



SHAMS DUBAI

PV ON BUILDINGS AND FIRE SAFETY: RECOMMENDATION FOR DRRG SOLAR PV SYSTEMS

VERSION 1.0 – EDITION 2015

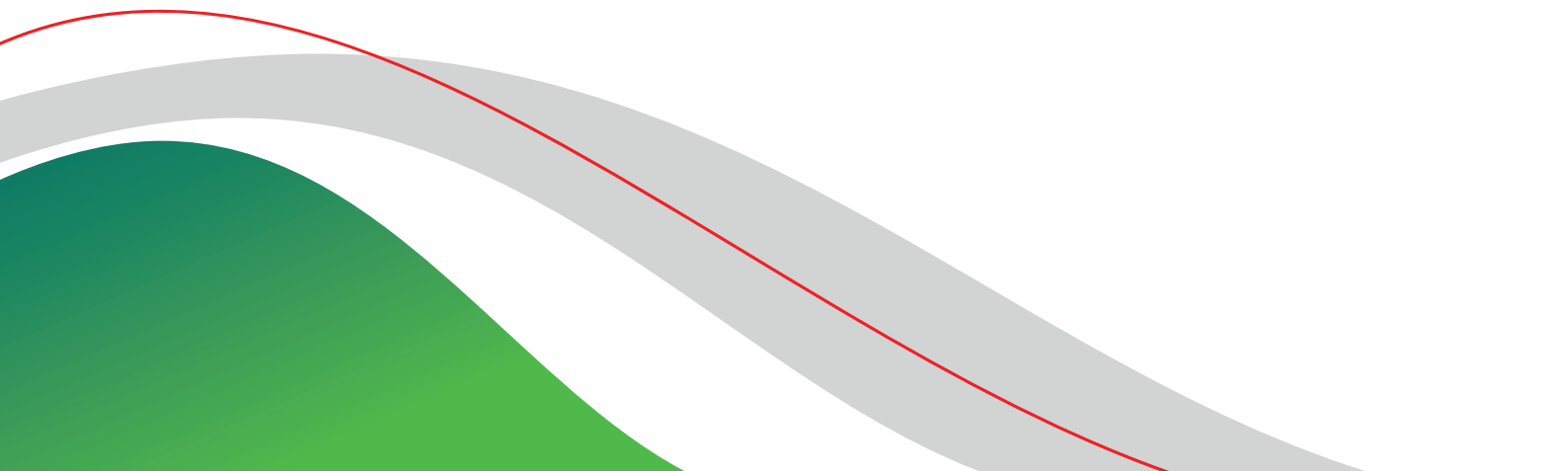


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1 INTRODUCTION

1.1 Scope

This document contains special considerations and measures against fire hazard to be applied when PV plants are to be mounted on buildings.

Fire hazard prevention is considered in view of the following:

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

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

In this document the measures 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).

1.2 Definitions

AC disconnect – Switch installed on an AC line that also complies with the requirements for a disconnect.

DC disconnect – Switch installed on a DC line that also complies with the requirements for a disconnect.

Building-integrated photovoltaic (BIPV) – Photovoltaic modules are considered to be building-integrated, if the PV modules form a building component providing a function. Thus the BIPV module is a prerequisite for the integrity of the building's functionality. If the integrated PV module is dismantled (in the case of structurally bonded modules, dismantling includes the adjacent building component), the PV module would have to be replaced by an appropriate building component.

Building-attached photovoltaic (BAPV) – Photovoltaic modules are considered to be building attached, if the PV modules are mounted on a building envelope and do not fulfill the criteria for building integration.

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

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

Photovoltaic (PV) components – Parts of a PV system.

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

Photovoltaic (PV) system / Photovoltaic (PV) plant – assembly of components that produce and supply electricity by the conversion of solar energy.

1.3 Reference documents

The following documents available on the Dubai Municipality website: <http://login.dm.gov.ae>; and Civil Defence website: <http://www.dcd.gov.ae>, are here quoted as a reference:

[A] Code of Construction Safety Practice (Government of Dubai – Dubai Municipality)

[B] UAE FIRE & LIFE SAFETY CODE OF PRACTICE (General Headquarter of Civil Defence) – Edition 2011

2 PRELIMINARY FIRE SAFETY CONSIDERATIONS ON BUILDINGS

PV plants on buildings may have several possible placements, however, visible and exposed to sunrays. According to the UAE FIRE & LIFE SAFETY CODE OF PRACTICE, buildings are divided into:

Lowrise Buildings: Occupancies or multiple and mixed occupancies, facilities, buildings and structures having occupiable or usable floors at or up to 15 meters from the lowest grade or lowest level of Fire Service Access into that occupancy.

