هيئة الكهرباء والماء
Electricity & Water Authority
Kingdom of Bahrain

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

Solar PV Systems
Impact on Aviation

Draft 1.0

August 2017

Table of contents

1 SCOPE

Although solar PV panels are designed to absorb light and to reduce reflections, in certain situations their glass surfaces can reflect sunlight and produce glint (a momentary flash of bright light) and glare (a continuous source of bright light). The light absorbing potential of the PV modules may be remarkably higher than many glass covers or windows, therefore the amount of light reflected and the glare effects are expected to be quite negligible. As a consequence there is little chance that solar PV systems located off airports can have an impact on aviation. On the other hand attention is necessary in regards to solar PV systems on airport and especially on airside. Safety reasons requires that the light reflected off the PV panels does not hit airport sites, especially considering their critical spots, and the solar PV equipment do not affect the communication, navigation and surveillance facilities located in selected airport areas particularly on airside.

This document review will summarize the studies performed and the recommendations developed by USA and European aviation authorities, particularly to process applications from developers who want to install solar PV systems on airports. The list of the relevant literature is reported in the next paragraph.

1.1 References

[1] P. Janssen et al., Technical feasibility study for a solar energy system at Amsterdam Airport Schiphol (AAS), RE&PQJ, Vol.1, No.8, April 2010

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

[3] Solar Trade Association, "Impact of solar PV on aviation and airports", ed. 3.0, April 2016, www.solar-trade.org.uk

[4] FAA, "Technical Guidance for Evaluating Selected Solar Technologies on Airports", FAA Solar Guide, November 2010

[5] FAA, "Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports", (http://federalregister.gov/a/2013-24729), Federal Register / Vol. 78, No. 205 / Wednesday, October 23, 2013 / Notices

[6] EASA, "Essential requirements for the safety and interoperability regulation of aerodromes", ERs Opinion 3-2007

[7] ENAC, "Impianti fotovoltaici" (Photovoltaics plants), DISP 35 2010, April 2010

[8] ENAC, "Policy per l'installazione e la gestione di impianti fotovoltaici in aeroporto" ("Policy regarding the installation and management of solar PV plants in the airport area"), April 2010

[9] ENAC-ENAV, "Verifica preliminare – Verifica potenziali ostacoli e pericoli per la navigazione aerea" (Preliminary assessment – Assessment of potential obstacles and hazards for the aero navigation"), February 2015

2 SOLAR PV POWER GENERATION AND THE IMPACT ON AVIATION

Solar PV systems can be installed on the rooftop of buildings or can be ground mounted. However, normally these solar PV power generating systems, small-scale or utility-scale, are located off airports. Because of the prospected reduction of load demand recently we see an increasing request of PV systems on airports, where large rooftops and cleared open space are usually available.
Airside authorities thus have investigated whether the solar PV systems and in general the power generating plants based on the renewable energy resources are compatible with aviation. In addition to glint and glare, also radar interference and physical penetration of airspace were evaluated. For the above reasons these authorities require that solar projects, rooftop or ground mounted, located on airport, are suitably assessed in regards to any possible impacts on aviation. The same procedure could also be recommended for the assessment of solar PV systems located near airports.
This document illustrates the results of the analyses performed by the authorities listed below.

- FAA – Federal Aviation Administration (USA)
- EASA – European Aviation Safety Agency (European Union)
- ENAC - Ente Nazionale Per L'Aviazione Civile (Italy)
- ENAV – Ente Nazionale di Assistenza al Volo (Italy)

2.1 Sources of the potential impact

This paragraph analyses the possible source of impact on aviation of:

- solar PV systems on or in the vicinity of airports, and
- solar PV systems off airports below air corridors (i.e. "en-route").

The solar PV technology generally consists of flat panels covered with specially manufactured glass which is designed to maximize absorption of light and minimize reflections. Furthermore most solar panels are now designed with at least one anti-reflective layer and some panels have multiple layers. The Figure 1 compares the light that single and antireflection glasses reflect: it is worth to note that the anti-reflection layer reduces to 1/3 the incoming light, while the reduction obtained with a single glass is about 13% the incoming light.

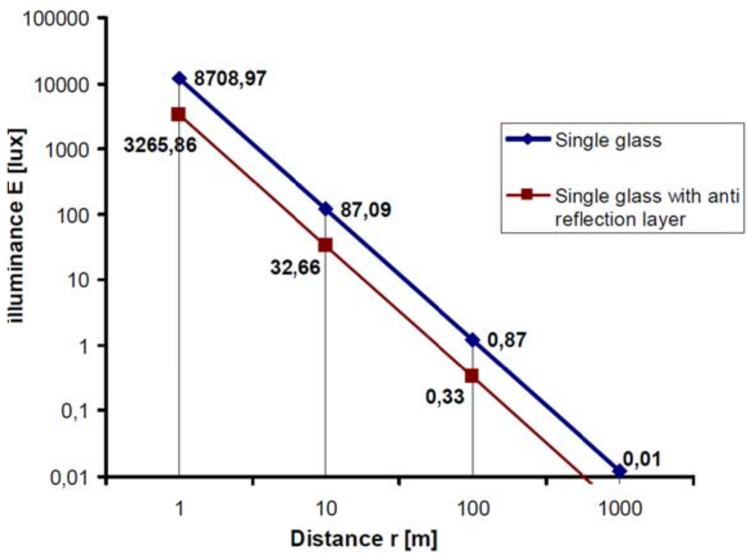

Figure 1 – Comparison reflection analysis [1]

