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Minimizing the dynamic effects of wind in solar plants through tracker wind design

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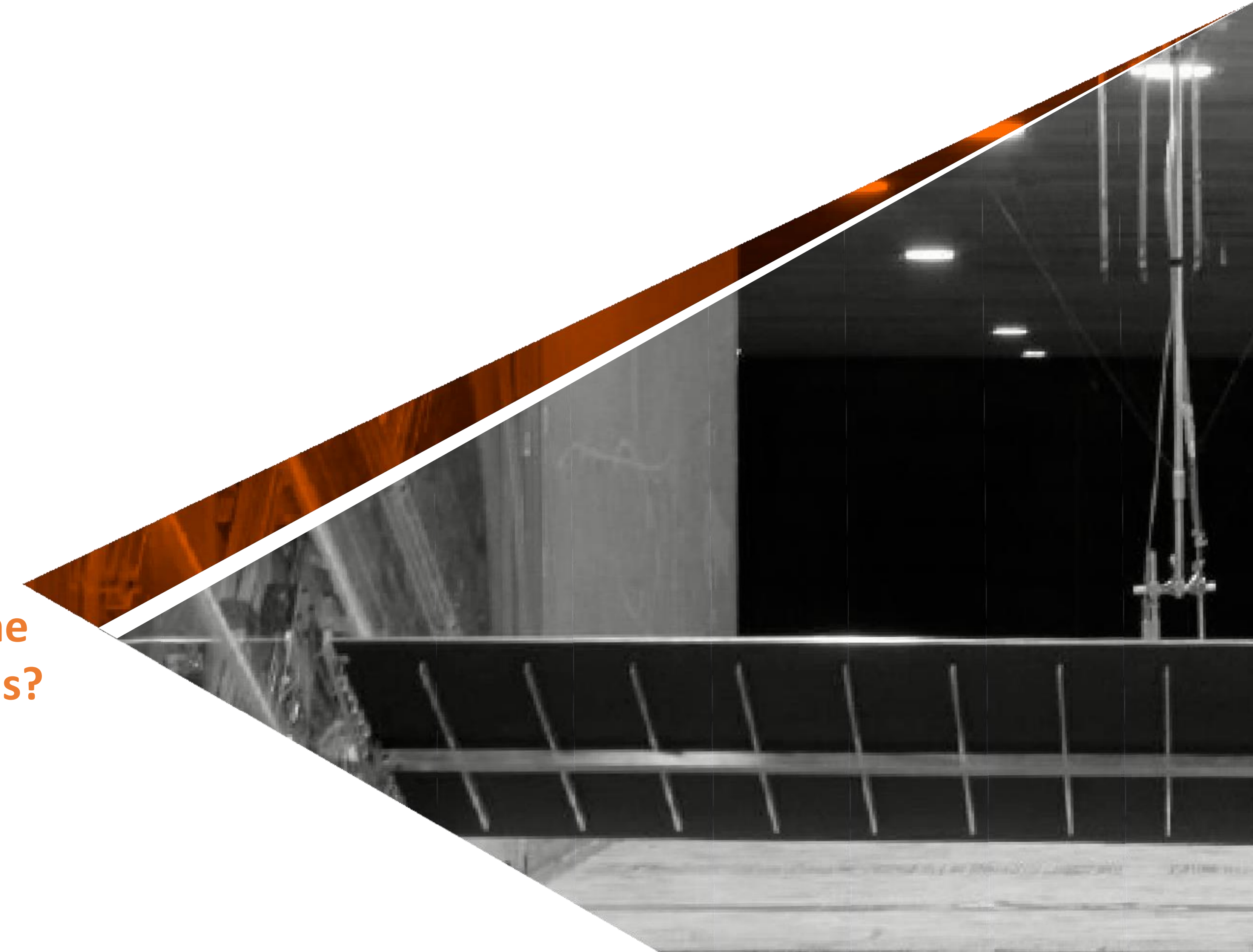
Content

- ✓ Solutions to prepare against extreme wind loads, through an exploration of the aeroelastic effects in tracker design analysis, including real case studies.
- ✓ Discuss the importance and impact of wind design tracker improvements, and how these can be realized.

A step ahead against extreme wind-loads: aeroelastic effects in tracker design

How does Soltec face extreme climate and high-wind speeds?



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Wind climate specialist

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Soltec

Soltec specializes in the **manufacture** and **supply of single-axis solar trackers** with global operations and workforce of **over 750 people** blending **experience** with **innovation.**

15 years
Company history

6+ GW
Production Capacity

5.5+ GW
Track-record

RWDI

Principal wind consultant on …

- 7 of the world’s 10 tallest buildings
  - Nearly half of the top 100 (according to CTBUH)
- Some of the world’s longest-span bridges

NAME	HEIGHT/SPAN (m)	LOCATION
Jeddah Tower	1,000	Jeddah, Saudi Arabia
Burj Khalifa	828	Dubai, United Arab Emirates
Shanghai Tower	632	Shanghai, China
Messina Strait Bridge (Suspension)	3,300	Sicily to Calabria, Italy
Golden Gate Bridge (Suspension)	1,280	San Francisco, CA, USA
Stonecutters Bridge (Cable-Stayed)	1,020	Hong Kong, China

Soltec + RWDI = Dy-WIND

- **Soltec** and the wind consultant leader **RWDI** started working in September 2017 to develop a new understanding of second order of effects.
- **RWDI** in collaboration with **Soltec** has developed an **innovative method** for comprehensive **dynamic analysis in tracker** wind-design = **Dy-WIND.** This innovative method was launched in **September 2018.**
- The studies have shown that certain **wind-design code standards** applied to solar trackers **are insufficient. There is no standard and specific code for trackers.**
- They do not consider the **aeroelastic effects** (or second order effects) produced by the action of wind on the tracker.
- It is necessary to find **new analysis methodologies** that improve the design of reliable tracker structures.

Study Case: pre Dy-WIND design

DESCRIPTION OF THE DAMAGES

Localised damages

- **1%** of the trackers collapsed. These trackers were part of the two exterior rows.
- **1%** of trackers surrounding the heavily damaged area, suffered medium to minor damages.

Module support lift and pressure failure

- Trackers that experienced the greatest amplifications of these loads, and collapsed, were the ones in the exterior rows (first and second row).
- The wind event originated as a strong wind from the west of the site, therefore those trackers that were tilted to the West suffered compression failure, and the ones tilted to the East failed due to wind lift.

Other components failure

- Failures identified in multiple other components can be traced back to the failure of the module supports.

