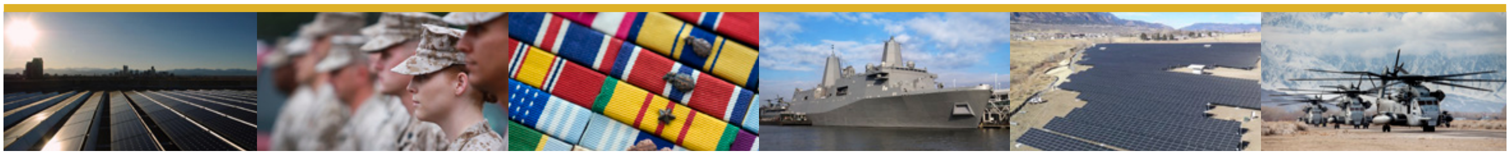

Analyzing Glare Potential of Solar Photovoltaic Arrays

Light reflected from solar photovoltaic (PV) panels may cause glare. It is important to consider potential impacts from glare when siting a solar PV array at or near airfields.

Glint and Glare Basics

Glint is a momentary direct reflection of light, whereas glare is an indirect reflection of light that can be both larger and of longer duration. PV arrays typically do not cause glint, but glare can be a concern. Glare intensity from PV arrays is generally low compared to that of buildings or snow and ice because the panels are designed to absorb sunlight and have textured glass and/or antireflective coatings that reduce reflectivity.

In conjunction with the U.S. Department of Energy, the Federal Aviation Administration (FAA) has determined that glare from solar PV arrays could result in ocular impact to pilots and/or air traffic controllers; therefore, a glare analysis is required for all proposed PV system installations within FAA-controlled boundaries. The FAA requests that the Solar Glare Hazard Analysis Tool (SGHAT), developed by Sandia National Laboratories, be used to complete any such analysis. Additionally, the FAA has established the following acceptance criteria:

- No potential for glare to the air traffic control tower (ATCT) at cab elevation
- Only glare with a low potential for after-image during the last two miles of the standard, straight-in landing approach.

The Department of Defense (DoD) has issued guidance recommending the use of SGHAT for impact analysis of solar PV on DoD air operations. Unlike the FAA, however, it does not specify allowable risk thresholds (i.e., acceptance criteria).

Glare Analysis

SGHAT can be used to determine whether a proposed solar PV project would have the potential for ocular impact. The tool has the capability of determining the following conditions:

- No glare
- Glare with the low potential to cause an after image[1]
- Glare with the potential to cause an after image
- Glare with the potential to cause eye damage.[2]

To perform the analysis, SGHAT requires information about local flight operations and design parameters of the PV array (i.e., array elevation, geometry, orientation, and tilt). Flight operations are modeled using either observation points (OP) or flight-path traces. An OP assumes a 360° unobstructed view from a vantage point defined by a specified longitude, latitude, and altitude. Flight paths are a straight line of OPs that restrict the view angle and downward azimuth, therefore, glare occurring behind and/or below the aircraft is not considered in the output. The tool also assumes perfect, clear-day conditions (i.e., maximum solar irradiance and no atmospheric attenuation), no line-of-sight obstructions (i.e., buildings, trees), and no use of ocular aids to reduce irradiance to the retina (i.e., sunglasses, tinted visor).

1. An image that continues to appear in one's vision after the exposure to the original image has ceased

2. It is highly unlikely that a PV array could cause glare with the potential to cause eye damage since the panels are designed to absorb sunlight

Naval Air Station Meridian Case Study

Naval Air Station (NAS) Meridian is a military airport located 11 miles northeast of Meridian, Mississippi, and is one of the Navy's two jet strike pilot training facilities.

When a solar PV installation was proposed at NAS Meridian, NREL worked closely with air operations and air wing personnel to develop a new methodology for analyzing and visualizing complex flight patterns. Aviators and air traffic controllers provided detailed information about flight patterns, landing approaches, altitudes, cockpit visibility, and line-of-sight. Based on this input, it was determined that non-linear flight paths could be replicated by a series of OPs in lieu of analyzing segments of flight paths. Both OPs and the minimum and maximum prescribed altitudes could be used to mimic the flight pattern and landing approaches. This ensured that results were robust and conservative.

Proposed PV system design parameters, provided by the developer, were assessed to identify the potential impact PV arrays could have on the numerous flight patterns and landing approaches for each runway, as well as the ATCT. Preliminary SGHAT runs showed that in order to ensure a complete and defensible set of results, more OPs were needed to fill in gaps. Results also indicated that average altitude for each flight segment was adequate to ensure robust results. In all, about 300 SGHAT runs were completed, which provided a thorough understanding of potential impacts on flight operations from the proposed PV systems.

SGHAT results can be difficult to interpret by personnel unfamiliar with the tool. Therefore, NREL also developed a new way to display the information in an easy-to-understand format. The novel method plotted the outputs along the flight paths, showing pilots where they could expect to encounter glare from the solar PV array(s). This information permitted aviators and air operations personnel to provide constructive feedback regarding PV system placement and design, which enabled the project to move forward in the development cycle.

Department of the Navy (DoN) flight operations are not the same as those for commercial air traffic. Flight patterns are much more complex, including more overhead routes. Landing approaches are often non-linear and generally steeper (up to 10°). SGHAT is capable of varying the steepness of descent (or glide slope), but does not have the ability to analyze curved flight patterns and landing approaches. To address these limitations, NREL has developed a new methodology for analyzing and visualizing complex flight patterns. The new approach provides conservative, defensible results that can be used as an aid in determining the development pathway for a PV system at a military airport.

Useful References

1. Federal Aviation Administration (FAA). 2010. Technical Guidance for Evaluating Selected Solar Technologies at Airports. Federal Aviation Administration-Office of Airports, Washington, DC; FAA-ARP-TR-10-1:162 pp. https://www.faa.gov/airports/environmental/policy_guidance/media/airport-solar-guide-print.pdf.

2. Federal Aviation Administration (FAA). 2013. Interim Policy, FAA Review of Solar Energy System Projects in Federally Obligated Airports. Federal Register; Vol. 78, No. 205, pg. 63276-63279. https:/www.gpo.gov/fdsys/pkg/FR-2013-10-23/pdf/2013-24729.pdf.

3. U.S. Department of Defense (DoD). 2014. Procedures Memo #4: Glint/Glare Issues on or near Department of Defense Aviation Operations. Office of the Secretary of Defense (OSD), Washington, DC. http://www.acq.osd.mil/dodsc/library/Procedures_Memo_4_Glint%20Glare%20Issues%20on%20or%20near%20DoD%20Aviation%20Operations.pdf.

4. Ho, C.K., C.A. Sims, J. Yellowhair, and E. Bush. 2014. Solar Glare Hazard Analysis Tool (SGHAT) Technical reference Manual. Sandia National Laboratories, Albuquerque, NM: SAND2014-18360. https://share.sandia.gov/phlux.

CONTACT INFORMATION

For more information, contact Alicen Kandt, Sr. Engineer, Alicen.Kandt@nrel.gov, 303-384-7518 or Steven Phillips, Project Manager, Steven.L.Phillips@navy.mil, 757-322-4029.

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
303-275-3000 • www.nrel.gov

NREL prints on paper that contains recycled content.

Prepared by the National Renewable Energy Laboratory (NREL), a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy; NREL is operated by the Alliance for Sustainable Energy, LLC.

NREL/FS-6A10-67250 • www.navy.mil • November 2016