The anti-reflective layer, made by Silicon Hydride or similar substances, in most cases is present in silicon-crystalline PV modules. Thin film PV modules may not have such a layer but usually they do not need it because of their internal structure. When present, the anti-reflective layer is placed on the front of the PV cells (i.e. behind the front glass). Unfortunately, the anti-reflective layer is useful to increase the PV module efficiency but is almost useless if we consider the light reflection of the component in whole, because in this case the reflection of the front glass plays the most important role.
Further issues can be related to physical size and electromagnetic interference. These PV panels and in general the overall installation including the technical rooms necessary, especially in case of large utility scale PV plants, are unlikely to have sufficient height to constitute a physical collision hazard to aircraft. Additionally, due to the low profiles of the solar PV panels, there is little risk of interfering with radar transmissions. As regards the potential impacts in terms of frequency interference, it is worth to notice that:

- solar PV panels produce DC current and this current flow cannot generate any radiating fields,
- further equipment including inverters and transformers connected by AC circuits will not cause electromagnetic disturbances assuming they comply with EMC directives and standards.

In the end glare by sunlight specularly reflected off the PV panels remains the only issue likely to be raised, because it may act as a distraction to pilots or air traffic controllers. The next paragraph analyses the potential impact of glare on aviation.

2.2 Analyzing the impact of glare

The concern of the aviation authorities focused on solar PV systems on or near airports. Actually the majority of solar PV systems are located off airports, and only few of them will lay below the air corridors (i.e. “en route”). Solar PV systems located off airports are unlikely to present glare/dazzle problems to pilots, for the following reasons [1]:

- dazzle/glare is likely to present a hazard only during critical phases of flight, especially approach and landing; normally the “en route” phase is not a critical phase
- dazzle/glare occurs almost exclusively at low angles of elevation; aircraft in the “en route” phase of flight will be at higher angles of elevation
- pilots in the “en route” phase are already subjected to glare from a number of existing sources such as large assemblies of parked cars, major glasshouse facilities and large bodies of water; these are not considered to require analysis and mitigation despite having potentially much higher luminosity values than PV panels
- the pilot view from most cockpits, particularly in the forward direction, is severely limited in the downward direction by the aircraft structure, thus blocking the line of sight to any source of glare on the ground.

In the light of the above, it is unlikely that a glare analysis is necessary for any solar facilities in the “en route” environment. Anyhow, in the event the impact on aviation of a solar PV system is rated significant, and an additional analysis is required, the following principles should be taken into account.

- PV panels are constructed from specially-treated low-iron glass, designed to minimize reflection and maximize transmission of light through the glass. Standard low-iron glass reflects approximately 7% of light. PV panels are expected to reflect a total of approximately 2% of the incident light.
- These values are lower than the reflectivity of other materials or the natural environment. The Figure 2 shows that the reflectivity of the solar PV panels is lower than the reflectivity of the vegetation and the rural environment, and much lower than the reflectivity of the water. However comparing the reflectivity of sunlight by different materials is not straightforward. Glasses, snow and calm water reflect the solar beams at a given angle, but all other materials diffuse the light in all directions and therefore the effect has less impact.

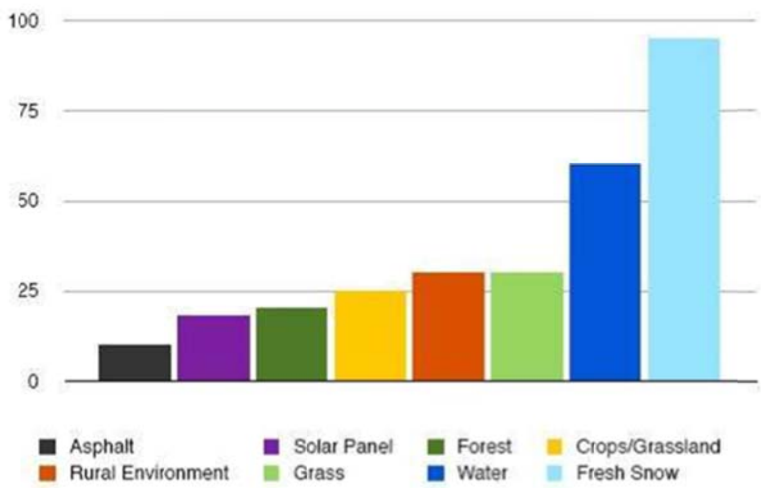

Figure 2 - Comparative reflection analysis [1]

Whereas solar PV systems cannot endanger "en route" aviation operations, concerns were raised when developers had attempted to install these systems on or near airport.
In order to assess the probability of glare occurring to pilots of aircrafts flying in the vicinity of a solar PV installation, or to controllers of air traffic control towers, a detailed analysis should assess the frequency with which specular reflections off the panels would be oriented towards these targets. For example such study will be required in case of on-airfield solar PV systems, knowing that for certain orientations the PV panel may create an hazard because of the specular reflections. In order to calculate the incidence of reflections to critical positions (taxiways/runways and control towers), the study should address the following issues:

- possible sources of reflection, in addition to PV panels
- PV panel orientation in azimuth and elevation
- sun azimuth and elevation angles for the solar PV site for specified periods

In addition to such type of study, a proved methodology and a detailed procedure should be defined and made available to developers in order they can be informed and aware of the steps required when proposing the installation of a solar PV system on or near airports.

3 ASSESSMENT PROCESS DEVELOPED BY THE US FAA

The foremost mission of the US Federal Aviation Administration (FAA) is to ensure a safe air navigation system. To meet this objective, the FAA performs studies of activities or constructions that could impact airspace. These studies review physical incursions of proposed structures into airspace, interference with radar communications, and any other conditions that might negatively impact air traffic, like specular reflections. Figure 3 provides a graphical illustration of the potential airspace conflicts.

