A tested and proven wind mitigation strategy to minimise risk

Trackers | Ensuring the stability of solar tracking systems and modules during wind events is one of the top concerns of solar site owners, project developers and EPC contractors. A poorly designed single-axis tracker can result in damage to solar trackers and modules, leading to costly downtime, insurance claims, or even possible injury. Todd Andersen outlines the innovative methods that engineers at Array Technologies have uncovered and use to address this major potential setback for solar projects

Credit: Array Technologies

Avoiding wind damage to trackers and modules is a key concern for solar project stakeholders

Single-axis trackers require that special attention be devoted to managing wind events. Dynamic wind forces can amplify the load on single-axis trackers, which can lead to damage, downtime, and higher cost of ownership.

During Array Technologies' 30 years as a leader in the solar tracker industry, our engineers have extensively studied and tested how wind interacts with modules and tracker systems. Both in simulations and in the field, they have vigorously tested wind's effects on solar sites and have closely examined the various solutions for addressing these issues that have become prominent in the industry.

In order to avoid accepting status quo methods or falling into "this is how it's always been done" thinking, Array has continued to observe and push forward to improve our methods.

Our perspective has been that if we truly understood the way tracking systems respond to various types of wind events, we could engineer a solution that is simpler and more intuitive, as well as far more effective, than previous iterations of tracker technology. It's a continuous process, and Array plans to continue this exploration of system response to wind events.

Through constant observation, adjustment, and implementation, our teams have developed the DuraTrack HZ v3, a tracker specifically designed and field-tested to withstand harsh weather and environmental conditions and operate in a simpler, more intuitive way.

DuraTrack reliably handles wind events with a fully integrated, patented, mechanically passive wind load mitigation system. Array's unique approach to controlling resonance minimises risk, protects the structure, and optimizes production, all without the use of complex communication systems, batteries, or power.

Typical wind mitigation methods and Array's patented, innovative approach

Many tracker mitigation methods stow the entire solar field in a flat position at 0 degrees, or at a low angle of up to 30 degrees. (Fig 1)

Array Technologies explored these stow angles with rigorous performance and reliability studies and experiments. As a result, our engineering team found that several problems arose with these typical stow methods and sought more effective ways to handle dynamic winds.

Below, we will outline the issues our engineers repeatedly found both in our own tests and in the solar industry's publicly available data.

