Qatar General Electricity & Water Corporation

PW-PWR/G2

Safety related to the installation of Solar PV Systems

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1 Purpose

The objective of these guidelines is to provide recommendations on how to ensure the safety of the installation, of workers, owners, and more generally of anyone who may find himself in the PV System installation site.

2 Scope

This document describes the hazards that materialise when a PV System is being implemented and provide recommendations on how to ensure the safety.

This document also addresses the main sources of hazard-specific for Solar PV Systems. Most topics are mainly focused on PV placed on buildings because, in this case, we have the presence of specific and important risk factors such as height and fire hazards. Solar PV Systems shall be designed, erected, commissioned, and maintained according to Qatari laws and standards applicable. Consultants and contractors involved in these activities shall be properly certified.

Furthermore, additional prescriptions shall be applied to solar PV Systems on buildings because the solar systems shall never become an additional source of hazard for the building itself and its occupants. Therefore, the prescriptions included in this document do not substitute or replace any other prescription for solar PV Systems or traditional systems unless this latter is only a subset of the firsts.

However, these prescriptions may also be adopted in PV Systems realised in places different from buildings, such as ground-mounted PV Systems, to obtain higher safety levels or meet specific requirements.

Fire Safety

Regarding the Fire Safety, the document contains special considerations and prescriptions against fire hazards when PV Systems are mounted on buildings. Fire hazard prevention is considered under the following points of view:

- PV Systems and their components shall not be a source of the fire.
- Should a fire originate from a PV System, it shall not propagate into the rest of the building.
- The PV System shall not interfere with the fire safety system of the building and with the firefighters, whatever the origin of the fire.

Different types of buildings are considered as regards the fire hazard, with different types of PV Systems, which are divided into externally mounted (BAPV) and building-integrated (BIPV).

In this section, the prescriptions adopted in countries with a high PV penetration have been considered. Particularly useful were the following: VDE-AR-E 2100-712 (Germany), Guida CEI 82-25 (Italy), UL 1699B (US).

Further, then the prescriptions listed in this document, depending on the results of the risk assessment, technical, installation, and maintenance measures can be selected to reach the intended safety level of the PV System and building. Since installation faults can increase the generally low risk of fire in a PV System, this document is recommended for each building-related PV System. It may be used when needed by the building owner, PV System owner, insurance company, financial institution, or another party.

To demonstrate that the Consultants/Contractors have designed and installed the PV System as per updated best practice and international standards, we require that specific tests are passed as specified in the Section “7.5 Labelling and Fire Protection” of the companion document “*CS-G2 Inspection and Testing Guidelines for Solar PV Systems Connected to LV and MV Network*”, particularly the paragraph “7.5.2 Fire Protection Verification”.

3 Abbreviations, Definitions of Terms & Key References

Abbreviations

AC	:	Alternating Current	AFCI	:	Arc Fault Circuit Interrupter
ASTM	:	American Society for Testing and Materials	BAPV	:	Building-Attached Photovoltaic Modules
BIPV	:	Building-Integrated Photovoltaic modules	$cos\ \varphi$	:	Power factor
DC	:	Direct Current	GHI	:	Global horizontal irradiance
IEC	:	International Electrotechnical Commission	IP	:	Interface Protection
IR	:	Infrared	ISO	:	International Organization for Standardisation
ITP	:	Inspection and Test Plan	LOM	:	Loss of Mains
LV	:	Low Voltage (namely 220/127 V or 380/220 V or 400/230 V)	LVRT	:	Low Voltage Ride Through
MV	:	Medium Voltage (namely 13.8kV or 33 kV)	MS	:	Method Statement
NEC	:	National Electrical Code	NFPA	:	National Fire Protection Association
P	:	Active power	P_{ELV}	:	Protected Extra Low Voltage
P_{nom}	:	Nominal active power of the equipment	POA	:	Plane of Array
PPE	:	Personal protective equipment	PR	:	Performance Ratio
PV	:	(Solar) Photovoltaic	Q	:	Reactive Power
RCD	:	Residual Current Device	ROCOF	:	Rate of Change of Frequency expressed in Hz/s.
S/S_n	:	Apparent Power	SELV	:	Safety extra-low voltage
SPD	:	Surge Protection Device	SR	:	Soiling Ratio
STC	:	Standard Test Condition	UL	:	Underwriters Laboratories
UV	:	Ultraviolet	V_{nom}	:	Nominal Voltage
WMO	:	World Meteorological Organization	CS	:	Customer Services Dept

Term	Description
AC Module	PV module with an integrated inverter in which the electrical terminals are AC only
Active Power	Active Power is the real component of the apparent power, expressed in watts or multiples thereof, e.g., kilowatts (kW) or megawatts (MW). In the text, this will be generically referred as *P* or P_{nom} in case of the nominal active power of equipment
Apparent Power	The product of voltage and current at the fundamental frequency, and the square root of three in the case of three-phase systems, usually expressed

<table>
<tr><th>Term</th><th>Description</th></tr>
<tr><td></td><td>in kilovolt-amperes (kVA) or megavolt-amperes (MVA). It consists of a real component (Active Power) and the reactive component (Reactive Power). This will be generically referred to S or S_n in case of the rated apparent power of equipment</td></tr>
<tr><td>Apparent power of an Inverter</td><td>The rated apparent power of an Inverter is the product of the rms voltage and current and is expressed in kVA or MVA.</td></tr>
<tr><td>Auxiliary Supply Power</td><td>Electricity supply for supporting auxiliary systems and services such as Interface Protection or circuit breaker and contactor opening coils.</td></tr>
<tr><td>Building-Attached Photovoltaic Modules (BAPV modules)</td><td>Photovoltaic modules are considered to be building-attached if the PV modules are mounted on a building envelope. The integrity of the building functionality is independent of the existence of a building-attached photovoltaic module.</td></tr>
<tr><td>Building Attached Photovoltaic system (BAPV System)</td><td>Photovoltaic systems are considered to be building attached if the PV modules they utilise do not fulfil the criteria for BIPV modules.</td></tr>
<tr><td>Building-Integrated Photovoltaic modules (BIPV modules)</td><td>Photovoltaic modules are considered to be building-integrated if the PV modules form a construction product 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 construction product), the PV module would have to be replaced by an appropriate construction product.

The building’s functions in the context of BIPV are one or more of the following:
mechanical rigidity or structural integrity
primary weather impact protection: rain, snow, wind, hail
energy economy, such as shading, daylighting, thermal insulation
fire protection
noise protection
separation between indoor and outdoor environments
security, shelter or safety
Inherent electro-technical properties of PV, such as antenna function, power generation and electromagnetic shielding etc., alone do not qualify PV modules to be building-integrated.</td></tr>
<tr><td>Building-Integrated Photovoltaic system (BIPV System)</td><td>Photovoltaic systems are considered to be building-integrated if the used PV modules fulfil the criteria for BIPV modules.</td></tr>
<tr><td>Circuit Breaker (CB)</td><td>As per the Kahramaa Electricity and Wiring Code definition</td></tr>
<tr><td>Connection Point</td><td>Also referred to as Point of Connection, is the interface point at which a PV System of the Consumer is connected.</td></tr>
<tr><td>Consultant</td><td>A qualified consultant for the design of grid-connected solar PV Systems.</td></tr>
<tr><td>Consumer</td><td>Any Person supplied with electricity services for his own consumption. In this context, this term will also be used to refer to a User owning a solar PV System.</td></tr>
<tr><td>Contractor</td><td>A certified contractor for the installation of grid-connected solar PV Systems.</td></tr>
<tr><td>Delay time (of a protection relay)</td><td>Indicates the minimum duration of a fault detected by the protection relay before the output of the protection relay is triggered.</td></tr>
</table>

Term	Description
Delivery Point	The interface point at which electrical energy is delivered by Kahramaa to a Demand Facility or Generating Unit or by a Demand Facility or Generating Unit to Kahramaa.
Distribution System / Distribution Network	Qatar electrical infrastructure (lines, cables, substations, etc.) at 33 kV and below, operated by Kahramaa. The Distribution network can be either a Medium or Low Voltage system for the scope of the present document and in accordance with international standards: • A Low Voltage (LV) Distribution System is a network with a nominal voltage lower than 1 kV AC or 1.5 kV DC. The LV network in the State of Qatar is 240/415 V ± 6%, 3 Phase, 4 Wire. • A Medium Voltage (MV) Distribution System is a network with nominal voltage included in the range from 1 kV AC up to 33 kV. The MV Distribution System nominal voltages in Qatar are 11, 22 and 33 kV. • Electrical network voltages equal to or higher than 33 kV are not considered in this document. According to the Transmission Grid Code, the 33 kV is considered a sub-transmission network. To avoid doubt, the term Distribution Network will be preferred in this document in place of Distribution System.
Electricity Transmission Network (ETN)	Qatar electrical infrastructure (lines, cables, substations, etc.) from above 33 kV up to 400 kV operated by Kahramaa.
Global horizontal irradiance (GHI)	Direct and diffuse irradiance incident on a horizontal surface expressed in W/m^2.
In-plane irradiance (Gi or POA)	The sum of direct, diffuse, and ground-reflected irradiance incidents upon an inclined surface parallel to the plane of the modules in the PV array, also known as plane-of-array (POA) irradiance. It is expressed in W/m^2
$I_{MOD\_MAX\_OCPR}$	PV module maximum overcurrent protection rating determined by IEC 61730-2 (Note: This is often specified by module manufacturers as the maximum series fuse rating).
Inspection	Examination of an electrical installation in order to ascertain correct selection, design and proper erection of electrical equipment.
Interface protection (IP)	Electrical protection part of the solar PV System that ensures the PV System is disconnected from the network in case of an event that compromises the integrity of Kahramaa's distribution network.
Inverter	Electric energy converter that changes direct electric current to single-phase or polyphase alternating current.
Irradiance (G)	Incident flux of radiant power per unit area expressed in W/m^2.
Irradiation (H)	Irradiance integrated over a given time interval and measured in energy units (e.g., kWh/m^2/day).
Islanding	Situation where a portion of the distribution network containing generating plants becomes physically disconnected from the rest of the distribution network. One or more generating plants maintain electricity supply to such isolated parts of the distribution network.
Load Flow	It is a numerical analysis of the electric power flow in a transmission and/or distribution systems. A power-flow study usually uses simplified notations such as a one-line diagram and per-unit system, and focuses on various parameters, such as voltages, voltage angles, real power and reactive power. It analyses the power systems in normal steady-state operation.

