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ESET Solar

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Surfing extreme winds: How 'Every-post self-locking' trackers eliminate torsional risks

15 June 2026

9:30 am – 10:30 am | CEST, Berlin

5:30 pm – 6:30 pm | AEST, Sydney

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Welcome!

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Do you have any questions? ❓ 🙋

Send them in via the Q&A tab. 👉 We aim to answer as many as we can today!

You can also let us know of any tech problems there.

We are recording this webinar today. 📹

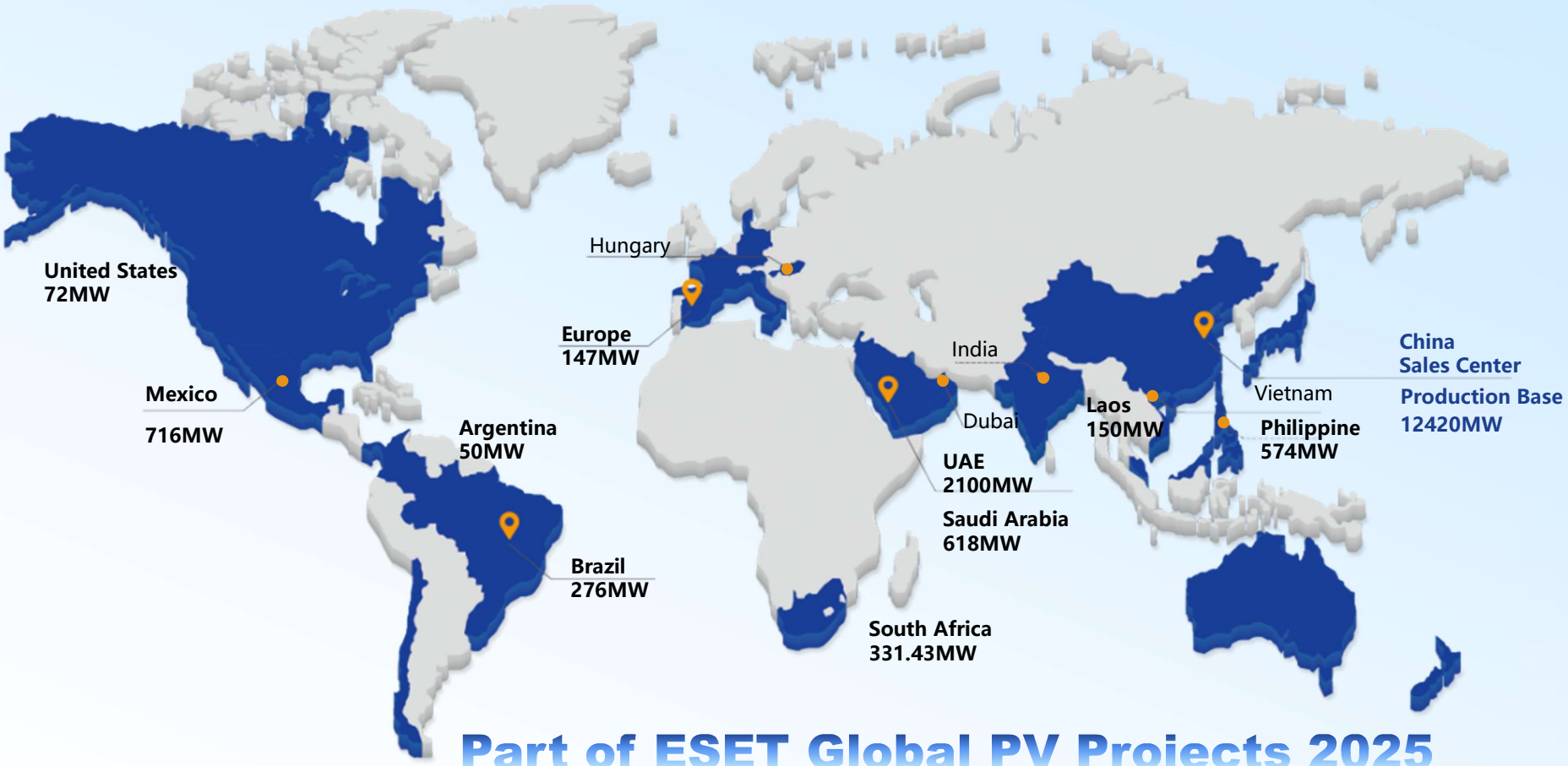
We‘ll let you know by email where to find it and the slide deck, so you can re-watch it at your convenience. 👀 💡

ESET SOLAR

How 'Every-Post Self-Locking' Trackers Eliminate Torsional Risks.