Study Case: pre Dy-WIND design

ROOT CAUSE ANALYSIS

Localised wind event

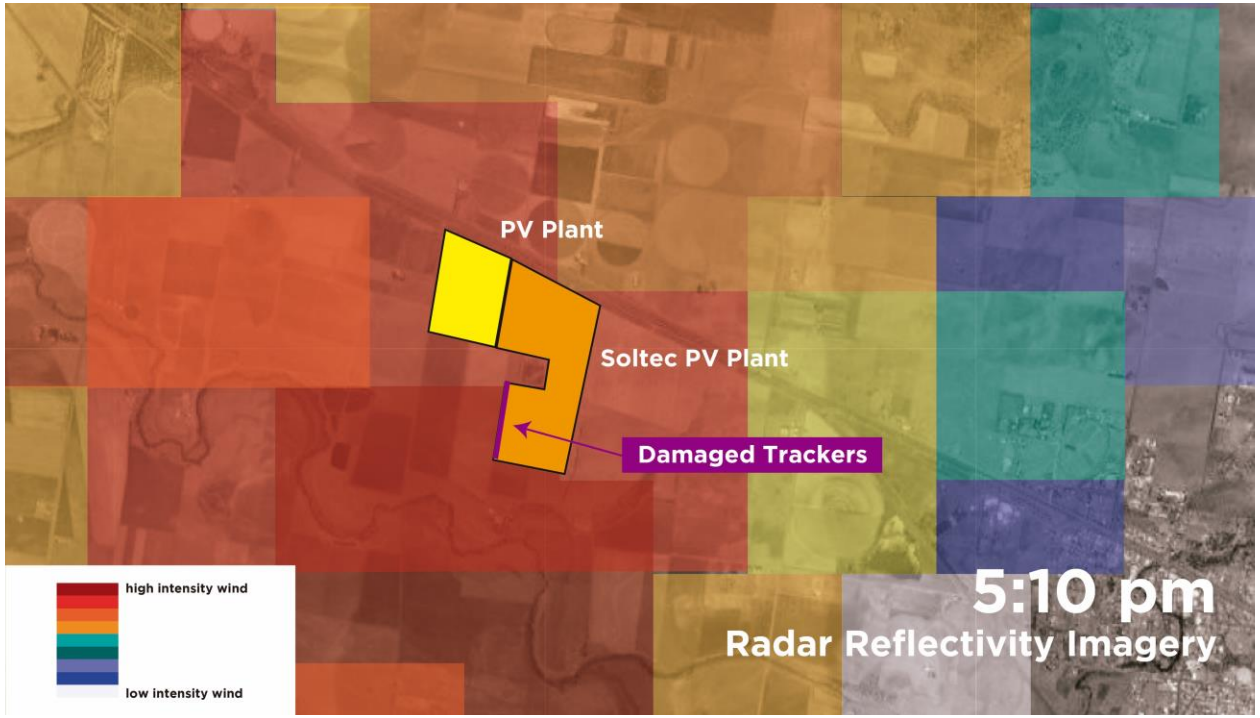
- **The types of failure observed in these structural members can only be produced by very strong, sudden and localized wind gusts** that exceeded the design wind speed of those members.

Dynamic design and fluttering

- Fluttering created an angular movement in the tracker such that the module rails failed from excess pressure or wind lift, due to the high wind impact on a **non-self stow**. In some cases, it was the entire torque tube that suffered a torsional failure.

Construction and commissioning

- Trackers rely on an active stow for withstanding the high wind events and accurately track the self-stow position, which was not possible when trackers were not operational.



Region of interest (outlined in red). Damage to solar trackers was reported within the shaded yellow region, in the southwest area within the region of interest. A nearby anemometer is located within the yellow dashed-lined region to the northwest of the region of interest.