Problem 1: Active stow requires an

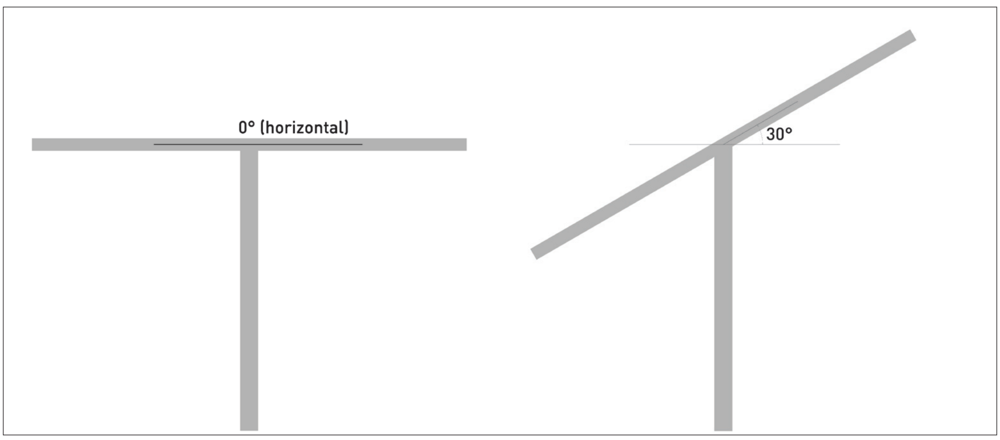

Figure 1. Traditional tracker stow angles

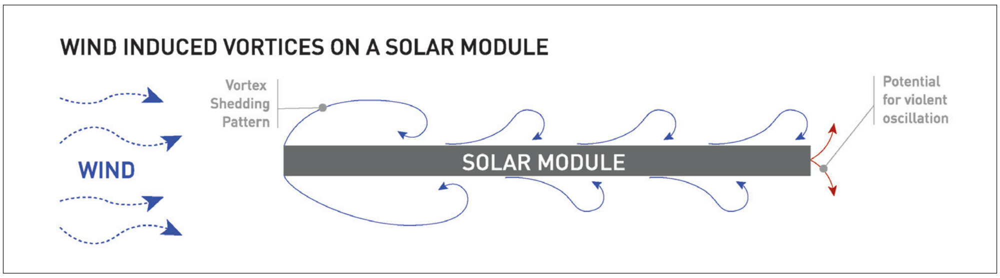

Figure 2. Vortex shedding

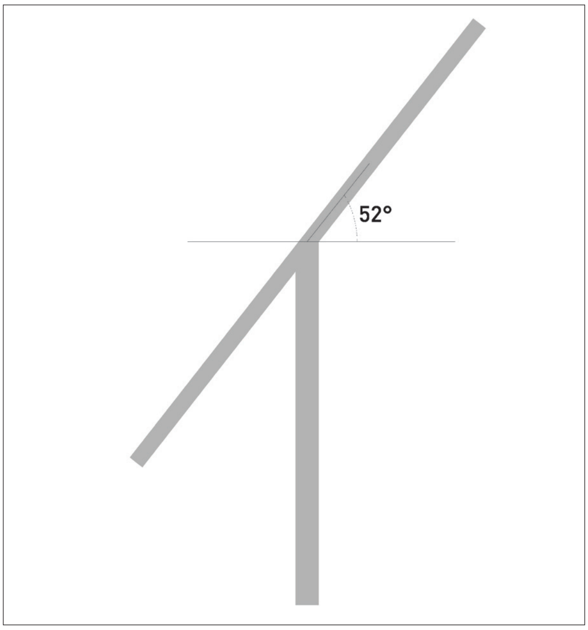

Figure 3. Array Technologies adjusts to full tilt angle

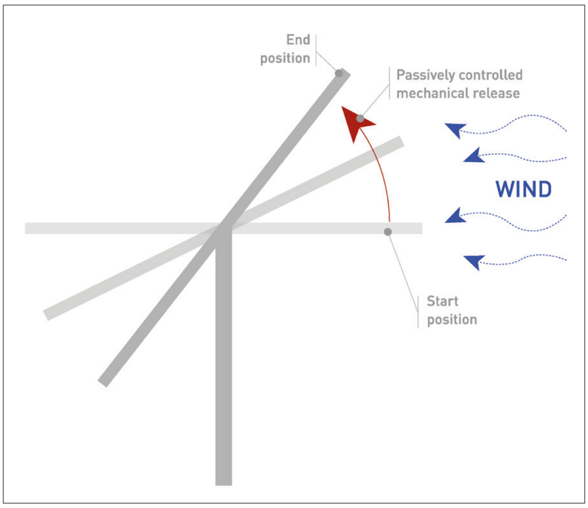

Figure 4. Array Technologies passively reacts to wind

uninterrupted power source (UPS) system or a battery backup, which adds complexity and more opportunity for the process to fail in real-world situations. These systems rely on an electronic sensor of some kind, such as an anemometer or another wind measurement tool. When this sensor picks up the signal that a certain threshold of wind is exceeded, it electronically sends the message to the trackers that they should transition into stow mode. This is usually a flat position parallel to the ground, or close to such a position.

The reasoning is that the wind drag loads are lower on horizontal modules than they are on modules at higher tilts. This is because at low tilts, the area of the module that is exposed to the wind is very small compared with the area that is exposed at high tilts.

As such, it is generally accepted that since wind loads during extreme wind events are lower on actively stowed trackers with modules at flat tilts, the tracker and surrounding support system do not need to be as heavy or substantial. In theory, structural demands are reduced, which allows for a lighter-weight, less expensive product.

Two major issues arise with this method:

- The complex signalling system leaves unnecessary room for error. If any part of the lengthy control chain of electronic components fails – from the sensor reading wind speed and velocity to the message travelling to the control system telling the tracker to move to stow – the results can be catastrophic. Every link in the command chain must be functioning properly in order for the system to work.

