هيئة الكهرباء والماء
Electricity & Water Authority
Kingdom of Bahrain

Technical Expert to develop grid connection guidelines and standards for the Kingdom of Bahrain

Design recommendations for Solar PV Systems

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1 SCOPE

The present document outlines the main issues that have to be taken into account when designing a solar photovoltaic (PV) system. The topics are mainly related to a low voltage and medium voltage grid connection range and, mainly rooftop mounted.
There is a general agreement on the benefits that PV systems provide to the environment, but one should be also aware that when these systems are installed on buildings all the suitable installation criteria must be adopted. Installations made not in accordance with best practice might not work properly and, most important, may reveal to be a source of danger. In principle, rooftop PV systems might create electrical, fire, structural, and weather-related hazards and for this reason there are several codes, standards and guidance documents that address any specific aspects in order to prevent all the possible risks. In past years, significant progresses have been made in many countries where a large number of PV systems has been installed: although a few aspects are still unsolved and there are still gaps that need to be pointed out, nowadays we assist to a general improvement in terms of regulation and standardization.
The purpose of this document review is to compile information on selected hazards and damage potentially created by the installation and operation of PV systems on roof structures.
The report summarizes the basic performances associated with PV panel installation practice and identifies the key installation features that may impact on them. These include performance under structural loading, wind loads, seismic loads, as well as hail, sand storms, and debris accumulation.[1]
The report reviews existing information in the literature related to best practices for installation to address the performance issues described above. A comprehensive reference section is provided.
Finally, recommendations are provided for selected topics in order to support Consultants and Contractors involved in PV installations.

1.1 Definitions

The most relevant definitions for the present document are listed below.
AFCIs – Arc Fault Circuit Interrupters: devices that protect specifically against arc faults. They automatically trip a circuit when they detect dangerous electric arcs. These devices are also known as Arc Fault Detection Devices (AFDDs).
Application – It is filled by an Applicant for a new Solar PV Connection. The application shall be made in a format prescribed and shall contain the required information.
BIPV – Building integrated photovoltaics – photovoltaic materials that are used to replace conventional building materials in parts of the building envelope such as the roof, skylights, or facades.
BAPV – Building applied photovoltaics – photovoltaic materials that are used to substitute conventional building materials in parts of the building envelope such as the roof, skylights, or facades.
EWA – Electricity and Water Authority. EWA operates the production transmission and distribution of electricity and water in the of the Kingdom of Bahrain.
Grid Connection: The connection of a PV System or Plant to the electrical grid
Low Voltage (LV) – according to international standards, a voltage below 1kV AC or 1.5kV DC. The actual range of the LV distribution system depends on the county. The Bahraini LV distribution system is operated at 400/230V AC.

[1] Important features related to fire hazards, that include the performance of PV modules and the impact on roof fire rating, the ignition hazards and the electrical hazards, are analysed in another document.

Medium Voltage (MV) – according to international standards, a voltage between 1kV AC and 35kV AC. Bahrain operates a 11 kV distribution system that can be referred as MV or HV system.

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

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

Producer: Any entity authorised by the Regulatory Authority to produce electricity connected to the network in the Kingdom of Bahrain. 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.

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

1.1 Reference documents

The following documents are here quoted as a reference:

[1] Commercial Roof-Mounted Photovoltaic System Installation Best Practices Review and All Hazard Assessment; Final Report; Dpt. Fire Protection Engineering; Univ. of Mariland, College Park, MD, USA (February 2014)

[2] Wind Load Analysis for Commercial Roof-Mounted Arrays, O'Brien and Banks, 2012 (http://solarprofessional.com/print-issue/june-july-2012)

[3] A. Asker, "Structural Design Statement and program analysis for buildings", Conference Sustainable Construction, 27-11-2013

[4] G.A. Kopp, S. Farquhar, M.J. Morrison, "Aerodynamic mechanisms for wind loads on tilted, roof-mounted, solar arrays", Journal of Wind Engineering and Industrial Aerodynamics , Volume 111, December 2012, 40-52

[5] A. Asker, "Implementing the new building codes to deliver earthquake-proof buildings", Conference Sustainable Construction, 27-11-2013