Rob Davis | c/o MetraWeather

Extreme Wind Climate Considerations

WIND CLIMATE MECHANISMS

Synoptic, Thunderstorm, Tropical Cyclones

Stow Regime

Impacts of climate change

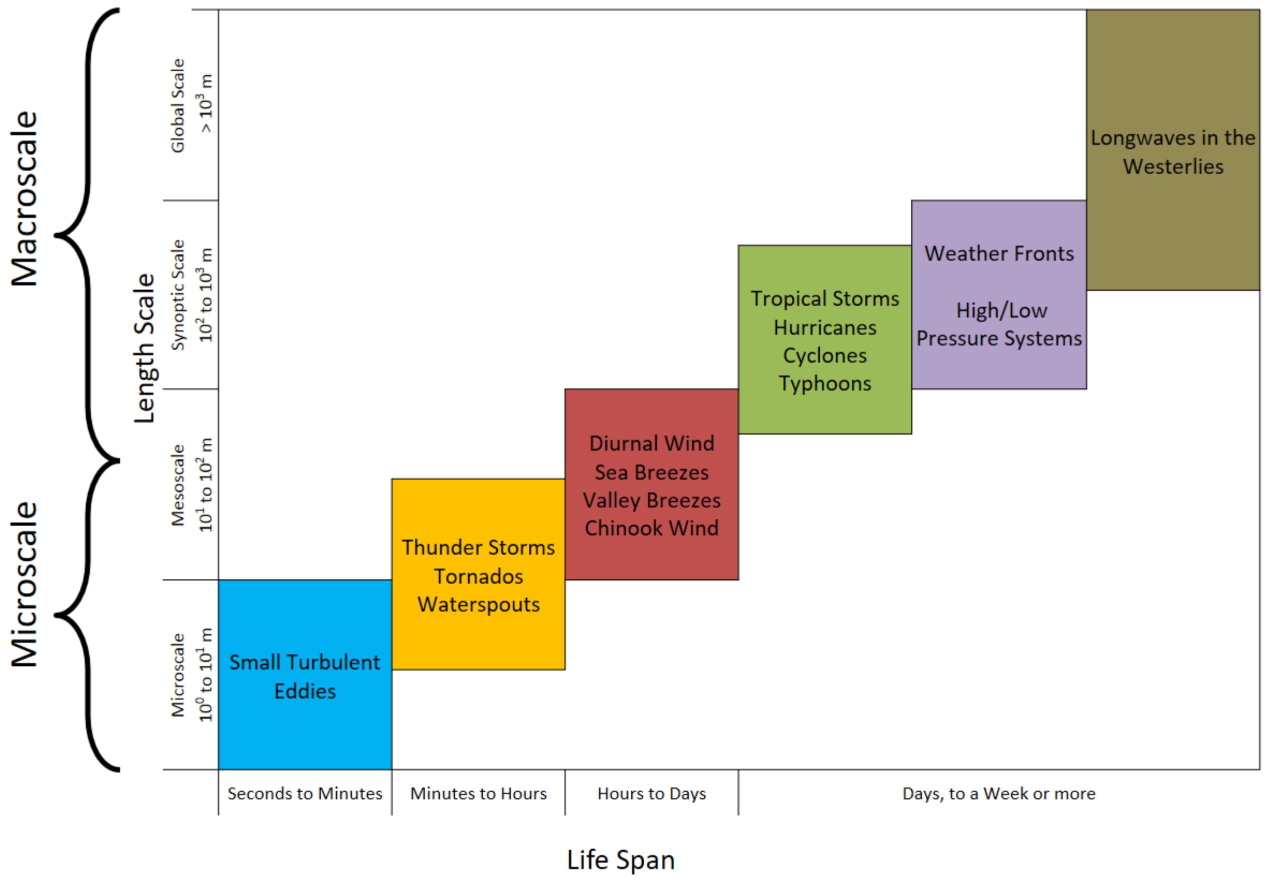
DESIGN WIND SPEED

Extreme Value Analysis

Local Code Considerations

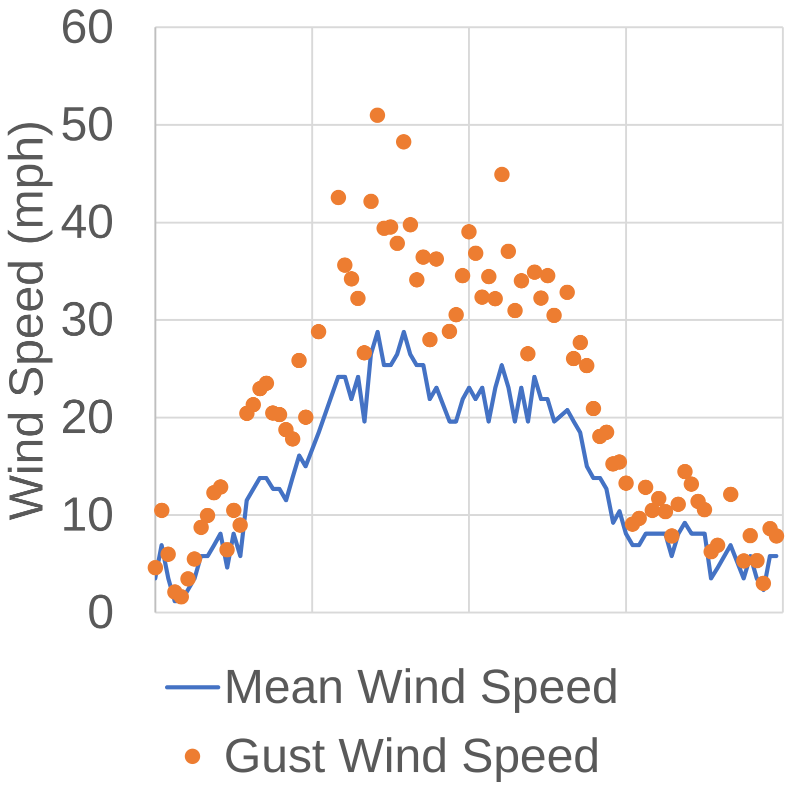
DIRECTIONALITY

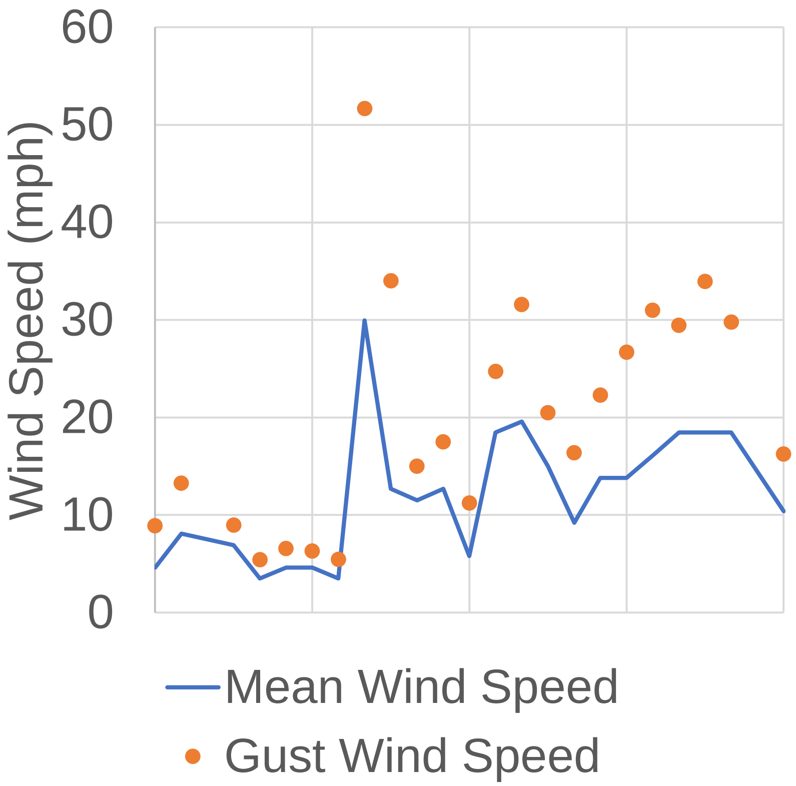
Predominate wind direction in high wind events



Wind Event Time Scale

2 Days vs 2 Hours





Site Specific Design Wind Speed

EXTREME VALUE ANALYSIS

Statistical fitting of historical wind speeds

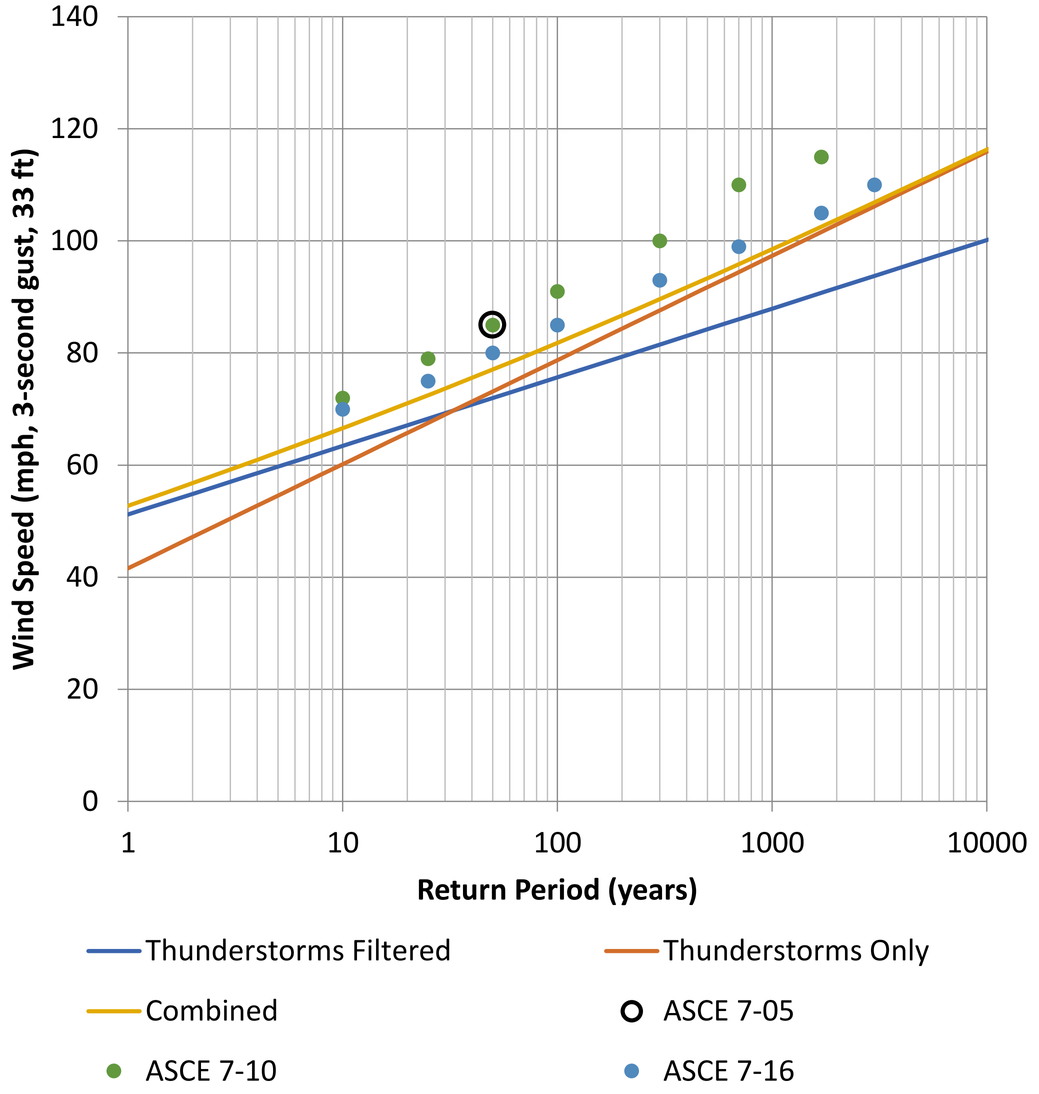
- Used to determine relationship between wind speed and return period for different wind climate mechanisms based on historical or modelled data

