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An analysis of the impact of PV farms on airport operation

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Abstract: Large PV installations are being built increasingly often in areas close to airports in Poland and around the world. These are not only roof installations but also large PV farms, allowing not only the supply of the energy for the airport itself but also the ability to sell the excess energy produced. The applied PV installations may cause in some cases negative impact in the form of e.g., electromagnetic fields and light reflections which may limit the visibility of pilots and air traffic controllers. The article presents an overview of various negative impacts of PV farms on the workings of an airport and the main factors influencing the occurrence of certain threats have been diagnosed. An assessment of the usefulness of the tool and method for simulation and the reduction of possible negative impacts is also presented.

Keywords: photovoltaic farm, PV installations on airports, PV farm impact

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Introduction

Global climate change as a consequence of years of increased greenhouse gas emissions require people to effectively resolve this problem. For this reason, more and more renewable energy installations are being built every year, significantly contributing to reduced pollution. Among the fastest growing industries of renewable energy sources in Europe and Poland is photovoltaic power. According to the report "The Photovoltaic Market in Poland 2022" prepared by the Institute for Renewable Energy (IEO), at the end of 2021 the installed capacity in the European Union in photovoltaics amounted to 158 GW. An increase in 2021 of 21.4 GW and a growth rate of 15% compared to 2020. According to the authors of the report, Poland most likely came second in terms of the increase in installed PV capacity in the European Union. Photovoltaic power production is the main driving force behind renewable energy in Poland and the installed capacity exceeding 10 GW already exceeds wind energy (Flizikowski & Mroziński, 2016; Idzikowski et al., 2022).

Areas of land around airports are increasingly more often indicated as potential locations for PV farms. This is due to the fact that large areas of land around the airports are flat and excluded from use. In addition, for a long time the aviation industry has been criticized by environmentalists for the excessive production of large amounts of carbon dioxide by planes and airports. According to data provided by the Air Transport Action Group (ATAG), air transport is responsible for 12% of all CO_2 emissions from transport sources. In many countries, airports are designing and planning investments in PV farms located on their land, on rooftops or the elevation of buildings. Due to the lack of shading facilities and the predominance of flat areas, airports are very good locations for the installation of PV systems. Airports with their surplus of land (e.g., buffer areas) can not only be self-sufficient but also generate enough electricity to send the excess back to the grid. The article presents an overview of various negative impacts of PV farms on the functioning of airports and the main factors influencing the occurrence of specific threats to airports from PV. The proposed tools and methods for simulating and limiting possible negative impacts were also presented (https://www.pv-magazine-australia.com/2018/09/06/northern-territory-airports-to-add-solar-farms; Flizikowski & Mroziński, 2016; Idzikowski & Cierlicki, 2021; Walichnowska & Idzikowski, 2021).

1. Possible threats related to the existence of a PV farm near an airport

The construction of a large number of glass surfaces of PV modules can cause light reflection from these surfaces in some areas. In many industries, e.g., automotive and transport, the phenomenon of sunlight reflecting from flat surfaces (water, snow, ice) is treated as harmful. It is recommended to use sunglasses, preferably with polarized lenses that neutralize glare. On a sunny day a driver without appropriate glasses has a more restricted field of view and much less comfort when driving. They have a special filter that neutralizes glare from the sun, reflects light, increases the contrast of vision and additionally protects the eyes against harmful UV radiation. These factors are the extremely important in the aviation industry where possible reflections of light coming from PV modules located at airports may cause threats to the security and operation of the airports (https://www.pagerpower.com/news/solar-panel-glare; www.forgesolar.com; Kantamneni et al., 2016; Sreenath et al., 2020).

In order to avoid the negative, potential impact of photovoltaic farms on air traffic, the Federal Aviation Administration in the USA (FAA) has defined conditions for the influence of solar radiation reflection. Apart from the obvious issues of aviation safety requirements, what should be first of all emphasized is the fact that modern PV modules are designed to absorb incident light, i.e., to reflect only a small amount of sunlight falling on them compared to most other surfaces and objects. This is due to the manufacturers' efforts to ensure that these modules absorb as much of the solar radiation as possible and thus produce as much electricity as possible. Research shows that typical PV modules reflect much less light than for example water and reflects a similar amount of solar radiation as a forest (Fig. 1) (https://www.solarchoice.net.au/blog/solar-panels-near-airports-glare-issue/; Ruesch et al., 2016).