Midrise Buildings: Occupancies or multiple and mixed occupancies, facilities, buildings and structures having occupiable or usable floors between 15 meters to 23 meters from the lowest grade or lowest level of Fire Service Access into that occupancy.

Highrise Buildings: Occupancies or multiple and mixed occupancies, facilities, buildings and structures having occupiable or usable floors more than 23 meters above from the lowest grade or lowest level of Fire Service Access into that occupancy.

Hazard content and hazard evaluation for the occupancies differ based on the material involved and its burning characteristics. The owner, consultants and contractors are asked to submit details such as occupancy description, operation and process involved and material usage in their occupancy for Civil Defence approval.

For life safety purpose, hazard evaluation of occupancies is categorized into:

- Light Hazard
- Ordinary Hazard
- High Hazard and Extra High Hazard

Hazards are categorized into Light, Ordinary, High and Extra High hazards. Therefore, fire detection, protection and suppression systems will need to be designed adequately, in order to effectively address the various categories of hazard.

Most of the occupancies are basically categorized as Ordinary Hazard, where materials (paper, records, books, computers, carpets, household plastic, home appliances, electronic and electrical office equipment, hospital equipment, furniture, wood, bedding and upholstery) are likely to burn with moderate rapidity or to give off a considerable volume of smoke.

Occupancies may also house other associated hazards, which fall into High Hazard category such as battery storage, flammable liquids such as Diesel in generators, laboratory chemicals, cleaning solvents in storage rooms, and fuel gas in kitchens and pantries.

Industrial and storage occupancies usually represent an Extra High Hazard with storage of rapidly burning and dense smoke generating materials such as plastic, tyres, highly flammable liquids and gases, combustible dust, processes and operations involving high temperatures and flames.

Multiple or mixed occupancies are combinations of various hazard content and hazard categories. Accordingly the code application in such occupancies is based on the most stringent requirements.

3 FIRE RESISTANT PV MODULES

The standard IEC 61730-2 includes the fire test (MST 23) for PV modules. The characteristics assessed in the fire test establish the fundamental fire resistance of PV modules serving either as roof covering materials or mounted onto a building over an existing roof. These modules may be exposed to fire conditions, and therefore need to indicate their fire-resistance characteristics when exposed to a fire source originating from outside the building on which they are installed.

The fire resistance classes range from Class C (fundamental fire resistance), to Class B to Class A (highest fire resistance). A minimum fire resistance rating Class C is necessary for any building-mounted module (BAPV). Certification to a higher level may be considered in order to satisfy specific conditions and requirements. Depending on the building class, design criteria and other relevant aspects, PV modules integrated in buildings (BIPV) may require specific, more advanced characteristics as regards fire hazard than those tested by means of IEC 61730-2. As a rule, a minimum fire resistance rating Class A or Class B is needed.

A PV module used in place of classified roofing material or mounted to or above an existing classified roofing material needs to comply with the following:

- Spread-of-flame test
- Burning brand test

These are based on ANSI/UL 790. Sufficient samples shall be provided to create a single test assembly for a single spread of flame and a single burning brand test.

Products that comply with these tests are not easily flammable, afford the measurable degree of fire protection to the roof deck, do not slip from position, and are not expected to produce flying brands

3.1 Spread-of-flame test

A test sample is to be mounted, and luminous gas flame applied, as described in 6.1 of ANSI/UL 790. The test is to be conducted with the module or panel oriented with respect to the test flame, so that the flame impinges only on the top surface of the module or panel.

The sample area of the test material should be not less than 1 m in width for all classes, 1.82 m minimum length for the fire safety Class A, 2.4 m minimum length for the fire safety Class B, or 3.9 m minimum length for the fire safety Class C, as measured from the leading edge of the sample.

For the safety Class A or B test, the gas flame is to be applied continuously for 10 min or until the spread flame (flaming of the material being tested) permanently recedes from a point of maximum spread, whichever is the shorter duration. For a safety Class C test, the gas flame is to be applied for 4 min and then removed.

During and after the application of the test flame, the test sample is to be observed for the distance to which flaming of the material has spread, production of flaming or glowing brands, and displacement of portions of the test sample. The observation is to continue until the flame has permanently receded from a point of maximum spread.



Figure 1 – Spread-of-flame test (LAPI laboratory)

3.2 Burning-Brand test

A test deck is to be mounted as described in 6.1 of ANSI/UL 790, with a few differences as specified in the standard IEC 61730-2.

The **fire safety Class A brand** is to consist of a grid, 300 mm square and approximately 57 mm thick, made of kiln-dried Douglas fir pine lumber that is free of knots and pitch pockets. The dry weight of the finished brand is to be $2000 \pm 150\text{g}$.

