GOVERNMENT OF DUBAI

Dubai Electricity & Water Authority

SHAMS DUBAI

SAFETY OF PEOPLE:
RECOMMENDATIONS FOR DRRG SOLAR PV SYSTEMS

VERSION 1.0 – EDITION 2015

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1 INTRODUCTION

1.1 Scope

This document outlines the main issues that have to be taken into account in order to safeguard the Safety of People when installing and connecting a new Renewable Resources Generating Plant (RRGP) to the electricity network, specifically a solar photovoltaic PV system. The topics are mainly related to a RRG in low and medium voltage range and, mainly rooftop mounted.

The documents listed below provide information to Dubai Citizens, Consultants and Contractors on the essential aspects to be considered during the connection of a Renewable Resources Generating Plant (RRGP) to The Distribution Network:

- DEWA Standards for Distributed Renewable Resources Generation Connected to the Distribution Network.
- DEWA Connection Guidelines for Distributed Renewable Resources Generation connected to the Distribution Network.

Although PV systems provide many benefits, various hazards are also 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 the relevant codes, standards and guidelines. Significant progress has been made in the past years in many countries with a longer tradition of PV technology use, however, there are still gaps that need to be pointed out.

The purpose of this document 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 document summarizes basic performance categories associated with PV panel installation practice and identifies specific hazards to be considered. These include safety of workers both in construction and operation phases (as well during the decommissioning). Safety concerns in PV solar installation are normally related to electrical hazards, and installing PV plants on rooftops additionally introduces the hazards associated to construction performed in elevation.

Safe installation requires compliance with relevant health and safety regulations. This document thus reviews existing information available in literature related to best practices for risks assessment in order to address the above issues. A comprehensive reference section is also provided in Section 1.3.

Finally, a PV system presents different types of hazards that apply at different stages of the plant life. The lifetime of a plant can be divided in the following four stages:

Permitting	Is the stage of design and evaluation of risks linked to the new RRGP and the environment where it will be installed
Constructing	Is the stage when workers with different skills mount the RRGP and connect it to the network grid. It comprises the inspection of the RRGP that is driven by DEWA inspectors
Operating	Is the phase of generating electricity, with the operation and maintenance of the RRGP
Decommisioning	At the end of life of plant and its components the RRGP should be dismantled and all the parts have to be recycled or disposed, and the site correctly remediated

The issues related to the Safety of People concern all four stages of the lifetime of a PV system, beginning from the permitting and design stage when potential safety hazards connected to the construction and operation of the PV system are to be identified and analysed.

Based on the Risk Assessment, recommendations are provided to support Consultants and Contractors involved in PV installations. The recommendations are summarized in Annex A.

1.2 Definitions

The definitions of most relevant terms contained in this 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 the US market these are also known as arc fault circuit interrupters: AFCIs.
Building-integrated photovoltaic (BIPV) – Photovoltaic modules are considered to be building-integrated, if the PV modules form a building component providing a function. Thus the BIPV module is a prerequisite for the integrity of the building's functionality. If the integrated PV module is dismounted (in the case of structurally bonded modules, dismounting includes the adjacent building component), the PV module would have to be replaced by an appropriate building component.
Building-attached photovoltaic (BAPV) – Photovoltaic modules are considered to be building attached, if the PV modules are mounted on a building envelope and do not fulfil the criteria for building integration.
DMM – Digital Multi Meter, a tool which can measure voltage, amperage, and resistance used for testing PV systems.
NOC – Non Objection Certificate – Certification that allows the actions that are specified in the same certificate.
Application for Connection – It is filed by an applicant for the Connection of a new RRG system. This application shall be made in a format prescribed and shall contain the required information.
Connection Agreement - Agreement which sets the terms and conditions for connection and the operation of a Generator of Electricity into the Power Distribution System.
CPE – Collective Protection Equipment.
Grid Connection - the connection of a Renewable Resource Generating Plant (RRGP) to the electrical grid.
HSE – Health Safety Environment.
H&S Induction training – health and safety awareness training provided to employees prior to commencing construction works in a specific site.
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.
LOTO – Lockout-tagout. Placement of a lock or tag on an energy-isolating device indicating that the energy-isolating device is not to be operated until removal of the lock or tag.
Medium Voltage (MV) Network – a Network with nominal voltage included in the range from 1kV up to 33 kV. In Dubai four voltage levels may be found on MV distribution network, namely 6.6 – 11 – 22 – 33 kV. The 11 kV voltage level is the most used and spread one.
MOL – Ministry of Labour (UAE – Dubai).
Network – plant and apparatus connected together in order to transmit or distribute electrical power, and operated by DEWA.
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.
Process – 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 in nature).

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

Photovoltaic 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.

Renewable Resource Generating Plant (RRGP) – a set of Renewable Resource Generating Units.

Renewable Resource Generating Unit (RRGU) – a Generating Unit that produces power exclusively from renewable primary resources. This Renewable Resource Generating Unit can be part of a Generating Plant that includes non-renewable resources. In this latter situation, the RRGU is the part of the Plant that is able to produce energy without input from non-renewable resource.

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

Toolbox talk – a short presentation to the workforce on a single aspect of health and safety.

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

1.3 Reference documents

The following documents are quoted as a reference:

1. DEWA Standards For Distributed Renewable Resources Generation Connected To The Distribution Network
2. DEWA Connection guidelines for Distributed Renewable Resources Generation Connected to the Distribution network
3. UAE Civil Defence department, "UAE Fire and Safety Code of Practice", 2011
4. Dubai Municipality, "Code of Construction Safety Practice", 2011
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. U.A.E. Labour Law. Federal Law n° (8) OF 1980
7. IEC/TS 60479-1 – Effects of current on human beings and livestock. Part 1: General aspects
8. IEC/TS 60479-2 – Effects of current on human beings and livestock. Part 2: Special aspects
9. IEC/TS 60479-5 – Effects of current on human beings and livestock. Part 5: Touch voltage threshold values for physiological aspects
10. IEC 61440 – Protection against electric shocks. Common aspects for installations and equipment

11. BUILD SAFE UAE, “Best Practice Guidelines for Working at Heights”, UAE, 2009

12. NFPA 70 US Electrical Codes - National Electrical Code Article 690: Solar Photovoltaic Systems

13. IEEE 1547, Standards for Interconnecting distributed Resources with Electric Power Systems

14. UL Standard 1703; Flat-Plate Photovoltaic Modules and Panels

15. 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

16. IEC 62257-7-1:2006-12 Recommendations for small renewable energy and hybrid systems for rural electrification – Part 7-1: Generators – Photovoltaic arrays

17. IEC 62257-5:2005-07 Recommendations for small renewable energy and hybrid systems for rural electrification – Part 5: Protection against electrical hazards

18. NFPA, “Fire Fighter Safety and Emergency Response for Solar Power Systems”, Quincy, May 2010.

19. OSFM, “Fire Operations for Photovoltaic Emergencies”, Sacramento, November 2010

20. J. Johnson et al., “Photovoltaic DC Arc Fault Detector testing at Sandia National Laboratories”, Eaton Corporation, Milwaukee, WI, USA

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

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

23. UK ECA, Guide to the Installation of Photovoltaic Systems, 2012

24. BS7671:2008. Requirements for Electrical Installations - IET Wiring Regulations 17th Edition

25. EHS-Trakhees-PCFC Design Development Regulations, Jebel Ali Free Zone Authority

2 CONVENTIONAL HAZARDS

This 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.

