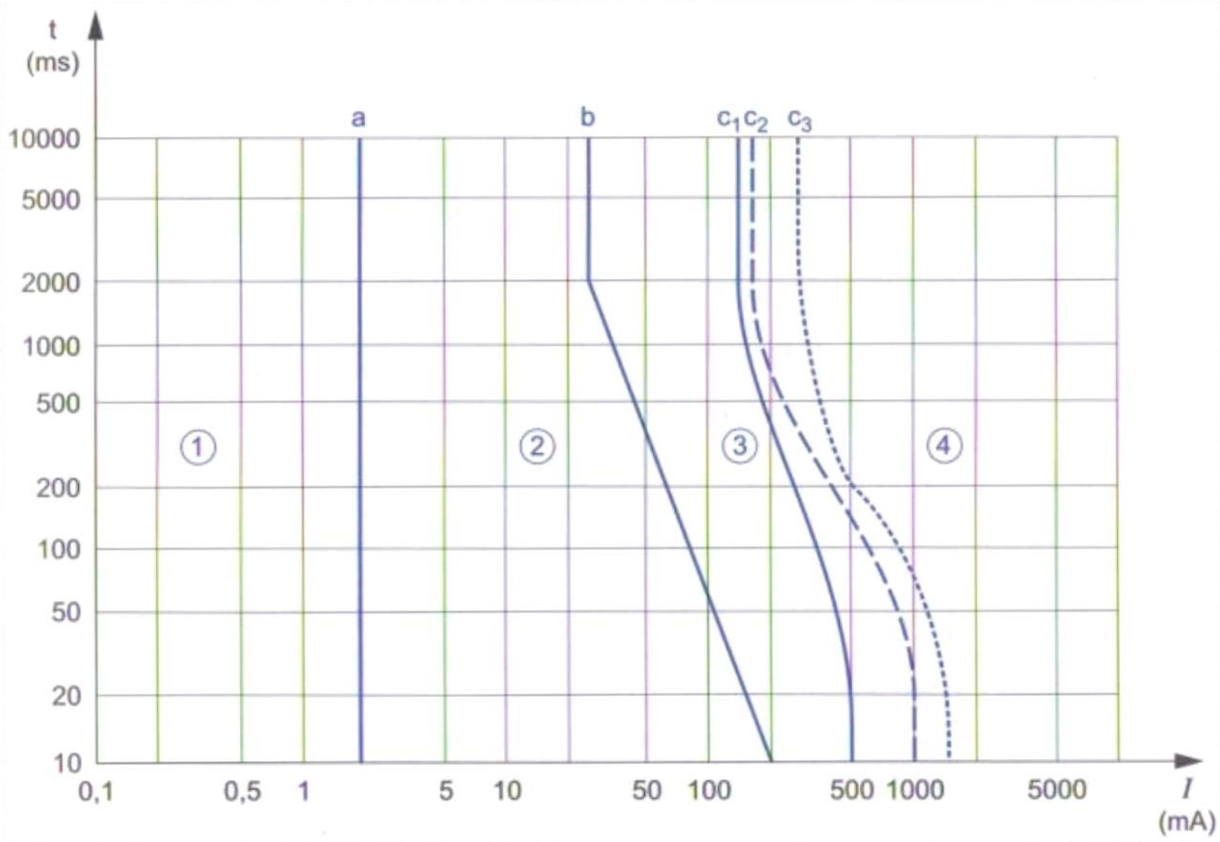


Figure 1 - Zones time/current of effects of ascending hand-to-feet DC current on human body

The Figure 1 gives useful information on the effects of DC current on human body but it considers only the worst case, which corresponds to the ascending hand-to-feet path of the current (positive applied to feet and negative to a hand). Things may also be different if one considers the path hand-to-hand as in Figure 2 (left image) or the descending path hand-to-feet (positive applied to a hand end negative to feet). The consequences of these last occurrences are actually less severe than those reported in Figure 1:

- Hand to hand – Thresholds for the cardiac ventricular fibrillation are to be multiplied by 2.5
- Hand to feet descending – Thresholds for the cardiac ventricular fibrillation are to be multiplied by 2

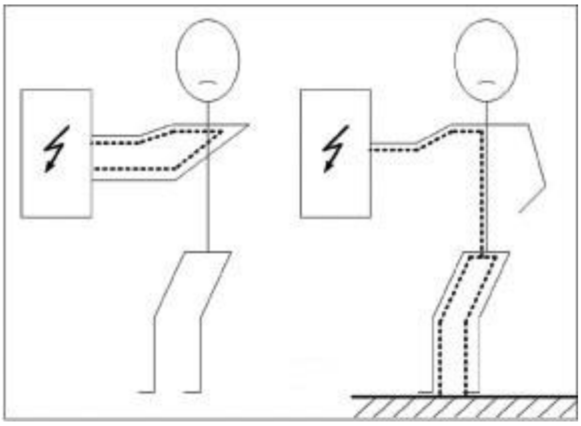


Figure 2 – Schematic representation of the hand-to-hand (left) and hand-to-feet (right) current path

In photovoltaic applications, hand-to-hand electric shocks may typically occur when the live parts of the terminals a PV module or a series of PV modules are touched simultaneously. As an example, this frequently happen when working on unfastened string cables.
Hand-to-feet electric shocks frequently occur in PV systems with a pole grounded. In this case, it is sufficient that the worker touch a single live part to close the fault circuit. Positive pole grounded PV plants are more hazardous than the negative pole grounded because of the ascending path of the current (Positive on feet and negative on hand).
The current that flows through the body depends on a great number of influencing factors, such as environmental conditions and contact area. However, the basic protection by the limitation of voltage is fulfilled in case of SELV or PELV circuits whose maximum voltage does not exceed:

- 60 V DC ripple-free (or 25 V AC r.m.s.) in dry locations and when large area contacts of live parts with the human body is not to be expected;
- 15 V DC ripple-free (or 6 V AC r.m.s) in all other cases.

If we consider these criteria applied to PV modules, we know that if they are illuminated their voltage is close to the open-circuit voltage Voc. If the nominal Voc of the given PV module does not exceed 60 V the component can be handled quite easily, at least in a dry environment. On the contrary, a series of PV modules whose open-circuit voltage exceeds 60 V (the open-circuit voltage of a string may reach up to 1000 V) have to be handled carefully and contacts with live parts need special provisions.
There are various measures to prevent electric shocks from PV modules in a site work or during maintenance. First of all prevention, hence knowledge about electricity and wiring is a must: the more a worker knows about hazards the more he can avoid risks. Even before going to a site any worker or engineer needs to become familiar with the project of the given PV system. It is necessary that possible hazards are well understood and every subject is informed and trained to adopt all necessary precautionary steps.
When several risks are to be faced at the same time as in the example shown in Figure 3 (source IEEE), the action to be taken cannot be left to improvisation and a careful planning is therefore necessary. In Figure 3, the main relevant dangers are obvious (fall, crushing, cuts, electric shock, etc.) but there are other cases where the dangers are more subtle and nevertheless they must be always identified in time.