The **fire safety Class B brand** is to consist of a grid, 150 mm square and approximately 57 mm thick, made of kiln-dried Douglas fir pine lumber that is free of knots and pitch pockets. The dry weight of the finished brand is to be $500 \pm 50\text{ g}$.

The **fire safety Class C brand** is to consist of a piece of kiln-dried non-resinous white pine lumber that is free of knots and pitch pockets. The dry weight of the finished brand is to be $9.25 \pm 1.25\text{ g}$.

Before application to the test deck, the brands are to be ignited so as they burn freely in still air (times and other details depending on safety class).

Each individual tests, whether fire safety Class A, B or C, is to be continued until the brand is consumed and until all evidence of flame, glow or smoke has disappeared from both the exposed surface of the material being tested and the underside of the test deck.

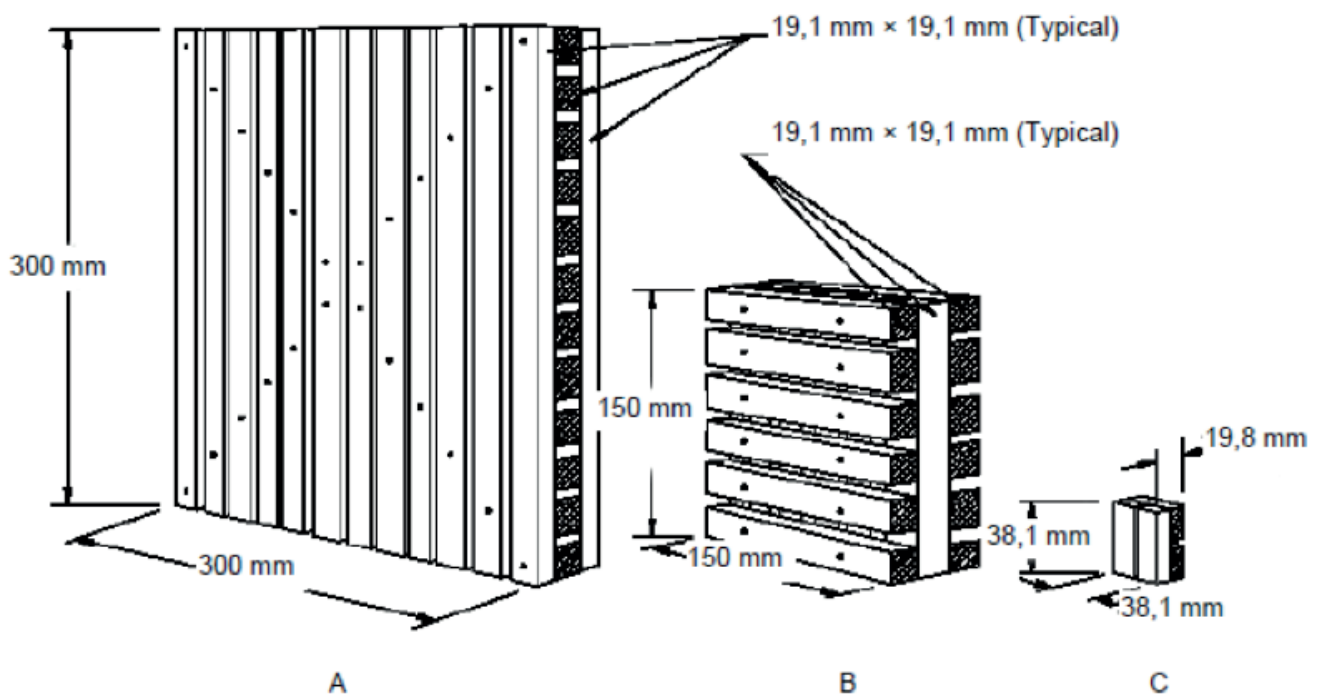


Figure 2 – Burning brand construction

3.3 Conditions of acceptance

At no time during the spread-of-flame or burning-brand tests shall:

- Any portion of the module or panel be blown off or fall off the test deck in the form of flaming or glowing brands.
- Portions of the roof deck, or portions of a module or panel intended for installation integral with or forming a part of the building roof structure, fall away in the form of glowing particles.
- The flame spread beyond 1.82 m for fire safety Class A, 2.4 m for fire safety Class B, or 3.9 m for the fire safety class C rating. The flame spread is to be measured from the leading edge of the sample.
- There be significant lateral spread-of-flame from the path directly exposed to the test flame. Spread-of-flame includes flaming on both of the top surface (the surface to which the external flame is applied) and in any intermediate channel, such as the space between stand-off and integral modules and the roof.