[6] M. Alshakhs, "Challenges of Solar PV in Saudi Arabia" Submitted as coursework for PH240, Stanford University, (2013)

[7] L. Sherwood, B. Backstorm, B. Brooks, A. Rosenthal, "Fire Classification, Rating Testing of Stand-Off Mounted Photovoltaic Modules and Systems", Solar America Board for Codes and Standards, (August 2013)

[8] R. Bkayrat, "Developing Solutions for the Environmental Challenges to Deploying PV Plants in Desert Areas", Solar Middle East Conference Proceedings (2013)

[9] Spaven Consulting, "Solar Photovoltaic Energy Facilities: Assessment of Potential for Impact on Aviation", Report No.10/344/RPS/1, January (2011)

[10] Pace University, "Inspector Guidelines for PV Systems", Brooks Engineering Vacaville, CA - US, (2006)

[11] California Energy Commission, "A guide to photovoltaic (PV) system design and installation", Prepared by: Endecon Engineering, (2001)

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

2 MECHANICAL DESIGN

The implementation of solar PV systems require a building permit is issued by the concerned authority, usually the local Municipality.

The building permit process includes the phase of design as well the risk evaluation for the solar PV plant in order to put in place, at design stage, all necessary preventive and corrective measures to prevent any hazards occur during construction or operation.

At this stage the authority may also give clear indication on what is allowed and what not, and how to prevent any actions that don't comply with the given permit.

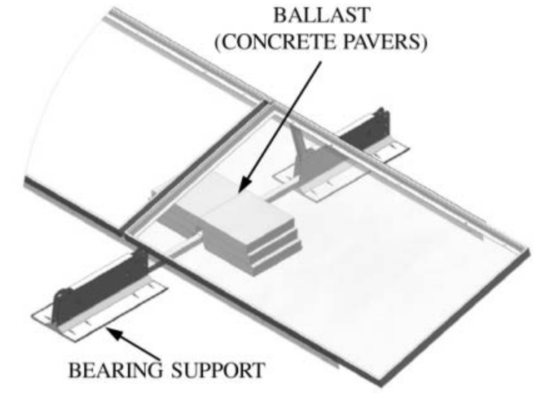
Consultants and contractors have to provide a detailed project construction plan, providing any information suited to aid in this process. These practices shall ensure that any environmental and also architectural impact is minimized.

Normally, the size of a PV system and its location are the factors which differentiate among the different paths of permitting process. Small scale systems usually placed on rooftops of residential and commercial buildings mainly involve mechanical design and construction in order to select and mount the structures adequate to support and fix the PV modules. Large (utility-scale) PV plants, usually ground mounted, have more environmental constraints to deal with like the use of land and the constraints linked to the construction in a wild site; in this case the placement and position of the PV plant can be the driver of a deeper environmental impact assessment. For instance a large PV plant near an airport might introduce impacts referring to potential sunlight reflection from PV modules, or a cleaning system that employs desalinated water would need a deeper evaluation on environmental impacts.

2.1 Type of mounting PV panels on buildings

The installation of a solar PV system on a building has different implications, it does not affect only the structural loading but it is also connected to additional effects such wind loads that can be particularly significant in case of storms. There are two main categories of mounting solutions, BAPV (Building Attached PV) and BIPV (Building Integrated PV), and are described below. There are three different BAPV methods of mounting PV systems on a roof plane structure:

1. Ballast only that are weighed down by heavy materials such as concrete to keep them located in the same position (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 (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 (Figure 3);
4. Structurally attached on tilted roof (Figure 4).



