حكومة دبي
GOVERNMENT OF DUBAI

هيئة كهرباء ومياه دبي
Dubai Electricity & Water Authority

SHAMS DUBAI

SAFETY OF ENVIRONMENT: RECOMMENDATION FOR DRRG SOLAR PV SYSTEMS

VERSION 1.0 – EDITION 2015

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1 INTRODUCTION

1.1 Scope

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

The following documents provide information to Dubai Citizens, Consultants and Contractors on the essential aspects to be considered during the connection of a RRGP to Low or Medium Voltage Distribution Network:

- DEWA Standards for Distributed Renewable Resources Generators Connected to the Distribution Network [1];
- DEWA Connection Guidelines for Distributed Renewable Resources Generators connected to Distribution Network [2].
- PV on building and fire Safety

There is a general agreement on the benefits that PV systems provide for the environment, but one should also be aware that prior to these systems being installed on buildings, all the installation criteria must be met. PV systems installed without adherence to regulations and best practice might not operate adequately and, most importantly, may pose danger to the environment and the people. In principle, rooftop PV systems can create electrical, fire, structural and weather-related hazards, and for this reason there are several codes, standards and guidance documents that if adhered to during design and installation, can safeguard against these risks. In recent years, significant progress has been made in many countries where a large number of PV systems have been installed. And, although progress in Research and Development (R&D) and Standardization is quite remarkable, a few aspects still need to be addressed further.

The purpose of this document is to present information on a variety of risks and hazards associated with PV systems on roof structures.

This document presents standard performance levels of PV Systems and identifies the key installation features or conditions that may impact on performance. These include performance under structural loading, wind loads, seismic activity, hail and sand storms, and debris accumulation. Important information related to fire hazards is also included and the impact of PV modules on roof fire rating, ignition hazards and electrical hazards are examined.

Finally, the lifeline of a PV system is presented and the different types of hazards that can apply at different stages of the plant life are outlined. The lifetime of a plant can be divided in the following four stages:

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

The issues related to the Safety of Environment concerns three stages of the lifetime of a PV system: the permitting stage when the PV system is designed; the constructing stage -that is mentioned with reference to aesthetic and architecture concerns and the decommissioning stage where attention is focused on the disposal of PV modules that reached their end of life.

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

1.2 Definitions

The definitions for most relevant terms contained in the document are listed below.

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

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

NOC (No Objection Certificate) – Certification that allows the actions specified in the same certificate.

Application for Connection – It is filed by an Applicant for the Connection of a new RRG system. This application shall be made in a format prescribed and shall contain the required information.

Connection Agreement – Agreement which sets terms and conditions for connection and operation of a Generator of Electricity into the Power Distribution System.

Grid Connection – The connection of a Renewable Resource Generating Plant (RRGP) to the electrical grid.

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

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

Medium Voltage (MV) Network – A Network with nominal voltage included in the range from 1kV up to 33 kV. In Dubai four voltage levels may be found on MV distribution network, namely 6.6 – 11 – 22 – 33 kV. The 11 kV voltage level is the most wide-spread used.

Network – Plant and apparatus connected together in order to transmit or distribute electrical power, and operated by DEWA.

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

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

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

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

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

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

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

Renewable Resource Generating Unit (RRGU) – Unit that produces power from renewable resources. It can be part of a Generating Plant that includes non-renewable resources. In this latter case, the RRGU in these Standards is the part of the Plant that produces energy without input from non-renewable resource.

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

1.3 Reference documents

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20. General Headquarters of Civil Defence, Ministry of Interior United Arab Emirates, "UAE Fire and Life Safety Code of Practice", Dubai (2011).

21. G Ball, "Grounding Photovoltaic Modules: The Lay of the Land", Solar ABCs Interim Report, Solar America Board for Codes and Standards Report, (March, 2011).

22. C. C. Grant, "Fire Fighter Safety and Emergency Response for Solar Power Systems", The Fire Protection Research Foundation, (May 2010).

2 GENERAL OVERVIEW

The installation of a Solar PV system can have an impact on the environment and as such, this impact needs to be evaluated in advance in order to highlight any possible drawbacks, and to adopt suitable prevention measures.

From a general point of view, the installation of Solar PV systems on rooftop of buildings may have an impact on such sites where people live, work and perform everyday activities. Hence, these sites will be referred to as the “built environment”.

A preliminary concern is related to quite common environmental aspects such as noise, waste, air, and water, in order to assess how these may affect people’s health. On the other hand, it is assumed that the installation of a rooftop system does not impact geology or soils.

The effects of Solar PV systems shall be analysed under a variety of aspects that may have an impact on the safety of the built environment, the severity of which shall be evaluated, so that the most relevant can be managed through adequate design in the initial - permit phase.

2.1 Noise

Solar PV systems are static generators of electricity; hence during operation, PV modules do not generate any audible sound.

However, inverters need cooling by fans or air conditioning, which can be source of noise. Noise is not expected at night when PV generation is off. Noise intensity is correlated to the inverter power and to its constructional characteristics. The PV plant designer is required to install the equipment according to the requirements of the manufacturer in order to ensure it can operate within the allowed temperatures and to prevent excessive (audible) noise.

Noise will be generated also during construction/installation and to a much lower extent during maintenance activities. However, the overall impacts of such noise would be below any typical threshold of significance.

Recommendation

Noise is not expected to be an issue as the electrical equipment is distant from areas where people actually live, or is segregated in service rooms. The detailed design shall take care of noise issues with reference to the actual equipment characteristics and the overall layout of the PV plant.

2.2 Solid waste

In principle, a solar PV system will produce solid waste during construction/installation and decommissioning. The Contractor will be required to clean up all waste material after the installation. With the implementation of best management practices in the handling of waste material from the site, there should be no impact to the environment from solid waste generated from construction/installation. In the decommissioning stage, the Contractor commissioned to dismantle the PV plant shall ensure that all kinds of waste such as electronic equipment is properly managed. However, to ensure proper management of any hazardous waste, there should be a procedure for recycling and the disposal of solar PV modules at their end-of-life.

In fact, PV modules at end-of-life will be the main source of solid waste from the decommissioning of a solar PV plant. Particular attention needs to be placed on submitting PV modules for adequate waste treatment, according to the type of module (e.g. silicon or thin film).

Waste PV modules may be expected also at the installation stage due damage during transportation or mounting stages. In addition, waste could occur during the plant operation stage due to need for module replacement. The management of PV modules at end-of-life is further illustrated in par. 7.1.

2.3 Air Quality

Solar PV systems are passive electric power generation systems. There is no combustion of material that might generate emissions. In fact, Solar PV systems provide a benefit for the environment as they lead to a reduction of CO2 emission. While there may be emission of some fugitive dust during construction and panel cleaning (if compressed air is used), it would be of minimal amount and duration without any expected significant impact on the surrounding air quality.

2.4 Hydrology and water quality

Solar PV panels do require periodic cleaning as to maintain efficiency in power generation. This cleaning would likely consist of a spray wash-down that might include a mild detergent biodegradable household cleaner. Although some fraction of residual water could also ultimately reach off site drainage, such a small amount of dust, debris and wash-down detergents would not be expected to impact water quality.In all cases where the availability of clean water is a concern, cleaning operations must be planned and managed carefully, in order to avoid any waste of water.Alternatively, cleaning may be performed by compressed air, which would eliminate the need for water and detergent.

Recommendation

The designer should define the cleaning procedure, most adequate for the layout of the PV system in the O&M Manual.

3 PERMITTING

Permitting is a process that takes place prior to the construction and installation of the Solar PV system.Permitting process includes the design phase and a thorough Solar PV system risk evaluation in order to be able to integrate all preventive and corrective actions during the design phase and ensure adequate prevention of risks both during construction and the operation of the system.

At the stage of permitting the authority should give clear indication on what is and what is not allowed in order to ensure the PV system is compliant with DRRG Standards [1] and other relevant international codes and regulations and are adhered to when installing a solar PV plant.

As regards the safety of environment, the Dubai Municipality should take charge and ensure all risks are assessed adequately during the permitting stage.

During the permitting stage, namely the process of design approval, Consultants/Contractors will have to provide a detailed design and technical documentation of the PV system, providing any information required to complete this process, as specified in the " DEWA Connection Guidelines for Distributed Renewable Resources Generation Connected to the Distribution Network" [2].

Adherence to the design and relevant standards and rules is a prerequisite in ensuring that both environmental and architectural impact of the PV system is minimized. Normally, the size of the RRGP and its location are the factors which differentiate among the different paths of permitting process. Large (utility-scale) RRGPs, usually ground mounted, have more environmental constraints to deal with like the use of land and the constraints linked to the construction on a wild site. On the other hand, the placement and positioning of the RRGP can be the driver of a deeper analysis of environmental impacts that could be introduced. For instance a large RRGP near an airport might introduce impacts referring to potential sunlight reflection from PV panels, particularly from front glass and frames.