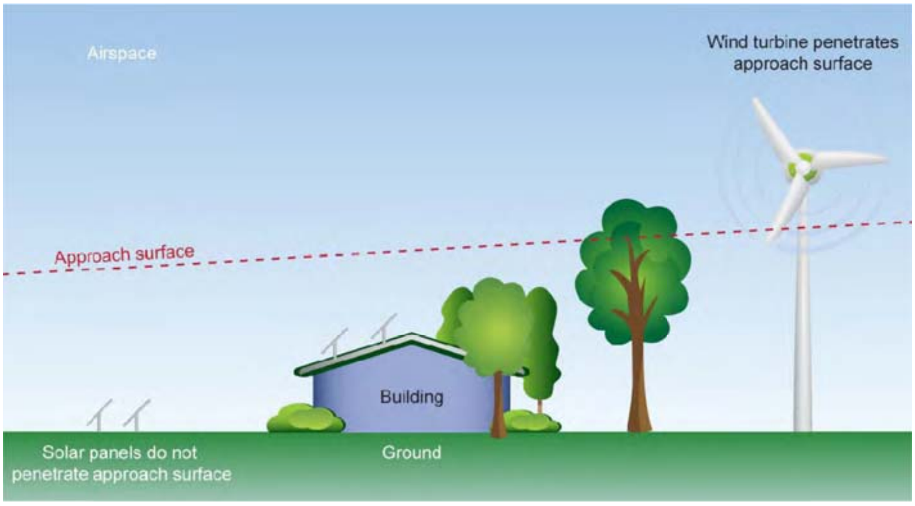

Figure 3 – Possible conflicts between aviation and renewable power generation (Source [4])

For on airport projects FAA requires the applicant fills and files the documentation necessary to assess the potential impact of the project on air navigation. For off-airport projects the local governments are expected to inform the FAA so that the agency can determine if the projects, especially large projects, presents any safety or navigational problems. The Figure 4 shows the assessment process.

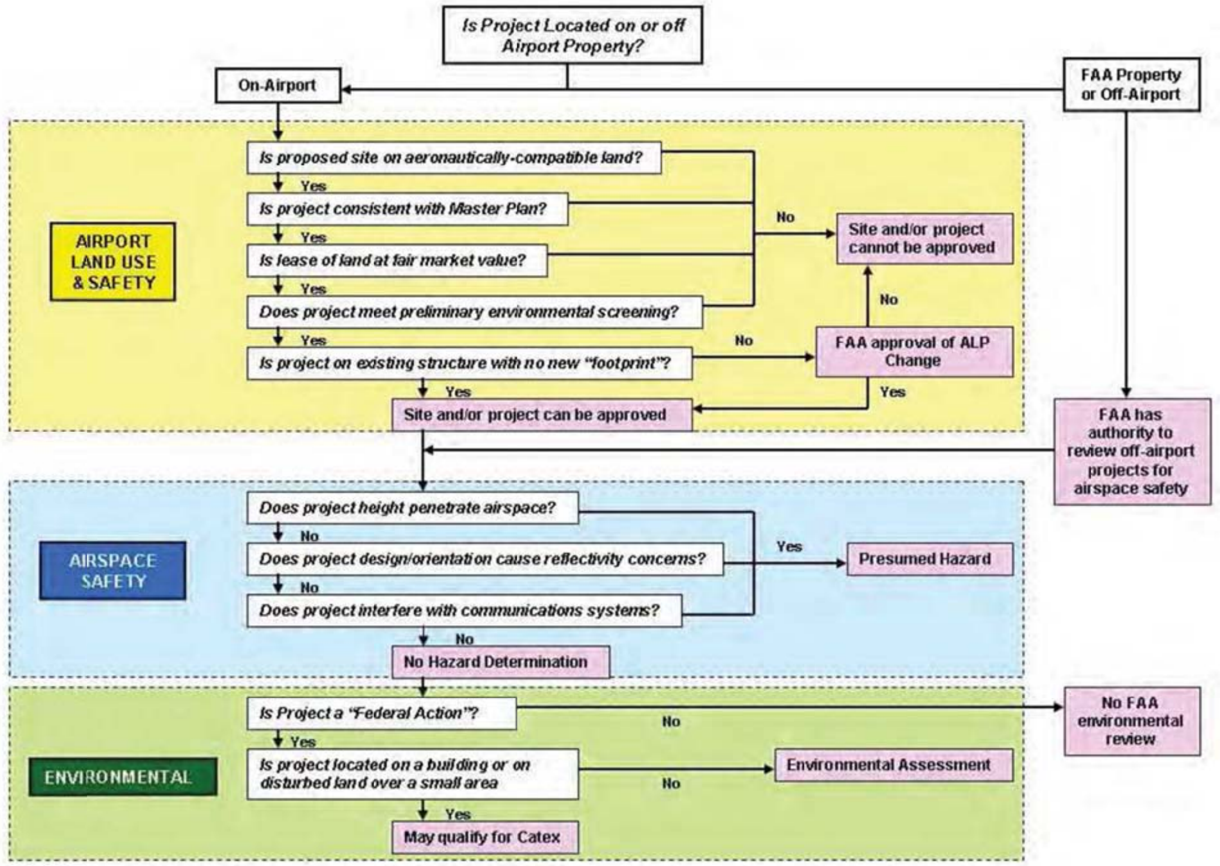

Figure 4 – FAA Technical Guidance, procedure for a project assessment [4]

The process, illustrated in the "Technical Guidance for Evaluating Selected Solar Technologies on Airports" [4] issued on November 2010, was developed prior the publication of the guidance, because the FAA was required to assess several on airport solar PV projects that received a "no hazard determination".