As an example, in figure 3 shows the result of a Class A burning-brand test on a PV module that can be certified only for a Class C fire test. The PV module fails the test

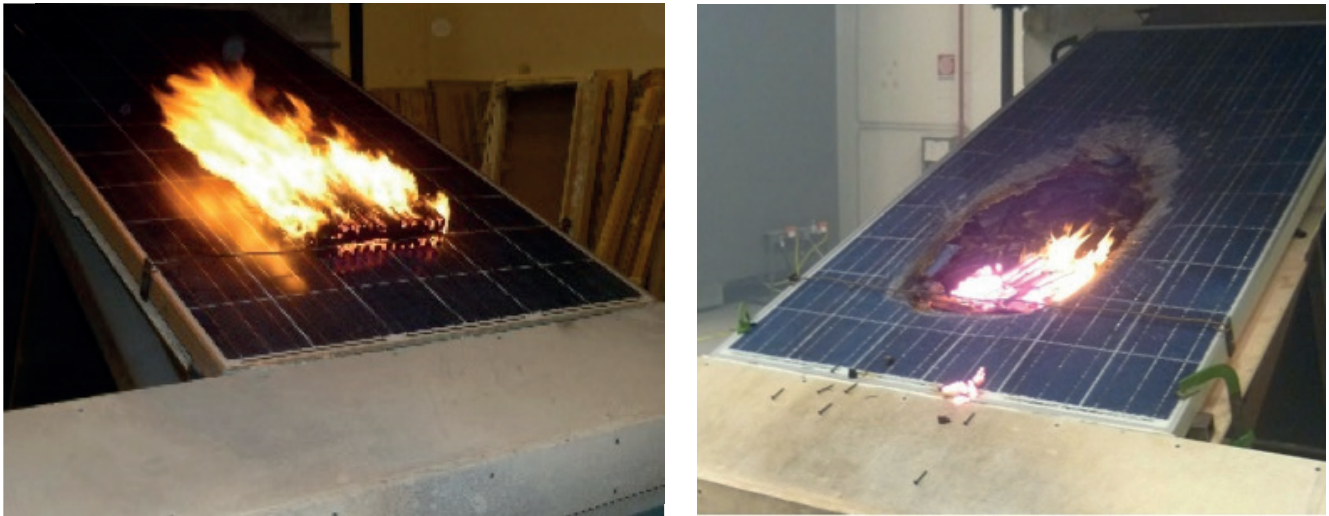


Figure 3 – Example of a Class A burning-brand test – the PV module fails the test (LAPI laboratory)

3.4 Further criteria

The UAE Fire & Life Safety Code of Practice uses as a reference various international Codes and Standards. Indicatively, the followings are considered: GCC Code of Practice; National Fire Protection Association (NFPA); International Code Council (ICC); British Standards (BS); European Standards (EN); Singapore Fire Code; and the Emirates Code of Practice for the Management of Dangerous Goods.

The adoption of further criteria for PV module assessment is valid, in particular, in case of BIPV, where the fire characteristics of PV modules shall fully met the design safety criteria adopted in the building's design. As a reference the following international and national standards give information for tests, which could be used:

- ISO 834-1, Fire-resistance tests – Elements of building construction – Part 1: General requirements
- ISO 834-3, Fire-resistance tests – Elements of building construction – Part 3: Commentary on test method and test data application
- ISO 5657, Reaction to fire tests – Ignitability of building products using a radiant heat source
- ISO 13501-5:2005, Fire classification of construction products and building elements – Part 5: Classification using data from external fire exposure to roofs tests
- ENV 1187-1/4: Test methods for roof coverings under the influence of a thermal attack of burning brands and radiant heat
- ANSI/UL 790: Standard Test Methods for Fire Tests of Roof Coverings
- ANSI/UL 1703-2013, Standard for Safety for Flat-Plate Photovoltaic Modules and Panels

The EU (ENV 1187) and the US approach to PV Fire Risk Assessment (UL 1703-2013) are described briefly in the continuation of the text.

ENV 1187

The ENV 1187 fire test methods, parts 1 to 4, differ in terms of radiant heat, the used brands, additional air flow (wind simulation), tilt angles, amount and size of the demanded test specimen. The pass criteria for each test method are described in EN 13501-5.

In general buildings, integrated PV systems shall be tested in conjunction with a defined mounting system following the installation instruction of the module manufacturer. When testing PV modules, the mounting material and the joints between modules as well as sealing materials have to be considered and included in the test set-up.

UL 1703-2013

After the changes to ANSI/UL 1703 (2013 edition), the fire classification rating approach takes into account the module or panel in combination with the mounting system and the roof covering products over which it is installed. Research tests demonstrated that fire class rating of the PV module alone determined according to ANSI/UL 1703-2012 may not predict the fire performance of the PV module, mounting system, and roof assembly as a system. From a safety perspective, the objective of the work turned towards promoting stand-off-mounted PV systems with improved performance and developing a system-based test that would differentiate high performing from low performing designs. Thus, it was decided to pursue the development of a new fire classification test for the PV modules, the mounting components, and the roof assembly as a system.