Hence, in the permitting stage, a prospected solar PV plant shall be analysed in reference to any existing aspects that may have an impact on the safety of the built environment. The severity of such impacts shall also be evaluated and mitigation measures will be incorporated into the design.

3.1 Damages on PV installations: Statistical data

Statistical data can confirm that accurate design of a Solar PV system is of paramount importance in terms of safety. Comprehensive statistical data regarding damages that take place on PV installations are rarely available in a very detailed form. To our knowledge, one interesting exception comes from Germany where a private insurance organization, the German Insurance Association (GDV) which is the federation of private insurers in Germany, provided a very precise characterization of such damages in their status report on "Renewable energies – Overall survey of Engineering Insurers within the German Insurance Association (GDV) on the level of technological development and the technical hazard potential" published in May 2010 [3]. The information provided in the report is summarized below.

Statistical data is provided with reference to the number of the incidents recorded in the period 2004-2007, and the repartition of the associated costs. According to the report, the biggest number of incidents has no specific or clear origin, and the related cost is not the most relevant. Fire accounts for about 2% of the total number of incidents that however represent 26% of the observed cost of damages. Overvoltage was recognized to be the source of 26% of incidents, while other relevant number of incidents is due to the pressure of the snow and particularly due to storms. These 9% of incidents due to storms represented 25% of the costs of all damage events. Hence in Germany, fire and storms represent the most significant source of damage costs in PV plants. It is worth noting that the above data reflects the meteorological conditions typical of continental Europe with snow and storms affecting the land at such latitudes, while incidents of other types could arise in Dubai due to the exposure to quite different and harsh weather conditions. Nevertheless, to prevent the consequences of fire incidents as well as to avoid occasional storms effects, PV plants shall be designed and installed by putting very accurate attention to the local rules, the relevant standards and the best practice available from worldwide experience in the PV field. Type of mounting PV panels on buildings

The installation of a RRGP, in particular a solar PV system on a building has different safety implications. It does not affect only the structural load but also wind loads that can be particularly significant in case of storms. There are two main categories of mounting solutions, BAPV and BIPV, both described below.

There are three different BAPV (Building Attached) methods of mounting PV systems on a roof plane structure [4]:

1. Ballast only systems that are weighed down by heavy materials such as concrete to keep them located in the same position (see Figure 1). Ballast-only systems are not attached to the roof structure.

2. Attached roof-bearing systems that use friction clips to secure PV modules to the beams of the framing system. Supports are attached to the building by screws, clips, or adhesives (see Figure 2);

3. Structurally attached on flat roof. They are attached to the roof structure such that the load path is the same for both upward and downward forces (see Figure 3);

4. Structurally attached on tilted roof (see Figure 4).

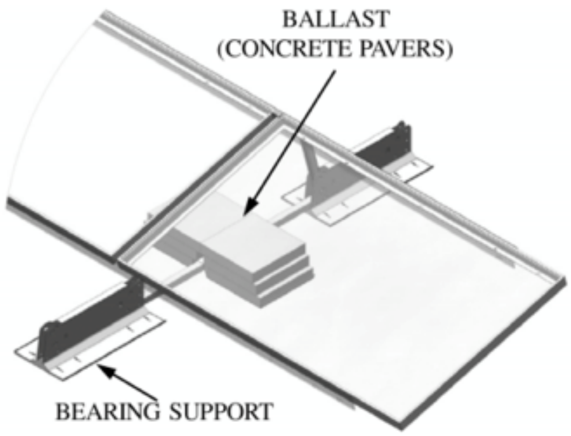


Figure 1 – Ballast only PV System

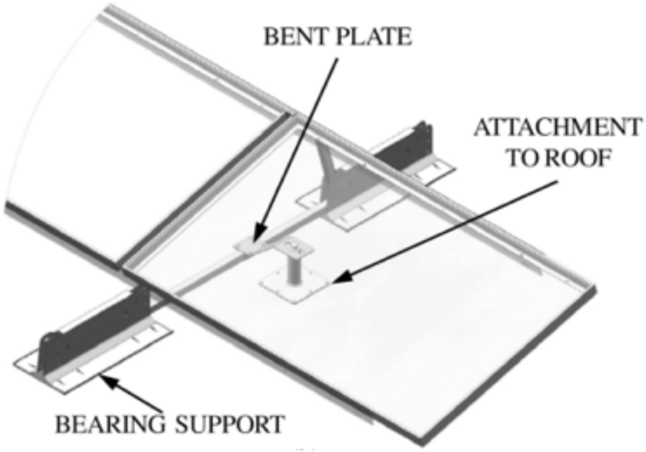


Figure 2 - Attached Roof-bearing PV System

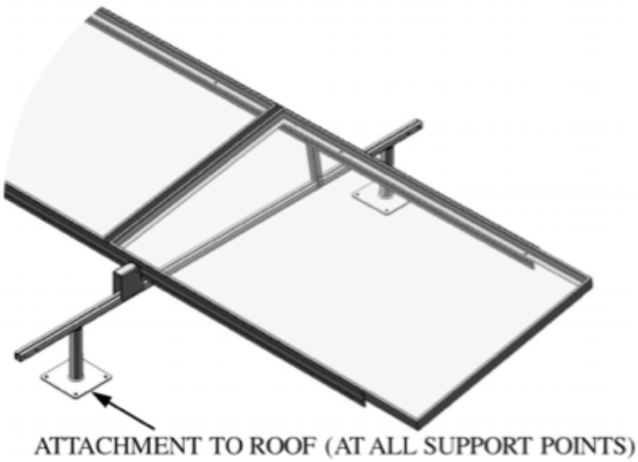


Figure 3 - Structurally attached on flat roof PV system

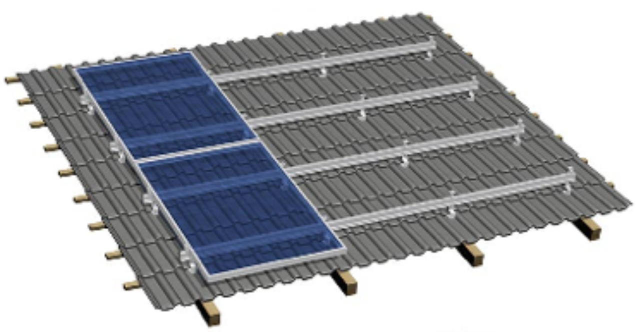


Figure 4 – Structurally attached on tilted roof

A further method for installing PV systems is the BIPV (Building Integrated), which is most similar to the attached roof bearing system. Building-integrated systems are integral with the roof or lay flat on the roof surface such that they do not affect the roof profile (see examples in Figure 5).