Term	Description
Loss Of Mains (LOM)	Represents an operating condition in which a distribution network, or part of it, is separated from the main power system (on purpose or in case of a fault) with the final aim of de-energisation. The protection that detects this condition is known as anti-islanding protection.
Main Meter	It is the bidirectional smart meter installed at the Connection Point which measures the amount of electric energy actually exchanged (import or export) by the Consumer with the distribution network.
Maximum Available Active Power Output	This is the Active Power Output based on the primary resource (for example, sun irradiance) and the maximum steady-state efficiency of the Solar PV System for this operating point.
Maximum Capacity (P_{max})	It is the maximum continuous active power which a Generating Unit can produce, less any auxiliary consumption associated used to facilitate the operation of that Generating Unit. The Maximum Capacity shall not be fed into the distribution network as specified in the *Connection Agreement*. In this document, this term is also referred to as Maximum Connected Capacity.
Micro-inverter	Small inverter designed to be connected directly to one or two PV modules (Note: A micro inverter will normally connect directly to the factory fitted module leads and be fixed to the module frame or mounted immediately adjacent the module).
Module Integrated Electronics	Any electronic device fitted to a PV module that provides control, monitoring or power conversion functions (Note: Module integrated electronics may be factory fitted or assembled on-site).
National Control Centre (NCC)	Main Kahramaa's facility used to operate and control/maintain the Electric Power System.
Peak Power (Wp)	The output power achieved by a Photovoltaic Module under Standard Test Conditions (STC). It is measured in W_p (W peak). The sum of the peak power of the photovoltaic modules of either a string or an array determines the peak power of the string and the array, respectively (usually measured in kW_p). The peak power of a photovoltaic array at STC is conventionally assumed as the rated power of the array.
Photovoltaic (PV) cell	The most elementary device that exhibits the photovoltaic effect, i.e., the direct non-thermal conversion of radiant energy into electrical energy.
Power Factor	It is the ratio of Active Power to Apparent Power.
Power Park Module (PPM)	A unit or ensemble of units generating electricity, which is either non-synchronously connected to the network or connected through power electronics, and that also has a single Connection Point to the ETN.
PV Array	Assembly of electrically interconnected PV modules, PV strings or PV sub-arrays. For the purposes of this document, a PV Array comprises all components up to the DC input terminals of the Inverter.
PV Module	PV modules are electrically connected PV cells packaged to protect them from the environment and protect the users from electrical shock.
PV String	A set of series-connected PV modules.
PV String Combiner Box	A box where PV strings are connected, which may also include circuit breaker, monitoring equipment, and electrical protection devices.
Rated Active Power	Represents the sum of the nominal active power of all the Solar PV Units which compose the Solar PV System; it is generally referred to as *Pnom* of the Solar PV System.

Term	Description
Reactive Power	Represents a component of the apparent power at the fundamental frequency, usually expressed in kilovar (kVAr) or Megavar (MVAr).
Reactive Power Capability	Defines the reserves of inductive/capacitive reactive power which can be provided by a generating system/unit. The reactive power capability usually varies with the active power and the voltage of the generating system/unit.
Residual Current Device (RCD)	A sensitive switch that disconnects a circuit when the residual current exceeds the operating value of the circuit, referred as RCD in this document.
Soiling ratio (SR)	A ratio of the actual power output of the PV array under given soiling conditions to the power that would be expected if the PV array were clean and free of soiling.
Solar PV System	This term also has the same meaning as Power Plant or User's System or Grid User, defined in the Transmission Grid Code. It is a solar PV installation of not more than 25 MW and not less than 1 kW capacity installed in one Premise and connected in parallel to Kahramaa's Distribution Network. This document aims to be considered a power plant with one or more Solar PV Units. Besides, circuits and auxiliary services are also part of a solar PV System. To avoid doubt, in this document, the generic term Solar PV System is considered equivalent to solar PV System. This PV System includes the PV array, controllers, inverters, batteries (if used), wiring, junction boxes, circuit breakers, and electrical safety equipment.
Solar PV System Meter	It is the smart metering installed at the output point of the solar PV System and measures the total energy produced from the Solar PV Units.
Solar PV Unit	A group of devices that collects the sun's irradiance in a Solar PV System, together with all plant and apparatus and any step-up transformer which relates exclusively to the operation of that part of the same Solar PV System. Only units that are Inverter based (i.e., Asynchronously connected to the Distribution Network through power electronics devices) are considered in this document. This definition will be equivalent to that of the Power Park Module as given in the Transmission Code. For the avoidance of doubt, in this document, the generic term Solar PV Unit will be considered equivalent to a solar PV Unit.
Standard test conditions (STC)	Reference values of in-plane irradiance (1 000 W/m2), PV cell junction temperature (25 °C), and the reference spectral irradiance defined in IEC 60904-3.
Switch	As per the Kahramaa Electricity and Wiring Code definition.
Testing	Implementing measures in an electrical installation to prove its effectiveness (Note: It includes ascertaining values using appropriate measuring instruments, said values not being detectable by inspection).
Time Current Curve (TCC)	The time current curve plots the interrupting time of an overcurrent device based on a given current level. These curves are used for the protection coordination and are provided by the manufacturers of electrical overcurrent interrupting devices such as fuses and circuit breakers.
THD (Total Harmonic Distortion)	Concerning an alternating quantity, it represents the ratio of the r.m.s. value of the harmonic content to the r.m.s. value of the fundamental component or the reference fundamental component.

Key References

[1] IEC 60529 – Degrees of protection provided by enclosures (IP code)
[2] IEC 60479-1 – Effects of current on human beings and livestock. Part 1: General aspects
[3] IEC 60479-2 – Effects of current on human beings and livestock. Part 2: Special aspects
[4] IEC/TR 60479-5 – Effects of current on human beings and livestock. Part 5: Touch voltage threshold values for physiological aspects
[5] IEC 61140 – Protection against electric shocks. Common aspects for installations and equipment
[6] IEC 60364-7-712 – Low voltage electrical installations - Part 7-712: Requirements for special installations or locations - Solar photovoltaic (PV) power supply systems
[7] IEC 62548 – Photovoltaic (PV) arrays - Design requirements
[8] IEC 62446-1 – Photovoltaic (PV) systems - Requirements for testing, documentation and maintenance - Part 1: Grid connected systems - Documentation, commissioning tests and inspection
[9] European Agency for safety and health at work, "Hazard identification checklist: OSH risks associated with small-scale solar energy applications", E-Facts 69, 2012
[10] Good Company, "Health and Safety Concerns of Photovoltaic Solar Panels", Eugene, 2010
[11] HSE Management System, "Electricity at work: Safe working practices", 2013
[12] BS 7671:2018. Requirements for Electrical Installations - IET Wiring Regulations 18th 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] Health and Safety Executive (HSE) – Safe use of ladders and stepladders
[17] Oregon Solar Energy Industries Association – Solar Construction Safety
[18] J. P. Dunlop – Photovoltaic Systems, 2013
[19] Health and Safety Executive (HSE) – Health and safety in construction (2006)
[20] Health and Safety Executive (HSE) – Health and safety in roof work (2020)
[21] Health and Safety Executive (HSE) – Managing health and safety in construction (2015)
[22] Qatar Construction Specifications, Latest edition
[23] IEC 62305-1:2010 Protection against lightning - Part 1: General principles
[24] IEC 62305-2:2010 - Protection against lightning - Part 2: Risk management
[25] IEC 62305-3:2010 - Protection against lightning - Part 3: Physical damage to structures and life hazard
[26] IEC 62305-4:2010 - Protection against lightning - Part 4: Electrical and electronic systems within structures
[27] IEEE 80 – Guide for Safety in AC Substation Grounding.
[28] PQ-PQQ-P1/G1- Guideline on the Documentation of the KM Management System

Companion Documents

The documents listed hereinafter have to be considered a compendium of the current document. Therefore, they should be carefully read in addition to this.

a) EP-EPP-P7/S1 Technical Specifications for the Connection of PV Systems to the Network
b) EP-EPP-P7/G2 Guidelines for Information in Basic and Final Design, latest revision
c) CS-CSI-P3-G2 Inspection and Testing Guidelines for Solar PV Systems Connected to LV and MV Network, latest revision
d) EPM-G2 Guidelines for the Eligibility of Manufacturers' Equipment, latest revision

4 Hazards Identification

4.1 Specific Reference documents for this Chapter

The following documents shall be considered a specific reference for the current Chapter.