Figure 3 – Example of installation of a PV system in presence of several risks

Insulating gloves can effectively prevent most electric shocks, but also not conductive footwear can further prevent a current from running through a person's body. Additional for prevention, any work site shall be fitted with appropriate barriers, warning marks (signage), and tags related to electrical hazards.

The installer shall also set measures in order to prevent hazards to the personnel in the case of lightning events which might occur during the installation activities particularly in the frame of rooftop installations.

2.2.2 General hazards in construction works

Though the project is mainly related to the installation of rooftop PV plants, the following hazards shall be considered due to the necessity of construction works:

- Hazards related to mounting and connecting of PV modules supporting frames, and PV modules installation;
- Hazards related to construction work required to enable the electrical connection of the PV plant to the network. In this case works such as excavation, use of mechanical means particularly at ground level.

2.3 Safety with reference to the activity in the site

According to the flow of the different activities to be performed when installing a PV plant, health & safety of workers is an issue to be taken into account at different stages and by different stakeholders.

- Inspection visits are envisaged in the preliminary evaluation of the prospected PV plant installation. Personnel shall be informed in case of specific hazards related to the site to be visited.
- Beginning from site preparation, during the installation and up to the completion, commissioning and connection of the PV plant, the presence of personnel / workers in a site shall be managed according to the required safety procedures. In case the access has to be granted to inspection personnel, the said personnel shall be provided all necessary information related to safety.
- When in standard operation, access to the PV plant shall be managed according to safety procedures stated in the O&M “manual of operation” that has to be issued by the Applicants.

2.4 Risk of falls

The falls usually represent the most important risk for PV on buildings because any accidental fall generally lead to death or to severe injuries. Falls concern people working at height on structure under constructions or that use ladders, platform, lifts, baskets or other personnel and material handling systems.

In construction sites the risk of falls is generally faced by using scaffolds, fencing or nets as well as any other Collective Protective Equipment (CPE) that are provisionally installed in order to safeguard workers.

Personal Protective Equipment (PPE) are useful to avoid falls as well. As a rule, they are used in conjunction with CPE, or as an alternative safety measure when CPE cannot be installed. PPE for working at height are mainly represented by harnesses properly anchored to one or more fixed points.

Anyway, as regards the risk of falls, in construction sites PV installations are similar to many other works that involve the placement and the fixation of glazing surfaces like windows or skylights.

On the other hand, one should consider that PV systems must be inspected and maintained during their lifetime and therefore an easy and safe access to all parts of the system has to be prepared for the personnel.

The application of proper measures aimed to guarantee a safe access to a rooftop PV system depend on the type of the considered installation. For instance, in case of a fully walkable flat roof with access from an internal ladder, a perimeter railing or fence is normally sufficient to guarantee the safety of works. On the contrary, on a sloped roof a number of lines and anchoring points has to be installed permanently. Their number and position must be sufficient to assure a safe access to every part of the PV system and shall avoid, in any case, dangerous effects like bottoming out or pendulum.

Another frequent source of danger is represented by transparent surfaces like skylights or similar, especially when they are close to PV systems. In these cases, the use of railings can be uneasy and the most effective solution is often represented by the use of safety nets placed just before the transparent surfaces (see examples in Figure 4). Safety nets may also be used to avoid falls into air gaps, holes and similar.

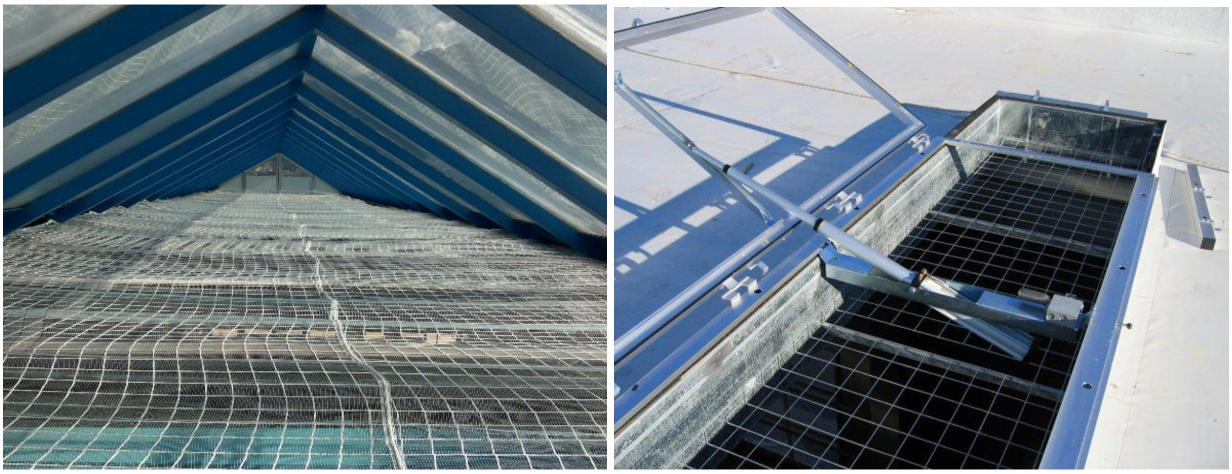


Figure 4 – Example of safety nets installed below skylights

The ways of access to a rooftop PV system should assure an easy and safe use. When the way of access is external, the installation of a permanent safety ladder is recommended. Nevertheless, in several cases this solution is not feasible because of technical of aesthetical reasons. In these cases the access is possible only by using a provisional ladder or other means like lifts or baskets. If a provisional ladder is to be used, the site should be equipped with proper anchor points in order to secure a ladder to steady points.

2.5 Further hazards (Exposure, Bites and Cuts)

Additional risks may also come from sharp edges, for example metallic components of supporting and fixation structures. PV modules frames that are metallic are finished so as to avoid injuries to installers, as well as the glasses covering the surface of frameless PV modules: anyway installers are expected to wear the suited PPE to prevent any injuries due to sharp edges.

2.6 Falling panels, flying glass

In addition to electrical hazards, there are also dangers from solar panels falling from the roof; either because they become detached from their fixings, or because the roof members have failed below them and they collapse into the building.

Not only is there a danger of being struck by a falling panel, but once it hits the ground it may cause the glass within it to shatter and be expelled outward with force: in such case the use of the appropriate PPE is recommended to avoid risks of cut.

