Solar World Congress 2025

INSTRUCTIONS FOR EXTENDED ABSTRACTS

AEROELASTIC STABILITY OF SOLAR TRACKER: WIND TUNNEL TESTING

Summary

This paper presents the aeroelastic characterization of the HexaTracker, a single-axis solar tracking system developed by Brametal, through wind tunnel tests conducted at CPP Wind (USA). The primary objective was to evaluate the structure's stability and inform the stow position strategy. Around 50 configurations were tested, covering various tracker characteristics and wind conditions. The results showed high critical wind speeds (Ucr), confirming the high torsional rigidity and structural damping of the HexaTracker. This allows for stow positions with low tilt angles, reducing structural demands on foundations, torque tubes, and PV modules.

Keywords: solar tracker, wind tunnel, aeroelastic stability

1. Introduction

The Brazilian solar industry has experienced significant growth in recent years. According to ABSOLAR, solar energy accounted for 19.5% of Brazil's energy matrix in 2024, ranking second in installed capacity. A large portion of this capacity is composed of ground-mounted solar power plants.

In such plants, PV modules, inverters, and support structures represent the majority of the capital cost. Single-axis trackers (SATs) are commonly preferred due to their ability to increase energy production compared to fixed structures Martínez-García et al. (2021). These trackers, typically oriented along a north-south axis, consist of PV modules mounted on a torque tube supported by multiple piles and driven by a central driver.

In Brazil, wind loads govern the structural design of these systems. Wind-induced forces, including torsional and axial loads, must be resisted by the structure’s elements such as piles, tubes, supports, and the PV modules themselves. Because trackers can operate across a wide range of tilt angles (−55° to +55°), they must be designed to withstand the wind load in any condition. Since the system is actively controlled, a common approach is to transition the trackers into a predetermined position during high wind events—this is known as the stow position. Thus, determining the stow position is a key step in the design process.

Due to the innovative nature of this type of structure, current standards and literature lack clear procedures for design. Therefore, it is strongly recommended to conduct wind tunnel tests to properly characterize the forces acting on the structure. In general, static tests combined with dynamic considerations allow for defining load cases and, consequently, for structural design.

However, due to their configuration, SATs are susceptible to aeroelastic torsional instabilities, which are not captured by static wind load assessments. Two major instability mechanisms are typically observed: Enshaei et al. (2023); Rohr et al. (2015), Zhang et al. (2023).

- Cyclical torsional divergence: Characterized by vortex formation on the windward edge of the structure, causing oscillations that can build up and lead to dynamic instability. This phenomenon is more likely to occur for low tilts and is highly dependent on the torque tube stiffness. See Figure 1.
- Vortex lock-in: Occurs at moderate tilt angles (10° to 25°), where alternating vortex shedding induces torsional oscillations. This mechanism is sensitive to the damping properties of the structure. See Figure 2.

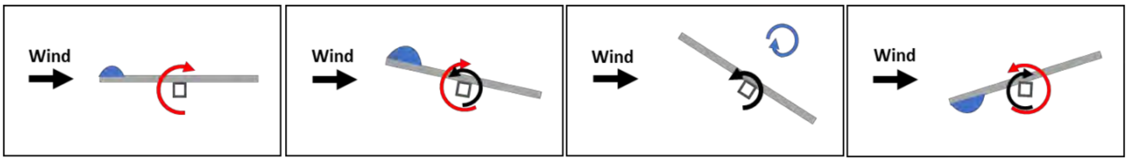

Fig. 1: Illustration of cyclical torsional divergence

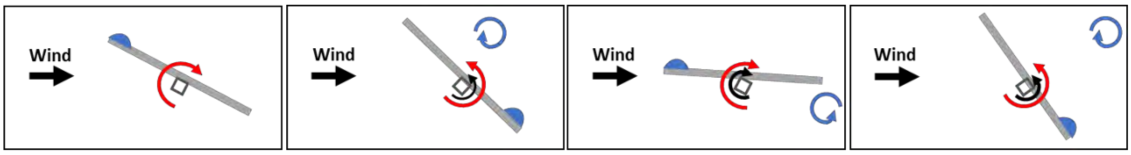

Fig. 2: Illustration of Vortex lock-in

These mechanisms may interact, and both can be characterized by determining the critical wind speed (Ucr) for different stow angles, leading to a complete stability curve.