The documentation filed by the applicant for on airport projects specifies the below information:

- location of solar PV panels, absolute and with reference to radar facilities and Control Tower
- verification that the solar PV panels are located outside of airport design prohibited areas
- verification that the solar facilities will not affect radar communications
- verification that solar PV panels will not physical penetrate airport imaginary surfaces, like the approach surface
- assessment of reflectivity including time periods when specular reflection may affect Control Tower and aircraft

As mentioned in Section 2.1, radar interference cannot be an issue based on the characteristics of the solar PV modules and the installation of equipment that fulfil the available international standards. Anyway to ensure such systems are further isolated the guidance required that solar PV projects are set back from major on-airport radar equipment by e.g. 500 feet (150 m).

Regarding the penetration of the imaginary surfaces, any potential impact can be assessed based on requirements issued by airport authorities that establishes standards for determining obstructions in navigable airspace. These imaginary surfaces extend out from the runway in a manner that reflects where aircraft are likely to fly while also accommodating unforeseen aircraft maneuvers. The height above the ground of the imaginary surface is lowest near the runway and increases at distance from the runway. Away from airports, airspace begins at 200 feet (60.96 m) above ground level. Airports must maintain vegetation, prevent building, and manage any temporary construction activity to conform with these requirements. Structures like communication towers and wind turbines, often higher than 200 feet, require an application is submitted for any new construction or modification. Structures shorter than 200 feet but located within 20,000 feet (6,096.00 m) of a runway may also penetrate navigable airspace. Solar panels, when tilted as expected to the south-facing sun, extend to a height of as little as 1 or few meters above ground, making it possible for siting close to runways without penetrating an imaginary surface. The Figure 5 shows a comprehensive representation of the imaginary surfaces that define the navigable aerospace.

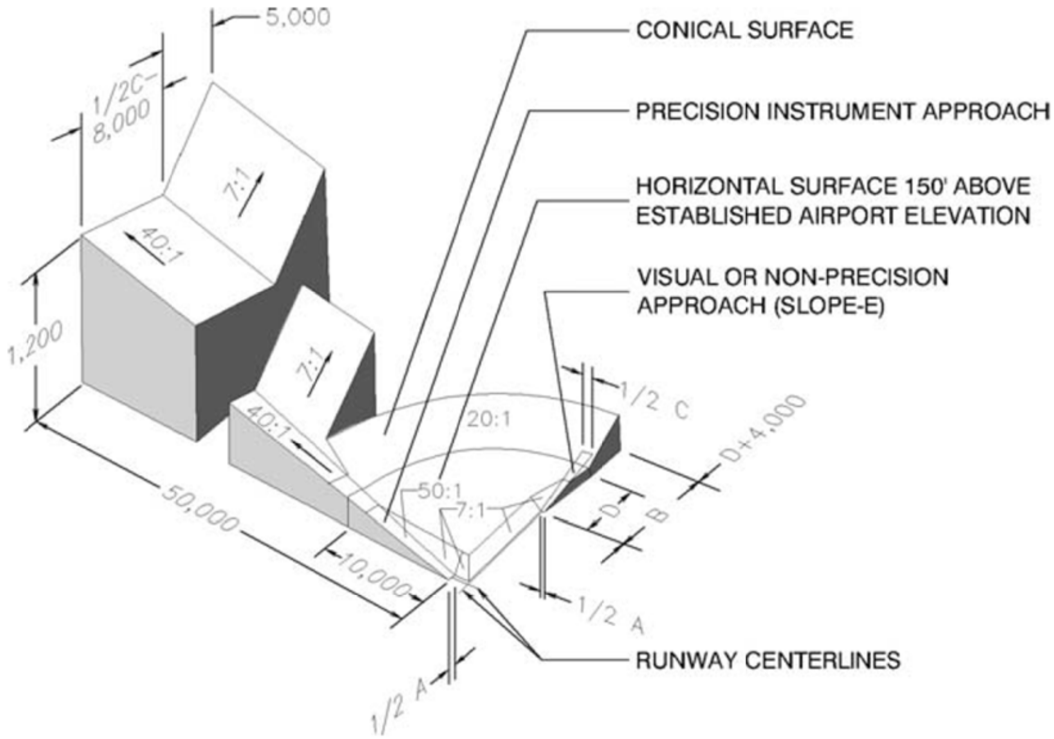

Figure 5 – FAA Technical Guidance, Imaginary Surfaces that Define Navigable Airspace [4]

In regards to the reflectivity, as reported in Section 2.2, today's panels reflect as little as 2% of the incoming sunlight. While the amount of light reflected off a surface is important, the nature of the reflected light is even more important when assessing the potential for flash blindness. Flash blindness can only occur from specular reflections. Specular reflection reflects a more concentrated type of light and occurs when the surface in question is smooth and polished. How much light the PV panels specularly reflect can be difficult to predict: however the panel covers are flat and made of glass so that much of the light can be reflected in a specular way. Additionally the more the angle of incidence the more the light that is specularly reflected. These specular reflections are responsible of glare.

The "Technical Guidance" the FAA published on November 2010 did not specify or recommend any methodology for carrying out a detailed assessment of glare, apart from the geometrical study

already mentioned. This type of study employs geometry and the known path of the sun to predict when sunlight will reflect off of a fixed surface like a solar PV panel and contact a fixed receptor like a control tower or any surface at a given point. The Figure 6 provides an example of such a geometric analysis.
Although the geometrical study can identify the sites hit by specular reflections and frequency of glare, it cannot quantify the amount of reflected light. This amount, if available, could be compared to an hazard scale specifying the threshold that should not be overcome in order to prevent glare.