3 ADDITIONAL INFORMATION ON HAZARDS RELATED TO PV INSTALLATIONS

Additional electrical hazards shall be taken into account when working with generators like solar panels. Only qualified persons or, at least, workers with H&S induction training on specific hazards, should be allowed to work on electrical equipment.
Arc flashes are certainly an issue when working with PV plants as they can be easily produced during installation and maintenance operations: all preventing measures should be applied to avoid arc flashes. More information is provided in the next paragraphs.

3.1 Arc flashes and Burns

An arc flash is an explosion that occurs as result of an arc fault, which occurs when a short circuit has been opened but the fuse has not blown or the circuit breaker has not been tripped. A spark, or arc flash, occurs between connections, which can result in fires or even ultraviolet eye damage. Arc faults are more likely to occur between corroded or loose connections. As with electric shock, another danger with arc flash relates to the reaction of the mind and the body of incident. The explosion might cause a worker to fall or jump into an even more dangerous position.
Arc faults are more likely to occur with high voltage electrical systems, but, since many PV systems can produce voltages in the range 600-1000 VDC, the possibility of an arc flash is to be considered.
Burns can occur in varying degrees when working with PV systems. At the lowest part of the temperatures' spectrum: thermal burns are caused by metal and glass components exposed to the sun. These components can reach temperature of over 90 degrees Celsius and can cause burns if prolonged contact is involved. At the extreme part of the spectrum the temperature can be at 9.000 Celsius degrees when an arc flash occurs. In between these extremes, exposed electrical conductors, in conjunction with hot temperatures, can cause fires that result in serious burns and need of immediate treatment.

Recommendations

Arc flashes have been recognised as hazards for PV system only since 1990. The knowledge of the phenomenon is part of the prevention procedures. Although faulty equipment can cause an arc fault, often the cause is the human behaviour: standing too close to an electric system, especially without protective gear, can be unwise. Furthermore, arc faults might be caused by loose conductors contacting each other: this is a result of parts not fastened properly or loose metallic tools creating a short circuit.
The kind of fire that can be produced by an arc fault is different from other kind of fires. Thus the PPE that should be used need to be different too: use clothing specifically rated for arc flashes. PPE safety rated for arc flashes should also include goggles that also protect from the extreme light emitted.

3.2 Testing for Voltage

Preventive measures involve the operation of voltage testing with specific gear. One such measure involves the use of a voltmeter: a tool that measures the amount of voltage that exists at any given point within an electrical system. It is important that anyone who is working with circuit knows if any voltage exists, and if so, what its strength is.
Testing voltage is particularly important for PV systems that handle voltages at any point. Given that modules are wired in series together in order to produce increasing amount of voltage, relying on an ammeter alone can be dangerously deceiving. Adding more modules in series will keep the current at the same low reading, while significantly increasing the voltage. An installer can be caught by surprise unless he is used to use a voltmeter: surprise is the last thing you need when working with such power

systems. Also the current will increase when string are parallel connected. For such systems, it may be safer to use a clamp-on ammeter to measure amperage. A DMM, which shorts a circuit to take the reading, can result in a large electrical arch: thus better work with a clamp-on voltmeter when working with systems that contain high amperage levels, unless a different measuring mean is required for a much more specific characterization of a PV string.

3.3 Earthing

Earthing is a safe measure to take in order to prevent unnecessary exposure to electrical hazards. To mitigate the effects of electrical hazards the workers can ground an electrical system in a way that allows the current to have a safe route to the ground. PV workers should ground individual components and the entire system. Proper earthing is simply another precaution to take, that ensures the safety of any electrical environment and of the people who may work on it.
In PV systems both DC circuits and AC circuits shall be grounded, DC and AC earthing system shall be bonded together or even be built as a unique system. For further details see the related standards and/or safety guidelines.
Earthing of PV support structures and frames PV is also required as a protection measure with reference to lightning phenomena. SPDs and surge arresters are normally provided by design as overvoltage protections in a PV plant. Lightning protection measures shall be adopted by design, as it is mentioned in the Appendix A of the document “Small Scale Grid-Connected Solar PV Systems-Technical Guidelines”.
In addition the installer and O&M supplier shall also set operational rules suitable to prevent hazards to the personnel in case of adverse meteorological conditions, when lightning strikes may occur.

3.4 Insulated tools

Yet one more safety measure in preventing exposure to electrical hazards is to employ insulated tools. The tools that the PV workers and installers use have to be made with insulating material. It is recommended to use rated insulated tools and never use them in case their rating is not appropriate. Use the proper insulation level in case of high voltage, use the same tools also for lower voltage operations as long as this measure avoid mistakes due to the different insulation level which can be confused during operation.

3.5 Specific risks while operating on PV electricity generators

Standard IEC 60364-712 on the electrical installations of buildings does outline some rules for protecting people. However, the current version of the standard does not go into much detail nor is it universally applied. Currently, the entire PV industry, from standards institutes down to installers, is learning as it goes from everyday lessons. That being said, the standard is being updated, and future versions will set substantial improvements over what it is currently available. And, in the meantime, there is no cause for undue concern about the safety of today’s PV installations.

In most cases, if a PV installation complies with the standard mentioned above and if the equipment is fit for purpose and properly installed, it will work just fine. Until a more complete standard becomes available, it makes sense to err on the side of caution. Concretely, this means ensuring the installation’s capacity is sufficient and choosing quality equipment installed by a trained professional.

The risk of electrocution occurs specifically to firefighters and other first responders called to a blaze commonly cut off power to the burning building as a safety precaution. If the building has a PV installation, however, the PV modules continue to generate voltage, even if the system is not actually connected to the AC grid. Yet, 3 – 4 connected modules are enough to generate more than 100 VDC. Residential and commercial installations include several modules with voltage usually in the range of 600-1000VDC.

Under these condition it should be adopted a solution beyond the traditional shutdown function in inverters that merely interrupts current flow and voltages remain dangerously high. In fact automatic DC breakers located on the inverter in the cabinet, cannot disconnect the voltage on the modules.

A more effective solution may be to install devices such as power optimizers connected to each module, a PV inverter and module-level monitoring. When power optimizers are connected, modules continue in “operation mode” only as long as a signal from the inverter is constantly renewed. In absence of this signal, power optimizers automatically go into safety-mode, shutting down DC current as well as voltage in module and string wires. In safety mode, the output voltage of each module equals 1V. For example, if firefighters disconnect a PV system from the electrical grid during daylight and the photovoltaic system consists of 10 modules per string, the string voltage will decrease to 10V.

Furthermore the installation of Arc Fault Detection Devices should be taken into account especially for large PV plants to prevent arrays are energised even if disconnected. The US national electric code requires the use of DC arc fault circuit protection on PV systems greater than 80 V mounted on or penetrating a building.