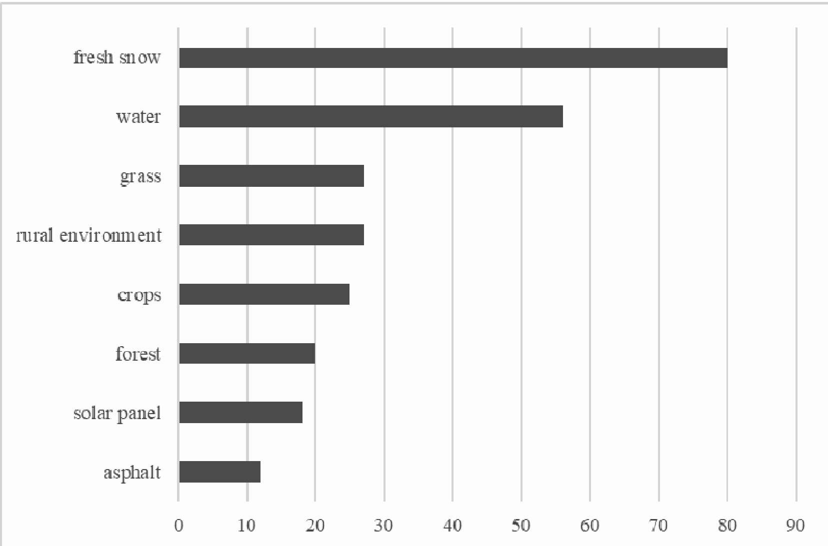

Fig. 1. Different surfaces in terms of the degree of solar radiation reflected (*own elaboration developed on the basis of the https://www.solarchoice.net.au/blog/solar-panels-near-airports-glare-issue/*)

According to the literature, the sun itself is the greatest threat to glare in aviation – especially when it is low above the horizon. In the study "Solar photovoltaic energy facilities: assessment of potential for impact on aviation", the analytical company Spaven Consulting indicates that after analysing databases on aviation incidents in Great Britain and the USA in 2000-2010, in the vast majority of these cases, the source of glare from the sun itself was the main cause of the incident. A few other cases were mostly reflections from water on the asphalt or from a nearby water body. Glare from PV modules or "similar objects" was never mentioned as a factor contributing to the accident (Nguyen & Pearce, 2013; Sreenath et al., 2019).

The maximum efficiency of a photovoltaic module requires that the incident sunlight is not reflected on its way to the PV cell layer. The key is to properly select the parameters of the reflection reducing layer, thanks to the appropriate refractive index. The anti-reflective properties are influenced by the thickness of the layer, the refractive index and even with a rough control of these parameters, it is easy to achieve a 4-5% reduction in reflection. It should be emphasized once again that these measures are used primarily to increase the efficiency of modules. But the effect of minimizing light reflections is achieved. Thanks to these measures, the panes of PV modules with ARC anti-reflective coating and surface texturing allow the increase of the module's efficiency from 3.5 to even 5% compared to modules covered with classic toughened glass with a reduced iron content which are lost due to reflecting solar radiation (Barrett et al., 2014; Ortega Alba & Manana, 2017; Yu Bin Zhu, 2018).

Another important threat that may occur during the operation of the farm is the generation of a magnetic field by the farm but according to research it is the so-called non-ionizing radiation, i.e., radiation that does not cause cellular damage and does not adversely affect the environment. It is worth emphasizing that all electrical devices generate an electromagnetic field and the amount of this radiation does not adversely affect the human body. Photovoltaic panels do not emit excessive so-called electromagnetic noise. Due to their low profile, photovoltaic systems usually pose little risk of interference with the radar. In addition, PV modules do not emit electromagnetic waves at distances that may interfere with the transmission of radar signals. Any electrical devices that carry concentrated current are buried underground and far away from any signal transmission. Research conducted so far, indicates that PV modules produce very low EME frequencies similar to electrical devices and cabling. Within 150 feet of the inverters, these fields had fallen back to very low levels of 0.5 mg or less and in many cases much less than background levels (< 0.2 mG) (Mostafa et al., 2016; Mukund, 2006; Tytko, 2020).

