Heliostat Consortium: Gaps Analysis on Wind Load for Achieving a Fully Competitive Heliostat Industry

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1. Introduction

The National Renewable Energy Laboratory (NREL), partnering with Sandia National Laboratories (Sandia) and the Australian Solar Thermal Research Institute (ASTRI), proposes to develop and manage a national laboratory-led U.S. consortium to support research, development, validation, commercialization, and deployment of low-cost and high-performance heliostats with optimized operation and maintenance (OM) for concentrating solar power (CSP) and concentrating solar thermal (CST) applications. This heliostat consortium (HelioCon) will work closely with the U.S. Department of Energy (DOE) and a board of advisors composed of CSP developers, component suppliers, utilities, and international experts to achieve DOE SunShot objectives for U.S.-manufactured heliostat cost, performance, and reliability. To further advance U.S. heliostat technologies, HelioCon will engage subject-matter experts and general stakeholders for direct, project-level collaboration, external consulting, and mission-specific panels or workshops.

In Year 1 of HelioCon, a roadmap study report will be developed to identify the high-priority gaps in advancing heliostat technologies. The paper here will present our initial findings on the topic of wind loading.

2. Scope of the topic

The topic of wind characterization and loading of heliostats due to wind has been identified by various stakeholders as a critical area of importance in the Concentrating Solar Power (CSP) Best Practices Study [1]. Currently field and wind tunnel-based measurements and simulation-based investigations are used to characterize wind loading and influence design of heliostats. Heliostats are exposed to atmospheric wind that imposes unsteady loads on the drives, torque tube, pylon, foundation and mirror support components. The wind-bearing heliostat components are designed for two conditions:

(a) serviceability with sufficient stiffness to minimize local deformations of the mirror surface, typically with a maximum slope error of the order of 1 mrad, during operation at all orientations
(b) survivability with sufficient strength to resist the maximum loads in operation and during high-wind events when the heliostat surface is aligned horizontally in the stow position.
Operating heliostats are characterized by maximum drag forces with increasing surface area with respect to the approaching wind, whereas stowed heliostats are characterized by maximum lift forces in a highly turbulent flow generated by upstream roughness in the atmospheric boundary layer (ABL). Static wind loads on heliostats are conventionally defined using non-dimensional aerodynamic coefficients that account for the heliostat shape depending on the structural design and ABL turbulence characteristics depending on the surface roughness of a field site. Wind load coefficients are used in combination with stow and survival design wind speeds to estimate the bending and torsional loads at the hinge and base of the heliostat pylon resisted by the torque tube, pedestal and foundation. Dynamic wind loads induced by coupling between the temporal variations of the wind loads and the dynamic properties of the heliostat structure, lead to unsteady pressure distributions and oscillations of the heliostat surface that impact the tracking accuracy and optical performance of the heliostat field.

Detailed understanding of the static loads and dynamic response of a heliostat design with respect to the local wind conditions at field sites are critical for heliostat designers and manufacturers to:

- reduce conservative manufacturing tolerances and material cost
- increase field efficiency and reliability and thus reduce risk of component failures due to high-wind events.

As wind loads increase with heliostat area, the required diameter and thickness of the pedestal, torque tube and mirror support trusses increase to ensure the combined bending and torsional stresses remain below the ultimate tensile stress of the material within an acceptable limit of safety [2, 3]. The maximum wind loads are highly sensitive to the variation of turbulent wind fluctuations with surface roughness and height in the lowest 10 m of the ABL [4]. This has significant implications due to:

- the significant variability of local wind conditions at different field sites
- the range of heliostat sizes and structural designs deployed in commercial fields
- wind-induced tracking errors significantly impacting the operational performance of power tower plants, particularly with increasing distance from the tower.

3. Gaps analysis

In the paper, the following analysis will be presented:

- The state-of-the-art in characterizing wind conditions and loading for design of heliostats
- The initial list of gaps on wind loading
- Gaps ranking
- Top-ranked gap analysis, justification and addressing strategy
- Impacts of top-ranked gaps.

References