Comparison to Building Code Values

- Building code defines applicable return periods based on importance category
- Requirements for site specific design wind speed are often defined in building codes and standards

Lack of Building Code Guidance

- Some countries lack modern wind design guidelines
    - Design wind speeds may be based on decades old analysis
    - Design wind speeds may not be available



Directionality of Extreme Wind Climate

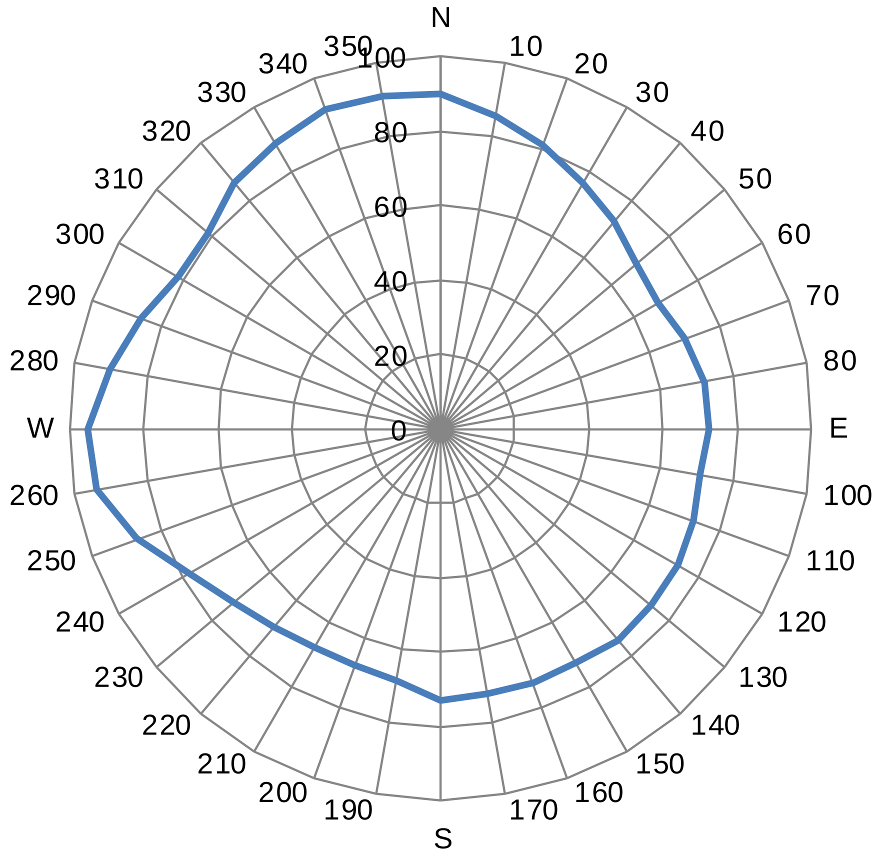
SITE SPECIFIC DIRECTIONALITY

Statistical fitting of historical wind speeds

- Used to determine directional variation of extreme winds

Comparison to Building Code Values

- Some codes do not have this information (ASCE 7, NBCC)
- Other codes have very generic information (some Eurocode NAs, AS/NZs 1170.2)
    - By their nature, these are conservative/generic
- Site specific directional assessment reflects local directionality, which is typically enveloped in code based directionality factors
- Codes provide one set of factors (if at all), whereas site specific values are provided ranges of return periods, which may be influenced by different wind mechanisms



Wind Speed (mph, 3-sec gust, 33 ft, open terrain)

Key Challenges of Single-Axis Trackers

Stow strategy / onsite wind monitoring

Drive system design

Prone to aerodynamic instabilities

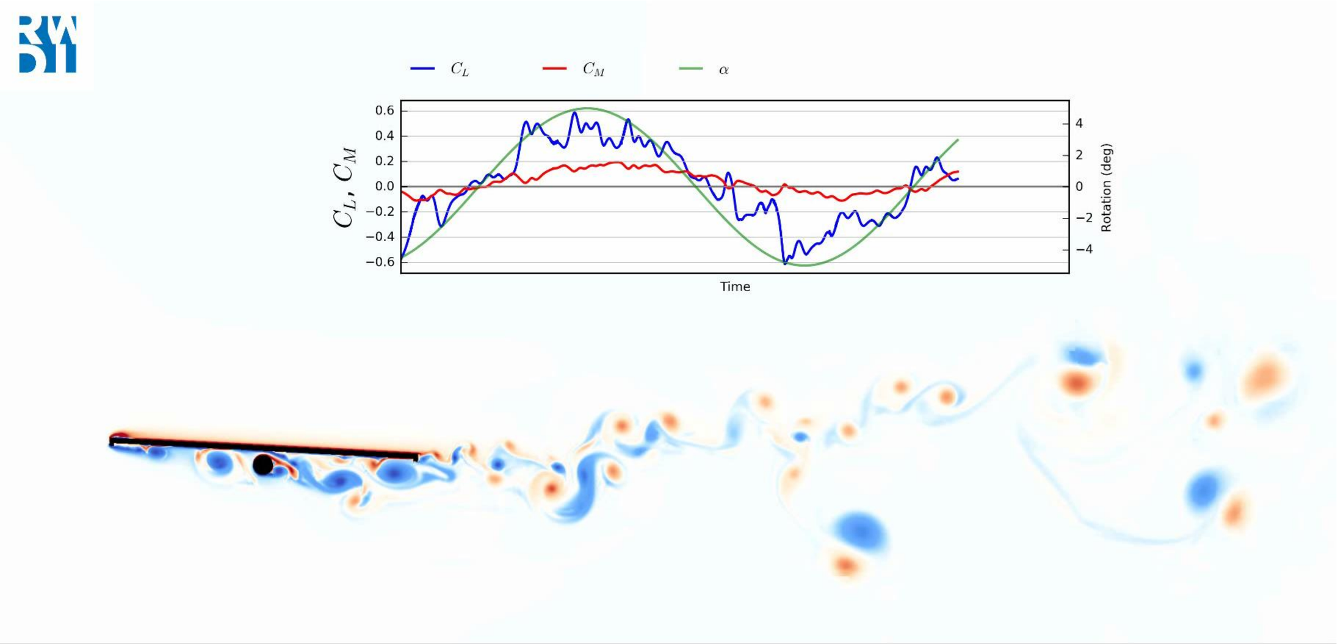
- Torsional Galloping (low tilt angle behavior)
- Torsional Flutter (high tilt angle behavior)