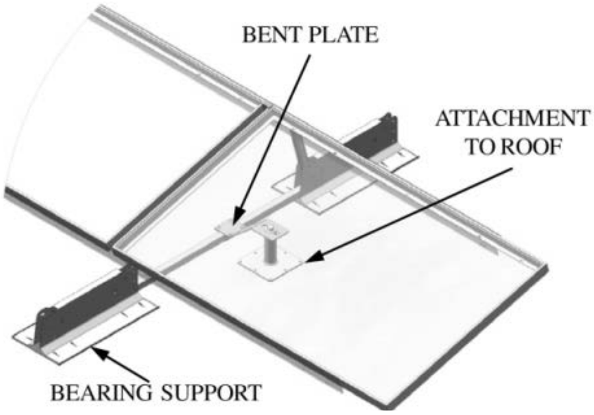


Figure 1 – Ballast only PV System

Figure 2 - Attached Roof-bearing PV System

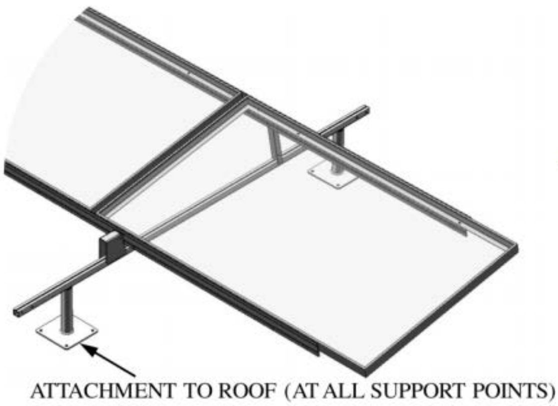


Figure 3 - Structurally attached on flat roof PV system

Figure 4 – Structurally attached on tilted roof

A further method for installing PV systems is the BIPV, 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.

It must be noted the difference between BIPV and BAPV:

- 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 5 shows the table with the mounting categories taken into account in the standards EN 50583-1/2 "Photovoltaics in buildings – PV modules / PV systems".

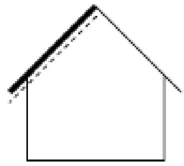
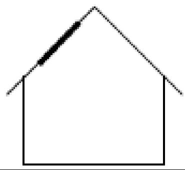
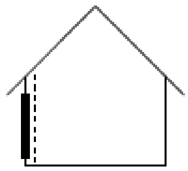
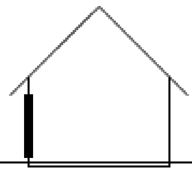
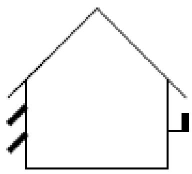
Category A:	**Sloped, roof-integrated, not accessible from within the building**	
	The PV modules are mounted in the building envelope at an angle of 0° - 75° with a barrier underneath preventing large pieces of glass falling onto accessible areas below	
Category B:	**Sloped, roof-integrated, accessible 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 5 - The table with the mounting categories taken into account in the EN 50583-1/2 – Photovoltaics in buildings – PV modules / PV systems

2.2 Loading assessment

The civil design of a roof-mounted system must carefully consider an appropriate mounting concept that secures the PV array, minimizes adverse effects on the integrity of the roof, and resists uplift. In addition, a careful assessment of the added roof load must be made.

There have been a number of systems globally which have failed due to the incorrect design and sizing of the support structure on rooftop systems. These failures tend to be high profile because there is a significant risk of endangerment to humans compared to ground-mounted systems.

A qualified engineer has to conduct structural load calculations. The structural integrity of the existing roof space should be assessed by means of visual inspection and design drawing review. Visual inspection can reveal damage or degradation of existing structural members. Load assessment calculations should consider:

- Assessment of the loads acting on the PV array and roof, including wind and seismic loads. The existence of the array will cause additional vertical wind loads onto the roof.
- Assessment of the roof structure to determine its spare load capacity.
- Comparison of the roof structure capacity with the new and existing applied loads.

In case load assessments reveal that the roof structure cannot accommodate the added weight of the solar PV system, structural reinforcements should be incorporated into the system design.

2.3 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 the 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 rooftops with the PV systems. As a consequence this issue is seriously considered in the literature, as it can be understood from the following extract: “Structural engineers must consider each of these loads separately and in combination to identify the worst-case loading situation”. 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 PV System 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, EN 1991-1/2/3/4

Consultants should consider the structural loads according to the practice used in Bahrain: whenever necessary the calculations shall be carried by using the appropriate methodology and building codes. More information regarding wind and seismic loading is reported in the following paragraphs.