- Health and Safety Executive (HSE) – Health and safety in construction (2006)
- Health and Safety Executive (HSE) – Managing health and safety in construction (2015)

4.2 Overview

The present section analyses, from a general point of view (e.g., installer, inspector, maintenance operator), the main aspects of hazards to prevent them by using effective practices and measures. Consultants or Contactors, to become accredited and apply for the connection of a Solar PV plant, shall have a minimum number of Certified Solar PV Installers to assure that their personnel possess the knowledge required to design and construct a solar PV plant.

4.3 Risks Analysis

4.3.1 Identification and tools

According to international best practices, 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 operation and maintenance, should be submitted for Risk Assessment. In the case of a PV System, this shall mean:

- Identify foreseeable hazards, assess their risks, and take action to eliminate or control them at the site where the installation will occur. Analyse the photovoltaic installation activities to know and evaluate the risks of every task inside every activity
- Assess the condition of the roof and the types of roofing materials, 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 their specific tasks
- Install the collective protection equipment (CPE) applicable to the specific installation, always considering that CPE is always implemented before 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 PV modules to the rooftop by:
    - Following safe work procedures for installing solar modules (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 required to perform each task and that they are properly maintained
    - perform a pre-work risk assessment of the roof and roof cavity and implement control measures

- ensuring the specific tools as provided in the equipment installation manuals are available
- following all of the prescribed safety precautions as per the equipment installation manuals

4.3.2 Risk probability and impact assessment

The Risk Probability and Impact assessment is based on the principle that a risk has two primary dimensions:

- Probability – A risk is an event that may occur, and the probability of it occurring can range anywhere from zero to below 100 per cent. It should be noted that 100 per cent is not a probability but a certainty and, therefore, cannot represent a risk. Also, zero per cent does not represent a risk.
- Impact – A risk on construction sites always has a negative impact. However, the size of the impact varies in terms of cost and impact on health, human life, or some other critical factor.

The most popular calculation for risk is by using the equation below:

$$Risk = Probability \times Impact$$

This result is frequently represented on a Probability and Impact Matrix (PIM) that allows potential rating risks on two dimensions. As shown in Figure 1, the probability that a risk will occur is represented on one axis of the chart and the impact of the risk, if it occurs, on the other.

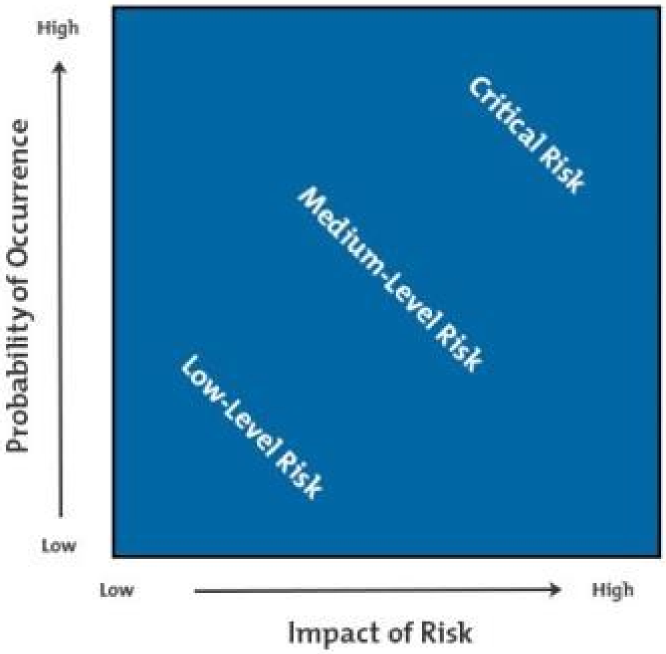


Figure 1 – Structure of a Probability and Impact Matrix

The Probability and Impact Matrix should be used carefully, especially when assessing high risky or catastrophic events, despite its popularity.

4.3.3 Personnel

When the installation is to be started, it shall be the responsibility of the Applicant to designate a person in charge of checking the correct execution of the prevention plans. The person in charge shall develop an emergency and evacuation plan. The risk assessment has to be done for all workers on the construction site. Workers and personnel of all the stakeholders: Applicant (Consultant or Contractor), EPC contractor, O&M supplier, and DSPs, workers ought to be aware of risks according to the said assessment.

All personnel working with different designations need to have technical qualifications, background, 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 starting an activity. He should be suitably trained to do the activities and have the knowledge & experience to perform activities on roofs and at high elevations.

Recommendations

Perform HSE risk assessment and use HS induction training and “Tool Box Talk” to prevent hazards in all kinds of operations required for installing PV System.

4.4 Proactive safety policies

Every employer has a legal obligation to maintain a safe and healthful workplace for employees. Taking risks is part of running a business, but some risks should never be taken or minimised as much as possible. One of these risks is the safety and health of the employees in the company. A proactive strategy means making sure accidents do not happen in the workplace. A proactive response to safety and health in the workplace must be implemented before an accident could occur.

The proactive improvement process is to first identify the hazard and anticipate the possible injury. The hazard is analysed, recommendations are proposed, and corrective actions and system improvements are implemented. The proactive improvement process predicts in order to prevent. Proactive strategies look forward. By emphasising accident prevention, a responsible sends a message of caring to all employees. The safety professional attempts to identify and analyse hazardous conditions and unsafe behaviours to predict future accidents. Proactive strategies are always less expensive than reactive strategies, and proactive programs are implemented to prevent future injuries and illnesses.

If considering some of the costs associated with accidents, it would become obvious that having a proactive safety policy in place is a smart investment and better for everyone involved. One lost workday injury might cost a company in terms of:

- Production down-time.
- Productive time lost by an injured employee.
- Productive time lost by employees and supervisors helping the accident victim.
- Cleanup and start-up of operations interrupted by an accident.
- Time to hire or train a worker to replace the injured worker until they return to work.
- Time and cost for repair or replacement of damaged equipment or materials.
- Cost of continuing all or part of the employee’s wages, plus compensation.
- Reduced morale among your employees and perhaps lower efficiency.
- Cost of completing paperwork generated by the accident.
- Fees and penalties.

4.5 General Jobsite safety

4.5.1 Evaluate and identify potential safety hazards and injuries

Evaluating and identifying potential safety hazards is a critical first step to eliminating risks and potential injuries. A good understanding of workplace hazards enables workers and technicians to prevent accidents and recover more quickly if an accident occurs. Each workplace presents its own unique set of occupational hazards.

Analysing your unique hazards:

- Leads to properly identifying safety training needs
- Helps identify the measures necessary to ensure the workplace is a safe one, such as the need for additional equipment and personal protective gear
- Helps determine how to eliminate or control hazards before they cause injuries

To take the first step in identifying hazards, it is important to learn the specifics of the work, along with when and where it takes place. Following are some examples of questions to consider when evaluating each job and job site:

- Are employees trained to perform the job with which they are tasked?
- Are safety policies and procedures in place and enforced?
- Have employees trained in-company (Contractor) safety policies and procedures?
- Who is the general Contractor or the subcontractor at the job site? What safety responsibilities are assigned to each?
- Is required personal protective equipment available and in good condition?
- What prep-work is required prior to the job?
- What are the general job site tasks and conditions?
- Are employees working from ladders or rooftops? Is fall protection required?
- What tools are being used to complete the job?
- Are severe conditions present, such as wet, windy, high temperature or cold weather?
- What post-job cleanup and work is required?

4.5.2 Evaluate the specific work situation

It is important to evaluate each specific situation to develop a list of the hazards and the potential injuries to occur. Understanding the hazards and potential injuries and the likelihood of an accident occurring enables to set up of a suitable safety policy for each specific situation. Using the collected information makes it possible to set up safety policies and procedures that reduce the risks associated with identified hazards. Typical construction work situations include:

- Using power tools.
- Working with scaffolds or ladders to access equipment and rooftops.
- Working in very hot conditions.
- Working with solar electric PV modules.

After evaluating the specific work situations, it would be necessary to identify the hazards and risks associated with those situations. Then select the appropriate action to address the hazard. The following example identifies hazards and the appropriate actions to address them by using the four points listed above. It is important to evaluate the specific conditions of the job site and identify actions to eliminate and control hazards in each case.

a) Using power tools

Working conditions include: using many different power tools and power cords on the job site.

Hazards include worn or frayed power cords and power lines (electric shock hazards), objects thrown from equipment such as saw blades (eye injury, laceration, puncture wound, and bleeding hazards), and sharp tools (laceration, puncture wound, and bleeding hazards).

Actions:

- Develop company personal protective equipment policy.
- Eliminate extension cord hazards by using battery-operated tools.
- Develop procedures for using power tools and extension cords.

b) Working with ladders to access equipment and rooftops:

Working conditions include: carrying and positioning ladders on walls and rooftops, climbing and working from step ladders and extension ladders.

Hazards include: lifting hazards from carrying ladders, fall hazards from accidents on ladders, and electrical hazards from contact with electrical power lines.

Actions:

- Develop proper lifting and carrying procedures for ladders.
- Develop proper ladder-use policies.

c) Working in very hot weather conditions

Working conditions include: working in summer on hot rooftops or in hot attic spaces.

Hazards include dehydration, the potential of passing out, heat exhaustion, heatstroke or death.

Actions:

- Reduce heat exhaustion risk hazards by working during cooler hours of the day.
- Develop hydration and safe practices while working in hot weather conditions.

d) Working with solar electric PV modules

Working conditions include: installing and performing maintenance on solar electric PV modules.

Hazards include: handling solar electric PV modules in the sun resulting in electric shock.

Actions:

- Develop policies and procedures for working with solar electric PV modules.