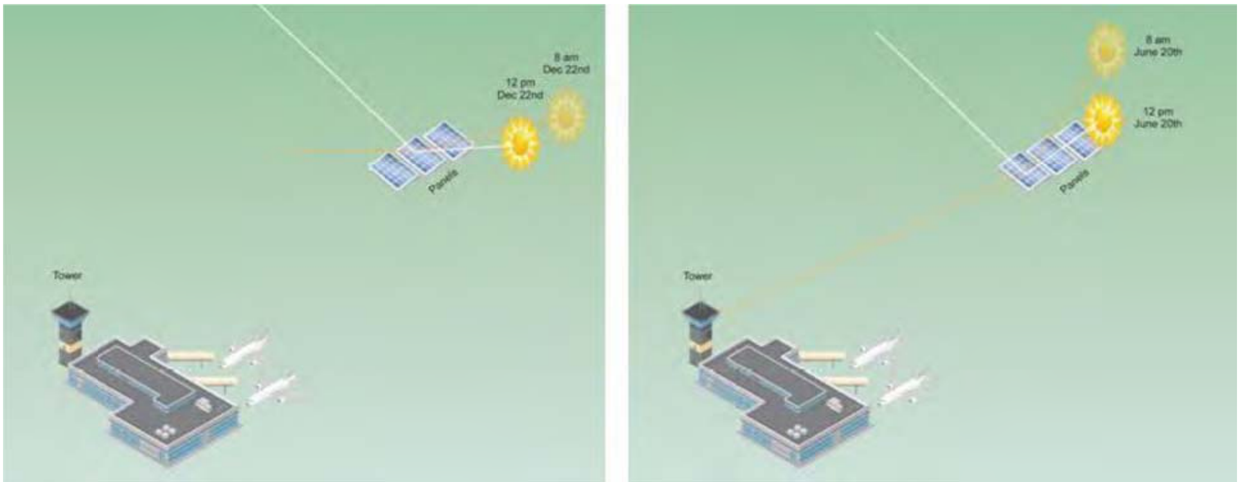

Figure 6 – Geometrical study of glare by the specular reflections from the PV panels (Source [4])

According to an official note issued on October 2013 the FAA communicated the intention of reviewing the "Technical Guidance" based on new information and field experience, particularly with respect to compatibility and glare.
FAA established a working group to develop a standard for measuring glint and glare, and for defining thresholds for when glint and glare would impact aviation safety. While notifying the users that the guidance was expected to change, in order to assure its temporarily replacement, FAA issued the "Interim Policy" 2013-24729 [5] setting the updated standards the working group had developed.
The "Interim Policy" also provided clarifications regarding the impact of solar PV systems on equipment required for communication, navigation, and surveillance (CNS) facilities including radar and NAVAIDS. The "Technical Guidance" required the airport sponsor to identify the locations unsuitable for the energy projects structures in the event the same might affect radar signals. Actually this meant the airport sponsor is responsible for limiting the risks for inference with CNS facilities by ensuring that solar PV systems remain clear of the critical areas surrounding CNS facilities. Knowing these critical areas are identified by the FAA, all the developers are required to do, is the siting the solar PV panels and equipment according to the applicable FAA circular. When the application is filed, the FAA that is responsible for evaluating the impacts to CNS facilities just needs to review the application by checking the proposed siting of the solar PV system.

3.1 Standard for Measuring Ocular Impact

The FAA Interim Policy [5] defined the methodology based on the Solar Glare Hazard Analysis Plot shown in Figure 7 as the standard for measuring the ocular impact of any proposed solar energy system on airports. To obtain approval (and update the "airport layout plan") the proposed solar PV system shall meet the following requirements:

- no potential for glint or glare in the cab of the airport traffic control tower, and
- no potential for glare or ''low potential for after-image'' (shown in green in Figure 7) along the final approach path[1]

The procedure requires the ocular impact has to be analysed over the entire calendar year in one minute intervals from when the sun rises above the horizon until the sun sets below the horizon. To do so the FAA agreed with the US Department of Energy (DoE) the free-of-charge availability of the Solar Glare Hazard Analysis Tool (SGHAT). This tool was designed to determine whether a proposed solar energy project would result in the potential for ocular impact as depicted on the Solar Glare Hazard Analysis Plot.