2.4 Wind loading

An additional complexity to having PV systems on rooftops is that the PV system will be exposed to wind forces and as a result will have to be capable of withstanding those 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.”.
The vertical profile of synoptic wind velocities can be modelled by using the standard logarithmic profile model, where the velocity increases monotonically with height and reaches its maximum at the top of the building.

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, EN 1991-1-4.
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, EN 1991-1-4, C.E.N., Brussels.

Consultants should consider the wind composition in Bahrain, that is different from other regions like Europe and the Americas, also because of the presence of sand and debris during storms.

2.5 Seismic loads

In case of PV plant installed on roofs, the seismic load shall be treated as a structural load, 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. Guidelines have been developed in order to assist engineers when designing PV system for installation on rooftops.
SEAOC (Structural Engineers Association of California) developed a 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 such report are mentioned in the document "Commercial Roof-Mounted Photovoltaic System Installation Best Practices Review and All Hazard Assessment" [1], 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).
Consultants should evaluate the seismic loads based on the seismic hazard potential in Bahrain.

3 WEATHER RELATED PHENOMENA

This section reviews weather related phenomena, because there are events that may represent hazards for the operation and the integrity of the solar PV equipment.

3.1 Sand storms

The Middle East is located in a region that has frequent dust storms and dusty conditions. Deposits of dust on the surface of PV module 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 objective of a PV study based on field tests. Four mono-crystalline PV modules and two polycrystalline modules were tested at outdoor conditions for several months and power output was monitored daily.

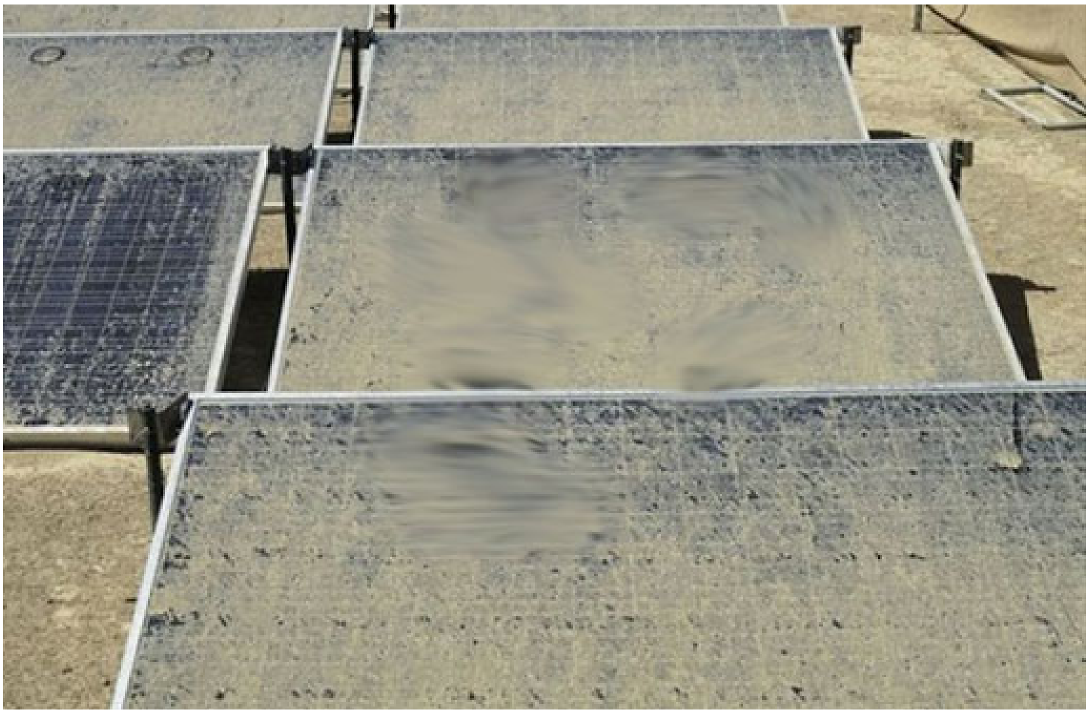


Figure 6 - Effect of sand deposit after sandstorm

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 performed 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/cm^2/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 on 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 has to be considered that sand storm causes degradation of PV modules and, more in general, wires, structures, etc. Effects of abrasion can be in some way tested by means of the IEC 60068-2-68.
Nevertheless also sand deposit may affect safety because they may give origin to "hot-spot" on PV modules with unpredictable consequences. "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; the effect is dangerous in case of very high irradiance: when "Hot spot" produces very high temperature on cells and back-sheet (up to 180°C) so it could be a cause of ignition of fire.