DEWA enrolled Consultants or Contactors wishing to obtain DEWA Solar PV Certification so that they can apply for the connection of a Solar PV plant, shall have in their team, the required minimum number of Certified Solar PV Installers. This will ensure that their personnel possess the knowledge required to safely design and construct a Solar PV plant.

2.1 Risks assessment

According to international best practises and the UAE Fire and Safety Practice Code [3], each party wishing to perform an installation shall conduct a Preliminary Hazard Analysis (PHA) to identify HS hazards, analyze environmental aspects and impacts, and estimate any potential HSE risks.

Activities pertaining to the installation as well as those activities conducted during operation and maintenance should be subject to a thorough Risk Assessment.

In the case of a PV plant this shall include the following:

- 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 within each and every activity;

- Assess the condition of the roof and the types of roofing material used, 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;

- Safely access and work safely on the roof and control the risk of falls and injuries;

- 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 individuals not involved in the work area are kept away from the work area by utilising barricades or similar control systems;

  - checking that tools and 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 implement adequate control measures.

Before initiating the installation, the Applicant in accordance with the Dubai law, is required to:

- Designate a person in charge of checking the correct execution of the prevention plans
- 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 DEWA workers are to be made aware of risks according to the said assessment [5].

All personnel working on the installation need to have relevant technical qualifications and suitable experience and competence to perform their tasks safely.

Prior to gaining site access, each worker will have to attend the H&S Induction Training and “Toolbox Talk”. All workers should follow the Dubai Municipality Code of Construction Safety Practice [4] and all related legal requirements (e.g. [6]), and any additional relevant DEWA Procedures.

Recommendations

- Always perform the HSE Risk Assessment and make available to all parties involved.
- Use the H&S Induction Training and “Toolbox Talk” for prevention of hazards in all operations required for the installation of PV Plant.

2.2 Principal hazards for the safety of people

2.2.1 Electric shocks

The work environment shall be managed according to Dubai Municipality Code of Construction Safety Practice [4] and all other related legal requirements.

There are many sources of electric shocks when working on PV systems but only those aspects related to the DC current arising from photovoltaic components are considered herein, because they are specific to PV systems and differ considerably from those related to AC applications ([7] - [10]).

Whether activities take place in a household or within 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 at preventing and minimizing these risks.

A common mistake with electrical hazards is the underestimation of the risks related to the electrical shock, especially if the subject is a healthy adult. On the contrary, one should always consider that electric shocks, apart from being potentially lethal, could cause severe physiological impact on a human body. Hazardous situations such as results of startle reaction can cause muscle contraction, which in turn can lead to falls and other injuries. Depending on the working conditions and the environment, the consequences of falls can thus be far worse than the original electric shock (severe injuries or death).

Figure 1 shows the four zones of current-magnitude/time-duration,in which the below listed pathophysiological effects may occur (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 c2 and c3 correspond to a probability of 5% and 50% respectively.

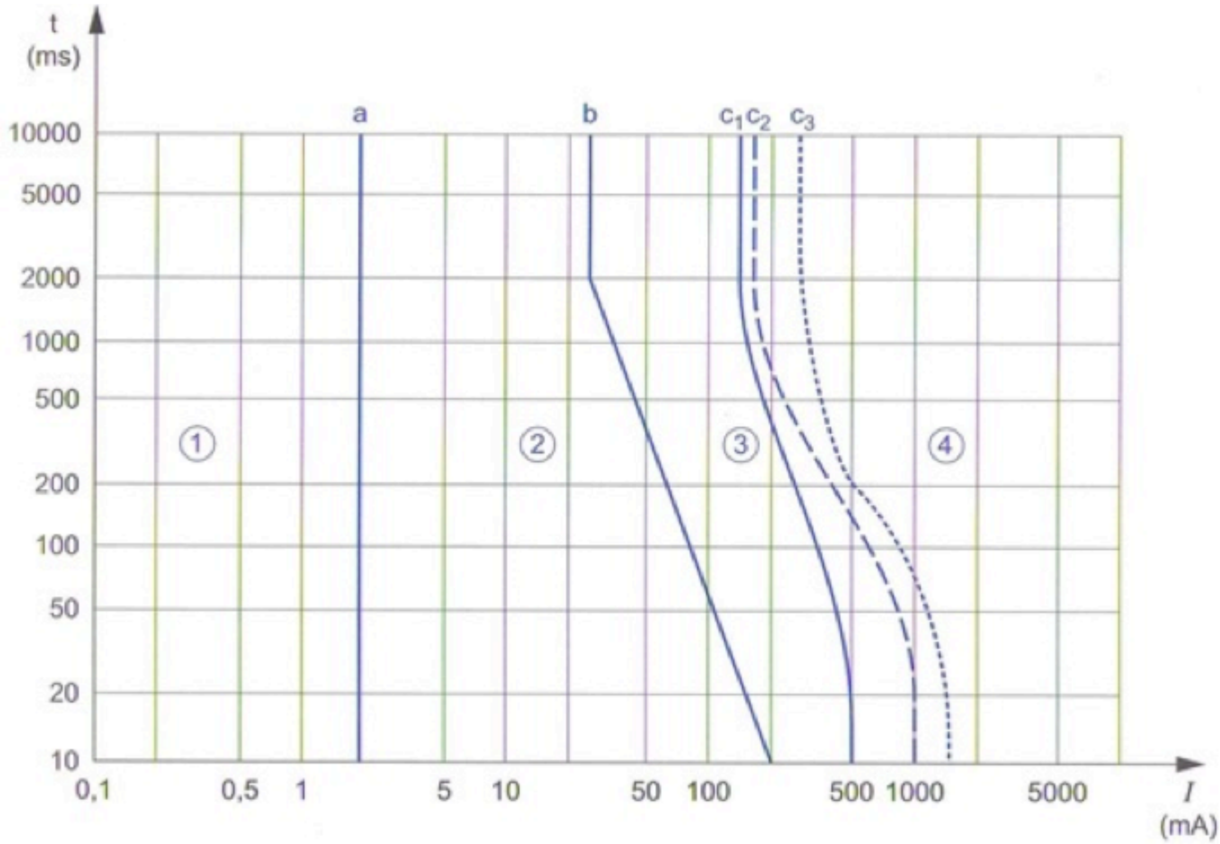


Figure 1 - time/current zones and effects of ascending hand-to-feet DC current on human body

Figure 1 provides useful information on the effects of DC current on human body but it considers only the worst-case scenario, 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 less severe than those 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