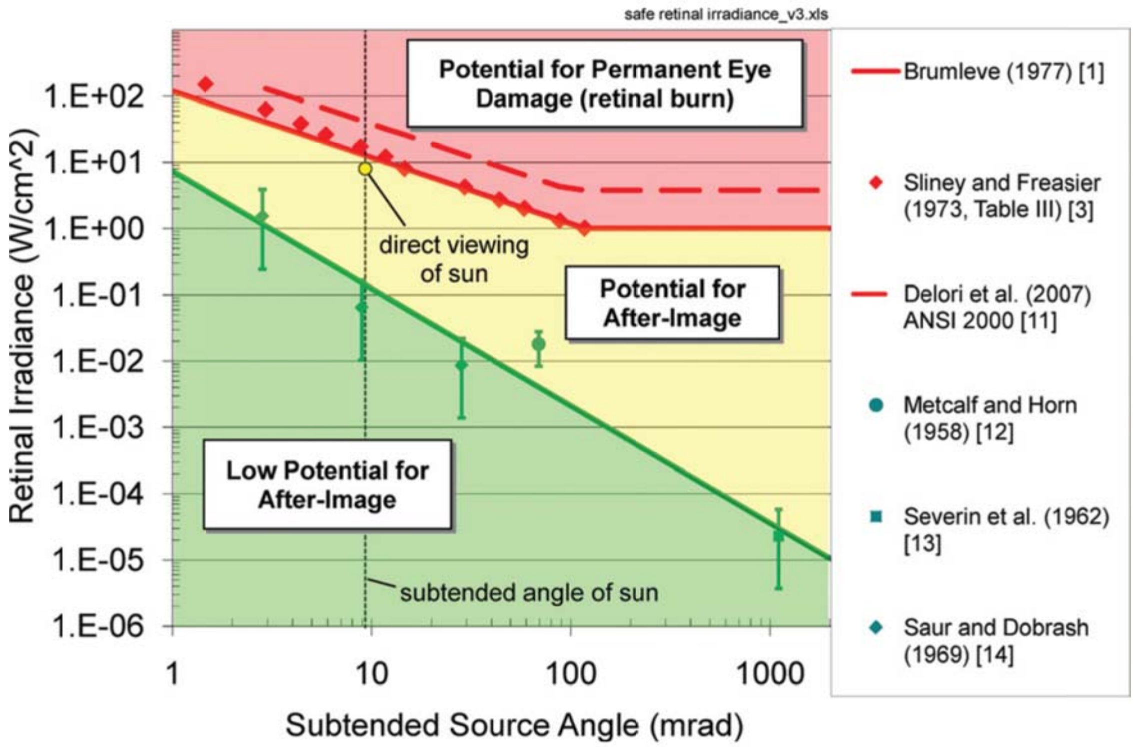

Figure 7 – Solar Glare Hazard Analysis Plot (Source [5])

The SGHAT employs an interactive Google map where the user can quickly locate a site, draw an outline of the proposed solar PV system, and specify critical areas sites like airport traffic control tower cab and final approach paths. Site data are automatically recorded providing the information for sun position and vector calculations. The orientation and tilt of solar PV panels, reflectance, environment, and ocular factors are entered by the user. If glare is found the tool calculates the retinal irradiance and subtended source angle (size/distance) of the glare source to predict potential ocular hazards ranging from temporary afterimage to retinal burn. The results are presented in a plot that specifies when glare will occur throughout the year, with colour codes indicating the potential ocular hazard. Because the tool also predicts the energy production, it can be used for evaluating alternative designs, layouts, and locations to identify configurations that maximize energy production while minimizing glare. The tool is available at www.sandia.gov/glare.

[1] The final approach path is defined as 2 miles (3.22 km) from 50 feet (15.24 m) above the landing threshold

During the validity of the "Interim Policy" the FAA expected to receive comments and to make appropriate modifications before issuing a final policy. But, despite the FAA's intention to review the original technical guidance, this "Interim Policy" is still in force.

4 REQUIREMENTS ISSUED BY THE EUROPEAN EASA

Because each European country has its own aviation authority, energy policy and land management procedures, there is no unique process and methodology for assessing the impact of solar PV systems on aviation. The European Union has founded several institutions with the mission to provide common requirements, and each country is required to comply with these requirements by updating or issuing national laws and regulations. A similar process occurred with reference to the implementation of renewable energy sources.

The EASA – European Aviation Safety Agency – issued on 2007 the document "ERs Opinion 3-2007" [6] entitled "Essential requirements for the safety and interoperability regulation of aerodromes". The rationale of the Essential Requirement is given at Chapter 1-d "Aerodrome environment" (page 12), reported below:

> *"Other types of activities, which might create safety hazards for aerodrome operations, also need to be controlled. New developments in land use may affect the geographical data used as a basis when developing the arrival and departure routes. New buildings or other constructions, even if not identified as obstacles, may create dangerous effects of induced turbulence. Laser lights and other non-aeronautical lights may cause dazzling of, or be confusing to, the flight crew. <u>Large solar photovoltaic panels or wind turbines, in addition to possibly being hazardous obstacles, might respectively create dangerous intense light reflections or interference to radio navigation signals.</u> Human activities may also attract wild life to the vicinity of an aerodrome and so create increased risks for aircraft operations taking place there. <u>For such reasons ER C.2 has been developed, in order to require Member States to take measures to protect aircraft from such activities</u>, as described in Annex 14, Vol. I, Chapters 5 and 9, and associated parts of Volume II".*

The Essential Requirements ER C.2 is presented in the same document (page 17), as reported below:

" Essential Requirement C "Aerodrome Environment"

2) Hazards related to human activities and land use, such as but not limited to items on the following list, must be monitored and controlled. The risk caused by them shall be assessed and mitigated as appropriate:
   - *<u>a) any development or change in land-use in the aerodrome local area</u>*
   - *b) the possibility of building induced turbulence*
   - *c) the use of hazardous, confusing and misleading lights*
   - *<u>d) the dazzling caused by large and highly reflective surfaces</u>*
   - *e) ……."*

Indeed clauses a) and d) are involved when implementing a solar PV system on or near airports. In order to comply with these "essential requirement", institutions and authorities at national level began to work and issue the necessary laws and/or regulations.

The next paragraphs report the rules issued by the Italian aviation authorities.

