Arlington Microgrid Glare Study

prepared for

Snohomish County
Public Utility District No. 1
Arlington Microgrid Project
Everett, WA

Project No. 104583

Revision 0
1/31/2018

prepared by

Burns & McDonnell Engineering Company, Inc.
Fort Worth, TX

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## APPENDIX

- APPENDIX A - RESULTS
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# LIST OF ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Term/Phrase/Name</th>
</tr>
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<tbody>
<tr>
<td>ARC</td>
<td>Antireflective coating</td>
</tr>
<tr>
<td>ATCT</td>
<td>Air traffic control tower</td>
</tr>
<tr>
<td>FAA</td>
<td>Federal Aviation Association</td>
</tr>
<tr>
<td>PV</td>
<td>Photovoltaic</td>
</tr>
<tr>
<td>SGHAT</td>
<td>Solar Glare and Hazard Analysis Tool</td>
</tr>
<tr>
<td>TCH</td>
<td>Threshold clearing height</td>
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1.0 SUMMARY

Solar glare hazard analysis was performed on the proposed solar array in Snohomish County. The result indicates none of the flight paths are showing potential for after image glare.

1.1 Methodology

Solar glare hazard analysis is performed utilizing the GlareGauge module form Forge Solar. The Glare hazard analysis utilizes proposed general site locations and typical initial panel array orientation and tilt for the latitude for the site. Determination of glare occurrence requires knowledge of the following: sun position, observer location, and the tilt, orientation, location, extent, and optical properties of the modules in the solar array. Vector algebra is then used to determine if glare is visible from the prescribed observation points.

The area of the array is geo located and input to SGHAT.

1.2 Assumptions and Limitations

The following flight paths were selected for evaluation:
• Runway 11
• Runway 16
• Runway 29
• Runway 34

The following assumptions were made for the site and input data

• PV Orientation 180 degrees
• Tilt 30 degrees
• Panels with textured glass and with ARC
• All analysis based on straight-in approach and ATCT criteria
• Approach glide slopes per FAA published values TCH of 50’.

The following is a list of assumptions and limitations of the model and method used in SGHAT

• SGHAT does not rigorously represent the detailed geometry of a system; detailed features such as gaps between modules, variable height of the PV array, and support structures may impact actual glare results.
• SGHAT assumes that the PV array is aligned with a plane defined by the total heights of the coordinates outlined in the Google map.
• SGHAT does not consider obstacles (either man-made or natural) between the observation points and the prescribed solar installation that may obstruct observed glare, such as trees, hills, buildings, etc.
• The variable direct normal irradiance (DNI) feature (if selected) scales the user prescribed peak DNI using a typical clear-day irradiance profile. This profile has a lower DNI in the mornings and evenings and a maximum at solar noon. The scaling uses a clear-day irradiance profile based on a normalized time relative to sunrise, solar noon, and sunset, which are prescribed by a sun-position algorithm [2] and the latitude and longitude obtained from Google maps. The actual DNI on any given day can be affected by cloud cover, atmospheric attenuation, and other environmental factors.
• The ocular hazard predicted by the tool depends on a number of environmental, optical, and human factors, which can be uncertain.
• Single- and dual-axis tracking compute the panel normal vector based on the position of the sun once it is above the horizon. Dual-axis tracking does not place a limit on the angle of rotation,
unless the sun is below the horizon. For single-axis tracking, a maximum angle of rotation can be applied to both the clockwise and counterclockwise directions.

2.0 RESULTS

All flight paths analyzed show the glare produced either has zero or low potential for after-image. The results for all paths analyzed fall within the FAA acceptance criteria. Refer to Appendix A for full report results.

- Runway 11
  - No measurable glare predicted along this flight path.

- Runway 16
  - No measurable glare predicted along this flight path.

- Runway 29
  - Glare produced within the flight path for Runway 29 occurs in the months of May-July between 6:30 am and 7:00 am and has a duration of less than 10 minutes. This glare is beyond 50 degrees from the pilot line-of-sight and is not considered to be a glare hazard. There are 0 minutes of annual “green” glare – the minimum threshold considered to be a glare hazard.