Recommendations

A well designed PV plant suited to hot climate peculiarities should take into account the effects of sand storms and sand deposit on PV modules. Small scale PV system located in urban areas should be less exposed to sand accumulation. The periodically removal of sand, and debris too, should be taken into account by the owner of the plant as a common practice. Both at design stage and during operation, thus, it has to be pointed out how it will solve the problem of sand removal. When designing the PV plant, horizontal and very low inclinations of PV modules shall be avoided. At design verification by the Applicant or the Producer should be verified that the PV system has a dust removal system in the project or that there are procedures for dust and sand removal periodically.
In the case of utility scale PV plant, for the biggest facilities installed in the rural areas or in places with heavy sand storms this recommendation is more compulsory, particularly if the removal system is of wet type. The removal system, if wet type, should indicate the amount of water needed for cleaning and the system of supply. A comparison among different cleaning system should be set in order to rank the effectiveness of the system itself (i.e. monthly mc desalt water per square meter of PV panel).

3.2 Hail phenomena

Even if hail phenomena are seldom in Bahraini weather, the PV modules shall be tested and certified against hail damage according to the standard IEC 61215 series or IEC 61646, nevertheless the economic value of the PV installation can be protected also with an insurance that refund the damages caused by hail.

Figure 7 – Examples of hail damage on PV modules

Recommendations

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

3.3 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 build up on module surface. 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 undrained water floating on top of roofs or being the mere deposit last 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, also providing a significant amount of information on how fire spreads between PV panels and roof tops. In order to respect these concerns the IEC 60068-2-68 standard becomes important specifically in environment with sand and dust deposits.

In regions with temperate climates like Europe debris and dust are mainly composed by leaves and other vegetal residues as well as bird excrements, all combustible. In countries exposed to hot climates like Bahrain debris are mainly represented by sand deposits which hardly ignites but there could be the case of ignition of the roof membrane or other material improperly left on the roof caused by the effect of an “hot spot” on the panel; also bird’s leftover and nests could be common in Bahrain.

The main point is that a class A rated roof with a 5” mounted PV panel resists to ignition when exposed to hot embers. But when there is debris accumulated between the PV panels and the roof,

even when protected by 1/8” and 1/16” screens, and it is exposed to hot embers, the debris can ignite spreading the fire across the roof.
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%.

Figure 8 – Example of cleaning of PV modules

Debris deposit is composed by dust from pollution, sand and other debris that accumulated 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 (Figure 8). For ground mounted (utility-scale) PV plants of large capacity also mechanized systems might be used.

In the design stage of O&M a cleaning system and a cleaning procedure should be defined: the cleaning systems applicable are:

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

Recommendations

The designer shall include a description of the O&M procedure for modules cleaning and dust removal that will be annexed to the documentation for approval at the Design Approval stage. Proposal and identification of suitable cleaning method shall be the responsibility of the Applicant and also the choice of the Owner of the plant to avoid a decrease of performances of the PV plant, but also preserve the safety of the PV plant itself.

3.4 Maintenance of the PV modules

The high summer temperature in Oman is very often associated with very high humidity along the coast. Humidity affects solar PV in ways comparable to dust accumulation. Water vapour 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 that the PV modules envisaged for installation are certified according to the relevant International Standards, as also reported in the Connection Standards. Modules certification will guarantee the performance of the modules as well as of their components including cables and connectors.

Recommendations

The designer shall address maintenance of PV modules especially in the presence of severe weather conditions and particularly in case of high humidity should be addressed. Designers shall take care about the products selected to build the PV plants.