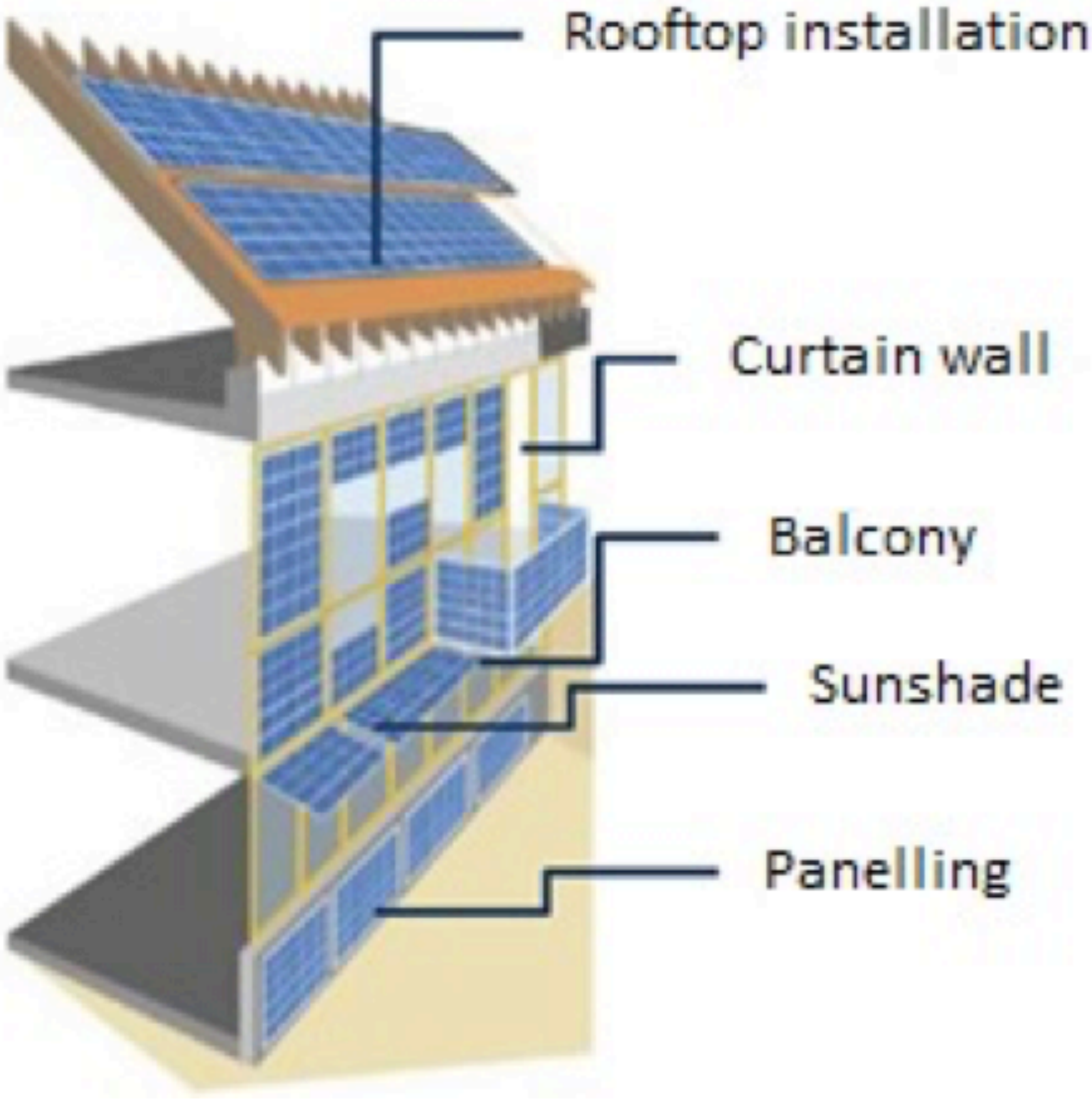


Figure 5 – Examples of BIPV installations

The difference, however, between BIPV and BAPV must be noted:

- **Building-integrated photovoltaic** - BIPV – Photovoltaic modules are considered to be building-integrated, if the PV modules form a building component providing a function as defined in the European Construction Product Directive CPD 89/106/EEC. Thus the BIPV module is a prerequisite for the integrity of the building's functionality (if the integrated module is dismounted it has to be replaced by an appropriate building component).

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

- As an example, Figure 6 shows the table with the mounting categories as defined in the prEN 50583 – Photovoltaics in buildings (Standard proposal, not yet released).

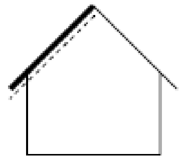
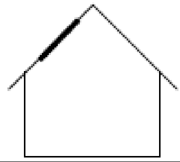
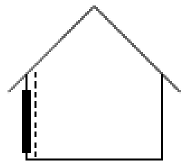
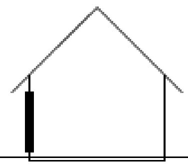
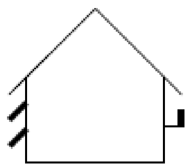
Category A:	**Sloped, roof-integrated, not accessible from within the building**	
	The PV modules are mounted in the building envelope at an angle of 0° - 75° with a barrier underneath preventing large pieces of glass falling onto accessible areas below	
Category B:	**Sloped, roof-integrated, accessible from within the building**	
	The PV modules are mounted in the building envelope at an angle of 0° - 75°	
Category C:	**Non-sloped (vertically) mounted not accessible from within the building**	
	The PV modules are mounted in the building envelope at an angle of 75° - 90° with a barrier behind preventing large pieces of glass or persons falling to an adjacent lower area	
Category D:	**Non-sloped (vertically) mounted accessible from within the building**	
	The PV modules are mounted in the building envelope at an angle of 75° - 90°	
Category E:	**Externally integrated, accessible or not accessible from within the building**	
	The PV modules are mounted onto the building and form an additional functional layer (as defined in 3.1) exterior to its envelope.	

Figure 6 - Mounting categories as defined in the prEN 50583 Standard proposal – Photovoltaics in buildings

3.2 Structural Loading

Installing PV panels onto roofs might introduce overloads that can affect their structural integrity. Not only does the roof support the dead load of the PV system itself, but also external forces introduce structural loading. Outside installations exposes the PV system and also the whole roof assembly, to specific weather conditions such as wind, hail, debris, and the effects of air temperature. These factors may determine stress conditions on PV modules and roof through wind up-lift, thermal expansion, and debris build-up. In some cases, excessive stress conditions can lead to damages or to the destruction of the rooftop. Consequently, this issue is dealt with in great depth in literature:

"Structural engineers must consider each of these loads separately and in combination to identify the worst-case scenario loading situation" - (O'Brien and Banks, 2012) ([4], [6]).

There are guidelines on the installation, maintenance, and testing of PV systems that can help to prevent failure of the system due to extreme external forces.

Guidelines depend on what type of mounting is used to attach the RRGP to the roof.

There are many codes for calculating structural loads and wind loads: for USA and Europe there are, respectively:

- A.S.C.E. Minimum design loads for buildings and other structures. ASCE Standard ASCE/SEI 7-05 American Society of Civil Engineers, Reston, Virginia, 2006.

- C.E.N. (European Committee for Standardization), Eurocode 1: Actions on structures - Part 1-4: General actions, prEN 1991-1-4.6, C.E.N., Brussels, 2004.

Dubai structural design for buildings is based on British codes mainly [7]. There are two codes of reference:

- "Dubai Wind Code" based on Eurocode 1 [8], and

- "Dubai Seismic Code for Dubai" [9].

Reference documents such as the mentioned codes or the "Green Building Regulations & Specifications" [10] are available from the Dubai Municipality.

3.3 Wind Loading

An additional complication of having PV systems on rooftops is that the PV system will be exposed to wind and as a result will have to be capable of withstanding these forces. PV systems must withstand escalated weather scenarios such as windstorms. Uplifts from strong winds can create appreciable additional loads or load concentrations. The very presence of the building changes the aerodynamic load because "there is a complex interaction between building generated vortices and the flow induced by the array, which depends on building height, the setback of the array from the roof edge, and other building parameters." [7].

Dubai has already set a standard for interaction of structures exposed to wind, with "Dubai Wind Code" (2013) [8] that gives the minimum loads that will be considered when designing structures for wind, including the main structural system, external facade elements, and other components that are exposed to wind.

The structure of wind in Dubai is dominated by three different wind phenomena:

- synoptic winds,
- Shamal winds, and
- thunderstorms

The vertical profile of synoptic wind velocities can be modeled by using the standard logarithmic profile model, where the velocity increases monotonically with height and reaches its maximum value at the top of the building. Shamal winds, which are the result of desert environment and climate in the region, reach their peak velocity at a height of about 200 m. The velocity becomes smaller as the altitude gets higher. The thunderstorms typically have their peak velocities around the height of 50 m.

The Wind Code serves conditions for vertical structures, for roofs and slanted structures as PV arrays the reference is still the Eurocode 1: Action on structures, prEN 1991-1-4.6:2002.

There are many codes for calculating wind loads: for USA and Europe there are, respectively:

- A.S.C.E. (American Society of Civil Engineers), ASCE 7-10, Wind actions on structures.
- C.E.N. (European Committee for Standardization), Eurocode 1: Actions on structures - Part 1-4: General actions - Wind actions, prEN 1991-1-4.6, C.E.N., Brussels, 2004.

On the other hand, the wind composition in Dubai is different from Europe mainly because of the following factors:

- Shamal winds;
- Presence of sand and debris during storms.

Therefore, in 2013 the Dubai Municipality issued the Dubai Wind Code.

Recommendation
Referral to the Dubai Wind Code is recommended. However, considering the fact that the Dubai Wind Code is subject to constant improvement and refinement, when important structures are being designed, more sophisticated assessment systems may be necessary (e.g. modelling and simulation) in order to verify or improve calculations.

3.4 Sand Storms

UAE is located in a region prone to frequent dust storms and dusty conditions. Deposits of dust on the surface of PV modules can prevent the solar irradiation from reaching cells through the glass cover. The density of deposited dust, its composition and particle distribution, will have an impact on the power output and current voltage and characteristics of PV modules. The effect of dust accumulation on the power output of solar PV has been the subject of a study based on field tests carried out in Dhahran [12]. Four mono-crystalline PV modules and 2 polycrystalline modules were tested in outdoor conditions for several months and power output was monitored daily.