Resonant vibrations

- General wind buffeting
- Wake resonance effect from upwind rows

Aeroelastic effects

- Self-excited forces
- Design Wind Loads



Components of Total Wind Load

Conventional Pressure Model Test +
DAF Approximation

$$[K]\{Z\} = \{F\}_{SE} + \{F\}_{BUFF} - [M]\{\ddot{Z}\} - [C]\{\dot{Z}\}$$

Stiffness Force

Self-Excited Force

Buffeting Force

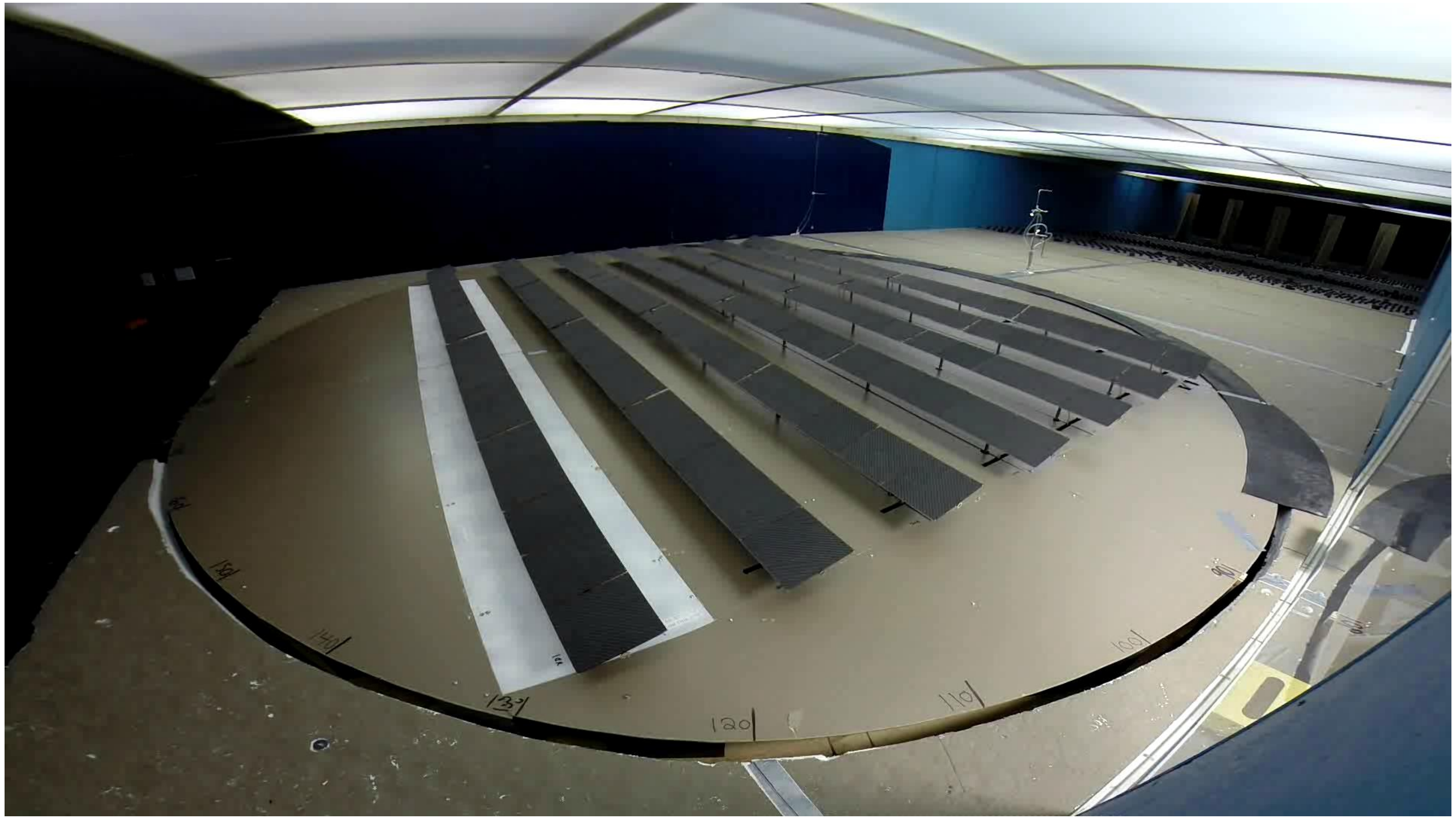
Inertial Force

Damping Force

Aeroelastic Model Test

Components of Total Wind Load

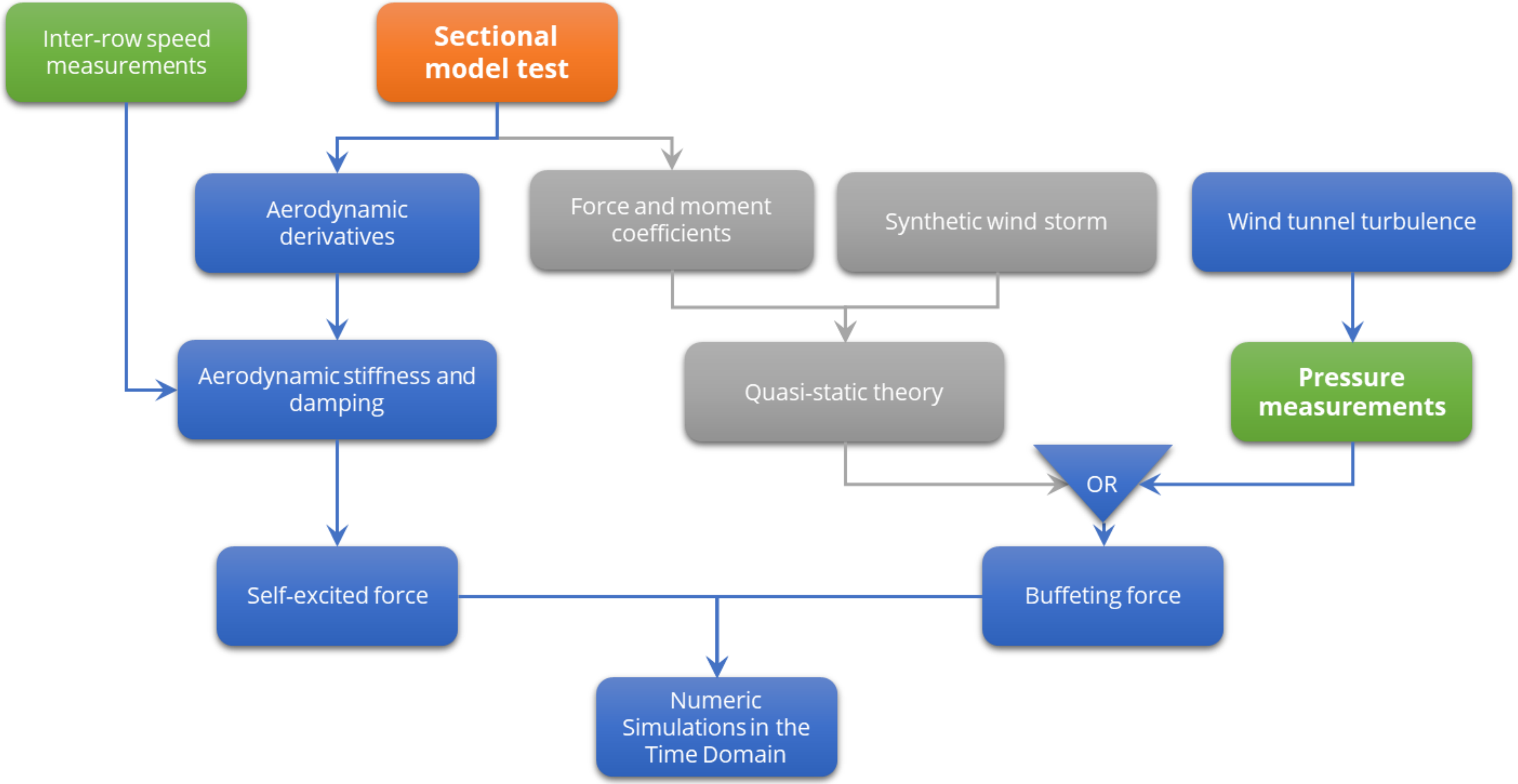
Full Aeroelastic Model (traditional)