The new fire classification rating tests in ANSI/UL 1703-2013 involves the combination of the module or panel, the mounting system, and the roof covering system. Because each of these three components has many products in the marketplace, testing every possible combination of the three components could mean thousands of required tests.

4 DESIGN AND INSTALLATION CRITERIA

This is not practical and could stifle market innovation. In response, a number of considerations and provisions were written into the new standard to reduce the number of required tests.

Basically, the installation of a PV plant on an existing building, depending on the components used and their location, may increase the fire risk of that building. This may be a result of:

- Interferences with smoke ventilation systems (e.g. partial or total obstruction of skylights, impediments to the opening of smoke extraction systems).
- Obstacle to cooling and fire extinguishing of combustible roofs.
- Risk of flame propagation to external or to internal areas of the building (presence of wiring on the rooftop of a building divided into several compartments, modification of the rapidity of fire development in a single compartment building).

Furthermore, possible exposure of firefighters to electric-shock risk has to be considered, given the voltage present in the daylight.

4.1 Basic requirements

PV plants shall be designed, built and maintained in a workmanlike manner. Components and equipment shall be properly made, tested and certificated. For this purpose the following documents shall be considered, as and where applicable:

1. IEC and CENELEC Standards
2. Rules, Standards and Guidelines issued by DEWA
3. Codes issued by UAE Civil Defence, Dubai Municipality and other relevant local institutions.

4.2 Prevention of fire propagation from PV plant to inside the building

The following list contains a minimum set of requirements to be adopted when installing a PV plant on a Low Hazard or Ordinary Hazard building. Further measures may be indicated in the Risk Assessment of the given building or required by the UAE Civil Defence:

- PV modules and their interconnections placed on a roof made of non-combustible material according to ASTM E 136 or EN 13501-3 (class A1);
- Interposition of a non-combustible layer between PV modules with their interconnections and the roof. The non-combustible layer shall be at least one-half-hour fire-rated; and
- Preparation of a new Risk Assessment for a PV plant to be approved by UAE Civil Defence.

In case of High Hazard or Extra High Hazard buildings, a proper set of safety measures shall be adopted and a new Risk Assessment is to be prepared for approval by the UAE Civil Defence.

4.3 Minimum distance from rooftop openings

PV modules, wirings, switchboard assemblies and other equipment shall not cover any ventilation system on the roof, e.g. skylights, smoke extraction systems or chimneys.

In order to ensure correct operation of smoke extraction systems, PV components and wirings shall be placed at a minimum distance of 1 m (top view) from their perimeter. The positioning of the equipment and the installation has to be in line with manufacturer's specifications and recommendations.

In order to avoid a sudden propagation of fire to external building areas, PV components and wirings shall be placed at a minimum distance of 0.5 m (top view) from the perimeter of skylights, chimneys or other openings.

Components and equipment installed internally or externally shall not obstruct in any way the existing means of egress.

Minimum elevation of the PV modules above the roof shall be 50 mm.

4.4 Emergency disconnection and wiring of PV plants

In case of Ordinary Hazard and High Hazard buildings, a manual emergency system for the disconnection of the PV modules from the internal electric plant of the building shall be present. Electrical disconnection may be made on DC side (typically when inverters are placed inside the building) as in Figure 4, or on AC side (typically when inverters are placed outside the building or in an outer cabinet or shelter) as in Figure 5. Although disconnection on DC side is possible as an alternative, it is not recommended. A proper fire-compartmented area can be used instead of an external placement of the disconnecter (DC or AC).

Figure 6 summarizes these scenarios (the manual call point is not necessary in case of One-and-Two-Family Dwelling). The passage of cables from PV modules inside the building before the disconnecter is allowed provided that inside the building they are placed in a channel with a fire-rated protection of at least one-half-hour.

In all above mentioned buildings, except for One-and-Two-Family Dwelling, electrical disconnection shall be operated by means of a manual call point installed at the height of 1.1–1.4 m above floor level and in a plain, accessible, well lit and free of hindrance place. The manual call point shall be close to an external access in order to be easily operated by personnel or firefighters.

The manual call point shall be in line with NFPA 72 and a proper label shall indicate that it triggers the disconnection of the PV plant.