Recommendations

For specific details, refer to IEC standards for installations as already reported in “safety for environment”:

- IEC 62548 – Photovoltaic (PV) arrays - Design requirements
- IEC 60364-7-712:2002-05 Electrical installations of buildings – Part 7-712: Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems
- Technical specifications IEC TS 62257-7-1:2006-12 Recommendations for small renewable energy and hybrid systems for rural electrification – Part 7-1: Generators – Photovoltaic arrays
- Technical specifications IEC 62257-5:2005-07 Recommendations for small renewable energy and hybrid systems for rural electrification – Part 5: Protection against electrical hazards

3.6 Hazards in case of fire

This type or hazard concerns mainly the fire brigade whose task, in this case, is to extinguish a fire that involves a PV system on a building or, more generally, on a construction. Different cases may occur:

1. The fire originates from PV modules which are typically placed on rooftop and there is a real danger of fire propagation to the underlying structure (see example in Figure 5).
2. The fire originates from the building whose rooftop is covered by PV modules, thus eventually the fire propagates to the roof and the PV modules catch fire (see example in Figure 6).
3. The fire takes origin from an equipment different from PV modules (inverter, combiner box, switchboard, etc.) and this could affect only marginally the PV array (se example in Figure 7, the fire took origin from a few combiner boxes).

Figure 5 – Example of fire originated in the PV array on a rooftop

Figure 6 – Example of fire originated in a house with a PV system on the rooftop

Figure 7 – Example of effects of a fire in a PV system originated in combiner boxes

The cases 1 and 2 have several affinities as regards the additional dangers for the fire fighters. In both cases one shall always take into account the presence of voltage on the PV system and consider the hazards related to specific actions aimed to mitigate the hazard. For example, cutting string cables may be useful to limit the extension of live parts (e.g. by isolating combiner boxes and inverters), but it is necessary that fire fighters have a sufficient knowledge of the PV system. Fire fighters should also be aware that these operations do not eliminate completely the presence of hazardous voltages in the PV plant.

In principle, the shutdown of an extended fire in a building usually needs the use of water and therefore the presence of a PV system with parts still live may represent a concern unless proper safety measures are adopted. A PV module, although damaged, can still produce power and may cause hazardous conditions ranging from perception to electrocution, thus the prescription on manipulating arrays and PV modules should be respected also by fire fighters. It is important that the protection equipment, like gear, boots and gloves shall be designed and tested for electrical shock as it is required to operate in PV plants.

Furthermore, fire fighters must be aware of potential trip, slide and fall hazards while operating on the roof, because PV modules and arrays can be slippery or fragile. Extreme caution must be taken near the roofline because modules or sections of an array could slide off the roof.

The case 3 is sometimes simpler to manage by the fire brigade because usually it may be faced as a fire originated by an electric circuit that requires special non-conductive extinguishers (e.g. water is not allowed). Additional complications may arise however if all the connections to the PV array have not been cut off. In these cases the PV array continues to feed the fire and thus fighting operations can be long and laborious (see the Figure 8 where a set of combiner boxes continues to burn despite fighting operations).

Figure 8 – Example of combiner boxes burning despite fighting operations, because they are still fed by the PV array

The risk of arc fault in a PV system can be reduced or minimized at design stage by adopting one of the following provisions:

- The installation of a manual call point that disconnects or short-circuits separately each module or groups of modules. This may be useful to prevent the risks listed at points 1, 2 and 3.
- Installation of an Arc Fault Circuit Interrupter (AFCI) to protect the DC side from series arcs. When AFCI detects a failure it disconnects the DC side of the PV plant and generates an audible signal. This may be useful to prevent the risks listed at points 1 and 3.

3.6.1 Danger of inhalation of hazardous fumes

In the event of a fire, it is theoretically possible for hazardous fumes to be released and inhalation of these fumes could pose a risk to human health. However, researchers do not generally believe these risks to be substantial given the short-duration of fires and the relatively high melting point of the materials present in the PV modules.

3.7 Marking and warning signs

PV Systems shall be marked. Marking is needed to provide for example emergency responders with appropriate warning and guidance with respect to isolating the solar electric system. This can facilitate identifying energized electrical lines that connect the solar panels to the inverter, as these should not be cut when venting for smoke removal.

There are mainly two issues to bear in mind while labelling a PV plant:

- Labeling for normal operations and
- Labeling for fire fighters

The PV systems' areas of concern for fire fighter safety and fire-fighting operations include energized equipment, trip hazards, restricting venting locations, limiting walking surfaces on roof structures, etc.

In several countries, there are guidelines prepared by fire fighter corps establishing the minimum standard for the layout design, marking, and installation of solar photovoltaic systems and intend to mitigate the fire safety issues.

Understanding signs provide valuable information in refinement the safety and health management strategies. Safety signs usually contain four components: signal words, hazard statement, noncompliance statement and some instructions. Moreover, colour of warning labels should attract the attention of viewers. Different signal colours characterize different ranks of risk because of the consequences of cultural effect or physiological reactions. Usually, red characterizes the highest rank of hazard, followed by other colours. In addition, warning labels should have signal words, such as danger, caution and instruction, to recognize the ranks of hazard. Usually, danger represents the highest rank of hazard, caution points to an intermediate rank and instruction indicates the lowest rank.

Each sign type has a specific 'safety colour' associated with that type of safety message & a special graphic shape. The 5 types of safety sign described by BS 5499 part 1 (Specification for geometric shapes, colours and layout) are:

Prohibition: signs which have a main safety colour of red, with a contrast colour of white and a crossed through circle in red with a graphical symbol colour of black.

Mandatory: action signs have a main safety colour of blue, with a contrast colour of white and a circle in blue with a graphical symbol colour of white.

Hazard: (warning) signs have a main safety colour of yellow, with a contrast colour of black and a yellow equilateral triangle with smooth corners and black border with a graphical symbol colour of black.

Safe Condition: Escape Route and Safety Equipment signs have a main safety colour of green, with a contrast colour of white and a green rectangle or square with a graphical symbol colour of white.

Fire Equipment: signs have a main safety colour of red, with a contrast colour of white and a red rectangle or square with a graphical symbol colour of white.

For residential applications, the marking may be placed within the main service disconnect. If the main service disconnect is operable with the service panel closed, then the marking should be placed on the outside cover. For commercial application, the marking shall be placed adjacent to the main service disconnect in a location clearly visible from the location where the lever is operated.

All labels must be clear, easily visible, constructed and affixed to last and remain legible for the lifetime of the system. The warning signs must be compliant with the Oman reference legislation.

Therefore, in Oman warning signs have to be in line with British Standard BS 5499 Graphical Symbol and Signs – Safety Signs, including fire safety signs. Specifically comply with Part 1: Specification for geometric shapes, colours and layout. Moreover, Part: 5 Signs with specific Safety meaning.