- Intricate Construction
- Complex Instrumentation
- Limited in practical flexibility

Dy-WIND:

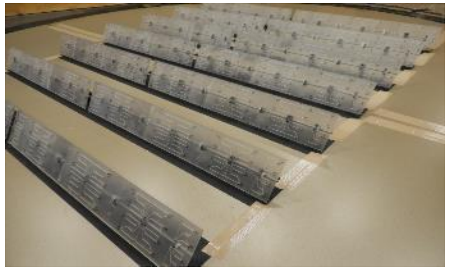
Hybrid Dynamic Wind Analysis for Multi-Row Tracker Design



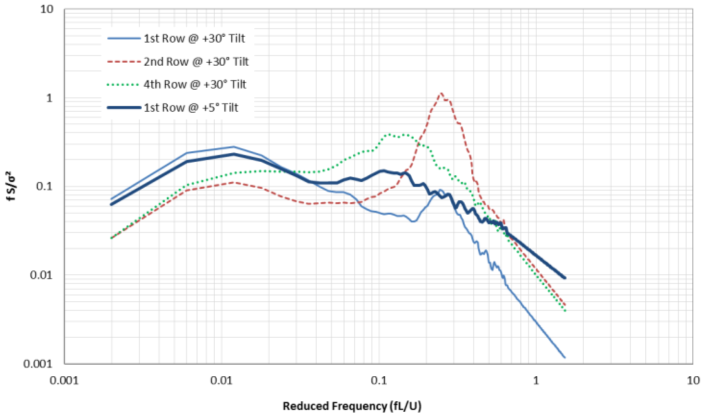
Dy-WIND:

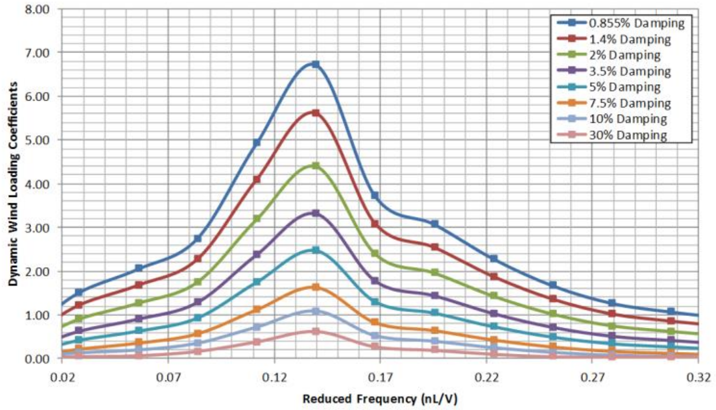
Hybrid Dynamic Wind Analysis for Multi-Row Tracker Design

Rigid Model Tests (Wind Pressure/Speed)



Power Spectra/Dynamic Amplification Factors ("DAF")



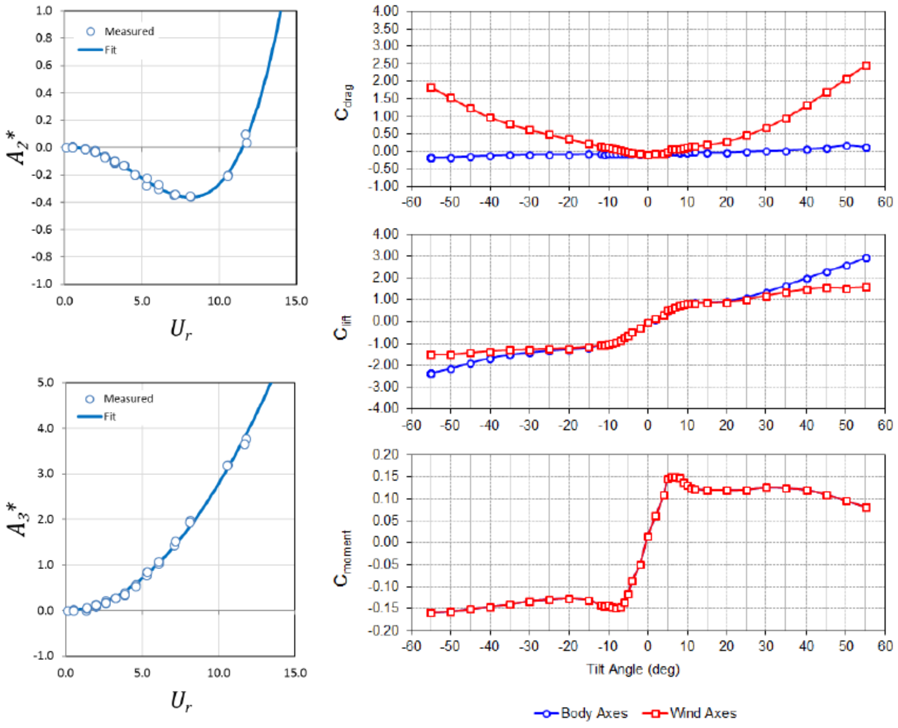


Dy-WIND:

Hybrid Dynamic Wind Analysis for Multi-Row Tracker Design

Aeroelastic Sectional Model Tests

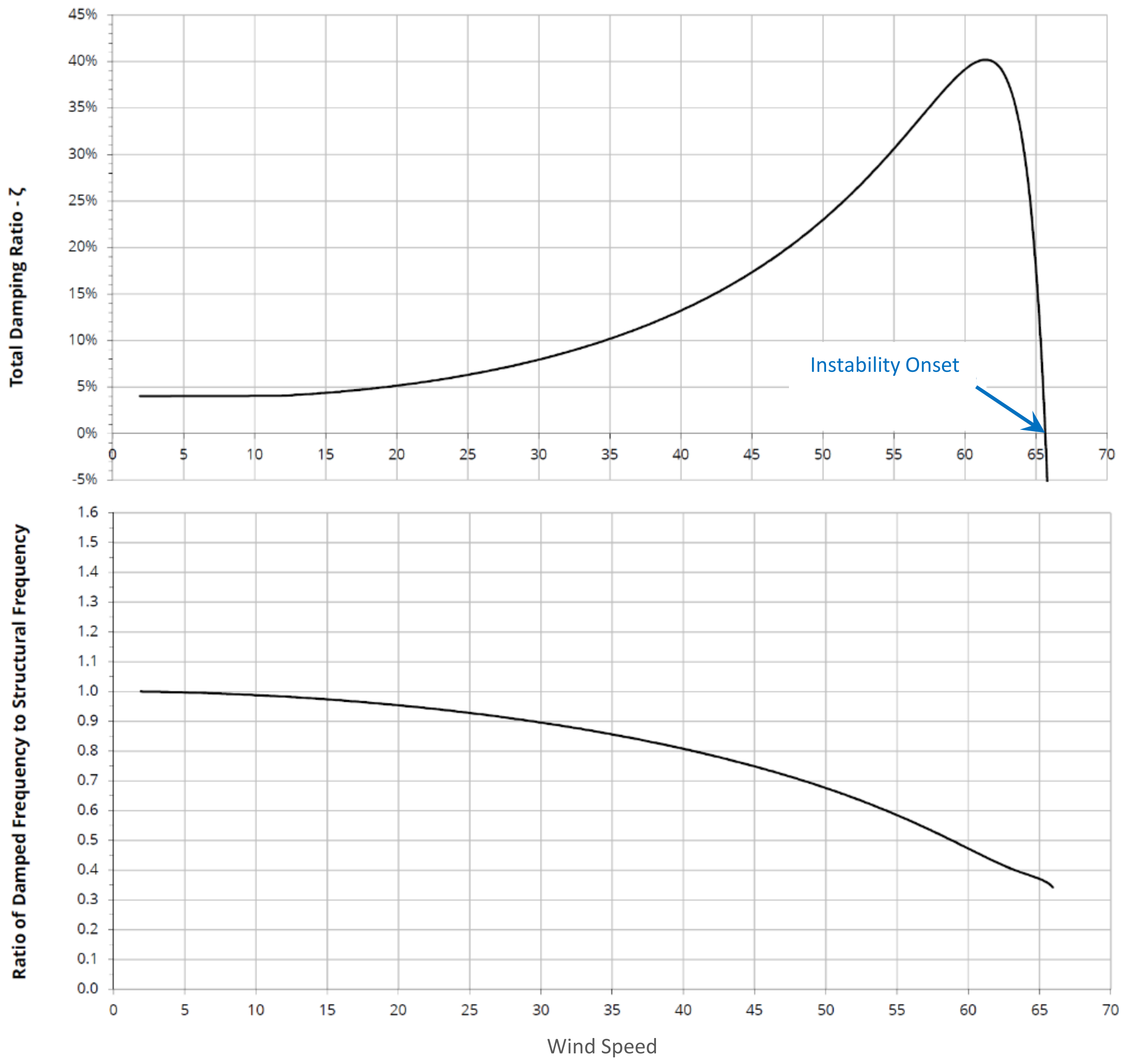
Aerodynamic Derivatives/Static Coefficients



Dy-WIND:

Hybrid Dynamic Wind Analysis for Multi-Row Tracker Design

Non-Linear 3D Flutter Analysis ("FAM")



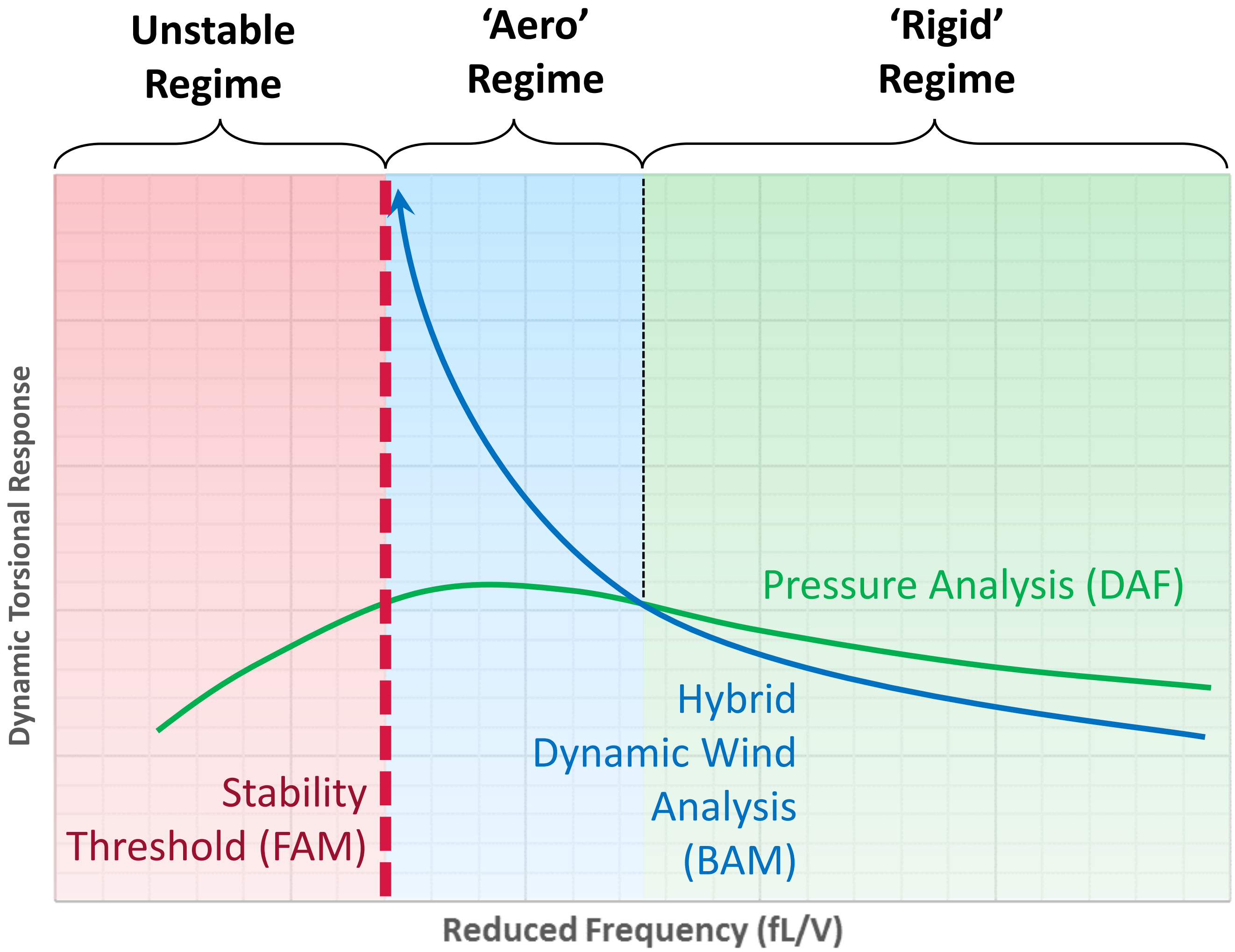
3D Buffeting Response Analysis (“BAM”): Multi-Row Array

Dy-WIND:

Hybrid Dynamic Wind Analysis for Multi-Row Tracker Design

Dynamic torsional response

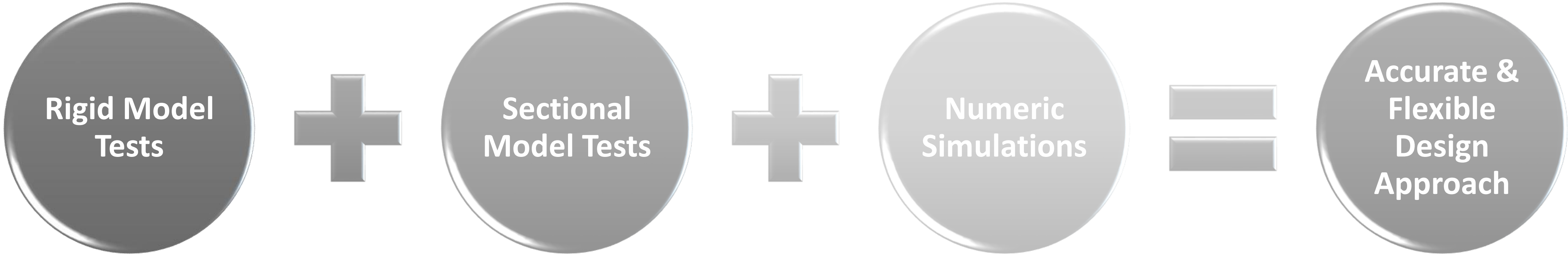
- tilt angles
- averaging areas
- damping ratios
- mode shapes
- mass properties
- wind speeds
- natural frequencies
- mitigation devices



Dy-WIND:

Hybrid Dynamic Wind Analysis for Multi-Row Tracker Design

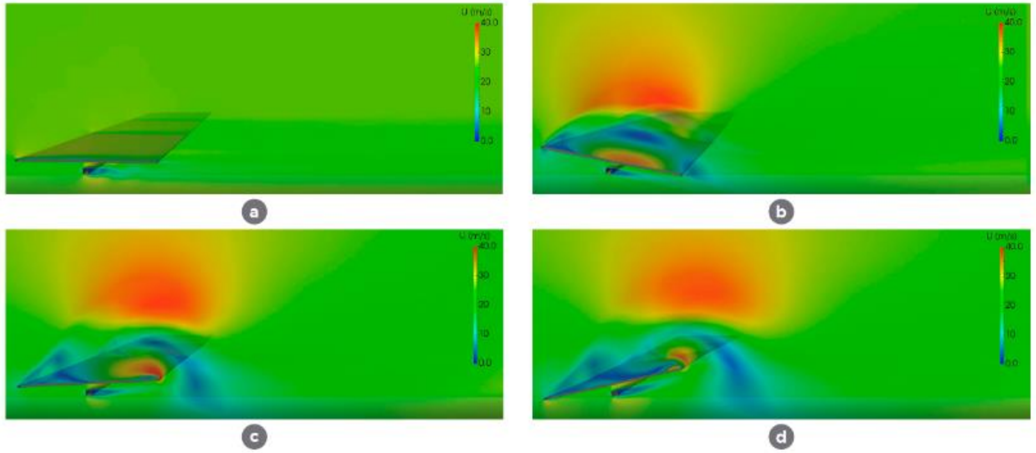
The hybrid model



How does Soltec face extreme climate and high-wind speeds?

Dy-WIND Tracker design

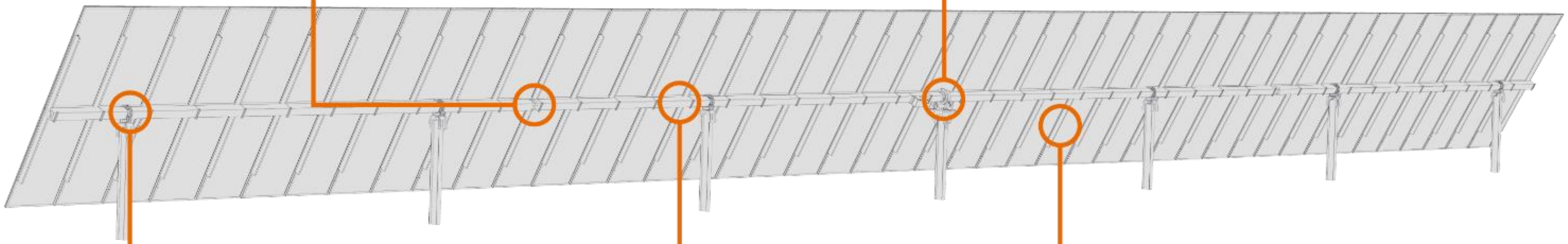
- **Dy-WIND** is a combination of DAF + FAM + BAM as a new standard in tracker multi-array.
- **Dy-WIND** is the innovative and code-challenging analysis method applied to solar tracker wind-design, based on accurate wind-loading analysis.
- BAM uniquely reveals the maximum tracker deflection due to wind forces, and the resulting maximum torque moment on axis elements. These dynamic considerations significantly increase common static tolerance specifications.
- A **key finding** is that while tracker response may be stable (damped signal output) with no risk of torsional galloping, the corresponding torque moment may be greater than the slewing drive or torque tube tolerances allow.



How does Soltec face extreme climate and high-wind speeds?

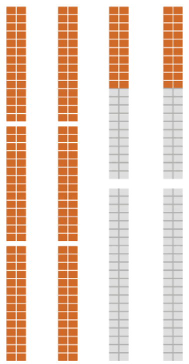
Dy-WIND DESIGN

- The section coupler assembly increases tube stiffness with optimized specifications of material, cross-section, and fastening.
- Reinforced slewing drive with specialized features



- Rotation Bushings on simple piles regulate torque-tube frictional stress, making a more rigid structure against torsion.
- Robust torque-tubes to improve stiffness
- Robust mounting rails for modules

Dy-WIND tracker design provides efficient structural solutions for PV plant design challenges

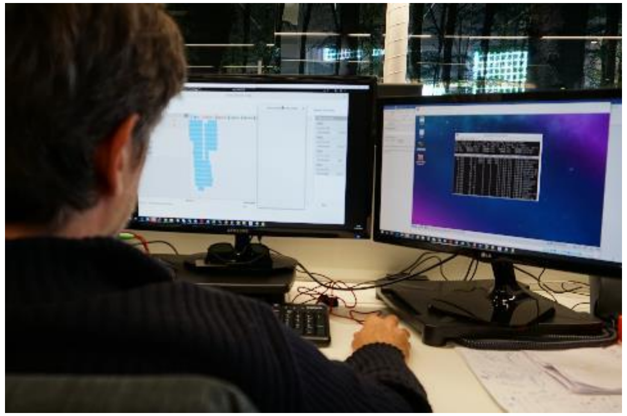


How does Soltec face extreme climate and high-wind speeds?

SPD: Surge Protection Device

Some PV installations are very regularly exposed to lightning and overvoltage, which can considerably reduce the life expectancy of the electronics devices.

Integrated SPD in the tracker controlled avoids the lightning current passing through the electronic device, reducing the risk of damage.



TMS: Tracker Monitoring System

Expert technical support for:

- Alarms management
- Analysis of any events or anomalies detected
- Analysis of the tracker and gateways parameters showed by TMS: roll, target roll, current motor, status bits, working mode, status link, wind alarms, etc.
- Reporting to maintenance company in case any anomalies are detected
- Service report to be delivered once a month

How does Soltec face extreme climate and high-wind speeds?

Self-stow

From the moment in which the first solar module is installed on the tracker structure until the PV plant is commissioned, Soltec has identified a risk window that must be addressed. In this regard, Soltec is already implementing in all electronic controllers the self-stow feature by leveraging the self-powered back-up batteries.

Onsite meteorological station

These stations measure wind speed and wind direction. Soltec's stations are comprised of an anemometer, and a pyranometer, as well as cameras to be able to watch and record what is happening in the PV plant.

THANK YOU

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Questions and discussion

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