In case of BIPV not installed in fire compartmented areas it is necessary to adopt one of the following further measures:

- The manual call point also disconnects or short-circuits separately each module or groups of modules each of them having an open circuit voltage at STC not greater than 120 VDC.
- Installation of an Arc Fault Circuit Interrupter (AFCI) to protect the DC side from series arcs in accordance with NEC Section 690.11 and UL 1699B. When AFCI detects a failure it disconnects the DC side of the PV plant and generates an audible signal

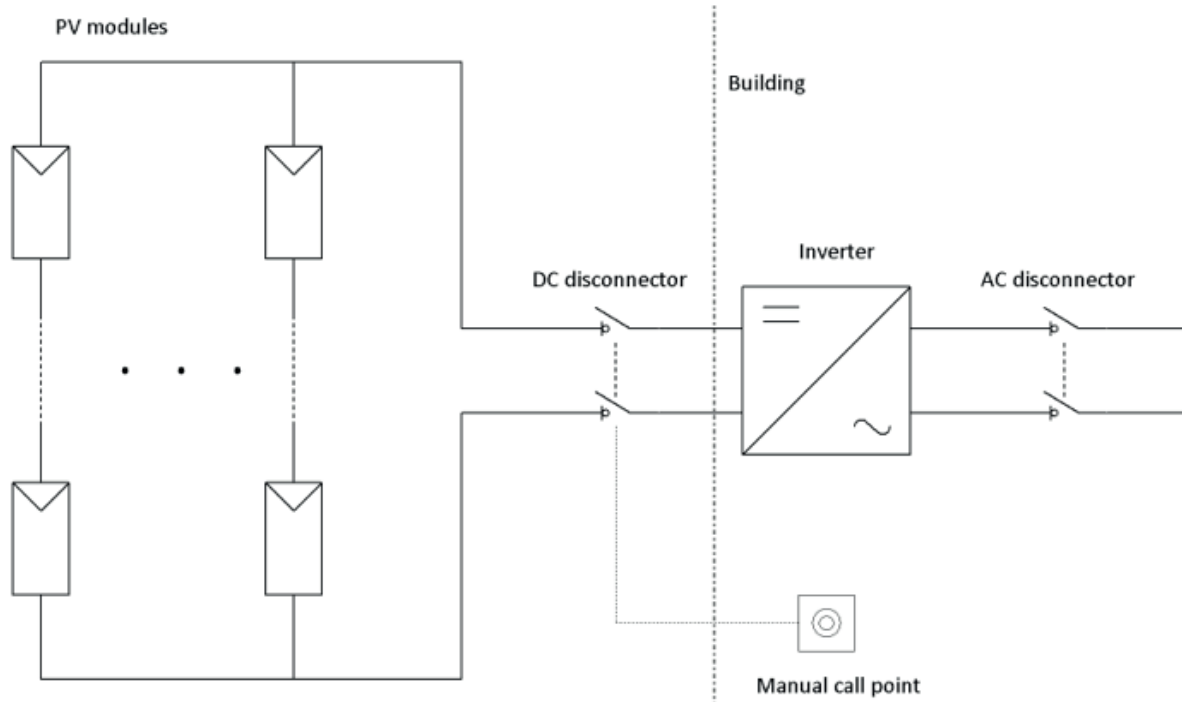


Figure 4 – Disconnection from a manual call point in case of inverter inside the building

