

SUNLINK WIND LOAD CAPABILITY AND ROOFTOP WIND LOAD CAPABILITY

1. Introduction

The Eastwood Energy (EE) SunLink PV Module Mounting System is a field-deployable light alloy structure that orients and secures PV modules on flat rooftops in the built environment. Buildings are constructed and used in a context consisting of site, structure, surfaces and services. PV systems interact with and are integrated into all these elements. The SunLink MMS is the primary interface for a PV system in respect to the site, the structure and the surfaces.

In this document, wind effects on the SunLink system and on rooftops are discussed. Load effects resulting from other environmental influences (e.g., seismic, snow) are treated separately.

Wind resistance requirements for buildings are specified in building codes. To verify that SunLink is compatible with a building setting, EE refers to the International Building Code, 2003 edition, Section 1609, which in turn refers to Section 6 of ASCE 7-98 (currently ASCE 7-02) “Minimum Design Loads for Buildings and Other Structures.” In the California built environment, the California Building Code, 2001 edition, Part 2, Volume 2 recognizes design in accordance with national standards such as ASCE 7-02. See for instance, Section 1615 (and Section 1615A):

“...any structure may be, designed in accordance with approved national standards.”

All buildings incorporate a Main Wind Force Resisting System (MWFRS) that allows transfer of received wind loads to the building foundation and to ground. In turn, the building surface system (cladding) is attached to the MWFRS. For a PV system, the cladding of interest is the roof. PV systems are placed on top of the roofing system and impose loads on that system that are in turn transferred to the MWFRS. A PV system may be directly attached to the building MWFRS. Alternatively, the system incorporates ballast so that total mass is sufficient to resist wind loads.

2. Combination Loads on a Roof

Before consideration of wind loads, verify that the building roof and structure are sufficient to accept the distributed loads and the point loads that PV systems impose on roofs. Refer to ASCE 7- Section 2.0 in order to determine an appropriate basis for evaluating combinations of loads.

In the specific context of a PV system, distributed loads refer to the total weight of the PV system in reference to the plan area occupied, expressed as pounds per square foot (psf). Point loads arise from the fact that PV systems typically consist of sections that are either elevated off the roof (e.g., modules in “ventilated” configuration) or that locally concentrate mass (e.g., as perimeter ballast). Some portions of the PV system are in direct contact with the roof and others are not. Therefore point or concentrated loads refer to the total weight of the PV system in reference to the area in direct contact with the roof, and are also expressed in terms of pounds per square foot.

Distributed loads vary with row separation, a function of local latitude, module tilt angle and self-shading spacing. Concentrated loads are a function of the PV system architecture and in particular of the MMS design. The SunLink system tilt bracket base, an essential element of the SunLink architecture, may be varied in contact area in order to limit concentrated loads. Tilt bracket bases transfer both gravity loads (PV system weight) and wind-imposed loads to the MWFRS.

3. SunLink Wind Force Resistance

PV modules have a large surface area relative to weight. At useful tilt angles and ASCE 7- design wind loads, PV modules experience uplift, drag and side forces. These wind-induced forces are resisted by SunLink MMS engineered features that create a balanced and efficient load path for transfer of wind loads imposed on the modules to the MWFRS.

SunLink was static load tested in accordance with the procedural guidelines of ASTM E 1830-01 to withstand upward (negative) loading equivalent to 140 mph wind loads applied normal to the module back surfaces arranged as a four-module panel configuration oriented at a 20° tilt angle.

Equivalently, SunLink was static load tested with downward (positive) loading equivalent to 140 mph wind loads applied normal to the module front surfaces arranged as a four-module panel configuration oriented at a 10° tilt angle. This phase of testing included verification of individual module electrical functional performance before, during and after 50-psf (140 mph) static loading.

1. Test Report: Proof Load Testing of SunLink Photovoltaic Module Mounting System, Report No. 2004525 by D. A. Kienholz, Ph.D., Principal Engineer, CSA Engineering, Inc., Mountain View, CA, July 2004 reviewed by C. D. Johnson, Ph.D, P.E.-M.E. (CA)
2. Test Report: Final Report on Electrical Open-Circuit Performance during Static Load Test, by J. T. Mead, P.E.-E.E. (CA), Lodi, CA, August 2004

As summarized above, when a PV module is positioned normal to the atmospheric surface level air stream at ASCE 7 wind loads with the module leading edge up relative to the trailing edge, a net uplift force is imposed on the module. Most PV systems are oriented to the southern sky so the leading edge of each module in a tilted array is oriented to the north. For most US locations, winds are variable and often turbulent and should be assumed to approach from any angle.

The SunLink MMS was tested in the University of Washington Aeronautical Laboratory Kirsten Wind Tunnel. Test speeds ranged from 30 to 120 mph at tilt angles of 10 15 and 20-degrees in a four module landscape oriented panel configuration in row-wise arrangements of one, two, three and four rows. Each of the 12 test configurations was rotated through 33 discrete wind approach angles in order to determine system performance under any wind approach angle. Three-axis force and moment data was obtained for each test configuration. Force balance measurements were supplemented by visualization techniques in order to better understand system response to loads.