Frank Wang
Technical Support Director

Metavast Introduction



Part of ESET Global PV Projects 2025

50 GW+	12	30 GW+	3 GW	500 +
Global Shipment Volume	Smart Factories	Annual Capacity in China	Annual Capacity in KSA	Project Cases

PV Trakcer System

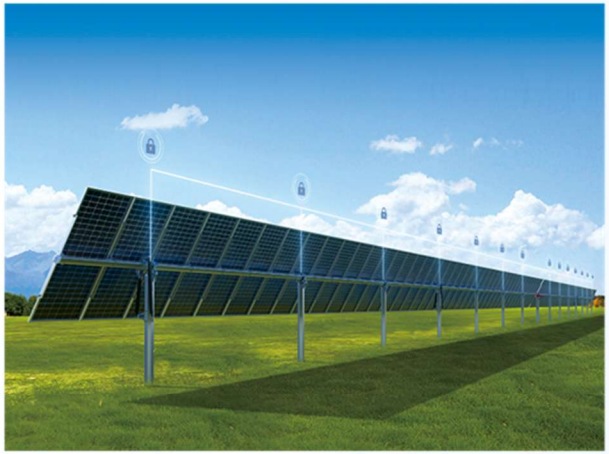
Flexible PV Mounting System

Fixed PV Mounting

Fixed PV Mounting

EPC

ESEEK-Steady



Ultimate Safety
Protection Against Strong Winds

Optimal Cost
Efficient Installation for Time and Effort Savings

Stable and Reliable
Stable Craftsmanship and Reliable Structure

Superior Efficiency
Smart Commissioning for Effortless and Worry-Free Operation

ESEEK-Twins

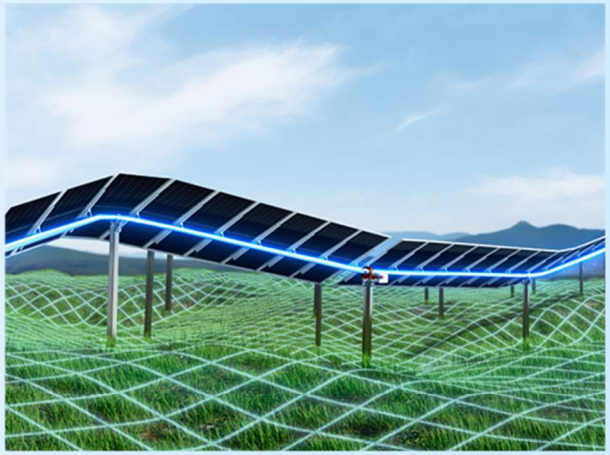
Worry-free Installation
Omni-directional Adjustment for Easy Installation

Ultimate Safety
Protection Against Strong Winds

Stable and Reliable
Stable Craftsmanship and Reliable Structure

Superior Efficiency
Smart Commissioning for Effortless and Worry-Free Operation

ESEEK-Climber



Terrain Adaptability
Slope Adaptation - Natural Fit

Structural Safety
All Posts Self-locking - Enhanced Wind Resistance

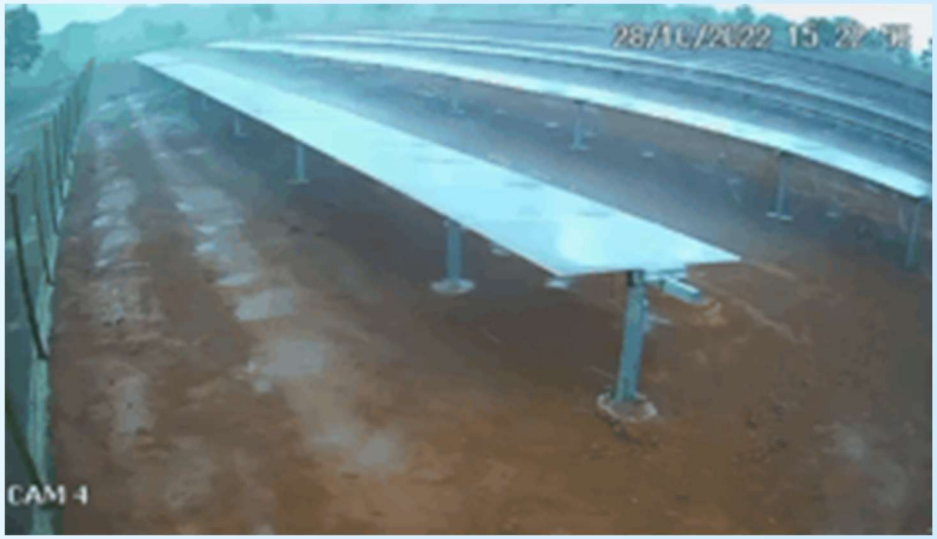
Flexible Installation
Retractable Connections - Simplified Modular design

Long-Term O&M Efficiency
Stress Control - Smart Maintenance

ESET Every Post Locking

Design Background

The specific manifestations of damage to PV Tracker



Plastic deformation caused by high rotation. **Wind shakes the rack.** Cracks grow bigger

kWh ANALYTICS 2026 Solar Risk Assessment

Trackers Twist along the row during rotation

Trackers don't move as one flat piece

Causes **>2% annual yield loss**

Leads to **microcracks** and premature failur

Lighter, larger modules = Softer structures

Everyday winds (10-15 mph) are enough to cause damage.