The review of the literature shows that there is currently a lot of work on the aspects of aviation safety and the functioning of PV installations. A method of hazard identification and risk assessment is a suitable technique for assessing the risk of solar PV systems in airports. The risk aspects related to the operation of an airport PV farm can be divided into light, mechanical, environmental and electrical impacts. This issue is summarized in Table 1 (Mostafa et al., 2016; Yu Bin Zhu, 2018; Tytko, 2020).

The most critical of the possible threats to the use of PV installations at airports are the presence of light reflections from PV modules (Mostafa et al., 2016).

Table 1. Potential factors that may affect the functioning of an airport (*own elaboration*)

Potential factor affecting the functioning of the airport	Description of the potential impact on the airport	Risk assessment
The occurrence of light reflections from PV modules	Sunlight falling on the PV modules is reflected and the generated light reflections may pose a threat to the eyesight of pilots or the airport traffic controller, causing visual impairment or lack of response in the event of an air traffic risk.	A high risk has been diagnosed. It should be verified at the stage of designing a PV farm with the use of specialized software and by applying the appropriate technology of PV modules.
Disruptions in the airport communication system: radar and communication systems	The presence of PV modules at an airport can affect the transmission of communication signals, thus influencing decisions made by air traffic controllers and pilots.	The impact was assessed as low risk which could be limited by the standard design of the PV farm taking into account the parameters of the airport.
Disturbed visibility by PV modules in restricted airport airspace	If the system of modules is installed in close proximity to restricted navigation airspace, it presents a risk to aircraft traffic and airport operations. It also affects the field of view of air traffic controllers.	The impact was assessed as low risk, which could be limited by the standard design of the PV farm taking into account the parameters of the airport.
Damage to PV modules by aircraft that got into the buffer space where PV modules are installed	In the event of a technical failure, the plane may leave the runway and hit the installed PV modules, which leads to injuries and economic losses to the aircraft and PV installations.	The impact was assessed as low risk which could be reduced by the application of appropriate security systems at the airport.
The occurrence of damage caused by detachment of PV modules or other elements from mounting systems during extreme weather phenomena	In the event of high winds or similar extreme weather, components such as PV modules, mounting structures, cables, metal parts may detach from the PV system and fall onto the runway. This poses a threat to the surface movement of the aircraft during take-offs and landings.	The impact was assessed as low risk that could not be predicted. The risk can be reduced by using assembly systems with increased strength.
Electrical risks from the PV system	The occurrence of certain electrical failures leading to electric shock and possible fire outbreak which in turn threaten human life and the destruction of airport property.	The impact was assessed as low risk which can be limited by the use of appropriate protection systems for PV installations.

2. Implements and methods to simulate and reduce possible negative impacts

To assess the potential effects of glare from photovoltaic installations. the Forge Solar online tool is used. The application is based on the SGHAT (Solar Glare Hazard Analysis Tool) technology awarded by R&D 100. SGHAT was developed by the American company SANDIA Laboratories. Forge Solar meets FAA and other legal requirements. Forge Solar is used to determine the presence of glare caused by the operation of PV installations located at the airport. The Forge Solar program provides a quantitative assessment of when and where glare will occur for an airport PV plant to be constructed, and provides information about the potential effects on the eyes.