  For this reason and because of the increased probability of a power failure during a severe wind event, the tracker may not properly stow, and the modules may be left at a high tilt position.

- When this happens, trackers designed to support lower wind forces from lower tilt angles may be structurally inadequate to support higher forces from higher tilt angles. This can result in solar modules twisting, in much the same way as an ice cube tray, which can cause structural damage to the torque tube, bearings, posts, and other structural components.

  The perturbation can lead to cracking or dislodging of modules and even damage to the tracker itself. Micro-cracking is also a major concern. Even if there is no visible damage, there may still be tiny abrasions on the solar modules that significantly reduce or even halt the site's ability to produce energy.

  Since trackers that take advantage of lower design forces from lower tilt angles are often constructed with less steel than average trackers, they may cost less up front. However, if lighter-weight trackers do not adequately protect against wind damage, using them can be far more expensive in the long run due to the costs of repairing structural damage and associated system downtime.

Problem 2: Even if everything does work correctly and the system stows flat, torsional galloping can still occur. Torsional galloping is the result of harmonic wind forces and vibrations destabilising single-axis trackers and modules. This occurs due to a phenomenon called vortex shedding, or sudden bursts of torque that build and release, causing modules to oscillate violently.

Vortex shedding (Fig. 2) and subsequent torsional galloping build more easily with trackers stowed at angles parallel to the ground. These destructive phenomena can happen at any wind speed, even low speeds if the wind is at the right angle to generate vortices that resonate with the natural frequency of the tracker system with the module stowed flat. This happens much more often when the modules are flat and very rarely at full tilt.

Systems affected by torsional galloping can experience significant issues with cracked or broken modules, and even twisted or damaged tracker structures. Obviously, the costs of this damage are significant. Not only must solar modules, trackers, and other hardware be replaced, but the fiscal effectiveness of the site decreases every minute that it's nonoperational.

Looking at things from a different angle with array solar trackers

Array's single-axis tracker and its inherent robustness, on the other hand, passively adjusts to a full tilt angle (Fig. 3). This relieves the wind load on the system and prevents the buildup of resonance, oscillation, and torsional galloping.

Introduction to DuraTrack HZ v3 key wind mitigation features

Array continuously studies wind mitigation by using extensive wind tunnel testing data. In addition, Array implements unique system simulation models on which wind tunnel-derived time series loads can be applied.

These system simulation models allow Array's engineers to understand not just the static wind load on the tracker but also the dynamic response of the tracker to different wind conditions.

The DuraTrack HZ v3 is the solar industry's only tracker to manage wind forces on a row-per-row basis without using active stows, sensors, or electricity, by implementing a fully mechanical, passive wind mitigation system.

This independence from an electrical power source is important because it also reduces the risk of danger to workers and equipment during a solar plant's construction. Trackers that need power leave contractors and installers subject to on-site weather conditions during the transitional period before such trackers are fully operational.

During powerful or even standard wind events, trackers which require power to stow can pose significant safety concerns to EPC contractors and workers. Panels that experience torsional galloping as a result of wind bursts can not only bend trackers even if they do stay in place, but they can also come loose and act as projectiles.

Array's wind mitigation system is fully operational immediately upon installation, with no need for power to the site. This means that the trackers will tilt and adjust as needed right away, avoiding potential damage to the new solar site and any potential hazards to the people building it.