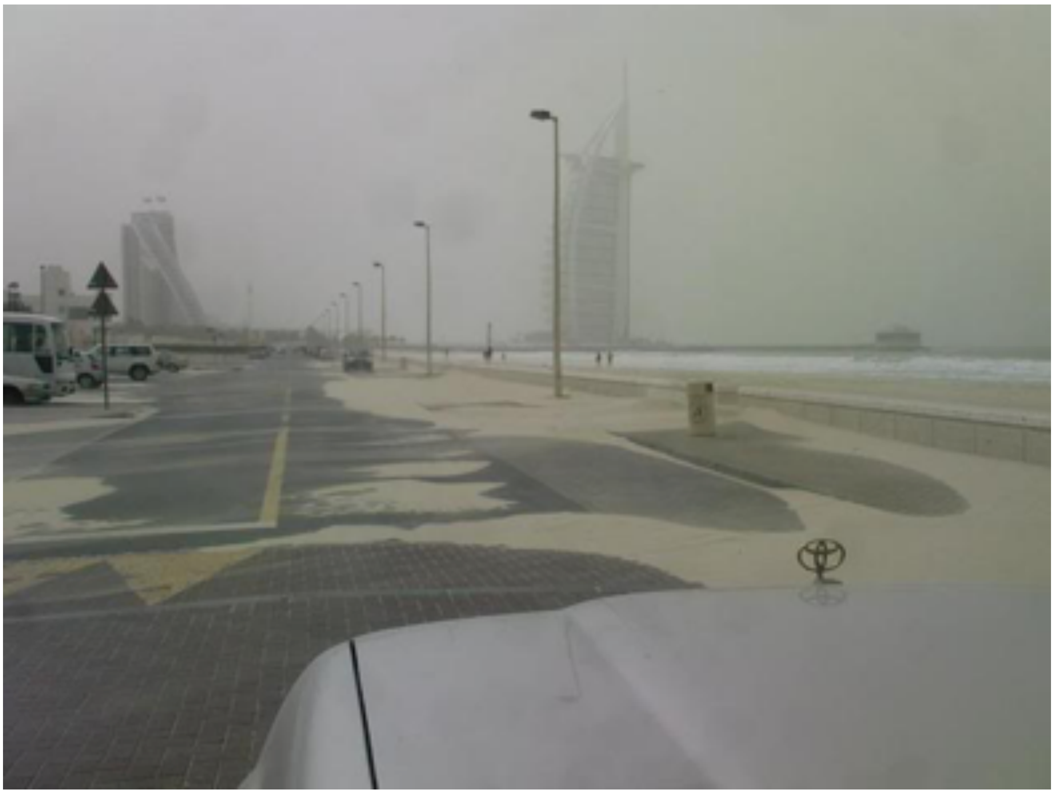


Figure 7 - Effect of sand deposit after sandstorm

It has been observed that the atmospheric dust scatters the solar radiation, in addition to dust deposits on PV surface, which also blocks PV module from direct solar radiation. A long period of PV module exposure to outdoor conditions gradually decreases power output if no cleaning is carried out to remove the dust.

More than 50% power output reduction has been observed over six months of no cleaning. It was also observed that a single dust storm in the month of March decreased the power output by 20% for all modules. The dust density was measured to be 0.0618 milligram/cm2/month. Another observation is that rainfall helps to clean the panels and restore its power output to higher levels. Rainfall, however, is not frequent in the region, so it can›t be relied upon for PV surface clean up. A study also showed that power output was sustained at high levels when it was cleaned up routinely once a week.

In addition to the reduction of performance of the panel it should be noted that sand storms cause degradation of PV modules as well as the wires and other structures. Effects of abrasion can be however tested by means of the IEC 60068-2-68, allowing the designer to select PV modules certified according to this standard, also mentioned in DRRG Standards [1].

Sand deposits may also affect safety because they can produce a "hot-spot" on PV modules, yielding unpredictable consequences.

A "hot spot" is typically produced by a partially shaded cell (or by dust): the shaded part absorbs power form the rest, reaching locally very high temperature. This is dangerous due to very high irradiance leading to very high temperatures in cells and back-sheet (up to 180°C) potentially igniting fire.

Recommendation

A well designed PV plant suited to UAE climate conditions should provide adequate provisions for dealing the effects of sand storms and sand deposit on modules. The periodically removal of sand and debris should be adopted by the owner of the plant as a common practice. At the design stage, the issue of sand removal will need to be determined. When designing the PV plant, the Consultant shall avoid horizontal or very low inclinations of PV modules. The dust and sand removal shall be addressed in the design documents, where proper procedures aimed to avoid or at least to reduce depositions will be included and explained.

In the case of utility, larger scale RRGPs in the rural areas or in places with heavy sand storms, this recommendation is particularly important, and especially if the removal system requires the use of water.

With removal systems, requiring the use of water, the amount of water needed should be clearly indicated. In addition, a comparison among different cleaning system should be made in order to rank the effectiveness of the system itself (i.e. monthly mc desalt water per square meter of PV panel).

3.5 Hail Phenomena

Even though hail phenomena are seldom in the UAE, some recent cases have been recorded, as shown in Figure 8 . Although PV modules are tested and certified against hail damage according to the standard IEC 61215 or IEC 61646, the economic value of the PV system investment can be further secured through adequate insurance.

Figure 8 – Examples of hail in Dubai. Most recent occurrence in March 2014 (Source Gulf News)

Recommendation

The best way to prevent a PV system failure from hail is to have the system tested and approved through a standard testing procedure. Typically, solar panels are already made and tested against hail effects. IEC 61215 or IEC 61646, depending on the PV technology, assure the quality of the PV modules and also provide a classification on the resistance to hail.

3.6 Debris and dust accumulation

Debris accumulation is another major hazard applicable to both roofs and PV systems. Partial shading is a problem that can arise from dirt buildup on module surfaces. Partial shading can decrease the effectiveness of the PV panels, which may dissuade consumers from accepting the new energy source. Having to periodically clean roof-mounted PV panels to eliminate cell shading may subject workers to increased incidence of fall and shock injuries.

Debris build up can be a result of (non-drained) water floating on top of roofs or deposits caused by wind. Not only does debris affect the efficiency of the panel, debris can also quickly turn into a fire hazard. Underwriters Laboratory (UL) created a study to determine how well screens would prevent ignition of debris accumulation between mounted PV systems [13], also providing a significant amount of information on how fire spreads between PV panels and roof tops. In order to address these concerns, the IEC 60068-2-68 standard gains in significance, specifically in environments prone to sand and dust deposits.

In Europe, debris and dust are mainly composed of leaves and other vegetal residues as well as bird excrements, which are all combustible. Although, debris in Dubai is mainly composed of sand deposits, which are difficult to ignite, there may also be considerable bird excrements and nests.

In particular cases, the drop in solar energy efficiency over 3 months without cleaning may reach up to 30-45%. The decrease in solar energy efficiency due to dust storms was measured to be 60% [14].

Figure 9 - Cleaning of PV panels

Debris deposit is composed of dust from pollution, sand and other debris that accumulates on the surface of the cells during operations. Debris can affect the performance of the system and should be removed with a cleaning system. This can be done manually by an operator in case of rooftop mounted PV modules, however for ground mounted (utility-scale) RRGP of large capacity, mechanized systems can be used (Figure 9).

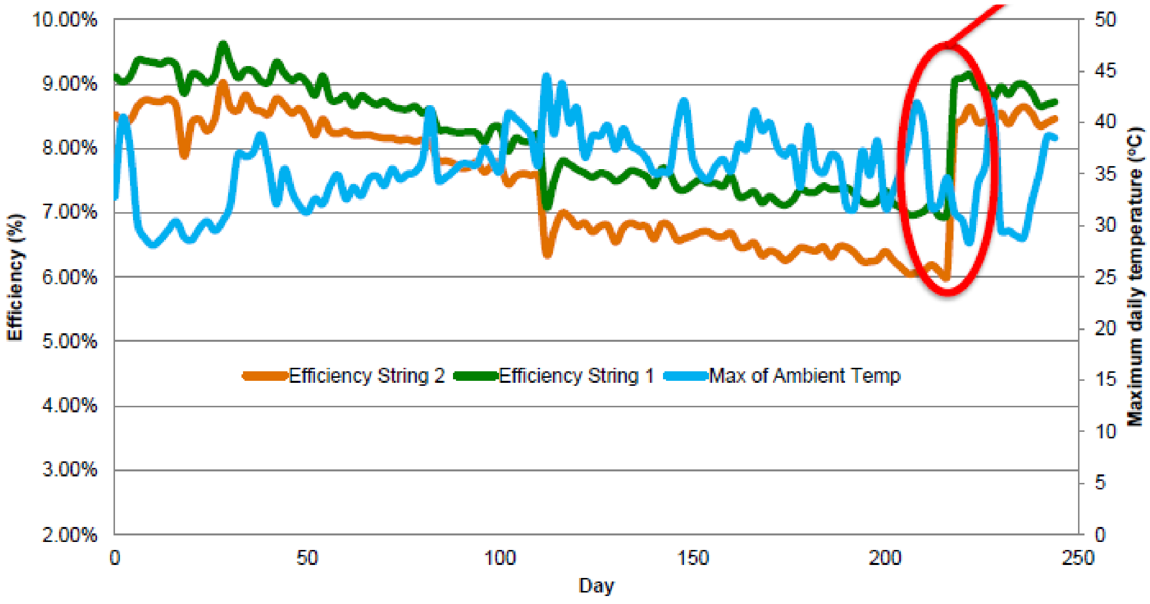


Figure 10 - Efficiency increase after cleaning [[14]]

In the design stage, during the development of the O&M arrangements, a cleaning system and a cleaning procedure should be defined. There are three cleaning methods:

- **Compressed air;**
- **Water based;**
- **Passive, with pre-treatment of the surface;**

The main environmental issue of concern here is the water consumption. A mild biodegradable household detergent cleaner should be used as mentioned in 2.4.