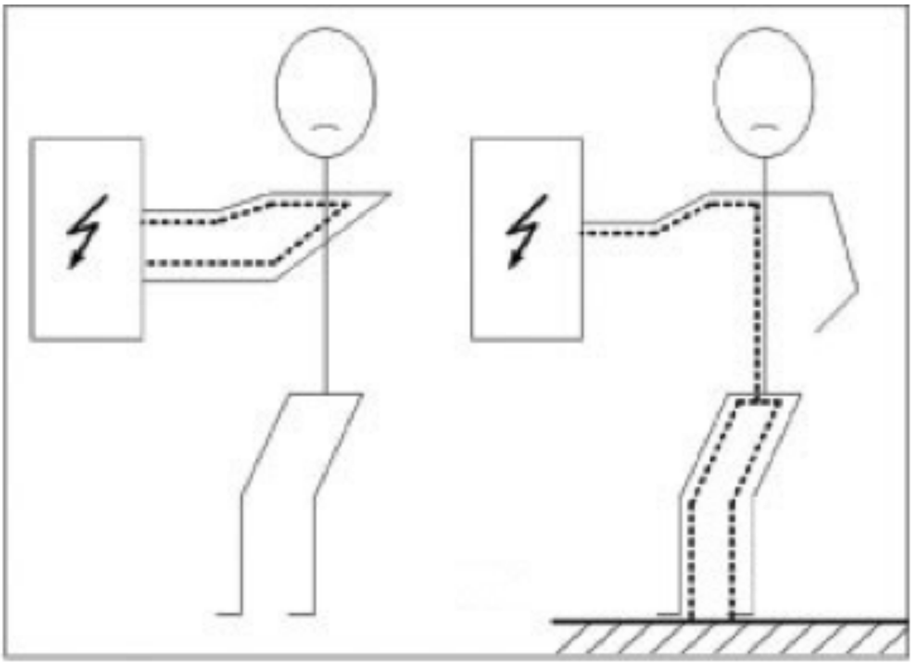


Figure 2 – Schematic representation of the hand-to-hand (left) and hand-to-feet (right) current path

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 happens when working on unfastened string cables.

Hand-to-feet electric shocks frequently occur in PV systems with a pole grounded. In this case, it only requires the worker to 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 limitation of voltage is fulfilled in case of SELV or PELV circuits where 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 V_{OC}. If the nominal V_{OC} 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 other hand, 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 precautions.

Various measures can be adopted in order to prevent electric shocks arising from PV modules during site work or maintenance. Although prevention is of utmost importance, adequate knowledge of electricity and wiring is crucial. The more a worker knows about hazards the more s/he will be able to avoid risks. Even before accessing a site any worker or engineer needs to become familiar with the project details of the given PV system. It is necessary that potential hazards are well understood and every subject is informed and trained to adopt all necessary precautionary steps and measures.

When several risks are present 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 a timely manner (prior to the beginning of any intervention) and precautionary steps and measures adopted.

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

Insulating gloves can effectively prevent most electric shocks, but also non-conductive footwear can further prevent a current from running through a person's body. Additionally, any work site shall be fitted with appropriate barriers, warning signs (signage), and tags related to electrical hazards.

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

2.2.2 General hazards during construction works

Although the project is mainly related to the installation of rooftop PV plants, the following hazards need to be considered due to the necessity of construction work:

- 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 electricity network. This may include excavation and the use of mechanical equipment particularly at ground level.

Recommendations

The above hazards shall be managed according to the available standard safety practices and preventive measures, relating to the Dubai Municipality "Code of Construction Safety Practice" [4] and to any other relevant law in force in Dubai.

2.3 Safety with reference to the activity on site

Different activities, at different stages are carried out when installing a PV plant, and as such, safety of people is an issue to be taken into account at different stages and by all relevant stakeholders.

- Inspection visits are envisaged in the preliminary evaluation of the prospected PV plant installation. No working or operational activity is envisaged. 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 on a site shall be managed according to the required safety procedures. In case access has to be granted to inspection personnel (e.g. DEWA, DM, Civil Defence, MOL), the said personnel shall be provided with 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 Applicant.

2.4 Risk of falls

Falls usually represent a high risk for PV systems on buildings, because any accidental fall generally leads to death or to severe injuries. Falls are specifically relevant to people working at height on structures under construction or that use ladders, platforms, lifts, baskets or other personnel and material handling systems.

In construction sites the risk of falls is generally mitigated through the use of 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) is very useful for preventing falls. As a rule, it is used in conjunction with CPE, or as an alternative safety measure when CPE cannot be installed. PPE for working at height mainly refers to a harness properly anchored to one or more fixed points.

The risk of falls on a PV site, are similar to many other activities on other sites that involve the placement and the fixation of glazing surfaces like windows or skylights.

Additionally, PV systems must be inspected and maintained regularly during their lifetime and therefore an easy and safe access to all parts of the system has to be put in place for the personnel.

The application of proper measures aimed to guarantee a safe access to a rooftop PV system depends on the type of the 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 personnel. However, on a sloped roof several lines and anchoring points have to be installed permanently. Their number and position must be sufficient to assure safe access to every part of the PV system and shall always avoid dangerous effects like bottoming out or pendulum.

Another frequent source of danger are the transparent surfaces like skylights or similar, especially when they are close to PV systems. In these cases, the use of railings can be difficult and often the most effective solution is 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.

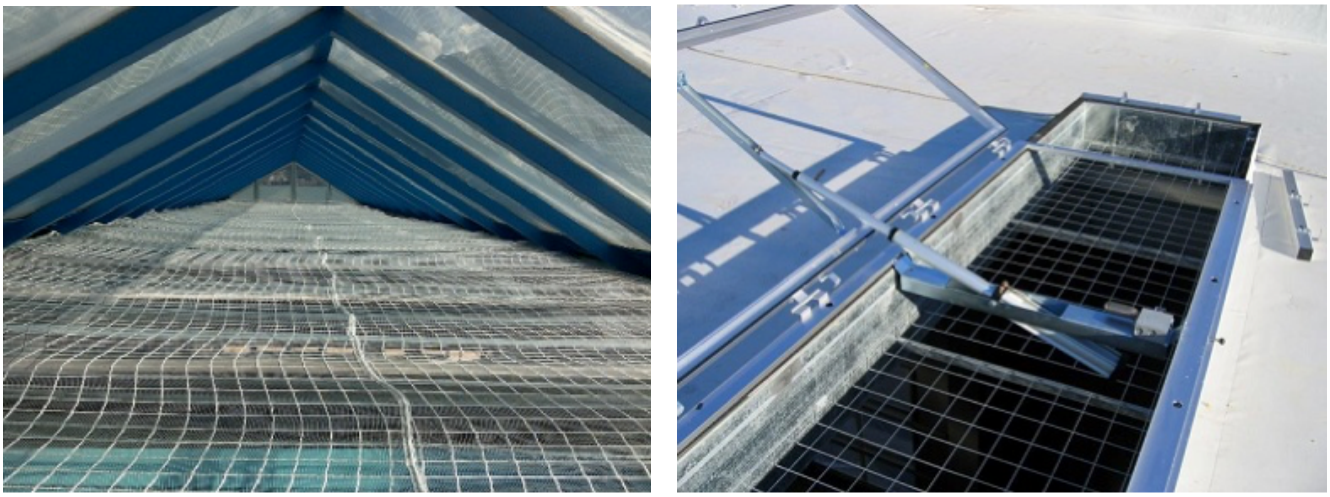


Figure 4 – Example of safety nets installed below skylights

The access way to a rooftop PV system should be easy and safe to use. When the access way is external, the installation of a permanent safety ladder is recommended. In certain cases this solution is not feasible due to technical or aesthetic 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.