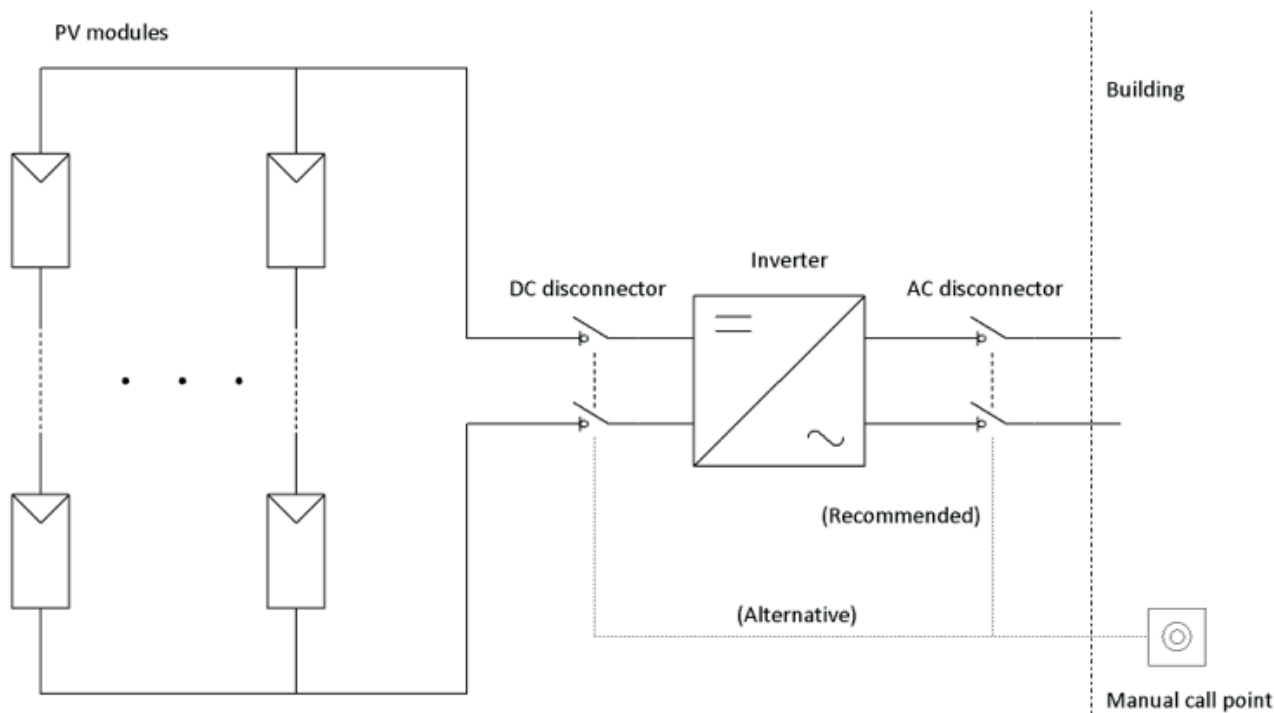


Figure 5 – Disconnection from a manual call point in case of inverter outside the building

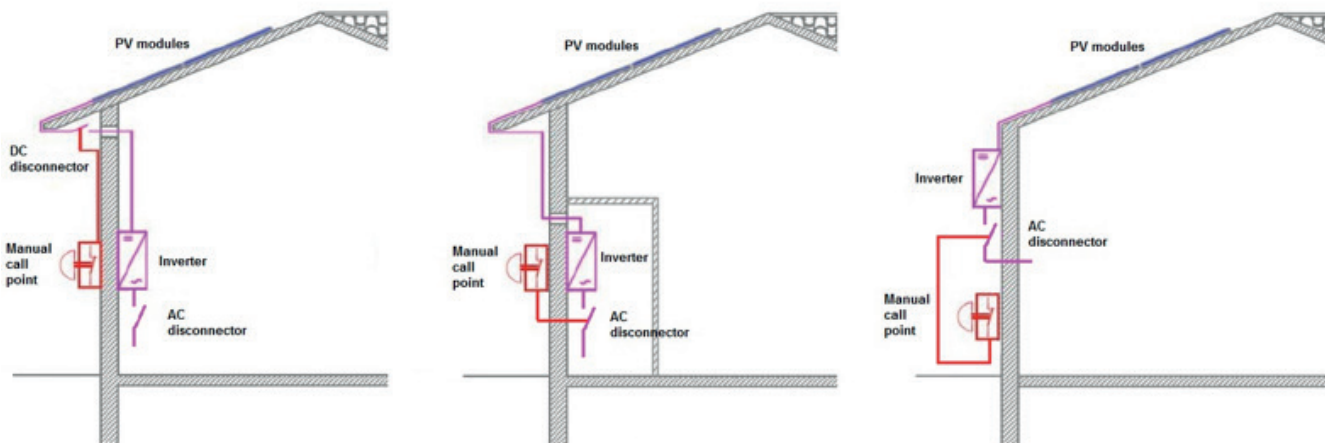


Figure 6 – Possible placement of the inverter and disconnector with the manual call point (when required)

4.5 Labeling and marking

A simplified site plan with the position of PV modules, cables and disconnectors as in the example of Figure 7, shall be exposed close to the main energy meter. If a manual call point is present in the building a further copy of the simplified site plan shall be clearly displayed on the side.