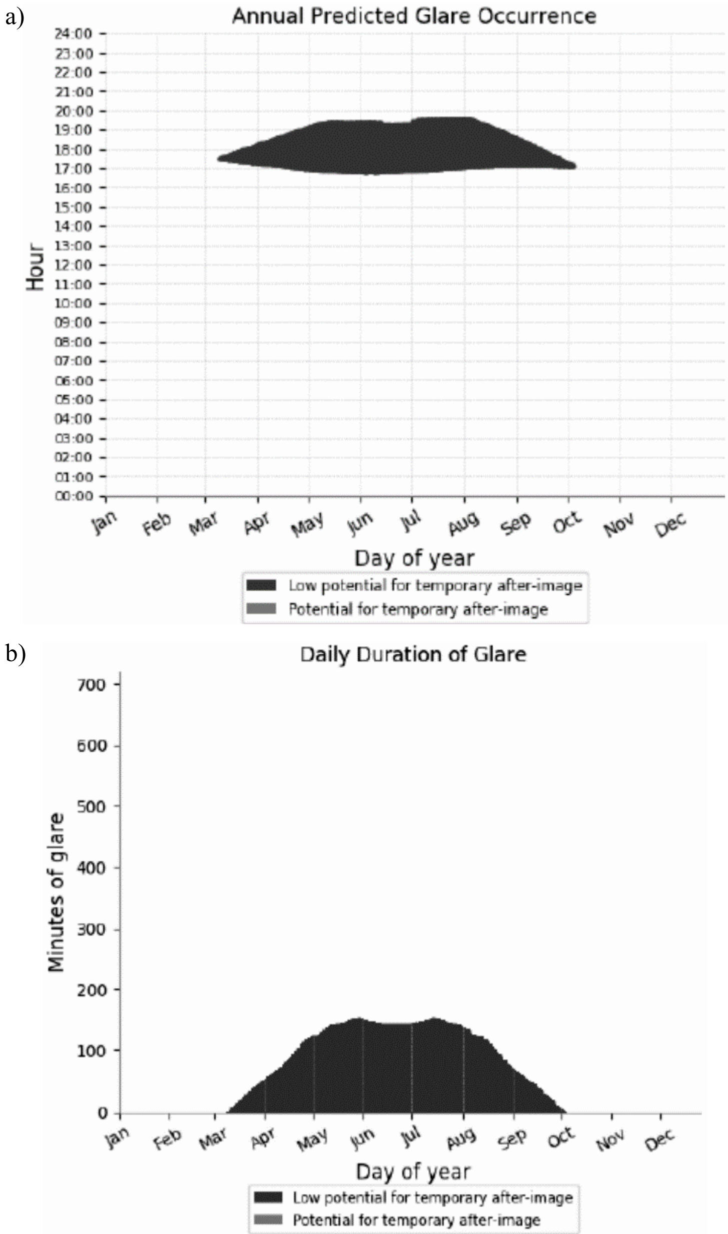

Fig. 2. An example of the interpretation of the cumulative results from the Forge Solar application for the assumed parameters: a) change in the predicted occurrence of light reflexes during the year, b) duration of light reflexes during the year (*own elaboration from the Forge Solar Application*)

The tool can also be used to optimize PV installation design (tilt and orientation) to evaluate alternative PV installation configurations, orientations and locations that not only mitigate glare but also optimizes energy production. It also has the ability to model fixed, uniaxial and biaxial photovoltaic PV systems (https://renews.biz/66679/solar-capacity-installations-in-2021-could-hit-209gw).

For the program as input data it is necessary to define the location of the airport, designate the area covered with photovoltaic panels that is to be used to build a PV farm, the value of direct irradiance, and the reflectance of the PV panel (PV module type). Functional data of the airport (location and length of the runway, aircraft approach paths, location of observation towers) are also added to the program. The user can define the PV installation location using the interactive Google map provided by the software. The latitude, longitude and altitude are collected automatically and are used to calculate the position of the sun and to calculate the incidence vector of solar radiation on the PV modules. The user must enter the outline of the proposed PV farm system, and along with the airport data, it is possible to define the orientation and inclination of the photovoltaic modules and the reflection coefficient. If glare is detected, the tool estimates the position and duration of solar glare throughout the year from user-defined vantage points. Then a graph of changes in the predicted occurrence of light reflections and the duration of light reflections during the year are obtained (Fig. 2). The tool can also predict the appropriate solar yield and allow the PV farm configurations such as slope, orientation, shape etc. to be modified to simultaneously mitigate glare and maximize energy production (https://renews.biz/66679/solar-capacity-installations-in-2021-could-hit-209gw).