Materials used for marking shall be weather resistant. For example, ANSI/UL 969 "Marking & Labelling Systems" shall be used as a reference standard for weather rating.

The minimum requirements for labelling a PV plant are described in the present chapter. Practical samples of marking are provided in "ANNEX b – examples of warning signs".

A simplified site plan layout with the position of PV modules, cables and disconnectors as shown in the example of Figure 15 shall be exposed close to the main energy meter. If a manual call point is available in the building a further copy of the simplified site plan shall be exposed on the side.

Circuit diagram & system information (Figure 9) shall be provided at the point of interconnection: the following information is to be displayed (typically all displayed on the circuit diagram):

- Circuit diagram showing the relationship between the inverter equipment and supply.
- A summary of the protection settings incorporated within the equipment.
- A contact telephone number for the supplier/installer/maintainer of the equipment.
- As a good practice shut-down and start-up procedures shall be detailed on this diagram.

The PV system shall be connected to an isolation switch that is located in an accessible place. This switch shall clearly show the ON and OFF positions and be labelled as 'PV system – main AC isolator'.

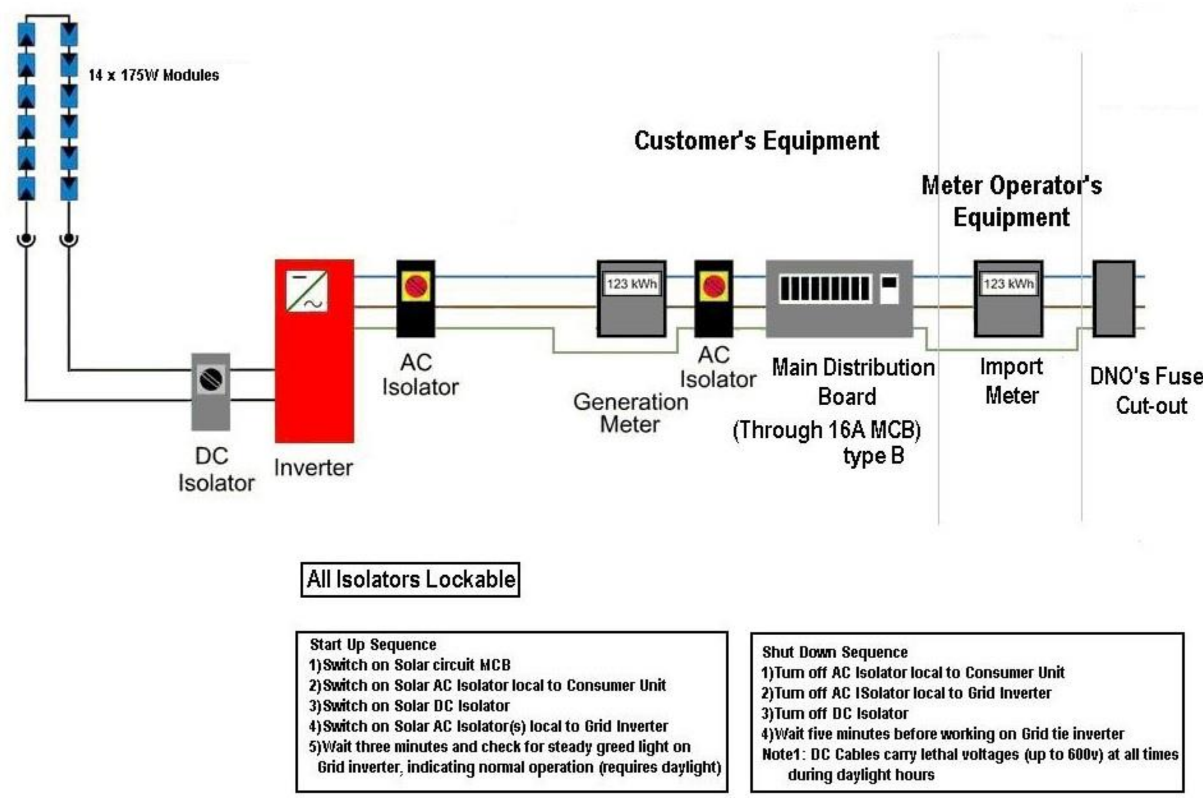


Figure 9 – Example of Circuit diagram & system information to be exposed in the building [13]

Dual supply labelling: it should be provided at the service termination, meter position and all points of isolation between the PV system and supplier terminals to indicate the presence of on-site generation and indicating the position of the main AC switch disconnector.

The peculiarity of a PV plant is to have two different circuits (bipolar): AC and DC. Warning signs shall thus inform of the presence of "WARNING PHOTOVOLTAIC SYSTEM DUAL POWER SUPPLY". Also, the DC circuit may be energized even if AC is disconnected. Therefore it is important to warn workers on the hazards of overvoltage at disconnection: "WARNING BIPOLAR PHOTOVOLTAIC ARRAY DISCONNECTION OF NEUTRAL OR GROUNDED CONDUCTORS MAY RESULT IN OVERVOLTAGE ON ARRAY OR INVERTER"

Inverter ventilation: inverters generate heat and should be provided with sufficient ventilation. Clearance distances specified by the manufacturer (e.g. to a heat sink) should be observed. Inverter locations such as Plant or Boiler rooms, or roof spaces prone to high temperatures, should be carefully considered to avoid overheating.

Failure to follow the recommendations of the manufacturer can cause a loss in performance as the inverter will de-rate as soon as it reaches its maximum operating temperature. This should be

highlighted within the operation and use manual, left with the customer and ideally with a label – "not to block ventilation" – placed next to the inverter.
It is recommended that inverters carry a sign 'inverter - isolate AC and DC before carrying out work'.
To ensure the Fire and Rescue Service are aware that a PV system is installed on the roof the following signs shall also be fitted.