Figure 9 shows the different options available in solving the problem of removing solid depositions from PV modules. Some of them are viable, while others need further development or refinement. For example, the possibility of applying a self-cleaning coating to the surface of the PV panels is promising. Such coating could stop dust and bird excrements from sticking to PV panels, keeping them clean, maintaining their efficiency, and thus ensuring a sufficient power production of the PV system.

Yet the actual efficacy of using coatings on PV panels is still to be thoroughly assessed, and the following aspects should be considered:

- Ideal coating would have mechanical and optical characteristics
- Coating life is at best 3 to 5 years and it is site specific
- Multiple re-application of coatings can degrade performance
- Suitable standards are needed for coatings on PV panels

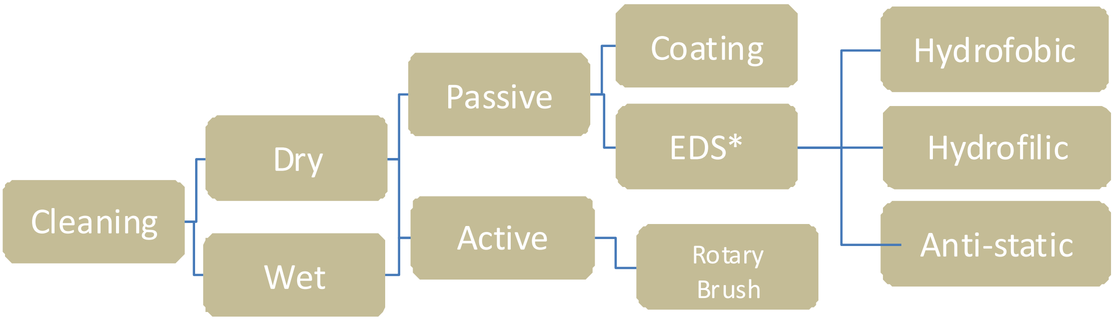


Figure 11 - Classification of cleaning systems of PV panels (* Electro Static Systems: ionization of dust particles) [14]

Recommendation

The Consultant shall include a description of the cleaning and dust/ debris removal procedures in the system's O&M Manual annexed to the documentation that has to be submitted at the Design Approval stage. The identification of a suitable cleaning method shall be the responsibility of the Applicant or his Consultant/ Contractor.

3.7 Sunlight reflection from PV panel surface

In general, light is specularly reflected from any smooth surface where the index of refraction is different from that of the air. The intensity of the reflection will be dependent on the angle between the sun and the solar panel, and the index of refraction of the panel.

Multiple reflections from the front and back surface of the glass are not apparent in solar panels since they are designed to absorb light and convert it into clean, usable energy. Normally solar panels reflect about 4% of incoming light, when, in comparison, a car window reflects about 8%.

An anti-reflective coating or glass can reduce the sunlight that is reflected and increase the amount of sunlight that is absorbed. Most solar panels are now designed with at least one anti-reflective layer and some panels have multiple layers.

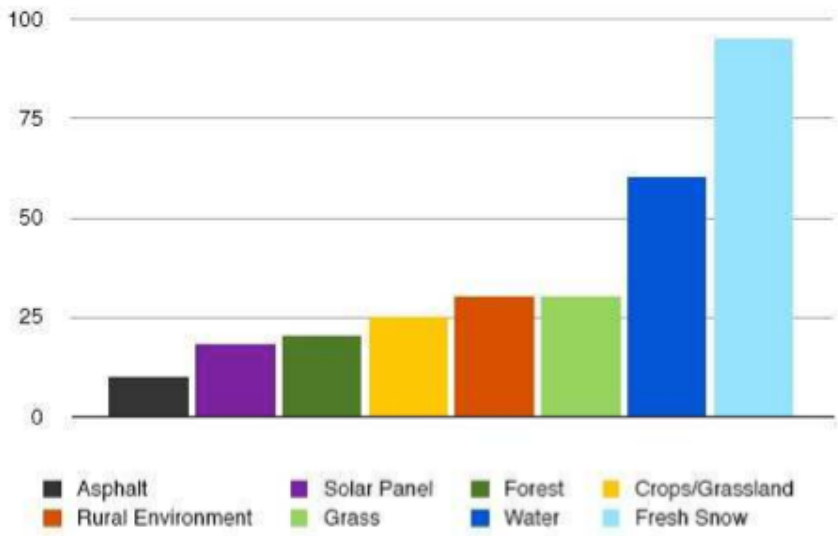


Figure 12 - Comparative reflection analysis [15]

Even if reflection is not a hazard issue in cities and populated areas, the reflections can present a nuisance to inhabitants in nearby buildings. In order to prevent this type of disturbance an assessment of reflections should be required, particularly for installation sites that are close to airport areas.

Recommendation

As a general measure, check the presence of anti-glare on panels especially when the location could affect visual interaction. In addition, the following should be considered:

- Some PV system installations might interact with airport activity. In this case a permit or NOC shall be issued from the Civil Aviation Authority of Dubai.

- Reflections from a PV system on a roof may hit the taller buildings near the installation. Check the PV system layout to prevent disturbance to inhabitants around the RRGP.

3.8 Seismic loads

Although Dubai is spread across an area rated by geologists as Zone 0 – meaning there is absolutely no risk of seismic activity in the area because there are no fault lines – to be on the side of caution, the Dubai Municipality has decided to amend some of the conditions and the requirements of structural design for earthquakes and wind loads [16]. Therefore, in 2013 the Dubai Municipality issued the Seismic Design Code for Dubai.

The updated building code states that buildings with 10 floors or more - as well as schools and hospitals - should be built to withstand quakes between 5.5 and 5.9 (Zone 2B), while residential buildings and offices between four and 9 floors should be designed for Zone 2A. This was decided after a 7.6 Richter scale magnitude quake in Pakistan, caused tremors of magnitude between 4.0 and 5.0 in the UAE.

In line with the new code, the extra weight of the modules and all roof hardware associated with the PV systems (e.g. modules, rails and associated hardware) must also be considered.

Whenever the seismic load has to be considered at design stage, the mounting system adopted for the given installation shall be specified and sufficiently detailed.

SEAOC (Structural Engineers Association of California) "developed a draft document that addresses the seismic hazards associated with rooftop PV systems: "Structural Seismic Requirements and Commentary for Rooftop Solar Photovoltaic Arrays" (SEAOC Report PV1-2012). The seismic requirements document is applied to all the three types of PV systems: ballast-only, attached roof-bearing systems, fully framed (or structurally attached) systems" (the BAPV types of mounting PV modules on flat roofs). Extracts of this document are quoted in the "Commercial Roof-Mounted Photovoltaic System Installation Best Practices Review and All Hazard Assessment" [4], as "for each of the three attachment methods there are separate requirements". For example, in case of fully framed systems, PV support systems that are attached to the roof structure shall be designed to resist the lateral seismic force Fp specified in ASCE 7-05 Chapter 13 (for reference, see also EN 1998 - EUROCODE 8 - Design of structures for earthquake resistance).

In case of PV plant installed on roofs, the seismic load has to be treated as a structural load and in some cases a seismic risk assessment could be required - for instance, when the total weight of panels and mounting structures exceeds the 10% of the total load acceptable on the roof structure.

Recommendation

The seismic load assessment must be considered. As a rule, design criteria comply with the Seismic Design Code for Dubai, although further investigations might be required for special projects.

3.9 Performance of components

The following section lists specific requirements with reference to the performance of selected components of the PV system.

Photovoltaic modules

Safety standards IEC 61730-1/2 are used as prescriptions and test criteria as regards the following:

- Electrical hazards: Dielectric withstands, Ground continuity, Accessibility, Cut susceptibility, Impulse voltage, Reverse current, Partial discharge.
- Mechanical hazards: Module breakage.
- Thermal hazards: Temperature test.
- Fire hazard: Fire resistance.

It is important to mention the 2013 revision of the Standard UL 1703 regarding the system fire class rating of module and panel with mounting systems in combination with roof coverings. Although the actual application of this part in the UL 1703 Standard is still debated it is important to note that although it will be effective only in 2016, further fire test have been introduced:

- Spread of flame at roof and module or panel interface over representative steep sloped roof
- Spread of flame at roof and module or panel interface over representative low sloped roof
- Burning brand on surface over representative steep sloped roof
- Burning brand between module or panel and representative steep sloped roof

Wirings

Usually PV cables comply with National Standards, i.e. 2 PfG 1169/08.07 (Germany), UTE C 32-502 (France), EA 0038 (Spain), CEI 20-91 (Italy), JCS 4517:2010 (Japan) UL 854 Use 2 or Subject 4703 PV-wire (USA), C22.2 No. 271-10 (Canada).