Data from wind tunnel testing was analyzed to determine the magnitude and direction of loads on the array at ASCE 7 wind loads. This data was then used to develop load cases for determination of operating stresses and deflections using the MacNeal-Schwendler MARC Analysis FEA codes.

1. Wind Tunnel Test Data Analysis: Eastwood Energy SunLink Module Mounting System (with Appendix 1 – UWAL data set) by Mark Lobo, Ph.D., NovaComp Engineering, Inc., Bothell, WA August 2004 reviewed by Nils Juhlin, Ph. D., P.E.-M.E. (WA)
2. Finite Element Stress Analysis: Eastwood Energy SunLink Module Mounting System by Mark Lobo, Ph.D., NovaComp Engineering, Inc., Bothell, WA August 2004 reviewed by Nils Juhlin, Ph. D., P.E.-M.E. (WA)

This information allows EE to quantify the forces and moments that act on the SunLink MMS and therefore loads that must be accommodated in the building MFWRs under ASCE 7 wind loads.

Lift is expressed as either uplift with a negative signed value, or downlift, with a positive signed value. Similarly, applicable drag force is expressed with a positive signed value. Related moments are evaluated to assess loads on the array field and in specific locations e.g., the perimeter.

If the array is directly attached to the building, then uplift, downlift and drag forces directly load the MFWRs. For ballasted arrays, downlift and drag forces are present. SunLink is an interlinked system. Therefore considering a contiguous array field, loads are distributed and the displacement of the center of pressure from the axis of symmetry, while measurable, is not significant. Typical provisions (e.g., local ballast) to secure the array perimeter provide sufficient restoring moment against loads imposed by center of pressure displacement.

4. Wind Loads on Roofs

The basis for MFWRs engineering are the basic wind speed values specified in ASCE 7- Section 6.0, Figure 6.1, which represent “nominal design 3-second gust wind speed in miles per hour (m/s) at 33 ft (10 m) above the ground for Exposure C category.” An MFWRs evaluation to assess the

suitability of a rooftop for installation of a PV system includes assessment of wind loads on the rooftop in consideration of the following additional criteria.

1. determination of the nature of the building occupancy and assignment of an importance category per ASCE 7- Section 1.0 and Table 1-1.
2. establishing a basis for assessing load combinations as set forth in ASCE 7- Section 2.0
3. consideration of regional climate that may result in “Special Wind Region” classification
4. evaluation of site exposure including directional effects and characteristics of the upwind fetch from various wind approach angles
5. determination of basic building characteristics e.g., rigid or flexible, open or enclosed
6. compilation of dimensional information for the building envelope
7. assessment of relevant attributes of components and cladding, with special attention to rooftop slope and cladding as this constitutes the PV system – building contact interface

Using the data and related materials summarized as 1-7 above and working through the procedure set forth in ASCE 7- Section 6.5.3, wind loads on the rooftop are determined. This process results in the values calculated using equations in ASCE 7- Section 6.5.12.2. These values give the wind loads on the rooftop that the PV system must withstand. The values, p , are expressed in pounds per square foot and can be retrospectively assessed in terms of basic wind speed equivalence since $q = .00256V^2$ where q is velocity pressure, psf and V is wind speed, mph, from Figure 6.1.

In most cases, the calculated wind load on the rooftop will be either greater than or less than the value obtained as $q = .00256V^2$. The “drivers” resulting in greater or lesser values are typically (not ranked): the importance category, the exposure class and the building envelope dimensions. Wind loads on rooftops vary. Edges and corners are more heavily loaded than center expanses. Rooftop features such as parapets, penthouses and roof-mounted equipment have variable effects from windward to leeward side. PV arrays arranged to minimize wind load effects require lower relative provision for anchoring and /or ballast resulting in lower installed cost.

5. Preliminary and Final SunLink Information

When EE provides an application engineering assessment for a SunLink installation on a given rooftop, accuracy of results is contingent on the availability of information that is summarized as 1-7 above. Resulting values may be revised upward or downward according to the dependence of specified values on calculations containing EE estimates as compared to actual values obtained as information becomes available from as-built drawings or from a site and building survey.

The accompanying EE SunLink drawing(s) and document(s) are marked either “preliminary” or “final.” Sources of information used by EE are specified. Preliminary drawings and documents enable structural engineers to make a code compliant assessment of a PV system incorporating SunLink, assuming that the engineer also obtains the information summarized as 1-7 above.

“Final” documents are prepared by EE as soon as the information summarized as 1-7 above is available to EE. Please note that obtaining building permits need not be contingent upon receipt of “final” information from EE. When combined with a code compliant assessment of the site and structure, “preliminary” EE information will often be sufficient to obtain a building permit.

Attachments: (1) SunLink Application Engineering Worksheet(s)
 (2) SunLink Layout and Installation Drawing(s)