The Build Safe UAE Association has released specific guidelines for working at height [11] that are common best practice to follow for preventing falls while working at height.

2.5 Other hazards (Exposure, Bites and Cuts)

Additional risks may also arise due to 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. However, the installers are still 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 arising from solar panels falling from the roof; either because they become detached from their fixings, or because of failure in the roof structure.

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. The use of the appropriate PPE is recommended to avoid risks of cuts and other injuries.

3 ADDITIONAL INFORMATION ON HAZARDS RELATED TO PV INSTALLATIONS

Additional electrical hazards need to be considered when working with generators such as solar panels ([12] - [17]). Only qualified personnel or, at least, workers with H&S induction training on specific hazards, should be allowed to work on this 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 eye damage due to ultraviolet rays. 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 during the incident. The explosion might cause a worker to fall or jump, causing an additional, even more severe injury.

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 V_{DC}, the possibility of an arc flash has to be considered.

Burns can occur in varying degrees when working with PV systems. At the lowest part of the 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 reach 9,000 degrees Celsius when an arc flash occurs. In between these extremes, exposed electrical conductors, in conjunction with hot temperatures, can cause fires that result in severe burns and the need of emergency treatment.

Recommendations

Arc flashes have been recognised as hazards for PV system only since 1990. Adequate awareness of the phenomenon is part of the prevention procedures. Although faulty equipment can cause an arc fault, often the most common cause is inappropriate human behaviour or human error. Standing too close to an electric system, especially without protective gear, can lead to severe or lethal injury. Furthermore, arc faults could 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 result from an arc fault is different from other kinds of fire. Thus, the PPE that should be used when such risks are involved needs to be specially suited. The PPE clothing and goggles used need to be specifically rated for arc flashes with adequate protection from the extreme light emitted.

3.2 Testing for Voltage

Preventive measures involve the testing of voltage using specific equipment. One such measure entails 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 circuits knows if any voltage exists, and if so, what its strength is.

Testing voltage is particularly important for PV systems that handle high voltages at any point in time. 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 familiar with the use of a voltmeter and surprise is the last thing one needs when working with such systems. In addition, the current will increase when string are connected in parallel. 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. As such, it is more suitable to work with a clamp-on voltmeter when working with systems that contain high amperage levels, unless a different measuring equipment and setup is required for a much more specific characterization of a PV string.

3.3 Earthing

Earthing is an important safety measure that needs to be followed 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 yet another necessary precaution and ensures the safety of any electrical environment and of the people who work in 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. References are provided in the Standards [1]: Appendix "C.9 – Electrical Installations" lists the standards relevant to the design of PV plants and includes matters relating to earthing (e.g. IEC 60364-5-54: Low-voltage electrical installations - Part 5-54: Selection and erection of electrical equipment - Earthing arrangements and protective conductors). Designers have the responsibility of designing PV plant earthing arrangements according to the applicable Standards and specific site conditions (e.g. rooftop PV plant in an existing building with earthing system available, or PV plant to be designed as a part of a brand new building). According to each specific PV plant installation the designer shall: measure the resistance of the existing earthing system, or assess its performance from available test reports or certifications and investigate the resistivity of the soil (in principle feasible for new buildings on green sites). Should a building not be equipped with an earthing system, the designer shall include design and installation of earthing system in the scope of work for a new PV plant installation.

Earthing of PV support structures and module frames is also required as a measure that safeguards during lightning. SPDs and surge arresters are normally provided through design as overvoltage protections in a PV system. Lightning protection measures shall be adopted through the design, as stipulated in the relevant standards mentioned in Appendix C.9 of the Standards [1]. The installer and the O&M supplier shall also set operational rules suitable for preventing hazards resulting from adverse meteorological conditions, such as lightning.

In addition, following the PV plant design and installation stage, the Contractor shall provide DEWA with all relevant information related to the earthing system, including documents such as the certification of a new earthing system or test result from periodic assessment of existing earthing system.

3.4 Insulated tools

Another important safety measure in preventing exposure to electrical hazards is the use of 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. The use of proper insulation level in case of high voltage, and the use of the same tools also for lower voltage operations are advised. This measure could prevent injuries arising from confusion due to the different insulation levels during the operation.

3.5 Risks while operating on PV electricity generators

Standard IEC 60364-7-712 [15] related to the electrical installations of buildings does outline some rules for protecting personnel. However, the current version of this 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 on a daily basis.

That being said, this standard is being updated, and future versions will introduce substantial improvements over what it is currently available. However, 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, there is no cause for concern. Until a more complete standard becomes available, it makes sense to err on the side of caution. In a nutshell, this means choosing quality equipment installed by a trained professional.

Firefighters and other emergency response teams are typically exposed to the risks of electrocution when called due to a blaze, commonly they cut off the power supply to the burning building as a safety precaution. If the building has a PV installation, the PV modules continue to generate voltage, even if the system is not actually connected to the AC grid. Yet, three or four connected modules are enough to generate more than $100V_{DC}$. Residential and commercial installations include several modules with voltage usually in the range of $600\text{-}1000V_{DC}$.

Under these conditions, a solution needs to be adopted that goes beyond the traditional shutdown function in inverters that merely interrupts current flow and allows voltages to 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 considered especially for large PV plants to prevent arrays remain energised even when 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 mentioned in document entitled "Safety of Environment: Recommendations for DRRG Solar PV systems"

- 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 [15]

- 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 [16]

- Technical specifications IEC 62257-5:2005-07 Recommendations for small renewable energy and hybrid systems for rural electrification – Part 5: Protection against electrical hazards [17].

3.6 Hazards in case of fire

This type or hazard concerns mainly the fire brigade and thus the safety of the people whose task, in this case, is to extinguish a fire that involves a PV system on a building or, more generally, on a construction ([18], [19]). Different scenarios may occur:

1. The fire originates from PV modules typically placed on rooftop, with 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 originates in equipment other than the PV modules (inverter, combiner box, switchboard, etc.) and this could affect only marginally the PV array (see example in Figure 7, the fire originated in a few combiner boxes).