Typical characteristics such as adequate UV resistance, working temperature ≥ 90 °C, proper voltage insulation and sheath are basically required for DC circuits in photovoltaic applications.

The European standard EN 50618 – Electric cables for photovoltaic systems (December 2014) encompasses the basic features for PV cables and applies to low smoke halogen-free, flexible, single-core power cables with cross-linked insulation and sheath; in particular, for use at the direct current side of photovoltaic systems, with a nominal DC voltage of 1.5 kV between conductors, and between conductor and earth.

The Standard EN 50618 also specifies the test required to be carried out on PV cables (electrical and non electrical) and the code designation "H1Z2Z2-K".

Recommendation

During the PV system design stage, designers shall consider all relevant International Standards mentioned in the "DEWA Standards for Distributed Renewable Resources Generators Connected to the Distribution Network", and follow the recommendations included in "PV on buildings and fire safety".

3.10 Ignition hazards

There are many causes of possible ignition in a RRGP. The causes of fire are not associated to the PV panels directly, but are actually linked to fault problems in the wiring and in the construction and maintenance. The following are the main causes of concern:

- The presence of debris under the panels or a surface of the roof with high index of flammability can cause ignition as long as the temperature under the panel is around 90°C or more depending on environmental conditions;
- Short circuit current or improper mounting of electricity boxes can cause ignition;
- Joule effect in the connection cables due to inadequate sizing during design stage or in the construction phase; and
- Possible damages to cables caused by rodents that can be avoided by adopting suitable cable protection.

Although fire classification of PV modules according to IEC 61730-2 (Classes A, B or C) is undoubtedly important, there are several further aspects to consider when PV modules are used in buildings. Characteristics such as thermal behavior, noise isolation and overall transparency may play a fundamental role under both functionality and a safety point of view.

Furthermore, the same PV module might be classified differently as regards the set of standards adopted (e.g. ANSI/UL or CEN). If one considers that each building component usually must comply with several standards in order to be eligible for use, as a rule the choice of suitable PV modules to be integrated into buildings (BIPV) shall take into account all the aspects related to the specific application.

The standards on fire prevention must be taken into account at design stage and during construction. It is also recommended that their correct application is constantly checked by all the subjects involved in the installation of the RRGP.

In addition, DEWA Inspectors (as well as inspectors from other responsible authorities such as DM) should check the installation during the construction phase, namely in the frame of the process for connecting the RRGP to distribution network, in order to avoid any potential hazards or damages.

Control checks shall involve:

- Check the readiness of the wiring connections and general cleanliness and order;
- Check the presence of any debris accumulation under the panels and check the fire ignition risks of the mounting surface.

PV modules add to the complexity of the traditional firefighter tactics that include roof cooling during the fire suppression operations. Although, the electrical and fire hazards associated with electrical generation and distribution systems are well-known, PV systems present unique safety considerations.

For example, in case PV modules are attached to a sloped roof, the air flowing in the gap between the backside of the PV panel and the roof surface can increase fire intensity, causing an even bigger hazard then the one posed with original condition of the roof.

The 2014 edition of NEC (NFPA 70) code states in 690.13(A) Location – “The PV disconnecting means shall be installed at a readily accessible location either on the outside of a building or structure or inside nearest point of entrance of the system conductors.”

It applies also to O&M operations when disconnection is requested:

i. Readily accessible - Capable of being reached quickly for operation, renewal, or inspections without requiring those to who ready access is requisite to climb over or remove obstacles or to resort to portable ladders, and so forth.

ii. Readily accessible provision is primarily for emergency operation. If the disconnect is not mounted in close proximity of the service entrance disconnect (usually within 1 m. of the meter location or service disconnect switch), then a diagram or directory must be provided to clearly identify where the disconnect device is located.

iii. A rooftop disconnect on a residential roof will normally not qualify as a readily accessible disconnect

Recommendation:

Specific recommendations are included in “PV on buildings and fire safety”.

3.11 Weather-related maintenance considerations

The high summer temperature in Dubai is very often associated with very high humidity along the coast. Humidity affects solar PVs in ways comparable to dust accumulation. Water vapor particles might reduce the irradiance level of sunlight that is required for PV panels to reach high efficiency.

The humidity associated with salty particles coming from the sea could reduce the lifetime of some parts of the PV plant: wiring materials, panels, array’s frames, mounting anchor. The designer shall assess and ensure that the PV modules envisaged for installation are certified according to the relevant International Standards, as specified in DRRG Standards [1]. Module certification will guarantee the performance of the modules as well as of their components including cables and connectors.

Recommendation:

The designer shall address maintenance of PV modules with respect to the severe weather conditions and particularly in case of high humidity. It is the responsibility of the Designers to ensure that the PV equipment selected for the installation are in line with all the required Standards as defined in the "DEWA Standards for Distributed Renewable Resources Generators Connected to the Distribution Network" [1]

3.12 Lightning

Lightning protection measures are required by design. The required Standards are listed in the "Standards for Distributed Renewable Resources Generators Connected to the Distribution Network" in Annex "C.9 – Electrical Installations" [1]. In particular, surge arresters (SPD) are specified at design stage because they play a fundamental role as regards the overvoltage protection in a PV plant. Additionally, grounding of PV support structures and PV frames, as well as specific wiring systems, is also part of the general protection measures normally required at design stage.

3.13 Earthing

Earthing is another important issue for the safety of a PV plant installation. The document "DEWA Standards for Distributed Renewable Resources Generators Connected to the Distribution Network" Annex "C.9 – Electrical Installations" [1] lists the standards that need to be adhered to in the design of PV systems and includes earthing (e.g. IEC 60364-5-54: Low-voltage electrical installations - Part 5-54: Selection and erection of electrical equipment - Earthing arrangements and protective conductors). Designers are responsible for designing PV system earthing arrangements according to standards and site conditions (e.g. rooftop PV system in an existing building with earthing system available, or PV system to be designed as a part of a brand new building). According to each specific PV system installation, the designer shall: measure the resistance of the existing earthing system, or assess its performance from available test reports / certifications, and investigate the resistivity of the soil (in principle feasible for new buildings on green sites).

Should a building not be equipped with an earthing system, the designer shall include design and installation of earthing system in the scope of work for the design of a new PV system installation.

4 CONSTRUCTION AND CONNECTION

As regards the roof characteristics and the position of the PV modules, when a PV system is not a BAPV or a BIPV, the modules and arrays have to be mounted on the roof with a proper structure.

Basically, like any other structure that needs to be placed on the roof, there are rules of good practice to follow and guidelines for yielding better system performance in relation to the shape of the roof and other objects already in place on the roof.

Good practice relates to both yielding good system performance and environmental compliance. As discussed, there are many issues to be considered in order not to negatively impact on PV system performance. One further key point is related to the possible presence of shadows on the panel surface under certain conditions (a time in the day or in the season when a portion of the roof or an artifact can affect part of the installation).

Without a doubt, the example shown in Figure 13, represents poor practice where a few technical errors are clearly visible:

- In spite of the little power of the systems, PV modules have several different orientations and inclinations. Unless the power conversion is made by using AC modules or DC optimizers, the system will be rendered rather inefficient.
- The use of long support structures to anchor the PV modules on the roof decreases the wind resistance of the whole structure and may jeopardize the stability of the rooftop.

On the contrary, even if faced with limited surface, a proper design may lead to an excellent result as shown in Figure 14.

Figure 13 – Example of a poor installation on a rooftop

Figure 14 – Example of an excellent installation with PV modules integrated in the rooftop

Recommendation:

Installing a solar PV system on a rooftop entails both integrating the electricity generation function and preserving the aesthetic and architectural values of the entire building. This especially applies when placing modules onto sloped roofs and facades. Consultants have to guarantee an aesthetically effective integration between the building and the PV system during the design phase. For RRGPs to be well integrated with building and landscape environment, Dubai Municipality shall set rules and best practices for installation of RRGP in different environments.

5 O&M – OPERATION AND MAINTENANCE

Operation and Maintenance issues are mostly treated in the "Safety of People" document and in particular in regards to the obligations of the Installer.

As far as environmental safety issues are concerned, Operation and Maintenance needs to address the following:

- Maintenance and cleaning recommendations, especially for rooftop PV systems;
- Use of water and compressed air generation for cleaning;

The identification of suitable cleaning method is a choice of the designer and a responsibility of the Owner as long as they want to avoid a decrease of the performance and the safety of the PV system.