- Runway 34
  - Glare produced within the flight path for Runway 34 occurs in the months of April-August between 6:00 am and 7:00 am and has a duration of less than 5 minutes. This glare is beyond 50 degrees from the pilot line-of-sight and is not considered to be a glare hazard. There are 0 minutes of annual “green” glare – the minimum threshold considered to be a glare hazard.
APPENDIX A - RESULTS
FORGESOLAR GLARE ANALYSIS

Project: Snohomish Glare Study
Arlington Airport

Site configuration: PV30 textured with ARC
Analysis conducted by Ryan Wubbens (rwubbens@burnsmcd.com) at 19:23 on 26 Jan, 2018.

U.S. FAA 2013 Policy Adherence

The following table summarizes the policy adherence of the glare analysis based on the 2013 U.S. Federal Aviation Administration Interim Policy 78 FR 63276. This policy requires the following criteria be met for solar energy systems on airport property:

- No “yellow” glare (potential for after-image) for any flight path from threshold to 2 miles
- No glare of any kind for Air Traffic Control Tower(s) (“ATCT”) at cab height.
- Default analysis and observer characteristics (see list below)

ForgeSolar does not represent or speak officially for the FAA and cannot approve or deny projects. Results are informational only.

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>STATUS</th>
<th>DESCRIPTION</th>
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</thead>
<tbody>
<tr>
<td>Analysis parameters</td>
<td>PASS</td>
<td>Analysis time interval and eye characteristics used are acceptable</td>
</tr>
<tr>
<td>Flight path(s)</td>
<td>PASS</td>
<td>Flight path receptor(s) do not receive yellow glare</td>
</tr>
<tr>
<td>ATCT(s)</td>
<td>N/A</td>
<td>No ATCT receptors designated</td>
</tr>
</tbody>
</table>

Default glare analysis and observer eye characteristics are as follows:

- Analysis time interval: 1 minute
- Ocular transmission coefficient: 0.5
- Pupil diameter: 0.002 meters
- Eye focal length: 0.017 meters
- Sun subtended angle: 9.3 milliradians

FAA Policy 78 FR 63276 can be read at https://www.federalregister.gov/d/2013-24729
SITE CONFIGURATION

Analysis Parameters

DNI: peaks at 1,000.0 W/m²
Time interval: 1 min
Ocular transmission coefficient: 0.5
Pupil diameter: 0.002 m
Eye focal length: 0.017 m
Sun subtended angle: 9.3 mrad
Site Config ID: 14487.2216

PV Array(s)

Name: PV array 1
Axis tracking: Fixed (no rotation)
Tilt: 30.0°
Orientation: 180.0°
Rated power: -
Panel material: Light textured glass with AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

<table>
<thead>
<tr>
<th>Vertex</th>
<th>Latitude (°)</th>
<th>Longitude (°)</th>
<th>Ground elevation (ft)</th>
<th>Height above ground (ft)</th>
<th>Total elevation (ft)</th>
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<td>0.00</td>
<td>130.78</td>
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<td>2</td>
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<td>131.30</td>
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<td>134.00</td>
<td>0.00</td>
<td>134.00</td>
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</tbody>
</table>
## Flight Path Receptor(s)

### Name: FP 11
- **Description:**
  - Threshold height: 50 ft
  - Direction: °
  - Glide slope: 3.5°
  - Pilot view restricted?: Yes
  - Vertical view: 30.0°
  - Azimuthal view: 120.0°

<table>
<thead>
<tr>
<th>Point</th>
<th>Latitude (°)</th>
<th>Longitude (°)</th>
<th>Ground elevation (ft)</th>
<th>Height above ground (ft)</th>
<th>Total elevation (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold</td>
<td>48.161674</td>
<td>-122.168811</td>
<td>125.49</td>
<td>50.00</td>
<td>175.49</td>
</tr>
<tr>
<td>Two-mile</td>
<td>48.179716</td>
<td>-122.202721</td>
<td>36.53</td>
<td>784.88</td>
<td>821.40</td>
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</tbody>
</table>

### Name: FP 16
- **Description:**
  - Threshold height: 50 ft
  - Direction: °
  - Glide slope: 3.0°
  - Pilot view restricted?: Yes
  - Vertical view: 30.0°
  - Azimuthal view: 120.0°