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

Figure 6 – Example of effects of a fire in a PV system - that originated in combiner boxes

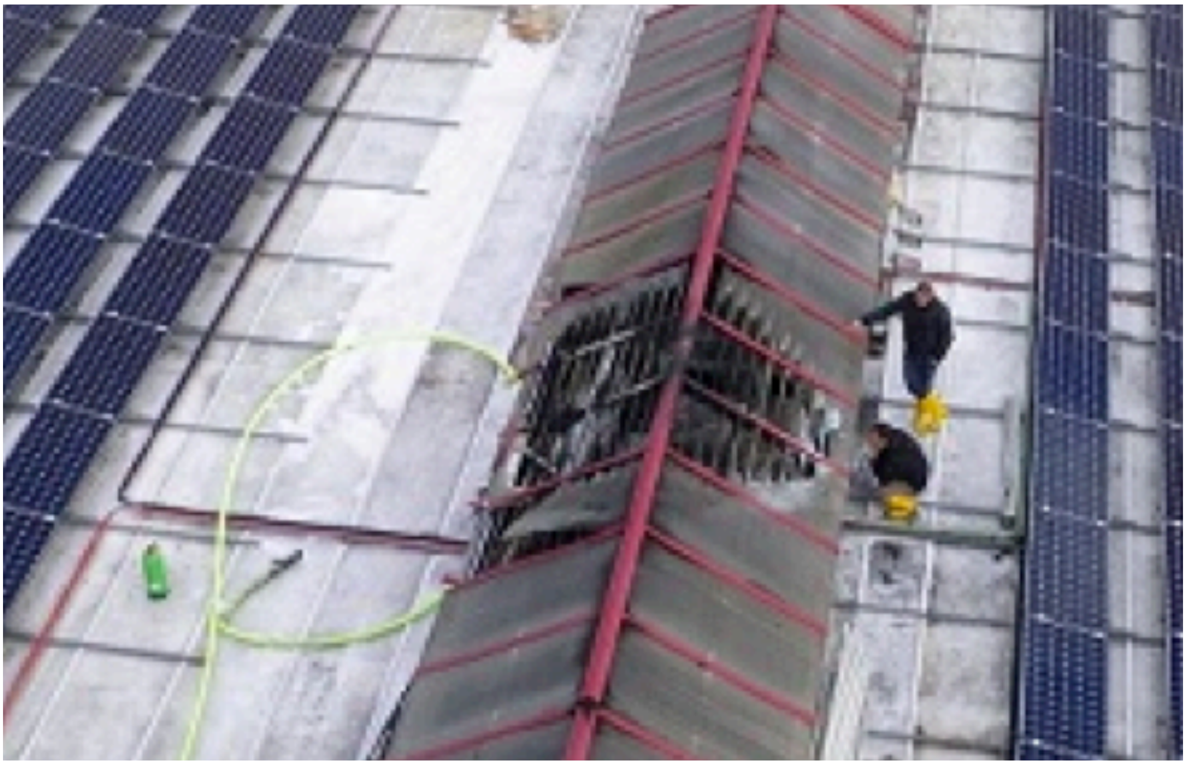


Figure 7 – Example of effects of a fire in a PV system - that originated in combiner boxes

Scenarios 1 and 2 pose a number of 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 for this to happen, the fire fighters must have sufficient knowledge of the PV system. Fire fighters should also be aware that these operations do not eliminate completely the presence of hazardous voltage in the PV plant.

In principle, in order to extinguish an extended fire in a building the use of water is often required 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 of an electric current above the threshold of 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 used by fire fighters, such as boots and gloves is designed and tested for electrical shock as required for PV plant fire interventions.

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.

Scenario 3 is sometimes simpler to manage by the fire brigade because it can be treated as a fire that originated through 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 Figure 8 where a set of combiner boxes continues to burn despite fighting operations).

Figure 8 – Example of combiner boxes burning despite fire 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 in Scenarios 1, 2 and 3 (see page 17).

- 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 in Scenarios 1 and 3 [20].

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 the 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. As such, apart from standard protective gear, no other additional procedures or protective gear is deemed necessary.

3.7 Marking and warning signs

All PV Systems shall be marked. Marking is required in order to provide, for example emergency response teams, 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:

- Labelling for normal operations and
- Labelling 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 is intended to mitigate the fire safety issues.

Signs are crucial elements of safety and health management strategies. Safety signs usually contain four components: signal words, hazard statement, noncompliance statement and some instructions. Moreover, color of warning labels should attract the attention of viewers. Different signal colors characterize different ranks of risk. Usually, red characterizes the highest rank of hazard, followed by other colors. 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 color' associated with that type of safety message and a special graphic shape. The 5 types of safety signs described by BS 5499 part 1 (Specification for geometric shapes, colors and layout) are:

- **Prohibition**: signs which have a main safety color of red, with a contrast color of white and a crossed through circle in red with a graphical symbol color of black.
- **Mandatory**: action signs have a main safety color of blue, with a contrast color of white and a circle in blue with a graphical symbol color of white.
- **Hazard**: (warning) signs have a main safety color of yellow, with a contrast color of black and a yellow equilateral triangle with smooth corners and black border with a graphical symbol color of black.
- **Safe Condition**: escape route and safety equipment signs have a main safety color of green, with a contrast color of white and a green rectangle or square with a graphical symbol color of white.
- **Fire Equipment**: signs have a main safety color of red, with a contrast color of white and a red rectangle or square with a graphical symbol color 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 UAE reference legislation and with the internal labelling procedures and applicable DEWA Standards.

UAE warning signs have to be in line with British Standard BS 5499 Graphical Symbol and Signs – Safety Signs, including fire safety signs. They must specifically comply with Part 1: Specification for geometric shapes, colors and layout [21], and Part 5: Signs with specific Safety meaning [22].

Furthermore DEWA requirements for branding and H&S specifications need to be followed such as:

A. DEWA & Dubai Govt. logo to be on top of each sign;

B. Text to be both in Arabic and English.

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 current 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 9 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 and system information shall be provided at the point after 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 labeled as 'PV system – main AC isolator'.

Dual supply labelling: according to [23], dual supply labelling 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 that it has two different circuits (bipolar): AC and DC. Warning signs shall thus read: "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 of 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, made available at the site 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'.