Recommendation

The designer shall issue a description of the O&M procedure for module cleaning and dust removal that will form a part of the documentation necessary for Project Evaluation and/or getting approval at the Design Approval stage.

6 INSPECTION

A RRGP is required to adhere to a range of guidelines, regulations and safety standards. DEWA personnel or other inspection bodies should ensure that the installation of RRGP is carried out to the exact specifications and meets all existing standards and regulations. The inspection shall verify that the design and installation of the plant has been carried out according to relevant specifications and international standards (see list in "DEWA Standards for Distributed Renewable Resources Generation Connected to the Distribution Network").

Issues related to safety and fire prevention to be assessed during inspection:

- Visual inspection of the generator field, including support structure, modules, mounting, cabling and shadowing;
- Visual inspection of the inverter and connecting boxes, including location and mounting;
- Visual inspection of the safety system and labeling, including lightning and overvoltage protection (presence of signal indicating the risk of electroshock);
- Visual inspection of cabling to the inverter, wiring layout and order of cables in the site;
- Earthing system and earthing connections according to design;
- Correct placement and position of cables and electrical distribution boxes;
- Compliance with the standards of electrical equipment used in the plant;
- General cleaning of the site (debris can be a cause of ignition of fire);
- Documentation: readiness and availability also in accordance with local legislation.

In order to carry out the installation of PV systems, a number of other processes are also required:

- Consultants/Contractors companies need to have Solar PV certified professionals on their team
- Guidelines for assessing the compliance of a PV system according to standard and design;
- Guidelines for assessing the operation and performance of PV system;
- Checklist for the above mentioned guidelines and requirements.

Recommendation

Procedures and documents related to the inspection required for the connection of a Solar PV system are detailed in the "DEWA Connection Guidelines for Distributed Renewable Resources Generation connected to the Distribution Network" [2].

7 DECOMMISSIONING

During the decommissioning phase there are a number of issues that need to be considered:

- Correct disconnection of the plant;
- Correct dismounting;
- Separation of recyclable parts;
- Correct disposal or separated materials; and
- Final remediation of the site.

The central issue in the decommissioning phase is the disposal of PV modules. In order to ensure an adequate decommissioning process, an economic scheme for financing the operations should be prepared in advance. Also, the decommissioning plan has to be consistent with the design and construction, particularly in case the RRGP was designed as a temporary installation.

Decommissioning issues include:

- Dismantling of the PV system: One must guarantee the correct disposal and/or recycling of PV panels and other part and materials (i.e. inverter and cables).

- Dismantling of metering devices.

- In case of replacement of PV modules, update of modules database is required. PV modules at their end of life that are definitely treated as a waste will be cancelled from the database.

- Restoration of installation site to its original condition.

Recommendation

A process of disconnection and decommissioning of Solar PV system needs to be carefully coordinated. The most important task to be considered is the appropriate disposal and the recycling of PV modules at end of life.

7.1 Solar Panel Recycling and end-of-life issues

The widespread use of solar photovoltaics has resulted in the installation of tons of panels that, in the future, will stop working due to age and will need to be disposed or recycled. The life duration of a solar panel is between 20 and 30 years. In order to be prepared to correctly dispose of this electric waste, both European Union and USA has defined strategies.

The Waste Electrical and Electronic Equipment Directive (WEEE Directive) is the law of the European Union regulating the treatment of electrical and electronic waste at the end of their life cycle. Since 2012, WEEE has set up the rules for the collection and recycling of photovoltaic panels. The Producers are now responsible for financing the take-back and disposal of the modules. The main goal of the Directive is to reduce waste volumes and foster innovation by making producers of electronic and electric products more responsible.

The European Union has decided to promote the practice of "Extended Producers Responsibility" for PV panels. This means that it will be up to the producers of the modules to collect and dispose of them of at the end of their life-cycle. End-users will not have to pay any additional cost to dispose of the PV modules and will have to be instructed by the producers on how to proceed with the take-back of the modules.

According to WEEE, there are four categories of producers: manufacturers, distributors or resellers, importers and internet or distance sellers. When first introducing panels to the multiple markets of the EU Member States, they must all comply with national WEEE regulations of these markets by adhering to a series of requirements, including a number of administrative and financial duties with the designated authorities. Producers are a key figure in the disposal and recycling of photovoltaic modules because they are ultimately responsible for the panels they sell in the European Union.

In the United States there is no federal directive on recycling electronic equipment and only 17 states ban disposal of electronics in landfills. In fact, among the 50 states, there are 50 different sets of waste reduction regulations, much like there are for the solar energy permitting process. But a number of individual cities and counties have started programs to support the recycling of electronic equipment – including PVs – based on the work of several independent organizations.

Recycling PV materials, especially the aluminum, silver, and rare earth materials, presents unique challenges since they require multiple technologies and variations within specific types of recycling technologies to completely separate the PV module components. The recycling rates are interesting (100 percent recovery of aluminum, 95 percent of glass, and 30 percent of rare metals) and there are already companies involved in this growing business.

Recommendation

It is recommended to follow the regulations in force in Dubai for the disposal of Waste Electrical Electronic Equipment including specific regulations for recycling and disposal of solar panels at their end-of-life.

ANNEX A – SUMMARY OF RECOMMENDATIONS

Item	Verification required	Recommended practice	Stakeholder	Notes
Structural Loading	To be checked before releasing a "Building permit"	Applicant issues PV design with reference to: A. Dubai structural load code for evaluating the load of plant; B. UL 2703 - mounting and clamping devices Dubai Municipality verifies the compliance of the project to the applicable standards and current practice before releasing the building permit	A. Applicant, B. Dubai Municipality.	Designers shall monitor the evolution of standards particularly prEN 50583 and any novel approaches to integration of PV in buildings (BIPV). SUPPORT DOCUMENT Checklist "B.1 Structural Loading and Wind Loading" in ANNEX B, to support evaluation of PV plant design.
Wind Loading	To be checked before releasing a "Building permit"	Applicant issues PV design with reference to: A. PV modules tested according to IEC 61215 or IEC 61646 (load of 2400 Pascal on front and rear faces) B. Dubai Wind code for evaluating the plant behavior; Dubai Municipality verifies the compliance of the project to the applicable standards and current practice before releasing the building permit	A. Applicant, B. Dubai Municipality.	DEWA check of PV modules compliance to standards in A: is already envisaged during verification of PV design. Designers shall monitor evolution of standards on novel approaches to assessment of PV structures. SUPPORT DOCUMENT Checklist "B.1 Structural Loading and Wind Loading" in ANNEX B, to support evaluation of PV plant design.

Item	Verification required	Recommended practice	Stakeholder	Notes
Sand Storms **Debris and Dust accumulation**	To be checked before releasing a "Building permit"	Sand removal procedures are to ensure that a method is specified to clean modules surface after a sand storm, in order to avoid sand deposits that can ignite PV module (hot spot). Applicant issues PV design with reference to: A. Modules compliant with IEC 60068-2-68 (environmental testing - dust and sand resistance); B. O&M report includes procedure for modules cleaning and dust removal. Dubai Municipality verifies the compliance of the project with applicable standards and current practice, and that the Applicant's O&M report includes provisions for dust/sand removal procedures before releasing the building permit.	A. Applicant, B. Dubai Municipality.	DEWA check of PV modules compliance to standards in A: already envisaged during verification of PV design. The Applicant to be provided with recommendation to design with modules inclination equal or higher than 10° to prevent excessive sand accumulation.
Hail Phenomena	None (already taken into account by means of PV standards)	Applicant issues PV design with reference to: A. IEC 61215 or IEC 61646 according to the technology of the solar PV module	A. Applicant.	DEWA checks PV modules compliance to standards in A: already envisaged during verification of PV design.
Sunlight reflection from PV panel surface	To be checked before releasing a "Building permit"	Assess the presence of anti-glare on modules when PV plant location could affect visual interaction, i.e.: A. Reflections in conventional structures B. Plants close to airport area which may be a potential source of light reflection: at preliminary design a permission (e.g. NOC) shall be asked from the Airside Compliance Authority. Dubai Municipality and/or General Civil Aviation Authority (GCAA) verify compliance of project to current practice.	A. Dubai Municipality B. Airside Compliance Authority	The minimum distance from airport needs to be assessed, for which this NOC request shall be considered mandatory (dependent on local codes and laws).

Item	Verification required	Recommended practice	Stakeholder	Notes
Seismic loads	To be checked before releasing a “Building permit”	Every PV module support structure on top of roof shall be verified according to Dubai Seismic Design Code (2013). Applicant issues PV design with reference to: A. Dubai Seismic Design Code to assess PV plant structures. Dubai Municipality verifies the compliance of the project with applicable standards and current practice before releasing the building permit.	A. Applicant, B. Dubai Municipality.	According to “Dubai Seismic Design Code (2013)” buildings of or higher than 10 floors as well as schools and hospitals shall be built to withstand quakes between 5.5 and 5.9 (Zone 2B). Buildings from 4 to 9 floors shall be designed for Zone 2A. See Checklist in ANNEX B, checks suggested in “B.1 Structural Loading And Wind Loading”.
Weather-related maintenance considerations	None	Applicant shall define the maintenance of the PV Plant in the O&M procedures, specifying minimum time before recheck of integrity of component and electrical parts.	A. Applicant B. DEWA	DEWA check of PV modules compliance to standards in A: already envisaged during verification of PV design.