4.5.3 Understanding potential injuries from identified hazards

Understanding potential injuries from identified hazards provide workers and technicians with information to evaluate the risks they are taking, e.g., serious injuries, including death, result from job site accidents. Just a few of the potential injuries from job site hazards include:

- Death
- Severe/traumatic/massive head/brain/skull injuries
- Broken/fractured/shattered bones
- Spinal injuries
- Punctured lungs
- Internal organ injuries
- Electrocution
- Burns
- Heatstroke
- Severe cuts or lacerations
- Serious back or neck injures
- Puncture injuries from falling onto items
- Eye injuries
- Strains and sprains

Once the job site evaluation and work are completed, safety strategies to remove or reduce accident risks should be developed.

5 Electric Shocks

5.1 Specific Reference documents for this Chapter

The following documents shall be considered a specific reference for the current Chapter.

- Health and Safety Executive (HSE) – Health and safety in construction (2006)

5.2 Overview

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 considered here because they are specific to PV Systems and differ considerably from those related to AC applications.

Whether activities are in a household or an industrial facility, people who work with electrical live parts must be aware of the related hazards. They must adopt all safety measures aimed to minimise 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, it should always be considered that electric shocks, which are directly harmful, might cause further physiological effects related to the current flowing through the human body. These situations are inconvenient or hazardous (such as the results of a startle reaction) and may concern the threshold of perception or threshold of pain or heat sensation. For example, electricity can cause muscle contraction, leading 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).

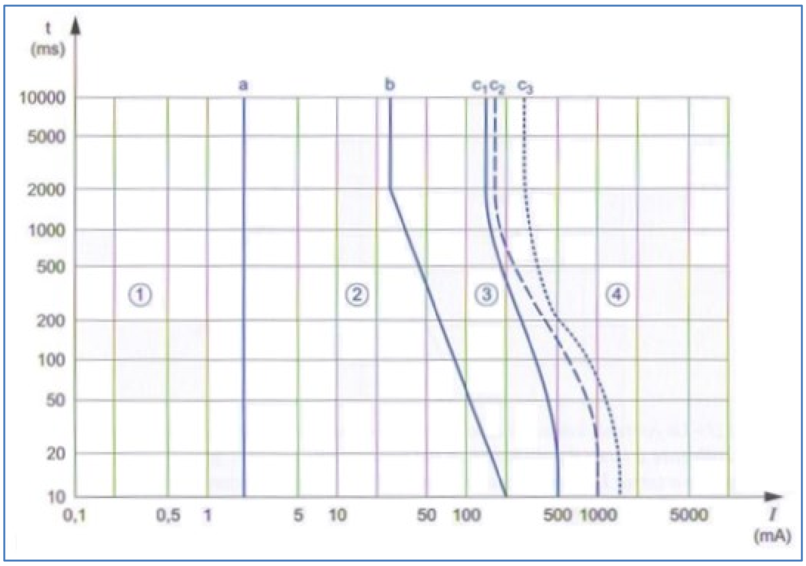


Figure 2 - Zones time/current of effects of ascending hand-to-feet DC current on the human body

Figure 2 it is shown 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. Further pathophysiological effects may occur in this zone, such as severe burns. Curves c_2 and c_3 correspond to a probability of 5% and 50%, respectively.

Figure 2 gives useful information on the effects of DC current on the 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 considering the path hand-to-hand as in Figure 3 (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 reported in Figure 2:

- Hand to hand – Thresholds for 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

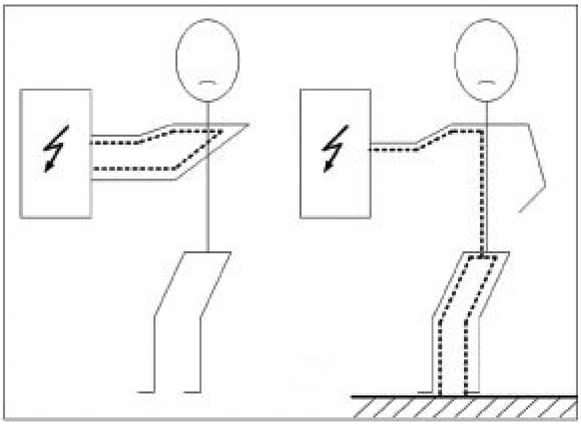


Figure 3 – Schematic representation of the hand-to-hand (left) and hand-to-feet (right) current path

In photovoltaic applications, hand-to-hand electric shocks may typically occur when the live parts of the terminals of 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 is sufficient that the worker touches a single live part to close the fault circuit. Positive pole-grounded PV Systems are more hazardous than 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 many influencing factors, such as environmental conditions and contact area. However, the basic protection by the limitation of voltage is fulfilled in the 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 live parts of 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 these criteria were applied to PV modules, it would be known that if they are illuminated, their voltage is close to the open-circuit voltage V_{oc}. 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 site work or during maintenance. First, 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. Possible hazards must be well understood, and every individual must be informed and trained to adopt all necessary precautionary steps.

When several risks are to be faced simultaneously, as in the example shown in Figure 4 (source IEEE), the action to be taken cannot be left to improvisation, and careful planning is therefore necessary. In Figure 4, the main relevant dangers are obvious (fall, crushing, cuts, electric shock, etc.), but there are other cases where the dangers are more subtle. Nevertheless, they must always be identified in time.

Figure 4 – Example of installation of a PV System in the 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. Additionally, 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 to prevent hazards to the personnel in case of lightning events that might occur during the installation activities, particularly installations on rooftops.

5.3 Safety Measures

5.3.1 Lightning Effects and Overvoltage

Whenever a solar PV System is installed on rooftops, the Consultant/Contractor shall also review the design of the lightning protection system to ensure it protects the PV System too.

In accordance with IEC 62305, the PV System shall always be protected against the effects of overvoltage by means of suitable measures aimed to avoid or mitigate the occurrence of overvoltage (e.g. metallic protections, shields) and/or to suppress them by proper devices as Surge Protecting Devices (SPDs). The need for SPDs should be assessed according to IEC 62305 (all parts) and appropriate protective measures implemented. IEC 62305-4 can provide a methodology for protecting electrical and electronic systems in a lightning environment.

In the case of a PV System installed on a building where an external Lightning Protection System (LPS) is present, the PV System shall not reduce the effectiveness of the LPS. It shall be properly integrated with compliance with IEC 62305-3.

Normally, the presence of a new PV System does not change the lightning risk; therefore, if the building has no external LPS this measure will not be required after the installation of the PV System. In this case and also in the case of a free-standing PV System, overvoltage protection may still be required to protect the PV array, the inverter and all parts of the installation.

However, if the physical characteristics or prominence of the building do change significantly due to the installation of the PV System, it is recommended that the need for a lightning protection system be assessed in accordance with IEC 62305-2 and, if required, it should be installed in compliance with IEC 62305-3.

5.3.2 Testing for Voltage

Preventive measures include conducting voltage testing with specific gear. One such measure involves using a voltmeter: a tool that measures the amount of voltage that exists at any given point within an electrical system. The personnel working with the circuit must know 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 an 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 uses a voltmeter: surprises are the last thing needed when working with such power systems. Also, the current will increase when strings 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. Thus, it better work with a clamp-on voltmeter when working with systems that contain high amperage levels unless a different measuring means is required for a much more specific characterisation of a PV string.

5.3.3 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 to allow the current to have a safe route to the ground. PV workers should ground individual components and the entire system. Proper earthing is another precaution to ensure 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 systems shall be bonded together or built as a unique system. For further details, see the related standards and/or safety guidelines.

Earthing PV support structures and PV frames is also required as a protection measure regarding lightning phenomena. SPDs and surge arresters are normally provided by design as overvoltage protections in a PV System. However, lightning protection measures shall be adopted by design.

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.

Earthing shall be made according to international standards:

- IEC 60364-5-54 for all LV installations;
- IEC 60364-7-712 and IEC 62548 specifically for PV Systems;

Earthing shall also be compliant with Kahramaa Electricity Wiring Code CS-CSI-P1/C1.

5.3.4 Insulated tools

Yet one more safety measure in preventing exposure to electrical hazards is to employ insulated tools. The PV workers' and installers' tools have to be made with insulating material. It is recommended to use rated insulated tools and never use them if their rating is inappropriate. Using the proper insulation level in case of high voltage, the same tools also for lower voltage operations as long as this measure avoids mistakes due to the different insulation levels that can be confused during operation.

5.3.5 Specific risks while operating on PV Systems

Standard IEC 60364-712 on the electrical installations of buildings does outline some rules for protecting people. However, the current version of that standard is not detailed and universally applied. Currently, the entire PV industry, from standards institutes down to installers, is learning as it goes from everyday lessons. The standard is being updated, and future versions will substantially improve what 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 complete standard becomes available, it makes sense to err on the side of caution. 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 cutting off power to the burning building as a safety precaution. However, if the building has a PV installation, the PV modules continue to generate voltage, even if the system is not 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 conditions, a solution should be adopted beyond the traditional shutdown function in inverters that merely interrupts the 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 optimisers connected to each module, a PV inverter and module-level monitoring. When power optimisers are connected, modules continue in “operation mode” only as long as a signal from the Inverter is constantly renewed. In the absence of this signal, power optimisers 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 Systems, to prevent arrays energisation even when disconnected. The US national electric code requires using 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 of PV Systems:

- 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 – Recommendations for small renewable energy and hybrid systems for rural electrification – Part 7-1: Generators – Photovoltaic arrays
- Technical specifications IEC TS 62257-5 – Recommendations for small renewable energy and hybrid systems for rural electrification – Part 5: Protection against electrical hazards

6 Risk of Falls

6.1 Specific Reference documents for this Chapter

The following documents shall be considered a specific reference for the current Chapter.