The interpretation of the results is based on the glare duration and colour code that defines the program. The colour code (green, yellow, red) identified for the given project assumptions by the program indicates the intensity of the light reflections recorded from a given vantage point. Program codes are an individual measure of the impact indicated by the application. Table 2 presents selected and diagnosed optimization possibilities in this area (Anurag et al., 2017; https://federallabs.org/technology/solar-glare-hazard-analysis-tool-sghat-1; https://federallabs.org/labs/sandia-national-laboratories-snl).

When investing in PV farms in different countries, the local requirements for investing in PV should be included in the project. For example, in Poland, art. 87a, sec. 1 Aviation Law: "Emission of a laser beam or light from other sources in the airspace zones – it is prohibited to emit or cause emissions in the airspace used for navigation of a laser beam or light from other sources towards the aircraft in a way that could cause glare, dazzle or afterglow and which may endanger the safety of the aircraft or the life or health of the crew or passengers on board". In analyses in other countries, the guidelines of the US Federal Aviation Administration, which issued recommendations for solar farms at airports, are often taken into account. 3.1.2 Reflectivity FAA Airport Solar Guide – Technical Guidance for Evaluating Selected Solar Technologies on Airports. These guidelines are included in the Forge Solar simulation program analysed in this article (www.faa.gov/airports/environmental/policy_guidance/media/FAA-Airport-Solar-Guide-2018.pdf).

Table 2. Glare limitation parameters for the designed PV installation with the use of Forge Solar (*own elaboration*)

Optimized parameter (unit)	Default value in Forge Solar	Glare reduction
PV modules orientation angle (degrees)	180° from the south	Possibility to limit light reflections. The parameter can be changed from 0° to 360°. During optimization, choose the parameter to reduce reflections and at the same time, obtain maximum production from the PV installation
Inclination angle of PV installation modules (degrees)	It depends on the latitude of the investment	Possibility to limit light reflections. Can be changed from 0 to 90°. During optimization, choose the parameter so as to reduce reflections and at the same time, obtain the maximum production from the PV installation
The capacity of the PV farm [kW]	Wide range of use of values	Possibility of improvement depending on the size and shape of the plot of land for investment. However, limiting light reflections may mean the necessity to limit the potential nominal power of a PV farm in a relevant location
Location of critical airport objects affected by the PV installation	Location of observation towers, aircraft approach paths, airport circles	The location and characteristics of sensitive objects significantly affect the possible occurrence of light reflection. This data is basically the same as it is difficult to change. The parameters of the PV farm should be adjusted to reduce light reflection

3. Conclusion

In order to do the simulation, it is necessary to define: the surface and position of the ground for the installation, the airport circles the defined runway approach zones – airplane approach paths and the location of both Aerodrome control towers or aerodrome controls (TWR). In addition to the associated parameters with air traffic, it is necessary to define the parameters characterizing the designed PV farm installation. The most important variable parameters here will be the azimuth of the PV installation and the inclination angle of the PV modules. After obtaining simulation results, which are characterized by the absence of harmful effects of light reflections for the assumed parameters, it is worth limiting the potential harmful effect of light reflections by the appropriate selection of PV module technology. The proposed actions on the part of the investor should concern the use of PV modules with a special anti-reflective coating (ARC) and special texturing. It is advisable to use both technologies. This will guarantee the reduction of potential solar radiation reflection by a few percent compared to standard technologies. The use of photovoltaic modules using these technologies will ensure that there is no risk of generating light reflections to a degree that hinders the work of TWR personnel and manoeuvres by planes (Mostafa et al., 2016; Yu Bin Zhu, 2018).

Producers of the PV module usually reduce the light reflectance of their modules by using a low iron content in high transmittance glass followed by an anti-reflective coating. In recemt generations of PV modules, special graphene layers have started to be used on the market. In addition, recognized manufacturers conduct Reflective Luminance Test of the glass used to build PV modules which determine the luminance levels for a specific angular setting of the PV module during operation. It is advisable to choose a manufacturer of PV modules that will offer modules in which glass was used for the construction with the best result of such a test and which will allow the verification of its parameters in relation to the proposed reference values. Another possible technology used to reduce reflection and glare from the existing PV installation is the use of PV modules with surface texturing. The simulations carried out clearly show the advantage of such a solution in relation to classic PV modules. The rough / textured surface of the PV modules reduces solar reflection (Flizikowski & Mroziński, 2016; Riley & Olson, 2011; Yu Bin Zhu, 2018).