Item	Verification required	Recommended practice	Stakeholder	Notes
Performance of components	To be checked before releasing a "Building permit"	PV Modules: Fire resistance class according to IEC 61730-2. All PV modules shall have IEC 61730-2 test certificate. BIPV: fire class of PV modules and other components of PV plants shall be in accordance with the fire class of the given structure. Installations different from BIPV: a proper assessment of fire hazard shall be done in buildings subjects to fire safety certificate. All other cases: use "C" fire class PV modules unless specific safety requirements necessitate a higher fire class and/or further safety measures. Wirings: Typical requirements for DC circuits in PV systems: UV resistance, working temperature >90 °C, proper voltage insulation and sheath. Recommended reference EN 50618:2014 "Electric cables for photovoltaic systems" (December 2014). Applies to low smoke halogen-free, flexible, single-core power cables with cross-linked insulation and sheath. In particular, for use at the DC side of PV systems, with nominal DC voltage of 1.5 kV, between conductors, and between conductor and earth. Dubai Municipality is advised to follow international standards required for the design of RRGPs according to the "Standards for Distributed Renewable Resources Generators Connected to the Distribution Network".	A. Dubai Municipality B. Civil Defense	There are no specific international standards on fire prevention for PV plants, but some accidents that occurred in Europe and US indicate the need to improve fire prevention, particularly for those installations most critical according to fire hazards. At present, several committees of different countries with the contribution of Civil Defence / Fire Brigades have issued guidelines for designing PV plants with the aim of preventing fire hazards. Dubai Civil Defence should be advised about that as the Stakeholder expected to deliver NOC for Installation of PV plant on rooftop of buildings for which a "fire safety certificate" is required. Ignition hazards. DEWA checks PV modules compliance with standards in A: already envisaged during verification of PV design. SUPPORT DOCUMENTS Checklist "B.2 Fire hazard for PV on buildings" in ANNEX B, to support designers, or inspectors involved in fire hazards evaluation. Report "PV on Buildings and Fire Safety", highlighting fire prevention measures that shall be adopted at design level.
Ignition hazards	To be checked before releasing a "Building permit"	Ignition hazards can be reduced to nearly null risk when: A. Standards are fulfilled (DEWA to check PV design at proposal); B. Accurate PV module and DC/AC wiring installations by the Applicant (PV plant tester declaration)	A. Applicant B. DEWA	

Item	Verification required	Recommended practice	Stakeholder	Notes
Construction	Check PV module mounting in built environment	Prevent the installation of a PV system with capacity in excess as compared to the surface available for placing the PV modules, thereby altering the building envelope This concerns both functional and aesthetic aspects (safety of build environment). It can be addressed at design level, to have PV plants efficient and well integrated with building and landscape environment. Dubai Municipality is advised to adopt best practices or set new rules for aesthetic principles of RRGP in different environments, with reference to the three different cases of RRGP usually recognized: completely integrated, partially integrated and ground mounted.	A. Applicant B. Dubai Municipality	Designers are expected to evaluate the issues involved in mounting and integrating PV modules on buildings according to best practices and standards. See Checklist "B.1 Structural Loading And Wind Loading" in ANNEX B.
Decommissioning		Applicant has to mention that a decommissioning phase will take place at end of life of equipment, particularly for modules in the design documentation. DEWA is expected to release a "demolition" NOC for disconnection of PV plant before decommissioning / dismantling operations start. Dubai Municipality is advised to oversee dismantling according to Dubai current practice and laws.	A. Applicant B. DEWA C. Dubai Municipality	DEWA to issue a "demolition NOC" for managing the disconnection of RRGP. Disposal of PV modules as well as of other equipment according to local rules issued by Dubai Municipality.

ANNEX B TO REPORT "SAFETY OF ENVIRONMENT – MAIN ISSUES"

B.1 – STRUCTURAL LOADING AND WIND LOADING

CHECKLIST

Ref.	Item to be checked	Result	Notes
1.	The placement of the structures complies with the project (Rooftop, Façade, Canopy, Ground, etc.)?	☐ Y ☐ N	
2.	The tilt of the PV modules complies with the project?	☐ Y ☐ N	
3.	The azimuth of the PV modules complies with the project?	☐ Y ☐ N	
4.	The dimensions of the PV modules are those specified in the project?	☐ Y ☐ N	
5.	The material used for the structures corresponds to the project (hot-dip galvanized steel, aluminium, stainless steel, etc.)	☐ Y ☐ N	
6.	Length, cross-section, diameters and thickness of the structures are those specified in the project?	☐ Y ☐ N	
7.	Structures are painted / covered / galvanized (or left unchanged) as specified in the project?	☐ Y ☐ N	
8.	Manufacturer's recommendations have been adopted in order to allow for the maximum expansion / contraction of the modules under expected operating temperatures?	☐ Y ☐ N	
9.	Proper care has been taken to prevent electrochemical corrosion between dissimilar metals?	☐ Y ☐ N	
10.	Methods used for attaching modules to frames and frames to buildings or to the ground are those specified in the project?	☐ Y ☐ N	
11.	PV modules and structures, in their entirety, are mounted according with manufacturer's recommendations?	☐ Y ☐ N	
12.	Behavior of modules supporting and/or anchoring structure was checked for concerned stress (e.g. load, wind, seismic) conditions according to codes and rules in force?	☐ Y ☐ N	
13.	Reflection issues?	☐ Y ☐ N	
14.	Proximity to airport area?	☐ Y ☐ N	
15.	The given minimum elevation of PV modules above the roof is 50 mm?	☐ Y ☐ N	

B.2 – FIRE HAZARD FOR PV ON BUILDINGS – CHECKLIST

B.2.1 - CHECKLIST FOR ALL BUILDINGS

Ref.	Item to be checked	Result	Notes
1.	Have the PV modules successfully passed the fire tests according to IEC 61730-2?	☐ Y ☐ N	
2.	Is the fire class of PV modules compatible with the fire class of the roof or of the structure on which the PV modules are placed?	☐ Y ☐ N	
3.	Is the maximum DC voltage of the PV plant not higher than 1000 V?	☐ Y ☐ N	
4.	Are the switch-disconnectors on DC side visible and reachable?	☐ Y ☐ N	
5.	Cables, connectors, plastic boxes, cable ducts and all potentially flammable components are labelled as fire-retardant according to applicable standards against flame and fire propagation?	☐ Y ☐ N	
6.	Is the PV plant accessible by means of proper corridors (at least 1 m width) along the perimeter and between the sections of the PV array according to the project? Has the rooftop or PV plant area a safe access (through stairs or other means)? Only in case of BIPV: The above provisions could be replaced by a proper placement of the PV system on the building (e.g. PV modules fully accessible only on the rear), and by specifying the procedures to guarantee a safe access to PV equipment.	☐ Y ☐ N	
7.	Are all smoke and heat extraction systems not covered by PV modules and/or other equipment and their operation is not in any cases limited?	☐ Y ☐ N	
8.	The given minimum distance is kept from PV components and wirings to smoke extraction systems (1 m) and skylights, chimneys and similar equipment (0.5 m)?	☐ Y ☐ N	
9.	Proper measures have been taken in order to prevent fire propagation inside the building? – Non-combustible roof, or – non-combustible layer between PV and roof, or – new risk assessment for the building	☐ Y ☐ N	
10.	In case of BIPV: – the PV system is installed in a fire compartment or – the manual call point disconnects separately each module or – a proper AFCI is installed on DC side	☐ Y ☐ N	

11.	A simplified site plan is properly placed in the building?	☐ Y ☐ N	
12.	Proper signs are used to indicate the area occupied by the PV plant and its wiring?	☐ Y ☐ N	

B.2.2 - CHECKLIST FOR ORDINARY HAZARD AND HIGH HAZARD BUILDINGS

Ref.	Item to be checked	Result	Notes
1.	In case of a high hazard building does the Risk Assessment take into account the presence of the PV plant?	☐ Y ☐ N	
2.	All components, wires and equipment fed by the PV array and before a switch-disconnector are placed outside the building or are in a fire compartmentalized room?	☐ Y ☐ N	
3.	Except for One-and-Two-Family Dwelling, it is possible to disconnect a portion of PV plant fed by the PV array by means of an emergency remote control (manual call point)?	☐ Y ☐ N	
4.	Are PV modules fitted individually with remote-controlled disconnectors?	☐ Y ☐ N	