5 REGULATIONS ISSUED BY THE ITALIAN AVIATION AUTHORITIES ENAC-ENAV

Following the EASA "essential requirements", the ENAC (Italian Civil Aviation Authority) and the ENAV (the Italian Air Traffic Control Organization) issued the documents that are listed below:

1. "ENAC – DISP 35 2010 Impianti fotovoltaici" [7] ("Photovoltaic Plants") April 2010, stating that each airport shall take advantage of the renewable energies to improve the energy efficiency and assure the sustainable development of the airport activities.
2. "ENAC – POLICY PER L'INSTALLAZIONE E LA GESTIONE DI IMPIANTI FOTOVOLTAICI IN AEROPORTO" [8] ("Policy regarding the installation and management of solar PV plants in the airport area") April 2010, allowing the installation of solar PV plants connected to the distribution network, in order to generate the electricity required for the airport activity and to send excess electricity to the grid; the policy does not allow solar PV plants installed for selling 100% of the generated electricity. For any solar PV plant to be installed on airport, the potential impact due to electromagnetic interference and glare has to be evaluated during the design phase.
3. "ENAC-ENAV - Verifica preliminare - Verifica potenziali ostacoli e pericoli per la navigazione aerea" [9] ("Preliminary assessment – Assessment of potential obstacles and hazards for the aero navigation") February 2015, stating types of plants, installations, structures which require a compatibility evaluation process in order to get approval. This process regards solar PV plants or buildings/structures, installed on airport or within 6 km from airport.

The latter document defines the procedure for the preliminary assessment of the project. The next paragraphs highlight the key recommendations set forth according to the "Preliminary assessment" procedure in [9].

5.1 Assessment of solar PV systems according to ENAC-ENAV

The assessment procedure is required for plants/structures inside or next to the airport area, that can interfere with the aero navigation, such as wind plants, solar PV plants, buildings/structures of significant height and with potentially reflecting surfaces, etc.

The procedure defines five (5) Sectors, of different area and shape, located at increasing distance from airport. Plants/structures to be constructed within these sectors and possessing specific characteristics must pass the assessment before they can receive ENAC approval. Again the characteristics that shall be investigated are the same as above: physical size, interference with communication, navigation and surveillance equipment, and specular reflections.

The required assessment is described here below with reference to Sectors shown by red colored areas, located on airport or at selected distance from airport, and applies to the airports equipped with the Instrument Landing System (ILS), that is, almost all the airports in Italy.

5.1.1 Assessment within the Sector 1

Sector 1 comprises the runway strip (Figure 8) that airplanes use for take-off and landing.

Assessment required:

- for any plants/structures within the Sector 1.

Figure 8 – Red area showing the Sector 1 (source: Italian aviation authorities ENAV-ENAC)

5.1.2 Assessment within the Sector 2

Sector 2 comprises the approach surface, starting from the Sector 1 ends, with tilt 1.2% (Figure 9).

Assessment required:

- for any plants/structures within 1350 m from Sector 1, regardless the height.
- for the plants/structures to be constructed after 1350 m from Sector 1, in case the top of the plants/structures reaches the approach surface.

Figure 9 – Red area showing the Sector 2 (source: Italian aviation authorities ENAV-ENAC)

5.1.3 Assessment within the Sector 3

Sector 3 is the imaginary surface starting from the ends of Sector 1 and Sector 2, with tilt 1.2%, maximum distance 2500 m from Sector 1 limits.

Assessment required:

- for any plants/structures within 200 m from Sector 1 or Sector 2, regardless the height.
- for the plants/structures to be constructed after 200 m from Sector 1 or Sector 2, in case the top of plants/structures reaches the imaginary surface.