- Health and Safety Executive (HSE) – Health and safety in construction (2006)
- Health and Safety Executive (HSE) – Health and safety in roof work (2020)

6.2 Main topics

Falls usually represent the most important risk for PV on buildings because any accidental fall generally leads to death or severe injuries. Falls concern people who work at height on the structure under construction or use ladders, platforms, 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, and any other Collective Protective Equipment (CPE) that is provisionally installed to safeguard workers.

Personal Protective Equipment (PPE) is useful for avoiding 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 is mainly represented by harnesses properly anchored to one or more fixed points.

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

On the other hand, it is important to consider that PV Systems must be inspected and maintained during their lifetime. Therefore, easy and safe access to all system parts has to be prepared for the personnel.

The application of proper measures aimed to guarantee safe access to a rooftop depends on the type of installation. For instance, in the 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 workers. On the contrary, on a sloped roof, several lines and anchoring points must be installed permanently. Their number and position must be sufficient to assure safe access to every part of the PV System and shall avoid, in any case, dangerous effects like bottoming out or pendulum.

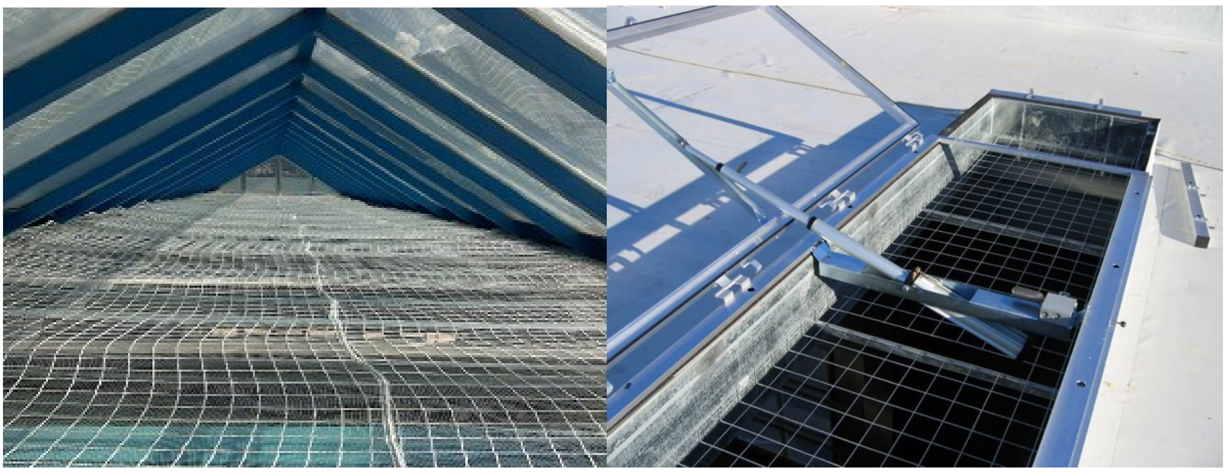


Figure 5 – Example of safety nets installed below skylights

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 safety nets often represent the most effective solution placed just before the transparent surfaces (see examples in Figure 5). Safety nets may also avoid falls into air gaps, holes and similar.

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

6.3 Ladders

6.3.1 Overview

Working with ladders can cause anything from mild sprains to serious back injuries and up to death in some cases.

Solar contractors typically use ladders to access roof areas. A common misconception regarding ladder safety is that care only needs to be taken when heights are involved. Accidents are unexpected, and a surprise fall from any height can force you to land on harmful items lying nearby or land in an awkward position that can cause serious injuries or death.

Because of the unexpected nature of falls, even falling from lower heights of 2 meters or less can cause serious back or neck injuries, puncture injuries from falling onto hazards, or broken bones and twisted ankles.

A major source of accidents involves improper setup and use of ladders. The employees using ladders must be properly trained to avoid serious injury or death.

Table 1 reports the result of identifying hazards and risks associated with typical construction work situations.

Table 1 – Hazards and risks associated with typical construction work situations

Work situation	Working conditions	Hazards	Actions
Using ladders for various tasks at the jobsite	Accessing roofs, working on wall-mounted equipment, working on many different height levels	Using an inappropriate ladder (fall hazard, shock hazard)	Select the correct ladder for the job
Loading and unloading ladders and carrying ladders to the work area	lifting on trucks and carrying ladders to the work area	lifting hazards from carrying ladders	Develop proper procedures for carrying ladders

Work situation	Working conditions	Hazards	Actions
Climbing ladders to access roofs	positioning ladders to reach rooftops, climbing up onto and down from roofs	setting up in unsafe areas, fall hazards from accidents on ladders, electrical hazards from contact with electrical power lines	Develop safe ladder use or alternative procedures for accessing the roof
Climbing ladders to work on wall-mounted equipment	setting up the ladder properly, climbing up and down safely	setting up in an unsafe area, setting up improperly, not securing the ladder properly, not climbing up or down properly, resulting in falls	Develop safe ladder practices for working from ladders
Using ladders to rest or hang tools and equipment on	working on ladders and resting tools on the top of the step ladders or on the steps of any ladders	items falling from a ladder resulting in impact-related injuries	Eliminate tool falling hazards by not using ladders to store your tools. Use a ladder or equipment specifically designed for tools.

6.3.2 Selecting the Correct Ladder for the job

Selecting the ladder is an important safety first step to use the proper tool for the job. Construction crews use ladders daily. Ladders come in different sizes and designs that are specific to certain tasks. Ladders are intended and built for a specific purpose and should always be used.

Table 2 shows three ladder types are typical in the construction industry.

Table 2 – Ladder types in the construction industry

Description	Image
Step ladder Step ladders are versatile free-standing ladders. Step ladders are designed to be used in the fully ‘open’ position. Step ladders are not designed to gain access to another level, such as a rooftop and should never be used. Nor should step ladders ever be used in the folded position leaned up against a wall or other structure.	

Straight or leaning ladder Straight ladders are the most basic ladder design and, because of this, are normally lighter and easier to manoeuvre into place. Size limitation is a common barrier to using straight ladders, and use a straight ladder only when long enough to reach your desired target properly. When used properly, straight ladders can work from or gain access to another level, such as a rooftop.	
Extension ladder Extension ladders are similar to straight ladders and normally used to reach higher areas. Extension ladders have a 'base' section and a movable 'fly' section. When used properly, extension ladders can work from or gain access to various levels and rooftops.	

6.3.3 Safe use of Ladders

Ladders can be used for work at height when a risk assessment has shown that using equipment offering a higher level of fall protection is not justified because of the low risk and short duration of use or there are existing workplace features which cannot be altered.

Short duration is not a deciding factor in establishing whether using a ladder is acceptable because risks should be considered first. As a guide, if the task would require staying up a leaning ladder or stepladder for more than 30 minutes at a time, it is recommended that alternative equipment be considered.

Ladders should only be used in situations where they can be used safely, e.g., where the ladder will be level and stable and reasonably practicable the ladder can be secured.

To use a ladder, the personnel need to be competent, i.e., have had instructions and understand how to use the equipment safely.

Appropriate training can help. Training can often take place on the job; if the worker is being trained, he should work under the supervision of somebody who can perform the task competently.

Before starting a task, the competent person should always carry out a 'pre-use' check to spot any obvious visual defects to ensure the ladder is safe to use. A pre-use check should be carried out:

- by the user;
- at the beginning of the working day; and
- after something has changed, e.g., a ladder has been dropped or moved from a dirty area to a clean area (check the state or condition of the feet).

	
Ladder showing the correct 1-to-4 angle (means of securing omitted for clarity)	**Correct** – use of a stand-off device to ensure a strong resting point. Do not rest a ladder against weak upper surfaces such as glazing or plastic gutters. Follow the manufacturer's instructions

Figure 6 – Correct angle and use of stand-off device

When using a leaning ladder to carry out a task:

- Only carry light materials and tools – read the manufacturers' labels on the ladder and assess the risks.
- Do not overreach – make sure your belt buckle (navel) stays within the stiles.
- Make sure it is long enough or high enough for the task.
- Do not overload it – consider workers' weight and the equipment or materials they carry before working at height. Check the pictogram or label on the ladder for information.
- Make sure the ladder angle is at 75° – you should use rule 1-to-4 (i.e., 1 unit out for every 4 units up) – see Figure 6.
- Always grip the ladder and face the ladder rungs while climbing or descending – do not slide down the stiles.
- Do not try to move or extend ladders while standing on the rungs.
- Do not work off the top three rungs, and make sure the ladder extends at least 1 m (three rungs) above where you are working.
- Do not stand ladders on moveable objects, such as pallets, bricks, lift trucks, tower scaffolds, excavator buckets, vans, or mobile elevating work platforms.
- Avoid holding items when climbing (consider using a tool belt).
- Do not work within 6 m horizontally of any overhead power line unless it has been made dead or protected with insulation. Use a non-conductive ladder (e.g., fibreglass or timber) for any electrical work.
- Maintain three points of contact when climbing (a hand and two feet) and wherever possible at the work position.

- Where one cannot maintain a handhold other than for a brief period (e.g., to hold a nail while starting to knock it in, starting a screw etc.), he will need to take other measures to prevent a fall or reduce the consequences if one happened.
- For a leaning ladder, one should secure it (e.g., by tying the ladder to prevent it from slipping either outwards or sideways) and have a strong upper resting point, i.e., do not rest a ladder against weak upper surfaces (e.g. glazing or plastic gutters – see Figure 6);
- One could also use an effective stability device.