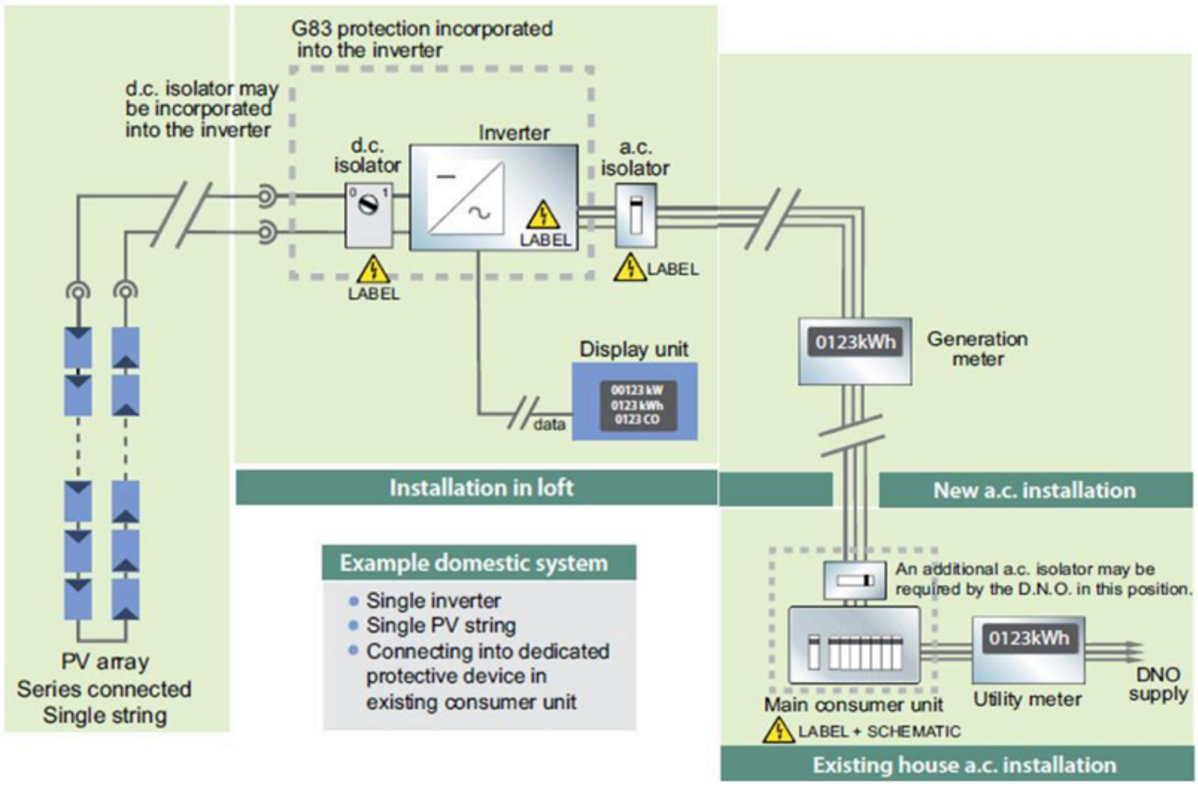


Figure 9 – Example of circuit diagram and system information to be exposed in the building [23]

To ensure the emergency response teams 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 D.C circuits both on all interior and exterior D.C 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 extinguish 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 D.C combiner and junction boxes.

The characteristics of the sign should inform that 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 a galvanized rigid steel conduit or electrical metallic tubing. A sign should be mounted on or next to the PV system disconnecting means, stating: "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 standards differentiate the warning by adding the sentence "PHOTOVOLTAIC SYSTEM VOLTAGE DURING DAYLIGHT HOURS", although this could be misleading as long as voltage can occur when a PV panel is illuminated by bright light (in principle even in the presence of full moonlight).

Adding information regarding the voltage maximum detectable (volts) as well the operating current (amps) is recommended.

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 along the 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, such as those specified in Figure 9. They shall also be placed in correspondence to 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 and 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 the relevant Standards and Regulations. During the installation phase and during working on the rooftop, reference needs to be made to the Dubai Municipality Code of Construction [4]. It is required that Markings be in Arabic & English or use appropriate local warning symbols, in order ensure signs are understandable to workers of different nationalities.

The applicant must be compliant with the relevant national legislation for warning signs. For fire hazards, applicants are to refer to the UAE Fire and Safety Code [3]. For work place signs during installation one should refer to the Dubai Code of Construction [4]. In addition the Applicant must comply with the internationally accepted procedures and standards for signs (color, dimension, physical characteristics, etc.).

ANNEX B contains a selection of warning signs that can be used at different locations in and around the PV plant.

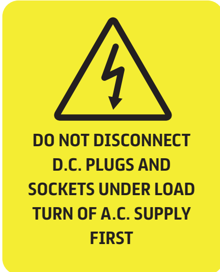
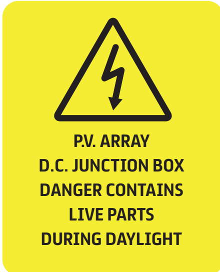
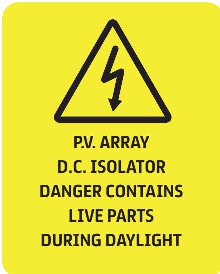
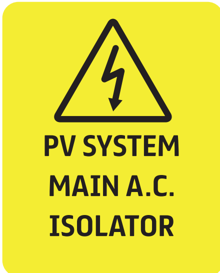
Requirements for the above said signs are specified in section 2.6.7 "System labelling and warning signs" of the "Standards for Distributed Renewable Resources Generators Connected to the Distribution Network" [1]. Particularly, section 2.6.7.2 "Identification of a PV installation" provides an example of a switchboard sign for identification of multiple supplies (according to BS 7671:2008 [24]), 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 signs 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 "Guide to the Installation of Photovoltaic Systems" [23], provides examples of warning signs for disconnectors, both DC and AC., that are shown in the following Table 1, along with the (suggested) Arabic translation.

Table 1 – Examples of warning signs for disconnectors [23]

Suggested placement in the PV plant	Warning messages	Warning signs	Arabic
Any accessible D.C. connectors	Do not disconnect D.C. plugs and sockets under load - turn off A.C. supply first.		
D.C. junction box, if any	PV Array D.C. Junction Box. Danger - contains live parts during daylight.		
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)	PV Array D.C. isolator. Danger contains live parts during daylight.		
Inverter	Inverter - Isolate A.C. and D.C. before carrying out work.		
Main A.C. switch-disconnector.	PV system - main A.C. isolator.		

LOTO (Lock-out tag-out) procedures shall be put in place by the installer, and described in the Operation and Maintenance Manual for delivery to the customer. The 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” [25].

4 CONSTRUCTION AND CONNECTION

Foremost, a PV plant shall be installed according to the rules and standards applicable to the specific site of construction: on a roof, flat or not, or on the ground. The main references are the Dubai Municipality's "Code of Construction Safety Practice" [4] and "UAE Fire and Safety Code of Practice" issued by Civil Defence [3]. Installers shall also consider any recommendations or DEWA requirements when applying for the PV plant connection.

Installers shall also consider the safety issues and the recommendations defined in Section 2 and Section 3 of this document, which provide information on conventional hazards, as well as those hazards that are much more specific to PV plants.

In order to be prepared for all potential hazards and to effectively safeguard the safety of the personnel involved in commissioning a PV plant, a thorough HSE Risk Assessment needs to be carried out in line with all applicable procedures. This Assessment will identify all potential hazards, stipulate any specific safety protection measures that need to be adopted and outline any specific training activities that should be carried out in order to ensure a safe PV plant installation process.

All workers involved in the PV plant installation under the responsibility of the Applicant shall attend H&S Induction Training prior to gaining access to the site, and receive "Toolbox talk" regularly and particularly prior to beginning any activity on the site. This will ensure all personnel is adequately informed of the hazards connected to the activity, and operating procedures recommended for safe performance of such activity. Personnel shall be suitably trained to carry out necessary activities and have the required knowledge and experience. This is particularly important with reference to the fact that such grid-connected Solar PV installations are a new skill and service in the local market.

Recommendations

A training program shall be made developed and delivered by adequate training organizations to inform and educate relevant personnel regarding hazards and protection measures in PV plant installation, which shall cover the broader range of involved topics (e.g. design, installation, testing and commissioning, operation and maintenance).

Although DEWA has developed the Solar PV Certification process, through which personnel is trained in all aspects related to Solar PV installations, including safety measures, the Applicant / Contractor must ensure all relevant staff are well informed and trained with respect to the health and safety risks and measures for any specific project.

5 SAFETY DURING O&M

PV plants operation and maintenance relates to the following: monitoring and/or assessment of electricity production and maintenance for optimum system performance.