2. Experimental setup

To capture the dynamic behavior of the structure under realistic conditions, aeroelastic tests were conducted at CPP Wind's facility in Denver, USA. The setup consisted of six tracker rows, with the geometric parameters (module size, tracker height, row spacing, etc.) defined to simulate the worst case field conditions.

The wind tunnel was configured to replicate atmospheric boundary layer properties, including turbulence intensity and terrain roughness. Various wind directions, stow angles, and structural damping scenarios were tested. In total, approximately 50 experiments were performed. See Figure 3.

Fig. 3: Experimental setup

3. Results

The main outcome of the aeroelastic tests was the stability curve, which presents the critical wind speed as a function of the tracker's stow angle. As expected, the lowest critical wind speed occurred at 0°. Higher tilt angles yielded even greater critical speeds, exceeding the physical wind speed limit of the tunnel (70 m/s).

Even at 0°, the structure exhibited high stability, with Ucr values exceeding 50 m/s. This performance is attributed to the high torsional stiffness of the torque tube, which is approximately 25% stiffer than an equivalent square profile. Additionally, significant damping was observed, stemming from the structural design, bearing systems, and external dampers. See Fig. 5.

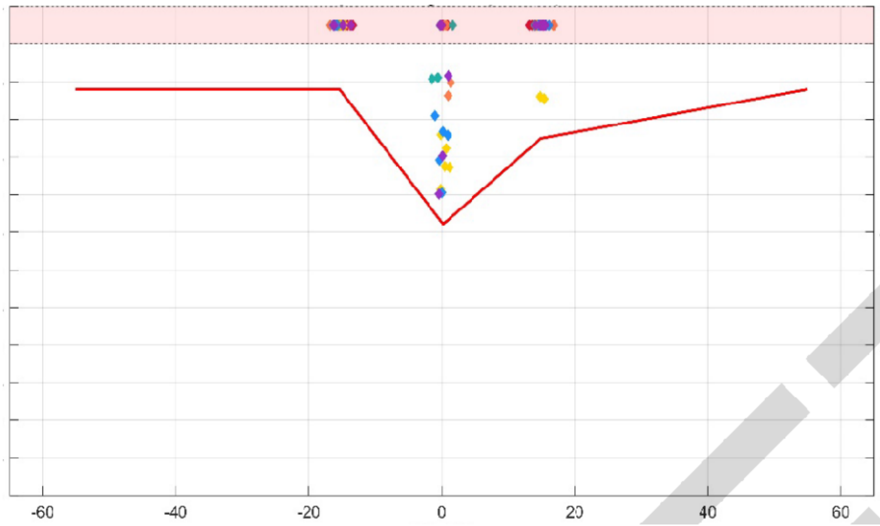

Fig. 5: Stability curve

4. Conclusions

Aeroelastic testing is essential for accurately assessing the dynamic stability of solar trackers. The results obtained in the tests demonstrate a robust aeroelastic performance, with high Ucr values even at low tilt angles. This enables the selection of stow positions with minimal inclination, balancing structural stability and reduced mechanical demands.

Lower tilt angles during stow reduce loads on all structural components, including torque tubes, piles, and PV modules. Consequently, this tracker design supports both safety and structural efficiency, contributing to more resilient and cost-effective solar installations.

5. References

Enshaei, P., Chowdhury, J., Sauder, H., & Banks, D. (2023). Wind tunnel testing of torsional instability in single-axis solar trackers: Summary of methodologies and results. Proceedings of the 21st Australasian Wind Engineering Society Workshop, Sydney, Australia, pp. 2-3.

Rohr, C., Bourke, P.A., Banks, D. (2015). Torsional instability of single-axis solar tracking systems. Proceedings of the 14th International Conference on Wind Engineering, Porto Alegre, Brazil, June 21-26, 2015.

Zhang, X., Ma, W., Li, H., Shao, Q., & Kang, X. (2024). Experimental investigation of the torsional aeroelastic instability of single-axis solar trackers. International Journal of Structural Stability and Dynamics, 24(5).

Martínez-García, E., Blanco-Marigorta, E., Parrondo Gayo, J., & Navarro-Manso, A. (2021). Influence of inertia and aspect ratio on the torsional galloping of single-axis solar trackers. Engineering Structures, 243.