- Location: next to the suppliers' cut-out in the building
- Size: this label shall measure at least 100 mm x 100 mm

Marking is required also for DC circuits both on all interior and exterior DC conduit, raceways, enclosures, cable assemblies, and junction boxes to alert the fire service to avoid cutting them, or be suitably informed in case they need to cut them to fight the fire. If deemed necessary such marking signs shall be placed every 10 feet, at turns and above and/or below penetrations, and at all DC combiner and junction boxes.
The characteristics of the sign should inform the system is a PV solar system, the content of the sign may be "CAUTION: SOLAR CIRCUIT".
Circuits shall be equipped with a means for remote disconnection located downstream from the photovoltaic array at the point where the circuit enters the structure. Control of remote disconnect shall be located within one meter of the building's main electrical panel. The remote disconnect DC array conductors that are routed through the building may be required to be in galvanized rigid steel conduit or electrical metallic tubing (not galvanized acceptable only interior building). A sign should be mounted on or next to the PV system disconnecting means with the words to the effect of "PV System Disconnect".
Grounded DC photovoltaic arrays shall have a warning label on the inverter or near the ground fault indicator at a visible location, stating: "WARNING - ELECTRIC SHOCK HAZARD"
Some national standard differentiate the warning adding the sentence "PHOTOVOLTAIC SYSTEM VOLTAGE DURING DAYLIGHT HOURS", though this could be misleading as long as a voltage can occur when a PV panel is illuminated by bright light (in principle even in the presence of full moonlight).
Adding the voltage maximum detectable (volts) is useful as well the operating current (amps).
The warning sign must be placed at least every 10 meters of the electrical duct from the arrays to the inverter's cabin and before all entrances and way out of the PV plant.
The area where PV modules, cables and other equipment are located, if accessible, shall be marked by proper signs as that reported in Figure 14. They shall also be placed in correspondence of each access door to the PV plant. The same signs shall be used to indicate cables before disconnectors and shall be placed every 5 meters along the cable.
These signs shall be UV resistant shall indicate the DC voltage as the Open Circuit Voltage at STC of the PV array. Their minimum size is 200 × 150 mm (w × h).

Recommendations

For all warning signs, first reference shall be made to those required according to standards and legislations. For the installation phase and during the working on the rooftop refers to the Local Municipalities code of construction. It is advisable to foresee to put in place warning sign in different languages (e.g. Arabic and English) in order to warn all workers coming from different countries.
The applicant must be compliant with the national legislation for warning signs. In addition comply with the internal marking department procedures and standards for sign (colour, dimension, physical characteristics, etc.).
As to the kind of information that shall be provided thanks to the placement of such signs, in ANNEX B a selection of such warning signs is presented that shall be adopted for different places of a PV plant.
Requirements for the above said signs are specified in 2.6.7 "System labelling and warning signs" of the "Standards for Distributed Renewable Resources Generators Connected to the Distribution Network" [15]. Particularly, Section 2.6.7.2 "Identification of a PV installation" provides an example of

switchboard sign for identification of multiple supplies (according to BS 7671:2008 [16]), and specifies the positions where such type of sign shall be located.
Section 2.6.7.3 “Labelling of PV array and PV string combiner boxes” provides an example of the sign that shall be attached to PV array and PV string combiner boxes as well as labels indicating “live during daylight” to DC combiner boxes and switches.
Section 2.6.7.4 “Labelling of DC disconnection devices” specifies that PV array DC switch disconnectors shall be identified by a sign affixed in a prominent location adjacent to the switch disconnector.
The warning signs for disconnectors, both DC and AC, are shown in the following table, along with the (suggested) Arabic translation.

LOTO (Lock-out tag-out) procedures shall be prepared by the installer, and described in the Operation and Maintenance Manual for delivery to the customer, whenever required; such manual shall specify also the position of the manual call point. LOTO procedures shall be according to rules and regulations of the relevant authorities. For example requirements related to LOTO procedures are specified in the standard “EHS Design Development Regulations”.

Table 1 – Examples of warning signs for disconnectors

<table>
<tr><th>Suggested placement in the PV plant</th><th>Warning messages</th><th>Warning signs</th><th>Arabic</th></tr>
<tr><td>Any accessible D.C. connectors</td><td>Do not disconnect D.C. plugs and sockets under load - turn off A.C. supply first.</td><td>
</td><td>
</td></tr>
<tr><td>D.C. junction box, if any</td><td>PV Array D.C. Junction Box. Danger - contains live parts during daylight.</td><td>
</td><td>
</td></tr>
<tr><td>Possible positions (according to the actual electrical design):
• adjacent to, or integrated into the inverter
• at the point of cable entry into the building (inverter inside a building)</td><td>PV Array D.C. isolator. Danger contains live parts during daylight.</td><td>
</td><td>
</td></tr>
<tr><td>Inverter</td><td>Inverter - Isolate A.C. and D.C. before carrying out work.</td><td>
</td><td>
</td></tr>
<tr><td>Main A.C. switch-disconnector.</td><td>PV system - main A.C. isolator.</td><td>
</td><td>
</td></tr>
</table>

4 SAFETY DURING O&M

In PV plants the operation and maintenance are overall represented by monitoring the electricity production and maintain the electricity production optimized. PV plants are typically stand-alone and therefore unattended during operation. The maintenance of PV plants is a mix of periodical inspection activities and check of the performance of single parts and components of the PV plant.
Depending the overall power and electrical design of the PV plant, some parts of the power circuits may be operating at MV, particularly following an inverter/transformer stage. Therefore, a proper maintenance has to be provided to such equipment in accordance to the design, the suitable safety rules, and the recommendations of the manufacturer.
The main maintenance operations are:

- Visual inspection of the site (interior and exterior)
- Cleaning operations of PV panels (with compressed air or desalt water)
- Inspection of overvoltage protection
- Control of joint panel (low voltage) and overvoltage protection
- Control of joint and distribution panels
- Control of medium voltage circuit

Specific electrical hazards are connected to the activities of maintenance on the electrical parts performed on PV plant. Specifically during array connection in installation and substitution of a PV panels there are hazards of electrocution. Also during inspection of the site there are risks of falls from the roof or accidents due to material falling while transportation, potential stumble or other causes.
Finally hazards associated to the specific activities performed inside the building of installation, i.e. risks from the industry where the installation's roof is located. Eventually risks can be observed during maintenance and cleaning operations in relation to the cleaning techniques and cleaning tools.
Workers involved in O&M should act in accordance with the statement of the risk assessment plan (HSE Risk assessment). For instance, if the PV plant is mounted on a rooftop without protected pathways and trenches workers have to wear harnesses and fasten them to a safe belay. Maintenance operation should be performed with the PV plant (or part of the PV plant involved in maintenance) disconnected and all arrays not energised except for those operations where it is not identifiable a specific risk.

Recommendations

O&M personnel to operate the Solar PV plant shall possess the same minimum qualification required to the personnel of the Contractor enrolled to apply for the connection of the same type of plant.
Also all workers and specifically for those of the O&M supplier shall receive the expected prevention information particularly perform "Tool Box Talk" and H&S induction training on the hazards of operations on a rooftop and on working close to PV generators and other electrical equipment. Workers shall be provided with suitable PPE when risk reduction measures at source are not sufficient.
Provide sufficient cooperation, communication and exchange of information among the different stakeholders involved in O&M activities (for example building owner, site manager and the workers and the supplier of cleaning services) in order to allow the safe performance of the work, especially if different companies and sub-contractors are involved. Thus, put in place measures to ensure communication of information to (e.g. migrant) workers who may not have a good command of the working language in order to allow them to perform their work safely.