PV plants are typically stand-alone and therefore unattended during operation. The maintenance of PV plants is a mix of periodic inspection activities and performance checks of both single parts and more complex components of the PV plant.

Depending on the overall power and electrical design of the PV plant, some parts of the power circuits may be operating at MV, namely downstream of an MV/LV transformer. Therefore proper maintenance has to be provided for such equipment in accordance with the design, the applicable 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 desalted 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 apply to maintenance activities on the electrical parts of the PV plant. Specifically during array connection during installation and replacement of PV panels there are potential electrocution hazards. In addition, during inspection of the site there are risks of falls from the roof or accidents due to material falling while being transported, tripping over or other causes.

Additionally, hazards can arise from the activities conducted within the building where the installation is taking place, (e.g. certain industrial buildings). And finally, risks can be observed during maintenance and cleaning operations in regards to the cleaning techniques employed and cleaning tools used.

Workers involved in O&M should act in accordance with 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 in those operations for which there is no identified risk.

Recommendations

O&M personnel designated to operate the Solar PV plant (with the exception of workers providing cleaning services, including cleaning of PV modules) shall possess the same minimum qualifications required of the Contractor's personnel. For qualification requirements see page 6.
All workers, including those carrying out the O&M shall receive the required risk prevention and safety information. All will be required to undergo the "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.

It is important to ensure adequate cooperation, clear and timely communication and exchange of information among the different stakeholders involved in O&M activities (for example building owner, site manager, 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. It is also crucial to ensure adequate communication of information to workers who may not have a good command of the working language (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.

6 INFORMATION FOR DEWA PERSONNEL AND FOR INSPECTORS

DEWA workers operate with reference to two levels of safety procedures: Corporate level and Department level.

At corporate level, safety issues are embedded in the procedures:

A. General Safety

B. Electrical Safe Working

C. PPE Issuance, Replacement and Maintenance

D. Permit to work

E. Identification of HS hazard, environmental aspects and impacts and HSE Risk Assessment

At department level, in compliance with corporate level procedures, there are safe working procedure(s) guidelines, specific to the job or task performed.

DEWA personnel involved in the preparation and the actual connection of PV plants to the electrical network will thus follow their department level safety procedures.

DEWA personnel may also be involved as inspectors in the PV plant testing stages. Information about the safety issues involved when operating and inspecting a PV plant shall be delivered to DEWA personnel by the Applicant. DEWA inspectors visiting a PV plant, even if not involved with any practical operation, will have to act in accordance with the appropriate safety guidelines and will be required to wear the adequate PPE.

All tests required for the PV plant verification shall be performed by the PV plant Applicant (particularly the technical staff designated for this purpose). For instance, one such test can be a verification of the suitability of connections among the wires of PV panels. Test and check on the quality of the wiring, other than manually, may be performed for example by using a thermal imaging camera.

Electrical hazards may occur during the connection or during the inspection of the PV plant or any inverter or switchboard in the connection cabin. DEWA personnel visiting the PV plant site will assist with such testing activity and they may be potentially exposed to the hazards even though they will not be involved in any operational activity. As such, DEWA employees present on site will have to act in accordance with the appropriate safety guidelines and will be required to wear the adequate PPE.

Information regarding all hazards present on site should be made available to DEWA in advance, so that DEWA personnel can be adequately prepared for inspecting and finally connecting the PV plant. The Applicant (particularly the technical staff such as Contractor or Consultant delegated for this purpose by the owner of the PV plant) shall prepare a document stipulating all hazards and safety measures to be adopted according to HSE Risk Assessment.

If DEWA staff is to be exposed to the same risks as other stakeholder staff, then they will be required to follow the same precautions and safety regulations as other personnel present on site, regardless of whether they are inspecting or carrying out interventions on site.

Recommendations

DEWA Department level procedures will be followed according to the hazards involved in the operations envisaged during the connection of the plant to the electric network.

The Applicant shall provide all information on hazards related to the PV plants so as to allow DEWA to analyze and evaluate such hazards and take the appropriate measures according to internal DEWA procedures.

The site may also be visited by the representatives of the Dubai Municipality or Civil Defence or any other authority concerned with occupational and safety matters in Dubai (e.g. Ministry of Labour).

In principle, the safety prevention measures described for DEWA personnel shall be applied for any inspector visiting the site.

The Applicant shall provide all information on hazards related to the PV plants so as to allow an inspector from any relevant organization or institution to analyze and evaluate such hazards and additionally take appropriate measures also according to own procedures.

ANNEX A - SUMMARY OF THE RECOMMENDATIONS

ANNEX A.1 – INSTALLATION

Item	Verification required	Recommended practice	Stakeholder	Notes
Conventional Hazards (Hazards common to electrical and construction works. Prevention of falls while working on rooftops)	According to DEWA procedures - when processing Connection Applications	Follow current safety guidelines ensuring safety of personnel performing electrical equipment installation particularly on rooftops or visiting or inspecting the installation site. Particularly: • Act in compliance to DM and Civil Defence rules, codes and "Legal requirements". • Perform HSE Risk Assessment • Deliver H&S induction training before allowing personnel (workers, inspectors, etc.) to gain access to the site • Ensure personnel attend "Tool Box Talk" • Ensure personnel have the required technical education, knowledge, working experience, and are suitably trained to do the required electrical activities also on live parts • Consider particularly safety issues relating to 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.	A. Applicant (or Installer) B. Dubai Municipality and/or any concerned authority (e.g. Ministry of Labour)	
3.1 Arc Flashes and Burns	To be checked by DEWA at design approval stage	The design should meet all requirements as to avoid faults during operation. During installation, check the integrity of wires and electric components, and follow the suitable installation procedures taking into account that many tasks must be performed on live parts.	A. DEWA B. Applicant (or Installer)	

ANNEX A.1 – INSTALLATION

Item	Verification required	Recommended practice	Stakeholder	Notes
3.2 Testing for Voltage		Installer and Contractor personnel shall use PPE with appropriate characteristics required to ensure safe interventions on electric parts of a PV plant. Workers shall have the required skills to operate on live parts and use equipment for testing voltage/current in the field.	A. Applicant (or Installer)	
3.4 Insulated tools		Installer and Contractor personnel shall use PPE with appropriate characteristics required to ensure safe interventions on electric parts of a PV plant. Workers shall be trained for using the needed PPE.	A. Applicant (or Installer)	
3.7 Marking and warning signs	To be checked by DEWA at design approval stage	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. DEWA requirements for branding and H&S specifications need to be followed. Examples of warning signs are specified in Annex B.	A. Applicant (or Installer) B.Dubai Municipality and/or any concerned authority (e.g. Ministry of Labour)	