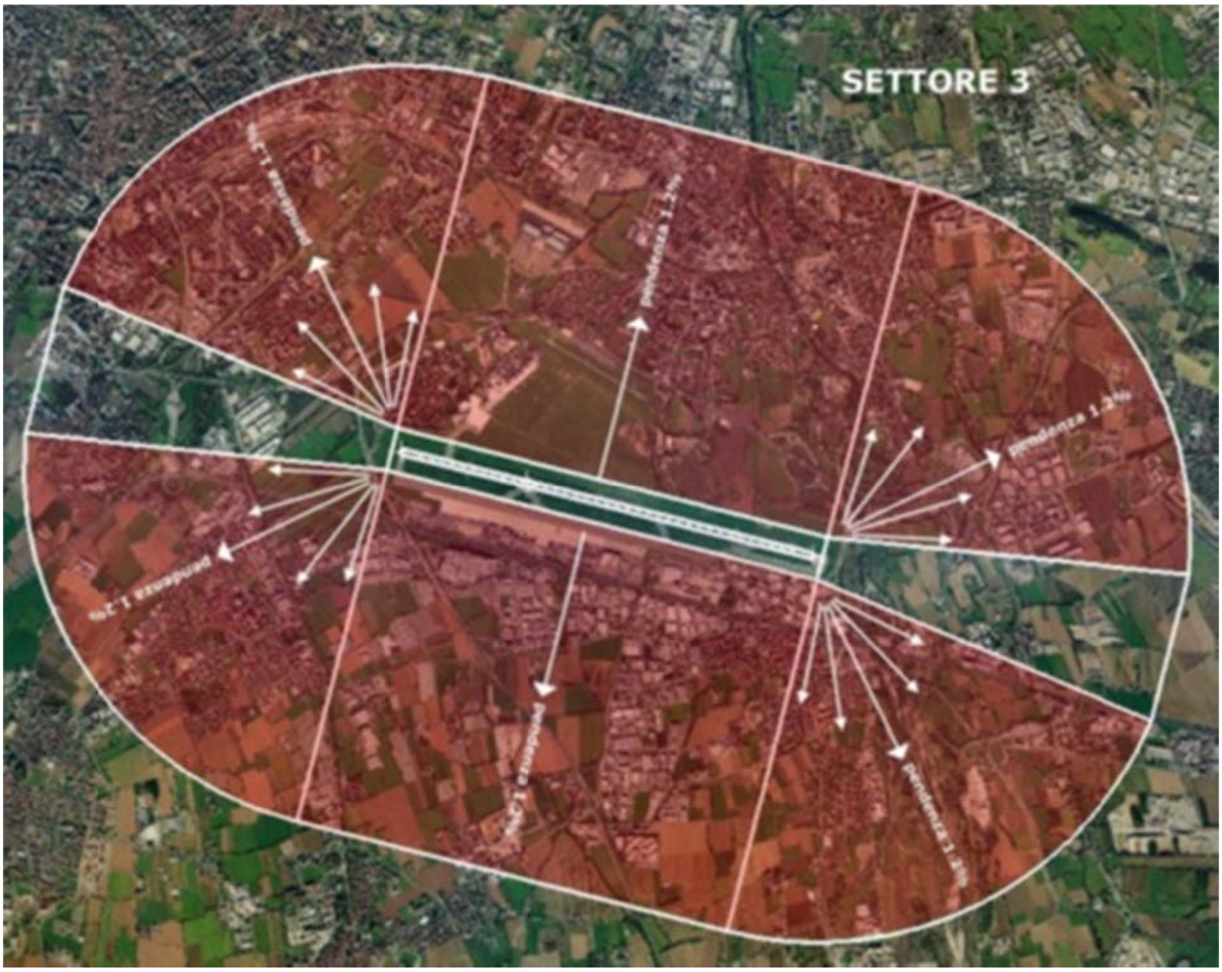

Figure 10 – Red area showing the Sector 3 (source: Italian aviation authorities ENAV-ENAC)

5.1.4 Assessment within Sector 4 and Sector 5

Two more sectors are defined, at increasing distance from airport ARP (Aerodrome Reference Point):

- Sector 4, circular surface at a height of 30 m from the lowest part of the runway, and at a distance of max. 15 km form the ARP. Assessment required only when the height reaches the imaginary surface of the sector
- Sector 5, circular surface starting form Sector 4 limits, at a distance of max. 45 km from the ARP. Assessment required for plants/structures higher than 45 m (60 m when in urban areas)

5.1.5 The assessment of the solar PV systems

The assessment of Solar PV projects or buildings/structures that can produce glare is required when:

- At least one of the conditions described in the procedure is met. Such condition can be met in case the solar PV project can affect the operation of communication, navigation and surveillance facilities. Similarly to the FAA requirements, the procedure requires that the siting of the solar PV equipment complies with the requirements set forth in the available ENAC circulars, in order to prevent any impact on the above said equipment. In this regards, the ENAC concerns mainly regard physical obstruction, knowing that electromagnetic interference is not expected when the equipment comply with the international standards and the electromagnetic compatibility directives.
- The construction site is located within 6 km from the closest ARP, and
    - the solar PV plant has a surface of or larger than 500 sqm, or
    - the overall surface of the PV panels is equal or larger than 1/3 (33%) of the plot affected by the plant construction.

  Particularly the procedure requires a study that certifies the absence of glare. This study must be included in the design package submitted for the ENAC evaluation, there is no requirements in regards to the methodology to carry out this study.

The ENAC-ENAV assessment is not required for the following solar PV systems:

- rooftop solar PV systems of overall surface lesser than 500 sqm, regardless the distance from airport, that don't modify the height of an already authorized building where the PV panels will be placed.
- solar PV plants to be developed in Sector 4 (at a distance larger than 6 km) and in Sector 5, assuming the height of solar PV modules don't reach the imaginary surfaces defined in these sectors.

ANNEX A - EXAMPLES OF SOLAR PV SYSTEMS ON AIRPORTS

A number of solar PV systems have been installed on airports. Some systems, ground mounted or on rooftops, are located on sites that cannot impact on aviation. When this potential impact was investigated suitably, proper siting of the PV modules was agreed between the developers/installers, the airport contractors, and the airside authority. The FAA Technical Guidance [4] reports several examples of solar PV system installed on airports.

The UK Solar Trade Association also performed an extensive research and found no examples of issues or sustained complaints arising on grounds of pilot distraction [3]. Some evidence of complaints from air traffic controllers was found with respect to one installation at Manchester-Boston regional airport, New Hampshire, USA. Air traffic controllers reported a patch of glare from panels for 45 minutes each morning, which was then resolved by changing the orientation of the panels with an acceptable 10% decrease of power generation. Furthermore this was an issue for traffic controllers only, whereas no pilots or aircraft reported any similar issues with glare.

The "Technical Guidance" reports case studies and examples of solar PV systems on airports, two of them are shown in the next pictures.

Figure 11 – Ground mounted PV panels at Metropolitan Oakland Int. Airport – California (source: [4])

Figure 12 – Solar Trees on Parking Garage at Boston's Logan Airport (source: [4])

Regarding the installation within the Italian airports, the ENAV installed PV plants, on airport rooftops or ground mounted in remote sites where air traffic control equipment are located. Information is available from the ENAV website https://www.enav.it/sites/public/en/ChiSiamo/Photovoltaic.html. The pictures show PV panels installed on airport or on sites below air corridors ("en route").

Figure 13 – PV plants in proximity of the tower within the Bari airport (source: ENAV website)

Figure 14 – PV plants in proximity of the tower within the Brindisi airport (source: ENAV website)

Figure 15 – PV plant in proximity of the ACC Radar located next to Brindisi (source: ENAV website)

Figure 16 – PV plant on the rooftop of an operational buildings (source: ENAV website)