Bibliography

Anurag, A., Zhang, J. & Gwamuri, J. (2017) General design procedures for airport-based solar photovoltaic systems. *Energies*, 10, 1194.

Barrett, S., Devita, P., Ho, C. & Miller, B. (2014) Energy technologies' compatibility with airports and airspace: Guidance for aviation and energy planners. *J. Airpt. Manag*., 8, 318-326.

Flizikowski, J., Mroziński, A. (2016) *Inżynieria instalacji fotowoltaicznych*. Monografia pod redakcją A. Mrozińskiego. Wydawnictwo Grafpol, Bydgoszcz.

Idzikowski, A., Cierlicki, T., Al-Zubiedy, A. & Zawada, M. (2022) Management the operation process of photovoltaic modules in terms of quality and performance evaluation – a case study. *Energies*, 15(5), 1652.

Idzikowski, A. & Cierlicki, T. (2021) Economy and energy analysis in the operation of renewable energy installations – a case study. *Production Engineering Archives*, 27, 2, 90-99.

Kantamneni, A., Winkler, R., Gauchia, L. & Pearce, J.M. (2016) Emerging economic viability of grid defection in a northern climate using solar hybrid systems. *Energy Policy*, 95, 378-389.

Mostafa, M.F.A., Aleem, S.H.E.A. & Zobaa, A.F. (2016) *Risk assessment and possible mitigation solutions for using solar photovoltaic at airports.* 18th International Middle-East Power Systems Conference, MEPCON 2016 – Proceedings.

Mukund, R.P. (2006) *Wind and Solar Power Systems: Design, Analysis and Operation*. 2nd ed. Boca Raton, CRC Press.

Mroziński, A. (2015) *Poradnik dobrych praktyk wdrażania instalacji odnawialnych źródeł energii*. Bydgoszcz, Wydawnictwo 1studio.pl.

Nguyen, H.T. & Pearce, J.M. (2013) Automated quantification of solar photovoltaic potential in cities. *Int. Rev. Spat. Plan. Sustain. Dev.*, 1, 57-70.

Ortega Alba, S. & Manana, M. (2017) Characterization and analysis of energy demand patterns in airports. *Energies*, 10(1), 119.

Riley, E.E. & Olson, S. (2011) *A study of the hazardous glare potential to aviators from utility-scale flat-plate photovoltaic systems*. International Scholarly Research Network ISRN Renewable Energy.

Ruesch, F., Bohren, A., Battaglia, M. & Brunold, S. (2016) Quantification of glare from reflected sunlight of solar installations. *Energy Procedia*, 91, 997-1004.

Sreenath, S., Sudhakar, K. & Yusop, A.F. (2019) SWOT analysis of solar PV systems in airport environment. *International Journal on Emerging Technologies*, 10, 2, 1-7.

Sreenath, S., Sudhakar, K., Yusop, A.F., Cuce, E. & Solomin, E. (2020) Analysis of solar PV glare in airport environment: Potential solutions. *Results in Engineering*, 5.

Tytko, R. (2020) *Photovoltaics*. Kraków, Wydawnictwo i Drukarnia Towarzystwa Słowaków w Polsce.

Walichnowska, P. & Idzikowski, A. (2021) *Energy analysis of the PV farm with a capacity of 140 MW.* Sciendo, QPI, 3, 369-376.

Yu Bin, Zhu (2018) The potential hazard analysis method of glare for photovoltaic near airports or within. IOP Conf. Series: Materials Science and Engineering, 392.

https://www.pv-magazine-australia.com/2018/09/06/northern-territory-airports-to-add-solar-farms/

https://www.pv-magazine-australia.com/2020/08/04/csiro-report-shows-flightpath-to-hydrogen-fuelled-commercial-aviation

https://federallabs.org/technology/solar-glare-hazard-analysis-tool-sghat-1

https://federallabs.org/labs/sandia-national-laboratories-snl

www.faa.gov/airports/environmental/policy_guidance/media/FAA-Airport-Solar-Guide-2018.pdf