The options for securing ladders are as follows:

- Tie the ladder to a suitable point, making sure both stiles are tied; see Figure 7 and Figure 8.
- Where this is not practical, secure with an effective ladder stability device.
- If this is not possible, securely wedge the ladder, e.g., wedge the stiles against a wall.
- If any of these options cannot be achieved, foot the ladder. Footing is the last resort. Avoid it, where 'reasonably practicable', using other access equipment.

As regards ladders used for access, in general:

- Ladders used to access another level should be tied (see Figure 8) and extended at least 1 m above the landing point to provide a secure handhold. At ladder access points, a self-closing gate is recommended.
- Stepladders should not be used to access another level unless specifically designed.

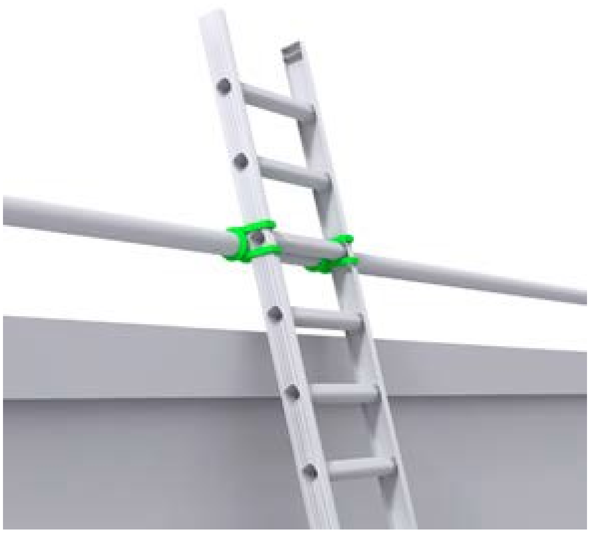
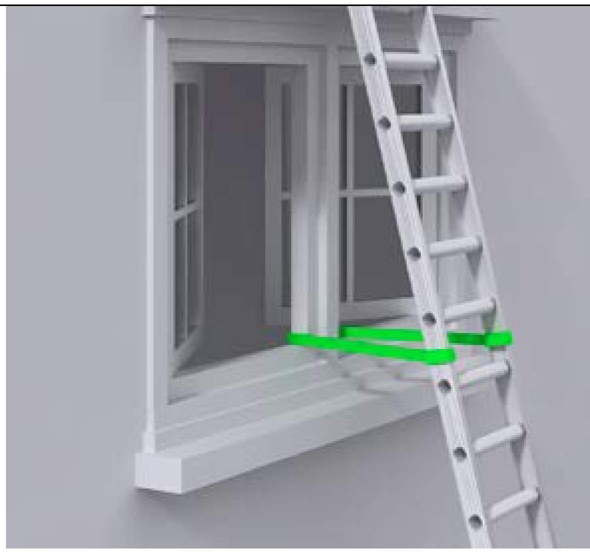
	
Correct – ladder tied at top stiles (correct for working on, but not for gaining access to a working platform/roof etc.)	**Correct** – tying part way down

Figure 7 – Tying

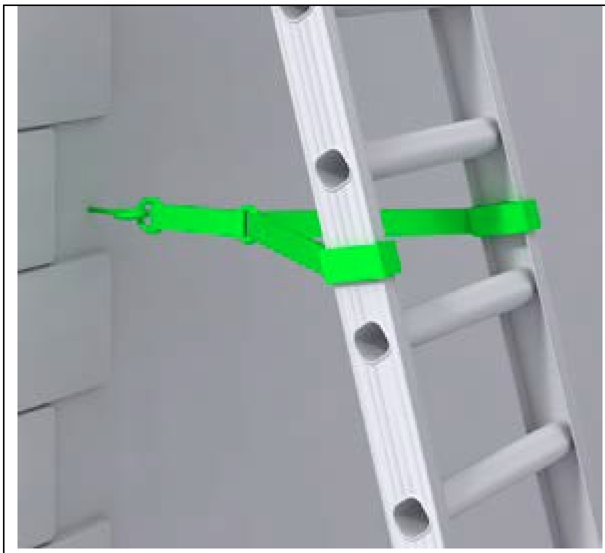
 Correct – tying near the base	 **Correct** – access ladders should be tied and extend at least 1 m above the landing point to provide a secure handhold

Figure 8 – Tying and access ladders

6.4 Fall and Trip Safety Hazards

Fall and trip hazards include anything in the workplace that could cause an unintended loss of balance and result in a fall.

Identifying fall hazards is to determine how to eliminate or control them before they cause injuries.

Fall prevention is more than just being safe on ladders and rooftops. Falls leading to serious injuries can happen anywhere. Thus, the job site evaluation needs to address potential falls wherever they happen.

Trip hazards, such as debris or tools lying on the ground or walking surfaces, can lead to injuries such as sprained ankles and increase the risk of falling. Trip hazards on rooftops create an unsafe environment that can lead to falls from the roof.

Falling from even the smallest heights can result in serious injuries, including death.

Just a few of the potential injuries from fall hazards include:

- Death
- Severe/traumatic/massive head/brain/skull injuries
- Broken/fractured/shattered bones
- Spinal injuries/ internal organ injuries

Fall protection means more than equipment. Fall protection includes the actions to eliminate fall hazards, prevent falls, and ensure that workers who may fall are not injured.

Planning for fall hazards, maintaining a clean job site, using personal fall-protection gear, and planning for emergencies will form the basis of fall risk-reduction strategy.

Typical fall-protection systems used by solar installers are the followings:

- Personal fall-arrest system: arrests the descent after a fall occurs
- Personal fall-restraint system: prevents a fall from occurring
- Guardrail system: prevents a fall from occurring

6.4.1 Personal Fall Arrest Systems

A personal fall-arrest system consists of an anchorage, connectors, and a full-body harness that works together to stop a fall and minimise the arrest force – see Figure 9. Other parts of the system may include a lanyard, a deceleration device, and a lifeline. Personal fall-arrest systems must attach to the rear D-ring.

The personal fall-arrest system is effective only if the personnel know how all components work together to stop a fall. Getting professional training in the proper use of the fall-arrest gear is highly recommended.

Figure 9 – Examples of personal fall-arrest systems

6.4.2 Personal Fall-Restraint System

Unlike the personal fall-arrest system, which is designed to stop a fall, a personal fall-restraint system prevents a worker from reaching an unprotected edge to prevent a fall from occurring. The system consists of an anchorage, connectors, and a body harness or a body belt.

The attachment point to the body belt or full-body harness can be at the back, front, or side D-rings.

The anchorage for a fall-restraint system must support a given weight or be designed and installed with a safety factor of at least two.

6.4.3 Guardrail Systems

A guardrail system consists of a top rail, mid-rail, and intermediate vertical member.

Guardrail systems can also be combined with toe boards that prevent materials from rolling off the walking/working surface.

Guardrail systems must be free of anything that might cut the worker or snag a worker's clothing. Top rails and mid-rails must be at least one-quarter-inch thick to reduce the risk of hand lacerations; steel or plastic banding cannot be used for top rails or mid-rails.

6.4.4 Warning Lines

A warning line system is a barrier erected on a roof to warn employees that they are approaching an unprotected roof side or edge – see Figure 10.

It designates an area in which roofing work may occur without using a guardrail, body belt, or safety net systems.

Figure 10 – Example of warning line

7 Additional Risks

7.1 Specific Reference documents for this Chapter

The following documents shall be considered a specific reference for the current Chapter.

- Health and Safety Executive (HSE) – Health and safety in construction (2006)

7.2 Overview

Additional electrical hazards shall be considered when working with generators like PV solar modules. 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 Systems, 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 upcoming paragraphs.

7.3 Arc flashes and Burns

An arc flash is an explosion that occurs due to 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, resulting 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 mind and body toward the 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 of 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 temperature spectrum: thermal burns are caused by metal and glass components exposed to the sun. These components can reach a temperature of over 90 degrees Celsius and cause burns if prolonged contact is involved. At the extreme part of the spectrum, the temperature can be at 9.000 Celsius 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 the need for immediate treatment.

Recommendations

Arc flashes have been recognised as hazards for PV Systems 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 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: parts not fastened properly or loose metallic tools creating a short circuit.

The fire produced by an arc fault differs from another fire. Thus, the PPE that should be used needs to be different. Use clothing specifically rated for arc flashes. PPE safety rated for arc flashes should also include goggles that protect from the extreme light emitted.

7.4 Exposure, Bites and Cuts

Additional risks may also come from sharp edges, for example, metallic components of supporting and fixation structures. PV module frames that are metallic are finished 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.

7.5 Falling modules, flying glass

In addition to electrical hazards, there are also dangers from solar modules falling from the roof; either because they become detached from their fixing structure or because the roof members have failed below them and collapsed into the building. Thus, it is always required to use an adequate fixing structure to withstand the weight of the PV modules and prevent them from falling or getting blown by the wind.

There is a danger of being struck by a falling PV module, but once it hits the ground, it may cause the glass within it to shatter and be expelled outward with force: in such a case, the use of appropriate PPE is recommended to avoid cut risks.

8 Marking and Warning Signs

8.1 Specific Reference documents for this Chapter

The following documents shall be considered a specific reference for the current Chapter.

- Health and Safety Executive (HSE) – Health and safety in construction (2006)

8.2 Marking and Warning

PV Systems shall be marked. Marking is needed to provide, for example, emergency responders with appropriate warning and guidance concerning isolating the solar electric system. This can facilitate identifying energised electrical lines that connect the solar modules 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 System:

- Labelling for normal operations; and
- Labelling for firefighters

The PV Systems' areas of concern for firefighter safety and fire-fighting operations include energised 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 intended to mitigate fire safety issues.