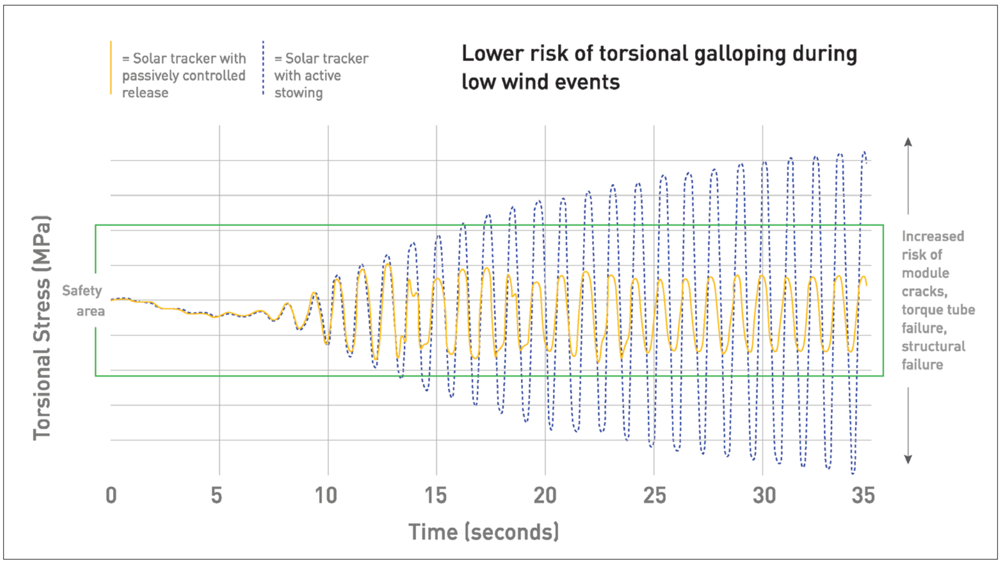

Figure 5. Tracker simulation performed by Array Technologies using multi-body dynamics software and wind tunnel data provided by industry leading wind consultants

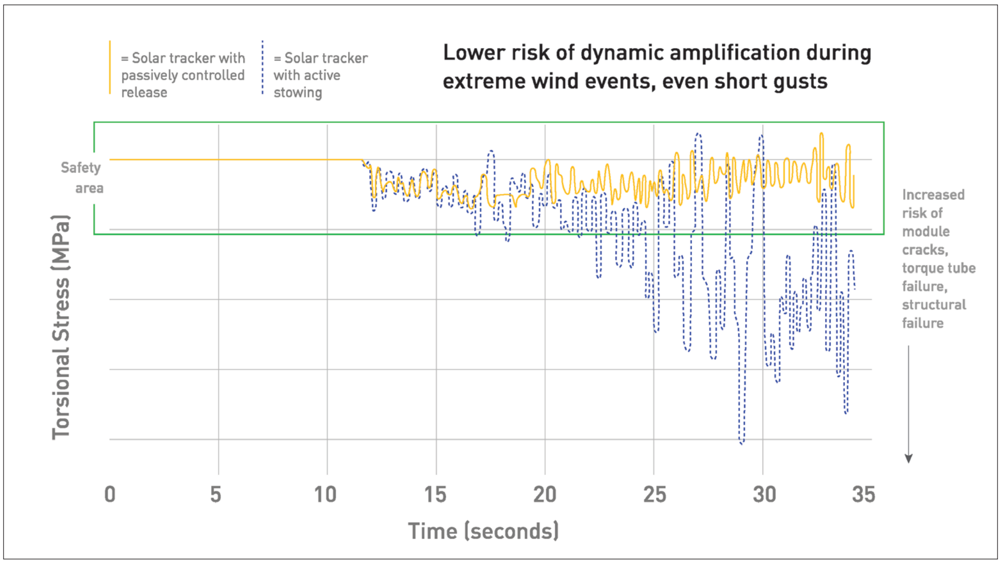

Figure 6. Tracker simulation performed by Array Technologies using multi-body dynamics software and wind tunnel data provided by industry leading wind consultants

Low wind speed response

Array trackers implement a patented, passively controlled mechanical release that activates automatically if the wind load exceeds the safety threshold established by engineers, where galloping and oscillation can occur.

The release allows a single row of trackers affected by wind of enough force, or wind from just the right angle, to rotate to a higher tilt. When this happens, the wind vortices are disrupted. The exterior row diverts the impact, protecting the rows behind it from unsafe wind levels and from the need to tilt themselves.

This automatic response by the tracker limits the harmonic wind forces, and the resulting torsional oscillations are reduced to an acceptable level that will not cause damage to the structure.

The chart in Figure 5 shows actual wind tunnel-derived loads applied to a full tracker system simulation model during low wind speed events. Array's DuraTrack HZ v3 passive stow is shown in yellow. Trackers with active stow are shown in blue.