ANNEX A - SUMMARY OF THE RECOMMENDATIONS

ANNEX A.1 – INSTALLATION

Item	Recommended Practice
Conventional Hazards (hazards electrical and in construction works, for works on rooftops, prevention equipment and measures including PPE as needed to prevent falls)	Follow current safety guidelines allowing safety of personnel performing electrical equipment installation particularly on rooftops or visiting or inspecting the installation site. Particularly: – Act in compliance rules, codes and "Legal requirements". – Perform HSE risk assessment – Deliver H&S induction training before allowing personnel (workers, inspectors, etc.) to access the working site – Allow personnel attend "Tool Box Talk" – Ensure personnel have the required technical education, knowledge, working experience, and suitably trained to do the expected electrical activities also on live parts – Consider particularly the issues of performing activities on rooftops at elevation from ground level Adopt systems suitable to prevent falls from rooftop, like static line systems, including travel restraint systems and fall-arrest systems, roof-edge protection systems, including modified scaffolding, safety mesh and guardrail. Verify the use of appropriate PPE to prevent falls.
Arc flashes and Burns	The design shall be appropriate to avoid faults during operation. During installation check the integrity of wires and electric components, and follow the suitable installation procedures considering that many tasks must be performed on live parts.
Testing for Voltage	The personnel of the installer shall use PPE with appropriate characteristics in relation to works on electric parts of PV plant. Workers shall have the skills needed to operate on live parts and use equipment for testing voltage/current in field.
Insulated tools	The personnel of the installer shall use PPE with appropriate characteristics in relation to works on electric parts of PV plant. Workers shall be trained for using the needed PPE.
Marking and warning signs	The design shall include the installation of appropriate warning signs indicating the presence of the PV plant and of the related electrical equipment. Warning signs shall be in line with British Standard BS 5499 Graphical Symbol and Signs –Safety Signs, including fire safety signs. Requirements for branding and H&S specifications need to be followed. Examples of warning signs are reported in Annex B.

ANNEX A.2 – MAINTENANCE MANAGEMENT

Item	Recommended Practice
Safety during O&M (Prevention of falls working on rooftops)	In addition to recommendations in A.1: The O&M supplier (and the Installer) shall prepare guidelines for workers during cleaning of panels: cleaning has more potential hazards since the panel surface is more slippery and panels are often slanted and not on horizontal on a flat surface. Adopt systems suitable to prevent falls from rooftop, like static line systems, including travel restraint systems and fall-arrest systems, roof-edge protection systems, including modified scaffolding, safety mesh and guardrail. Verify the use of appropriate PPE to prevent falls.
Safety during O&M (Cleaning operations)	The O&M supplier (and the Installer) shall prepare guidelines for correct use of tools for cleaning for O&M workers; Prevention of damage to the PV panels, wiring, connectors, panel fixing systems. Workers performing cleaning activities shall be aware of potential electric risks in case PV panels were damaged.
Safety during O&M (O&M management)	The O&M supplier (and the Installer) shall prepare guidelines for correct exploitation of maintenance procedures, including substitution of electrical parts and/or PV components. In case of disconnection of the PV Plant the guidelines for disconnection and safety operation during specific electrical checks shall be fulfilled, also in cooperation with DISCOs.

ANNEX A.3 – INFORMATION FOR DISCO PERSONNEL AND FOR INSPECTORS

Item	Recommended Practice
Information for DISCO personnel	The Applicant (or the Installer) shall provide a communication describing the list of hazards on the site where the PV plant is being installed. DISCO will process the said communication according to its safety prevention procedures.
Inspectors from other organizations (inspection visits not related to testing)	The Applicant (or the Installer) shall provide a communication describing the list of hazards on the site where the PV plant is located. The concerned organization will process the said communication according to its safety prevention procedures.

ANNEX A.4 – INFORMATION FOR FIRE FIGHTERS

Item	Recommended Practice
Information for Fire-Fighters	Fire-Fighters have to have an appropriate knowledge of a PV plant and use the most suited procedures when operating in the presence of a PV plant. A damaged PV panel can still produce current and being capable of producing hazardous conditions ranging from perception to electrocution: Fire-Fighter should respect the prescription on manipulating arrays and PV panels even when the panels are damaged. Detailed recommendations for Fire-Fighters are listed below. – Use PPE (protection gear, boots and gloves) certified for electrical shock as it is required to operate in PV plants. – Take into account the voltage and the current that are present in a PV plant. – Know the hazards related to specific actions, e.g. cut of individual conductors because of back feed. – Turning off a PV array is not as simple as opening a disconnect switch. There may be several points of disconnect for a PV plant. An alternative applicable could be to cover with tarps the array. Caution should be exercised when deploying tarps on damaged equipment as a wet tarp may become energized. – Consider potential trip, slide and fall hazards in case of a rooftop PV plant. PV panels and arrays can be slippery or fragile. Avoid, or exercise extreme caution, near the roofline since modules or sections of an array could slide off the roof. – Fires under an array but above the roof may breach roofing materials and decking, allowing fire to propagate into the attic space. Hazard of rooftops collapse in case of fire can be an issue when listed in the risk assessment: a layer of flammable insulation in the rooftop can be harmful and potentially introduce new risks of the entire structure of rooftop and PV arrays.
Information for Fire-Fighters	Fire-Fighters have to be aware of the potential electrical hazard from energy produced by Solar PV plants. – Even when isolated at the inverter or fuse box, the system may remain 'live' between the PV panels and the isolation point. This presents a potential DC electrical shock hazard for fire-fighters at structural incidents - not just throughout daylight hours - but even possibly in minimal light levels during the night (e.g. bright moonlight or from scene lighting). In principle even at night, when illuminated by artificial light sources such as fire department light trucks or an exposure fire, PV systems are capable of producing electrical power sufficient to cause a lock-on hazard.
Danger of inhalation of hazardous fumes	Fire-Fighters have to be aware that in the event of a fire, it is theoretically possible for hazardous fumes to be released and inhalation of these fumes could pose a risk to human health. Experts do not generally believe these risks to be substantial given the short-duration of fires and the relatively high melting point of the materials present in the PV modules.

ANNEX B – EXAMPLES OF WARNING SIGNS

Examples of warning signs, hazard information in English and Arabic.