<table>
<thead>
<tr>
<th>Point</th>
<th>Latitude (°)</th>
<th>Longitude (°)</th>
<th>Ground elevation (ft)</th>
<th>Height above ground (ft)</th>
<th>Total elevation (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold</td>
<td>48.169334</td>
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<td>133.85</td>
<td>50.00</td>
<td>183.85</td>
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<td>Two-mile</td>
<td>48.198242</td>
<td>-122.157300</td>
<td>44.16</td>
<td>693.15</td>
<td>737.30</td>
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</tbody>
</table>

### Name: FP 29
- **Description:**
  - Threshold height: 50 ft
  - Direction: °
  - Glide slope: 4.0°
  - Pilot view restricted?: Yes
  - Vertical view: 30.0°
  - Azimuthal view: 120.0°

<table>
<thead>
<tr>
<th>Point</th>
<th>Latitude (°)</th>
<th>Longitude (°)</th>
<th>Ground elevation (ft)</th>
<th>Height above ground (ft)</th>
<th>Total elevation (ft)</th>
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<tbody>
<tr>
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<td>167.59</td>
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<td>407.75</td>
<td>498.31</td>
<td>906.06</td>
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</table>
GLARE ANALYSIS RESULTS

Summary of Glare

<table>
<thead>
<tr>
<th>PV Array Name</th>
<th>Tilt (°)</th>
<th>Orient (°)</th>
<th>&quot;Green&quot; Glare</th>
<th>&quot;Yellow&quot; Glare</th>
<th>Energy kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV array 1</td>
<td>30.0</td>
<td>180.0</td>
<td>0</td>
<td>0</td>
<td>-</td>
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</tbody>
</table>

Total annual glare received by each receptor

<table>
<thead>
<tr>
<th>Receptor</th>
<th>Annual Green Glare (min)</th>
<th>Annual Yellow Glare (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FP 11</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>FP 16</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>FP 29</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>FP 34</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Results for: PV array 1

<table>
<thead>
<tr>
<th>Receptor</th>
<th>Green Glare (min)</th>
<th>Yellow Glare (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FP 11</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>FP 16</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>FP 29</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Name: FP 34
Description:
Threshold height: 50 ft
Direction: °
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 120.0°

<table>
<thead>
<tr>
<th>Point</th>
<th>Latitude (°)</th>
<th>Longitude (°)</th>
<th>Ground elevation (ft)</th>
<th>Height above ground (ft)</th>
<th>Total elevation (ft)</th>
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<tbody>
<tr>
<td>Threshold</td>
<td>48.154756</td>
<td>-122.156210</td>
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<td>171.02</td>
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<td>Two-mile</td>
<td>48.125848</td>
<td>-122.155453</td>
<td>98.54</td>
<td>625.94</td>
<td>724.48</td>
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</table>
Receptor | Green Glare (min) | Yellow Glare (min)
---|---|---
FP 34 | 0 | 0

**Flight Path: FP 11**

0 minutes of yellow glare
0 minutes of green glare

**Flight Path: FP 16**

0 minutes of yellow glare
0 minutes of green glare

**Flight Path: FP 29**

0 minutes of yellow glare
0 minutes of green glare

---

**Flight Path: FP 34**

0 minutes of yellow glare
Assumptions

"Green" glare is glare with low potential to cause an after-image (flash blindness) when observed prior to a typical blink response time. "Yellow" glare is glare with potential to cause an after-image (flash blindness) when observed prior to a typical blink response time. Times associated with glare are denoted in Standard time. For Daylight Savings, add one hour.

Glare analyses do not account for physical obstructions between reflectors and receptors. This includes buildings, tree cover and geographic obstructions.

The glare hazard determination relies on several approximations including observer eye characteristics, angle of view, and typical blink response time. Actual values may differ.

Hazard zone boundaries shown in the Glare Hazard plot are an approximation and visual aid based on aggregated research data. Actual ocular impact outcomes encompass a continuous, not discrete, spectrum.

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SE 1/4, SECTION 22, TOWNSHIP 31, RANGE 5 EAST, WM

SHEET: 12/08/17
DATE: 12/08/17
REVISION: XX

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