ANNEX A.2 – MAINTENANCE MANAGEMENT

Item	Verification	Recommended practice	Stakeholder	Notes
5 Safety during O&M (Prevention of falls while working on rooftops)		In addition to recommendations in Annex A.1: The O&M supplier (and the Installer) shall prepare guidelines for workers during cleaning of panels. Cleaning carries more potential hazards since the panel surface is more slippery and panels are often slanted and not 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.	A. O&M supplier (and the Installer)	
5 Safety during O&M (Cleaning operations)		The O&M supplier (and the Installer) shall prepare guidelines for the correct use of cleaning tools for O&M workers; Apart from ensuring workers' safety, this will prevent any damage to the PV panels, wiring, connectors and panel fixing systems. Workers performing cleaning activities shall be aware of potential electric risks in case PV panels are damaged.	A. O&M supplier (and the Installer)	
5 Safety during O&M (O&M management)		The O&M supplier (and the Installer) shall prepare guidelines for correct maintenance procedures, including replacement of electrical parts and/or PV components. In case of a need of disconnection of the PV Plant, the guidelines for disconnection and safety operation during specific electrical checks shall be fulfilled. Whenever required disconnection may be performed in cooperation with DEWA.	A. O&M supplier (and Installer) B. DEWA	

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

Item	Verification	Recommended practice	Stakeholder	Notes
6.1 Information for DEWA personnel (Inspection related to testing at mechanical completion, and at grid connection stage)	To be checked by DEWA when receiving request for PV plant inspection	The Applicant (or the Installer) shall provide a document describing the list of potential hazards on the site where the PV plant is being installed. DEWA will process this information according to its safety procedures.	A. Applicant (or Installer) B. DEWA	
(Inspection visits not related to testing)		The Applicant (or the Installer) shall provide a document describing the list of potential hazards on the site where the PV plant is located. The concerned organization (e.g. DM, Civil Defence, and Ministry of Labour) will process the said information according to its safety procedures.	A. Applicant (or Installer) B. Dubai Municipality, Civil Defence and/ or any concerned authority (e.g. Ministry of Labour)	

ANNEX A.4 – INFORMATION FOR FIRE FIGHTERS

Item	Verification	Recommended practice	Stakeholder	Notes
3.6 Hazards in case of fire		Fire Fighters have to have appropriate knowledge PV plant technology and use the most suited procedures when operating on a site with of a PV plant. A damaged PV panel can still produce current and can cause hazardous conditions ranging from perception to electrocution. Fire Fighters 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. • Take into account the voltage and the current that are present in a PV plant. • Know the hazards related to specific actions, (e.g. due to the voltage and current present don't cut 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 could be to cover the array with tarps. 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. • 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. .	A. Fire-Fighters B. Civil Defense	

ANNEX A.4 – INFORMATION FOR FIRE FIGHTERS

Item	Verification	Recommended practice	Stakeholder	Notes
3.6 Hazards in case of fire		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 - not only during 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.	A. Fire-Fighters B. Civil Defense	
3.6.1 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.	A. Fire-Fighters B. Civil Defense	

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 of danger of electrical hazards

Figure 12 - Warning sign more specific in regard to electrical live parts presence

Figure 13 - Warning sign with a list of emergency contact numbers

Figure 14 – Example of simplified layout indicating the compulsory use of insulated tools

Figure 15 – Signs to be used to indicate the presence of a PV plant

Figure 16 - Example of sign required on PV array combiner boxes (On-Site Guide BS 7671:2008 (2011)

Figure 17 - Example of switchboard sign for identification of multiple supplies (On-Site Guide BS 7671:2008 (2011)

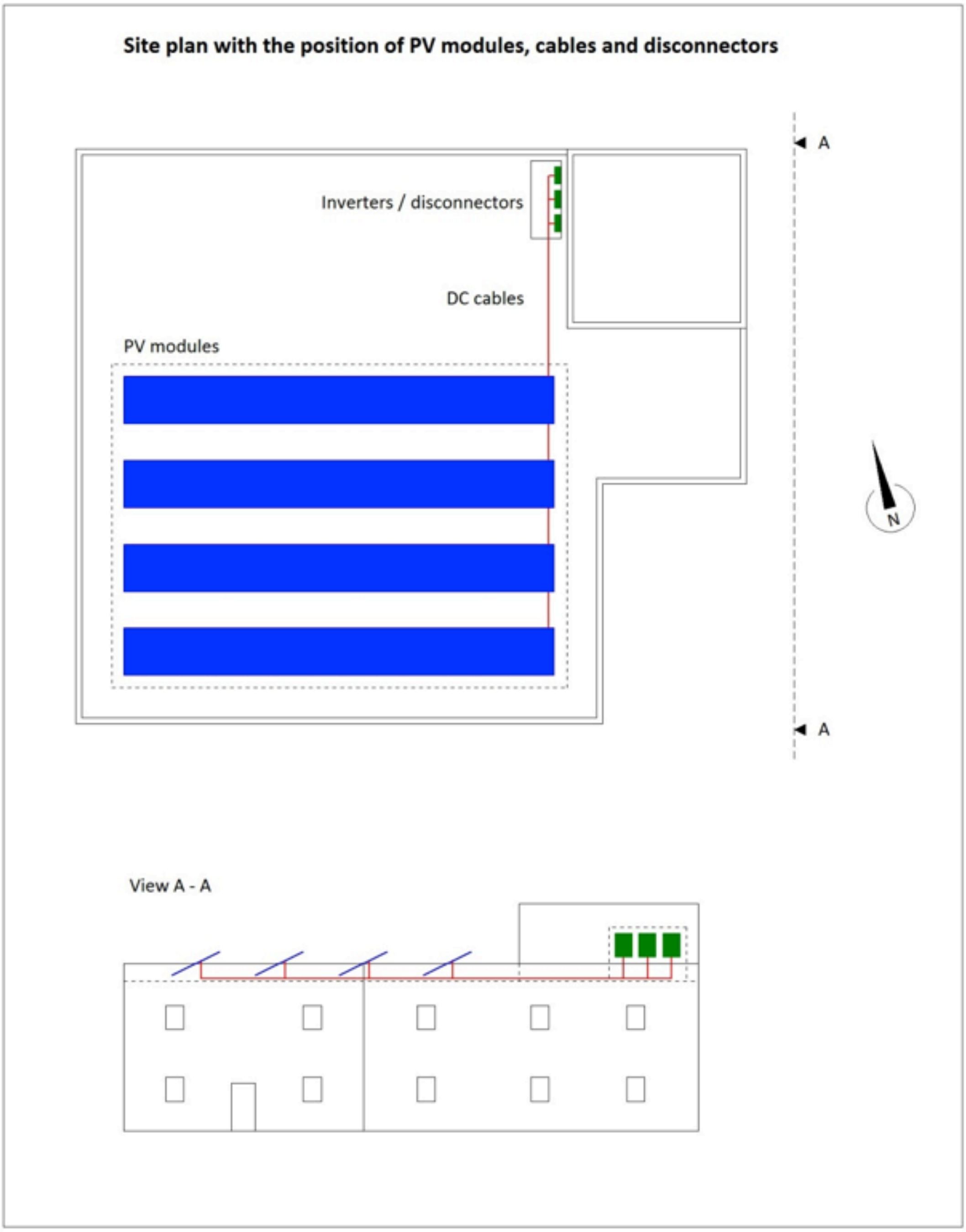


Figure 18 – Example of simplified layout indicating main part of the PV plant to be exposed in the