Figure 10 - generic warning for PV plant's panels on the roof

Figure 11 - Warning with specification danger of electrical hazards

Figure 12 - Warning sign more specific on electrical live parts presence

	Emergency contact numbers
…	Ambulance
…	Civil Defence
…	Police
…	Health Authority
…	Distribution Company

Figure 13 – Template of warning sign with specification of emergency contact numbers

Figure 14 – Signs to be used to indicate the presence of a PV plant

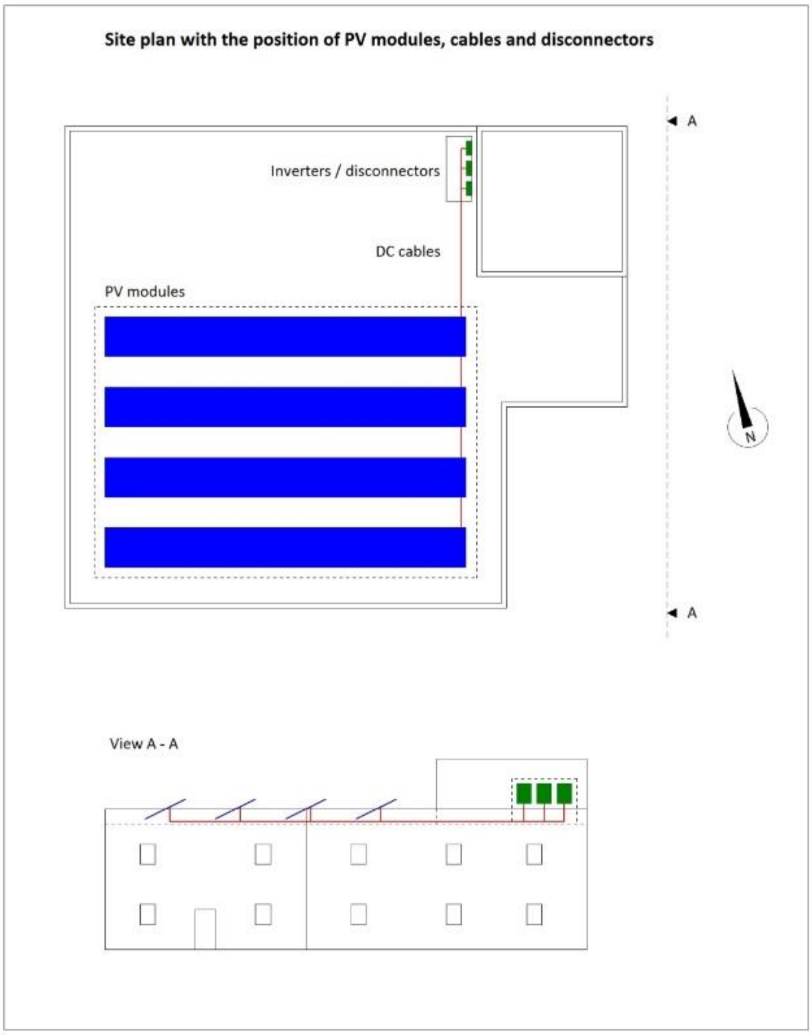


Figure 15 – Example of simplified layout to be exposed in the building

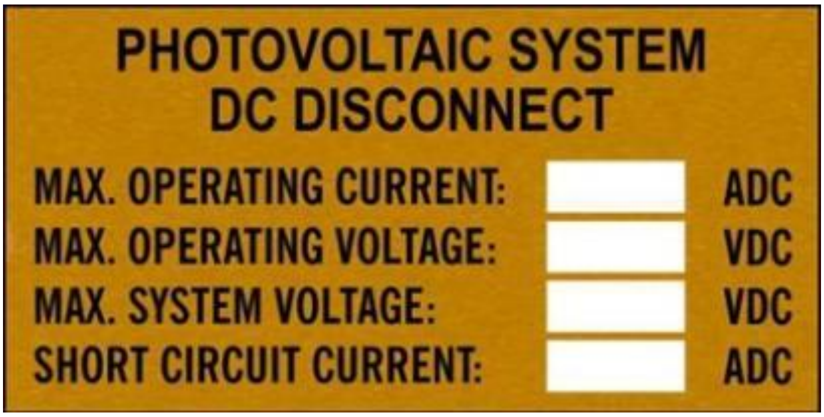
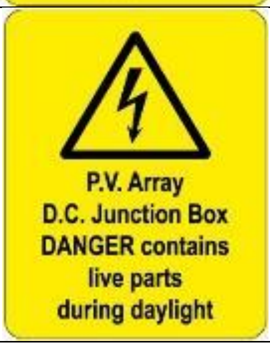
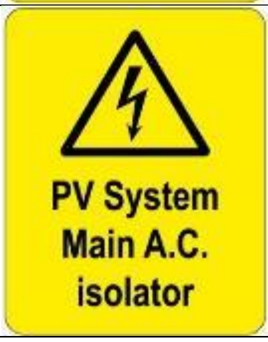


Figure 16 - Warning sign with specification of voltage and current operating in the PV systems

Figure 17 – Generic warning for PV systems

Figure 18 - Warning with specification of the dual power supply

English	Arabic
	
	

 P.V. Array D.C. Isolator DANGER contains live parts during daylight	 أنظمة خلايا شمسية. مفتاح تيار مستمر. خطر بعض الأجزاء معرضه للجهد الكهربي أثناء النهار
 INVERTER - Isolate A.C. and D.C. before carrying out work	 INVERTER قم بعزل التيار المتغير والمستمر قبل البدء بالعمل
 PV System Main A.C. isolator	 أنظمة خلايا شمسية. مفتاح التيار المتغير الرئسي


Do not disconnect D.C. plugs and sockets under load Turn off A.C. supply first
PV System Main A.C. isolator
D.C. CABLE DANGER High Voltage
P.V. Array D.C. Isolator DANGER contains live parts during daylight
SOLAR PV MODULE DANGER - Contains live parts during daylight
INVERTER - Isolate A.C. and D.C. before carrying out work
P.V. Array D.C. Junction Box DANGER contains live parts during daylight
WARNING - DUAL SUPPLY
Do not work on this equipment until it is isolated from both mains and on-site generation supplies
Isolate on-site generator at ....
Isolate mains supply at ....
لا تفصل كابلات التيار المستمر أثناء التشغيل قم بفصل كابلات التيار المتغير أولاً
أنظمة خلايا شمسية. مفتاح التيار المتغير الرئيسي
كابلات تيار مستمر خطر جهد عالي
أنظمة خلايا شمسية. مفتاح تيار مستمر. خطر بعض الأجزاء معرضة للجهد الكهربي أثناء النهار
ألواح خلايا شمسية. خطر - أجزاء معرضة للجهد الكهربي خلال النهار
INVERTER قم بعزل التيار المتغير والمستمر قبل البدء بالعمل
خلايا شمسية. علبة توصيل تيار مستمر. خطر- تحتوي على أجزاء معرضة للجهد الكهربي أثناء النهار
تحذير - مصدر مزدوج للطاقة.
لا تقم بالعمل قبل فصل المفتاح الرئيسي ومفتاح مصادر الطاقة
فتح مفتاح مصادر الطاقة........................
فتح المفتاح الرئيسي ....