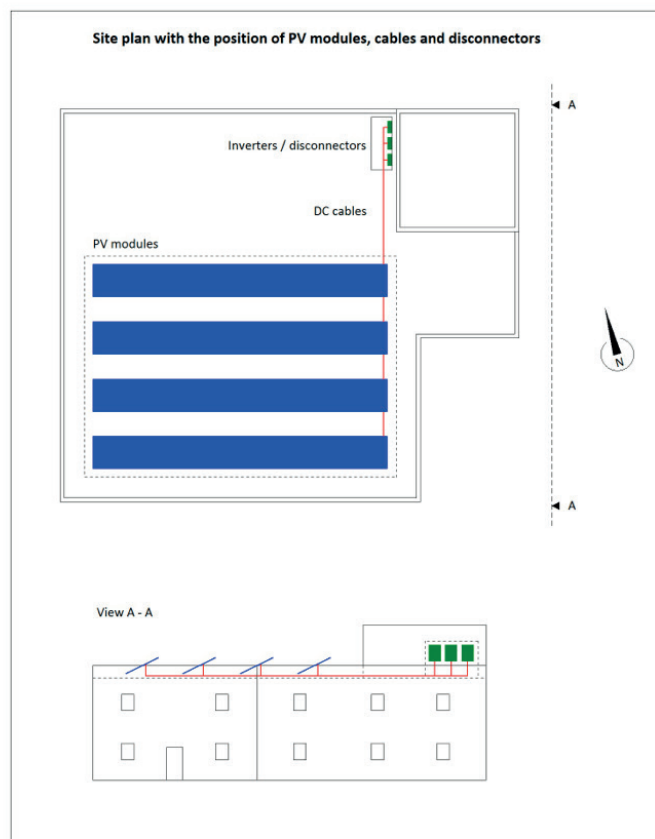


Figure 7 – Example of simplified site plan to be displayed in the building

The area where PV modules, cables and other equipment is located, if accessible, shall be marked by proper signs as indicated in Figure 8. They shall also be placed in correspondence to each PV plant access door. The same signs shall be used to indicate cables before disconnectors and shall be placed every 5 meters along the cable. These signs shall be UV resistant, and shall indicate the DC voltage as the Open Circuit Voltage at STC of the PV array. Their minimum size is 200 × 200 mm (w × h).



Figure 8 – Sign to be used to indicate the presence of a PV plant

4.6 Summary of design and installation criteria

Criteria	Descriptions	Notes
1 Basic requirements	<p>A. Fulfillment of applicable standards, rules and codes:</p> <p>A.1. IEC and CENELEC standards</p> <p>A.1.1. IEC 2-61730 Fire Class C (BAPV)</p> <p>A.1.2. IEC 2-61730 Fire Class A or B (BIPV)</p> <p>A.2. Rules, Standards and Guidelines issued by DEWA</p> <p>A.3. Codes issued by UAE Civil Defence, Dubai Municipality</p> <p>A.N. Any other local competent bodies</p>	Applicable standards as specified in document "Connection Guidelines"
2 Prevention of fire propagation from PV plant to inside the building	<p>A. Low Hazard and Ordinary Hazard buildings, apply one of the following:</p> <p>A.1. Roof made of non-combustible material according to ASTM E 136 or EN 3-13501 (class A1)</p> <p>A.2. Roof segregated from PV modules / interconnections by interposing a non-combustible layer (minimum fire-rating: 30 min)</p> <p>A.3. Submit "risk assessment" document to Civil Defence for approval</p> <p>B. High Hazard or Extra High Hazard buildings:</p> <p>B.1. Submit detail design including safety measures and new "risk assessment" document to Civil Defence for approval</p>	
3 Minimum distance from smoke extraction systems and openings on rooftop	<p>A. Smoke extraction systems, PV modules, components and wirings:</p> <p>A.1. minimum 1 m (top view) from the perimeter of the systems</p> <p>A.2. placed and installed according to manufacturer's prescriptions</p> <p>B. Skylights, chimneys, any openings, PV modules, components and wirings:</p> <p>B.1. minimum 0.5 m (top view) from the perimeter of the openings</p> <p>C. Means of passage, PV modules, components and wirings:</p> <p>forbidden in obstructing positions</p>	

Criteria	Descriptions	Notes
<p>4 Emergency disconnection and wiring penetrations of PV plants</p>	<p>A. Ordinary / High Hazard buildings, manual disconnect on side: A.1. DC when inverters are inside building A.2. AC when inverters are outside building (outdoor or in cabinet/ shelter) Manual call point not necessary in case One-and-Two-Family Dwelling</p> <p>B. Cables penetration inside building without manual disconnect: provided cables inside building are in conduits with fire-rating protection of minimum 30 min</p> <p>C. Position of the manual call point: at 1.4 – 1.1 m above floor level and in plain, accessible, well lit and free-hindrance place, close to an external access for an easier emergency operation</p> <p>D. Standard reference for manual call point: in accordance with NFPA 72 and with label showing it actuates PV plant disconnection</p> <p>E. BIPV not installed in fire compartmented areas: adopt one of the following measures: E.1. Install manual call point disconnects or short-circuits separately each module or groups of modules with $VOC@STC < 120 \text{ VDC}$ E.2. Install Arc Fault Circuit Interrupter (AFCI) to protect DC side from series arcs in accordance with NEC Section 690.11 and UL 1699B</p>	
<p>5 Labeling and marking</p>	<p>A. Install warning signs in any area where accessible PV modules, components and wirings are located: A.1. in correspondence to each access door to the PV plant A.2. to indicate cables before disconnectors every 5 m A.3. signs shall indicate DC voltage as the $VOC@STC$ of PV array</p> <p>B. Size and characteristics of warning signs: B.1. signs minimum size 200 (w) x 200 (h) mm B.2. UV resistant</p> <p>C. Site plan with the position of PV modules, cables and disconnectors to be placed near: C.1. the main energy meter C.2. each manual call point, if any</p>	

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