Understanding signs provides valuable information for refining safety and health management strategies. Safety signs usually contain four components: signal words, hazard statements, noncompliance statements and some instructions. Moreover, the colour of warning labels should attract the attention of viewers. Different signal colours characterise different risk ranks because of the consequences of cultural effects or physiological reactions. Usually, red characterises the highest hazard rank, followed by other colours. In addition, warning labels should have signal words, such as danger, caution and instruction, to recognise the ranks of hazards. Usually, danger represents the highest hazard rank, 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 five types of safety signs described by BS 5499 part 1 (Specification for geometric shapes, colours and layout) are:

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

Mandatory: action signs have the 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 the main safety colour of yellow, with a contrast colour of black and a yellow equilateral triangle with smooth corners and a 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 the 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 applications, 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 system's lifetime. The warning signs must comply with the Qatari reference legislation, which is expected 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 meanings.

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

The minimum requirements for labelling a PV plant are described in the present Chapter. Practical marking samples 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 illustrated in Figure 11, 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 (see Figure 11) 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, shutdown and start-up procedures shall be detailed in the diagram.

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

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 the position of the main AC circuit breaker.

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

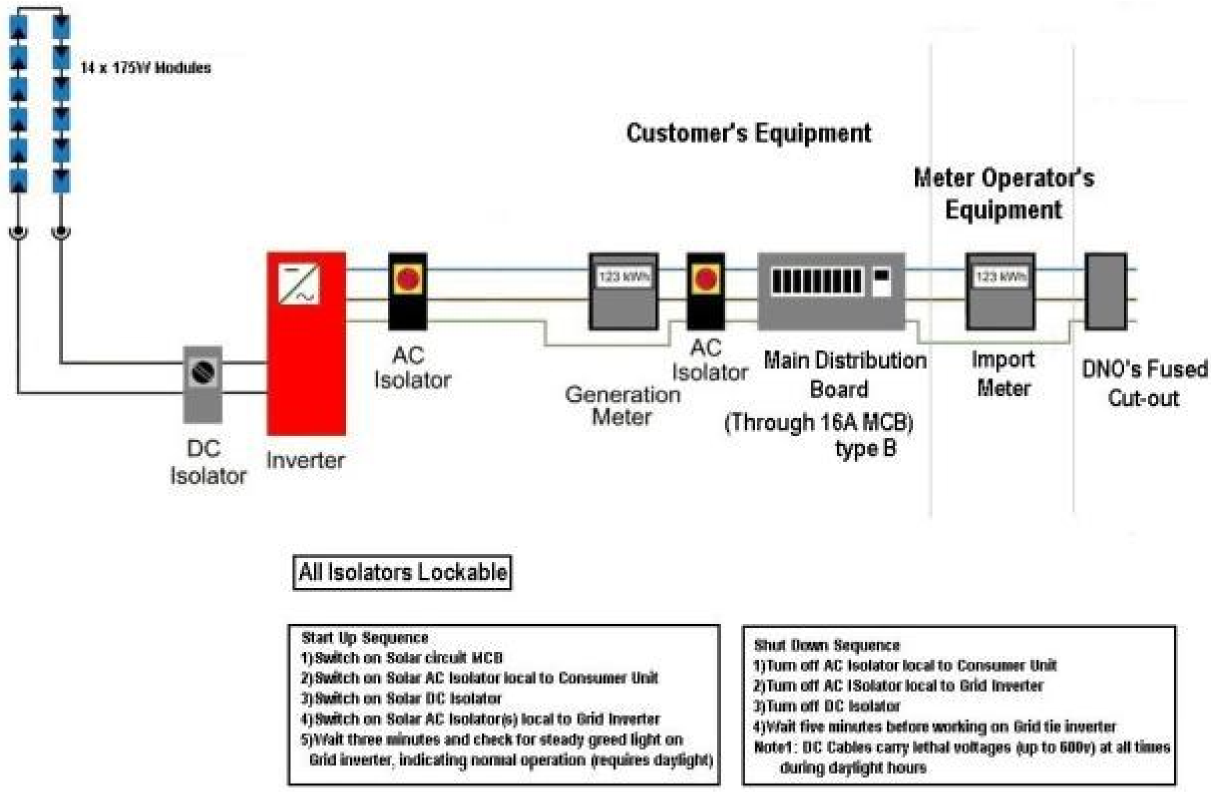


Figure 11 – Example of Circuit diagram & system information to be exposed in the building ***Error! Reference source not found.***

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

Failure to follow the manufacturer's recommendations 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’.

The following signs shall also be fitted to ensure the Fire and Rescue Service are aware that a PV System is installed on the roof.

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

Marking is also required for DC circuits both on all interior and exterior DC conduits, raceways, enclosures, cable assemblies, and junction boxes to alert the firefighter 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 the 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 galvanised rigid steel conduit or metallic electrical tubing (not galvanised acceptable only to 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 standards differentiate the warning by adding the sentence "PHOTOVOLTAIC SYSTEM VOLTAGE DURING DAYLIGHT HOURS". However, this could be misleading as long as a voltage can occur when a PV module is illuminated by bright light (in principle, even in the presence of full moonlight).

Adding the maximum voltage detectable (volts) is useful, as well as 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 System.

The area where PV modules, cables and other equipment are located, if accessible, shall be marked by proper signs, as reported in Figure 16. They shall also be placed in correspondence with each access door to the PV System. The same signs shall indicate cables before disconnectors and be placed every 5 meters along the cable.

These signs shall be UV resistant and 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, the first reference shall be made to those required according to standards and legislation. The installation phase and during the work on the rooftop refer to the Local Municipalities code of construction. It is advisable to foresee putting in place warning signs 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 signs (colour, dimension, physical characteristics, etc.).

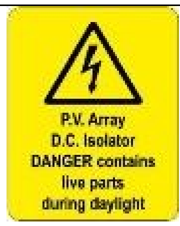
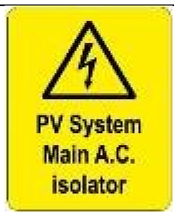
As to the kind of information that shall be provided thanks to the placement of such signs, in ANNEX B, a selection of such warning signs is presented that shall be adopted for different places in a PV System.

The warning signs for disconnectors, both DC and AC, are shown in the following table and 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 a manual shall also specify the position of the manual call point. LOTO procedures shall be according to the rules and regulations of the relevant authorities.

For example, requirements related to LOTO procedures are specified in the standard “EHS Design Development Regulations”.

Table 3 – Examples of warning signs for disconnectors

Suggested placement in the PV System	Warning messages	Warning signs	Arabic
Any accessible DC connectors	Do not disconnect DC plugs and sockets under load - turn off AC supply first.		
DC junction box, if any	PV Array DC 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 DC isolator. Danger contains live parts during daylight.		
Inverter	Inverter - Isolate AC and DC before carrying out work.		
Main AC circuit breaker.	PV System - main AC isolator.		

9 Safety during O&M

9.1 Specific Reference documents for this Chapter

The following documents shall be considered a specific reference for the current Chapter.

- Health and Safety Executive (HSE) – Health and safety in construction (2006)
- Health and Safety Executive (HSE) – Health and safety in roof work (2020)

9.2 Safety in O&M

In PV Systems, the operation and maintenance are overall represented by monitoring the electricity production and optimising them. PV Systems are typically stand-alone and therefore unattended during operation. The maintenance of PV Systems is a mix of periodical inspection activities and checks of the performance of single parts and components of the PV System.

Depending on the PV System's overall power and electrical design, some parts of the power circuits may be operating at MV, particularly following an inverter/transformer stage. Therefore, proper maintenance has to be provided to such equipment according to the design, the suitable safety rules, and the manufacturer's recommendations.

The main maintenance operations are:

- Visual inspection of the site (interior and exterior)
- Cleaning operations of PV modules (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 associated with the maintenance activities on the electrical parts performed on the PV System. Specifically, during array connection in installation and substitution of PV modules, there are electrocution hazards. Also, during the site inspection, there are risks of falls from the roof or accidents due to material falling while transportation, potential stumble or other causes.

Finally, hazards associated with the specific activities performed inside the building, i.e. risks from the industry where the installation's roof is located. Eventually, risks can be observed during maintenance and cleaning operations concerning the cleaning techniques and cleaning tools.

Workers involved in O&M should act following the statement of the risk assessment plan (HSE Risk assessment). For instance, if the PV System is mounted on a rooftop without protected pathways and trenches, workers must wear harnesses and fasten them to a safe belay. Maintenance operation should be performed with the PV System (or part of the PV System involved in maintenance) disconnected. All arrays are not energised except for operations that do not identify a specific risk.

Recommendations

O&M personnel to operate the Solar PV System shall possess the same minimum qualification required to the Contractor's personnel enrolled to apply for the connection of the same type of system.

Also, all workers, specifically 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 working close to PV Systems and other electrical equipment. Workers shall be provided with suitable PPE when risk reduction measures at the 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 cleaning services supplier) to allow a safe performance at work, especially if different companies and sub-contractors are involved. Thus, put in place measures to ensure communication of information to (e.g., expatriate) workers who may not have a good command of the working language to allow them to perform their work safely.