High wind speed response

In the case of a sudden high wind event, such as a gust enduring for less than a minute, Array's DuraTrack HZ v3 reduces torsional galloping and stress via the same passively managed system. The impact on solar equipment is minimal compared with the impact on equipment in systems that stow at lower angles.

In the chart shown in Figure 6, Array's passive system response to dynamic amplification during extreme or high wind events is shown in yellow. The response of active trackers is shown in blue.

DuraTrack HZ v3 prevents torsional galloping on all rows in the full solar plant individually. This is important because there will be times when modules are flat due to the location of the sun in the sky. For example, if heavy wind picks up at noon, the modules will be parallel to the ground in order to collect light energy from the sun directly above.

When the load threshold of the passive wind mitigation system is exceeded at this angle, the affected row of modules naturally and passively rotates. This disrupts the flow of wind and puts an end to galloping. If the wind changes direction or suddenly comes from another angle, it is possible that oscillation and the galloping response could activate again. However, the system would allow this to occur only up to a certain level before the tracker would passively cause another rotation, moving the tracker system once again to a safe position.

To be sure the wind mitigation issues were addressed in a comprehensive way, Array's engineers also designed the system for full wind loads occurring at full tilt angles. This ensures that the trackers are structurally sound and meet applicable structural design codes regardless of the tilt position of the modules and the wind speed.

More uptime and productivity with passive wind management

As previously mentioned, the exterior tracker rows generally take the brunt of high-wind events. This is an advantage for passive wind management systems, because usually only one or two exterior rows manage most of the force from the wind. The result is that the rest of the trackers remain at optimal operational tilt, reducing the impact on energy production even during a powerful wind event.

This works because the first two rows create a buffer zone to protect interior rows and prevent them from adjusting as well. Of course, winds can shift unpredictably, and sudden bursts may come from unexpected angles. There may be times when interior rows may need to adjust as well in order to protect the trackers from torsional galloping. However, the system automatically recalibrates twice daily at certain times, whether wind events take place or not. This resets the rows and positions them for maximum power production once the threat from any wind event has subsided.

With Array's passive wind mitigation system, there is still the possibility of some production loss in a wind event. However, the alternative with active sensing systems is to force the entire site into a nonoptimal position. In that case, no part of the site is producing power.

With Array's wind mitigation system, generally only a small percentage of the site's power production is reduced during a wind event. Any decrease in power production is corrected as soon as possible and without any exterior monitoring or intervention.

Financial implications with reduced project complexity, O&M cost, and risk

When site owners and developers are assessing potential trackers for resilience and sustained operation during wind events, levelised cost of energy (LCOE) and minimal investment risk are paramount for ensuring a profitable and successful solar site.

Wind mitigation is one of the most essential ways to protect assets in the form of people on the job, hardware in the field, and time and money invested in the project. It's undeniable that solar sites are often complex operations, from the first proposal through the commissioning ceremony and beyond.

However, we believe that reducing or eliminating the extraneous variables that leave room for error and increasing the integrity of single-axis tracker systems themselves are the answer to successfully mitigating wind effects long-term. This makes single-axis tracker sites more viable, more powerful, and more capable of withstanding anything Mother Nature forces on them over time.

Simple, intuitive, self-managed wind mitigation is the best way to diminish risk and maximise power production and cost savings. A passive wind management system reduces overall project complexity and operations and maintenance (O&M) costs, as well as the risk of failure and possibility of damage and downtime.

Reliability and the reduced need for maintenance create an opportunity for significant cost savings and boost profitability for key stakeholders, leading to a more financially successful solar project over time. ■

Author

Todd Andersen is chief engineer at Array Technologies. He is responsible for leading engineering efforts to study the dynamic behaviour of single-axis solar tracker systems while driving the continued reliability of Array Technologies' best-in-class solar tracker products. Todd brings over a decade of renewable experience to Array, drawing upon his years of experience in wind turbine support with GE Renewables. Todd holds a Master's Degree in mechanical engineering from Brigham Young University, with an emphasis in non-linear finite element simulation and structural dynamics.