3.5 Sunlight reflection

The Figure 9 shows that sunlight reflection on solar PV panels is lower than many common surfaces including vegetation and water, because calm water reflects more sunlight than solar panels. In general, light is specularly reflected on any smooth surface where the index of refraction is different from that of air. The intensity of the reflection will depend on the angle between the sun and the PV panel, and the index of refraction of the PV panel.

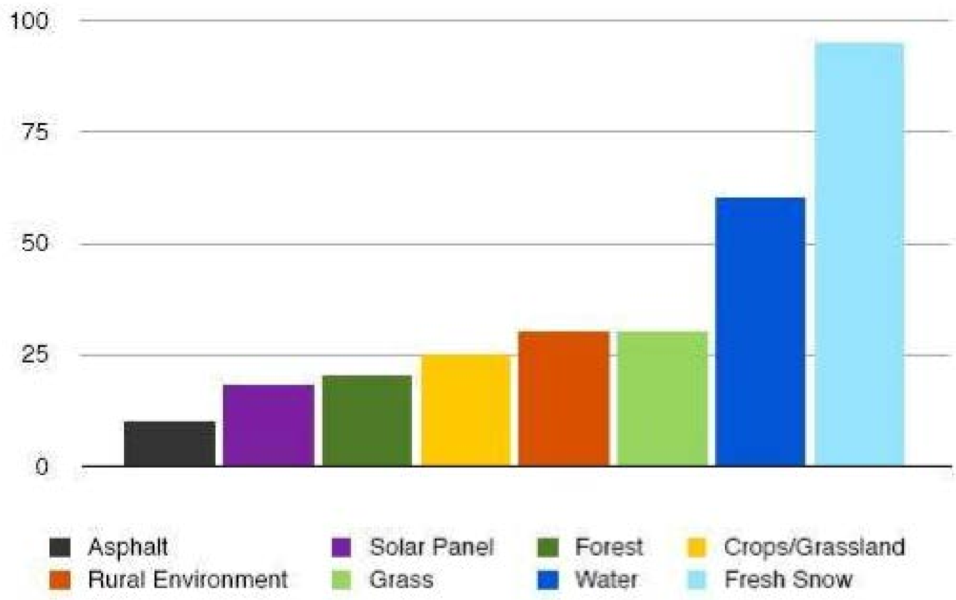


Figure 9 - Comparative reflection analysis [9]

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. At a normal incident 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.

Even if reflection should not be an issue in cities and populated areas, the case of reflections can be presented that irk the buildings around inhabitants. In order to prevent any disturbance to inhabitants in taller buildings around the PV system an assessment of reflections should be required. A detailed assessment can be required for installations on airport and sites near airport.

Recommendation

The installer shall check the presence of anti-glare in PV panels especially when the location could affect visual interaction. In addition consider that a PV system on a roof may hit the taller buildings near to the installation.

Assessment of impact on aviation can be required before installation of solar PV systems on airports and sites near airports is approved by the airside authority: a detailed analysis of this subject is provided in another report.

4 PERFORMANCE OF COMPONENTS

Specific requirements are described below 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:

- *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 can be useful to mention the revision made in 2013 of the standard UL 1703 on 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 and one should consider that it will be effective 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 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) encompass 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 EN 50618 describes also the test to be made on PV cables (electrical and non-electrical) and the code designation “H1Z2Z2-K”.

5 LIGHTNING

Lightning protection measures are required by design and the standards to be followed are listed in the "Standards for Solar PV Systems to be connected in parallel with the distribution networks of the Kingdom of Bahrain".
Particularly, SPDs and surge arresters are normally provided by design as overvoltage protections in a PV plant. Also earthing of PV support structures and frames PV shall be required by design as a general protection measure.

6 EARTHING

Earthing is a further issue for the safety of a PV plant installation. It is addressed by the IEC 60364-5-54: Low-voltage electrical installations. Part 5-54: Selection and erection of electrical equipment. Earthing arrangements and protective conductors. Designers shall be responsible to design 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, investigate the resistivity of the soil (in principle feasible for new buildings on green sites).
Should a building be not equipped with an earthing system the designer shall include design and installation of earthing system in the scope of work for a new PV system installation.