ANNEX A – Summary of the Recommendations

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 the safety of the personnel performing electrical equipment installation on rooftops or visiting or inspecting the installation site. Particularly: – Act in compliance with 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 to attend "Tool Box Talk" – Ensure personnel have the required technical education, knowledge, and working experience and are suitably trained to do the expected electrical activities also on live parts – Consider the issues of performing activities on rooftops at an elevation from ground level. Adopt systems suitable to prevent falls from a rooftop, like static line systems, including travel restraint systems and fall-arrest systems, and 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 concerning works on electric parts of a PV System. Workers shall have the skills needed to operate on live parts and use the equipment to test voltage/current in the field.
Insulated tools	The personnel of the installer shall use PPE with appropriate characteristics in relation to works on electric parts of a PV System. Workers shall be trained to use the needed PPE.
Marking and warning signs	The design shall include the installation of appropriate warning signs indicating the presence of the PV System 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.

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 the cleaning of modules: cleaning has more potential hazards since the module surface is more slippery, and modules are often inclined and not in a horizontal position on a flat surface. Adopt systems suitable to prevent falls from a rooftop, like static line systems, including travel restraint systems and fall-arrest systems, and 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 the correct use of tools for cleaning for O&M workers; Prevent damage to the PV modules, wiring, connectors, and module fixing systems. Workers performing cleaning activities shall be aware of potential electric risks in case PV modules are damaged.
Safety during O&M (O&M management)	The O&M supplier (and the installer) shall prepare guidelines for the correct exploitation of maintenance procedures, including the substitution of electrical parts and/or PV components. In case of disconnection of the PV System, the guidelines for disconnection and safety operation during specific electrical checks shall be fulfilled, also in cooperation with Kahramaa.

A.3 – Information for Kahramaa personnel and inspectors

Item	Recommended Practice
Information for DSP personnel	The Applicant (or the Installer) shall communicate the hazards list on-site where the PV System is installed. DSP will process the said communication according to its safety prevention procedures.
Inspectors from other organisations (inspection visits not related to testing)	The Applicant (or the Installer) shall communicate the hazards list on-site where the PV System is located. The concerned organisation will process the said communication according to its safety prevention procedures.

A.4 – Information for Fire-Fighters

Item	Recommended Practice
Information for Fire-Fighters	Firefighters have to have appropriate knowledge of a PV System and use the most suited procedures when operating in the presence of a PV System. A damaged PV module can still produce current and can produce hazardous conditions ranging from perception to electrocution: Fire-Fighter should respect the prescription on manipulating arrays and PV modules even when the modules are damaged. Detailed recommendations for Firefighters are listed below. – Use PPE (protection gear, boots and gloves) certified for an electrical shock as it is required to operate in PV Systems. – Take into account the voltage and the current that is present in a PV System. – Know the hazards related to specific actions, e.g. cutting off 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 System. An alternative applicable could be to cover the array with tarps. Caution should be exercised when deploying tarps on damaged equipment, as a wet tarp may become energised. – Consider potential trip, slide and fall hazards in the case of a rooftop PV System. PV modules and arrays can be slippery or fragile. Avoid or take 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 a fire to propagate into the attic space. The hazard of rooftop collapse in case of fire can be an issue when listed in the risk assessment: a layer of flammable insulation on the rooftop can be harmful and potentially introduce new risks to the entire structure of the rooftop and PV arrays.
Information for Fire-Fighters	Firefighters have to be aware of the potential electrical hazard from energy produced by Solar PV Systems. – Even when isolated at the inverter or fuse box, the system may remain 'live' between the PV modules and the isolation point. This presents a potential DC electrical shock hazard for firefighters 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 can produce electrical power sufficient to cause a lock-on hazard.
The danger of inhalation of hazardous fumes	Firefighters have to be aware that it is theoretically possible for hazardous fumes to be released in the event of a fire, 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

Some examples of warning signs and hazard information are reported in both English and Arabic below.

Figure 12 - Generic warning for PV System's modules on the roof

Figure 13 - Warning with specification danger of electrical hazards

Figure 14 - Warning sign more specific on electrical live parts presence

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

Figure 15 – Warning sign template with specifications of emergency contact numbers

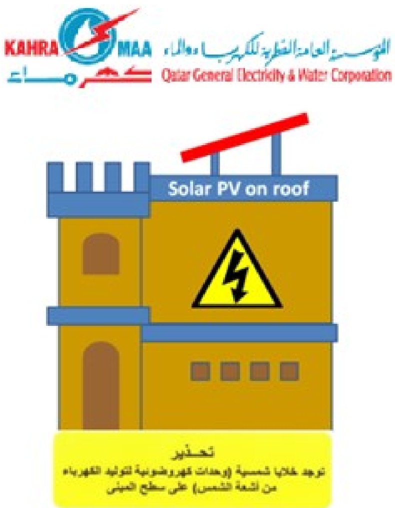


Figure 16 – Signs to be used to indicate the presence of a PV System

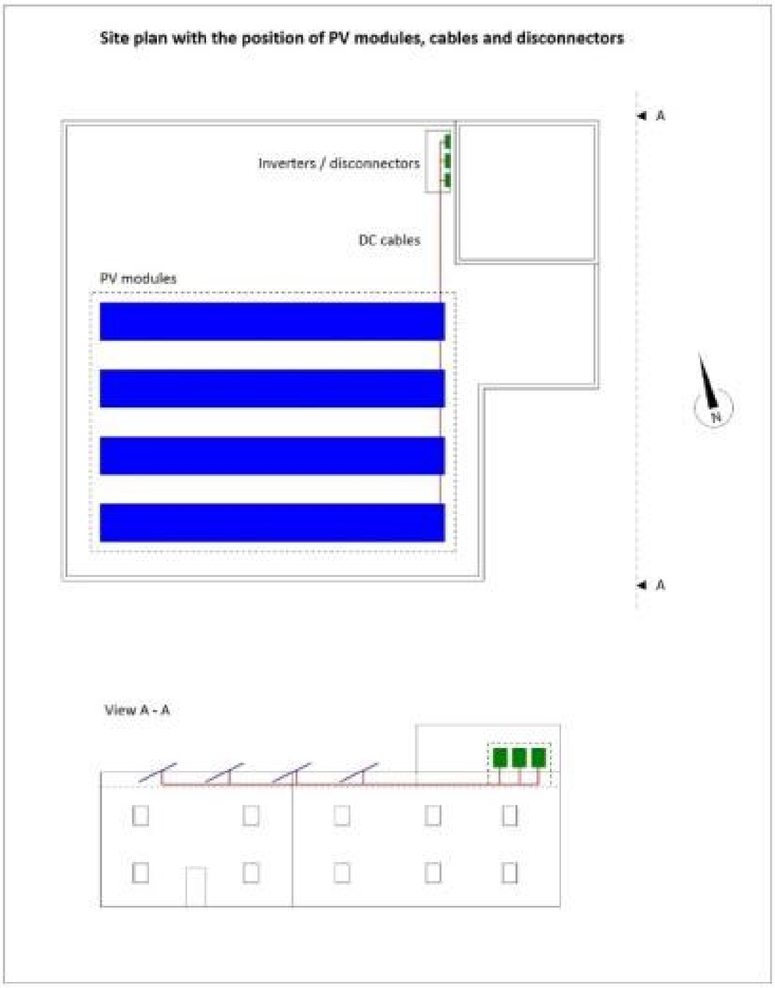


Figure 17 – Example of simplified layout to be exposed in the building

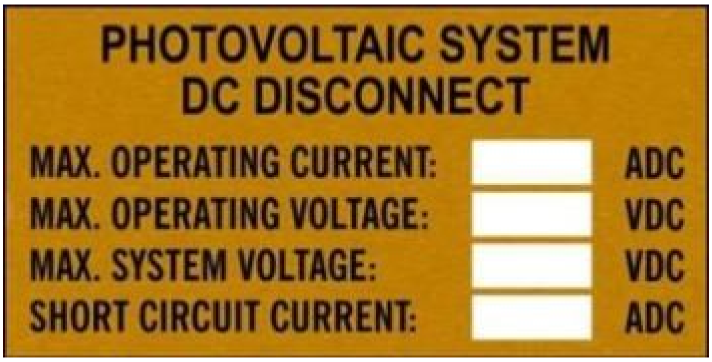
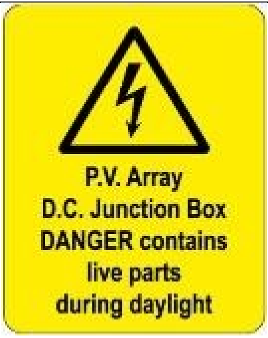
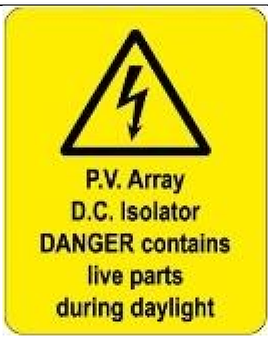
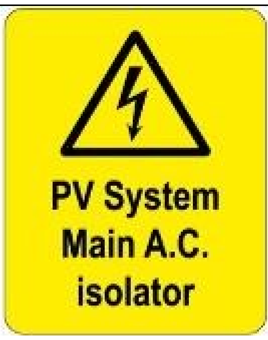


Figure 18 - Warning sign with specifications of voltage and current operating in the PV Systems

Figure 19 – Generic warning for PV Systems

Figure 20 - Warning with a specification of the dual power supply

More examples of warning signs with captions in English and Arabic are provided below.

English	Arabic
	
	
	
	
	


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 ألمستمر أثناء التشغيل قم بفصل كابلات التيار المتغير أولا
أنظمة خلايا شمسية. مفتاح التيار المتغير الرئسي
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 الرئسي ومفتاح مصادر الطاقة
فتح مفتاح مصادر الطاقة........................
فتح المفتاح الرئسي ....