The Hidden Killer: "Propeller Effect"

The Propeller Effect: How Tracker Operational Twist Can Reduce Total Yield by Over 2% and Increase Module Failure Risk

By: Frank Oudheusden & Christopher Needham (Azimuth Advisory Services)

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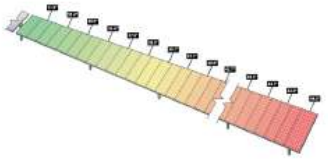
Single-axis solar trackers are designed to maximize energy capture, yet under normal operation, many rows experience measurable twist. Known as the "propeller effect," this occurs when the row gradually rotates from the actuator toward the row end, like the changing pitch of an aircraft propeller. Azimuth Advisory Services has developed proprietary models to estimate this effect. Twists approaching 20° have been documented or reported across several utility-scale projects representing hundreds of megawatts.

Figure 1: Row Twist Across a Typical 112-Module Row

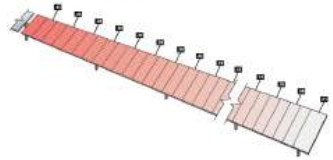


This creates two primary risks:

Annualized Yield Impacts:
Twist causes modules to deviate from their optimal tilt angle. This results in uneven irradiance across strings and row-to-row shading near row ends. In some cases, localized shading losses have exceeded 30% and are often misdiagnosed as backtracking errors. Controller adjustments can reduce visible shading, but do not eliminate the underlying row distortion. Because PV strings are limited by the lowest-performing module, even corrected systems can experience total row annualized yield reductions exceeding 2% at twists approaching 20°. IEC 62817 correlates ±5° of tracker accuracy with ~0.4% energy loss, including both motor accuracy and structural twist. Field observations suggest this may be conservative under higher twist conditions.

Potential Module Damage:
Repeated twisting places cyclic stress on modules. AAS has measured individual module twist of ~1° during routine tracking (Figure 2). Though small, this motion repeats with each tilt adjustment, resulting in hundreds of thousands of stress cycles over a project lifetime. Field observations show that glass and cell cracking frequently align with areas of highest individual module twist, often adjacent to the actuator (Figure 2).

Figure 2: Individual Module Twist Across a Typical 112-Module Row



As module sizes increase and structures become lighter, operational twist is a measurable and often under-modeled risk. Counterintuitively, twist is often highest on interior rows, where structures are optimized for material efficiency rather than stiffness.

Independent Engineers should evaluate the propeller effect during due diligence and assume realistic daily wind exposure, not just extreme natural catastrophe events. Moderate backside wind speeds of 10–15 mph can meaningfully increase twist, compounding both energy loss and fatigue-related stress over the system life.

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ESEEK-Steady

Single Row 1P Tracker

Up to 4 Strings 145 Meter Length per table

Open cover bearing seat

→ Less ssembling clearance

→ Easy installation & maintenance

All points self-locking to uniform distribution of torque

→ Prevent vibration diffusion, avoid flutter or vortex vibration

Axisymmetric damper

→ Lower Vibration amplitude

→ Higher critical wind speed

Diamond-shaped torque tube

→ Combined excellent round section torsional resistance & square section bending resistance

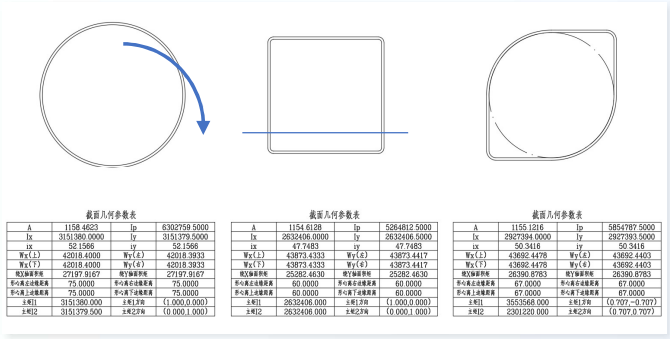
→ Lower W / T value and safer

ESEEK Steady Highlights

Stable Diamond-shaped beam

→ A diamond-shaped cross-section design combines the excellent torsional resistance of circular sections with the bending strength of square sections.

→ With a lower width-to-thickness (W/T) ratio, the material strength is not compromised, allowing for the true utilization of high-strength materials. Under the same material usage, compared to square main beams, the strength can be increased by more than 30%.



截面几何参数表

A	1158.4623	Ip	6302759.5000
Ix	3151380.0000	Iy	3151379.5000
ix	52.1566	iy	52.1566
Wx(上)	42018.4000	Wy(左)	42018.3933
Wx(下)	42018.4000	Wy(右)	42018.3933
纯X轴塑性矩	27197.9167	纯Y轴塑性矩	27197.9167
形心离左边缘距离	75.0000	形心离右边缘距离	75.0000
形心离上边缘距离	75.0000	形心离下边缘距离	75.0000
主轴1	3151380.000	主轴1方向	(1.000,0.000)
主轴2	3151379.500	主轴2方向	(0.000,1.000)

截面几何参数表

A	1154.6128	Ip	5264812.5000
Ix	2632406.0000	Iy	2632406.5000
ix	47.7483	iy	47.7483
Wx(上)	43873.4333	Wy(左)	43873.4417
Wx(下)	43873.4333	Wy(右)	43873.4417
纯X轴塑性矩	25282.4630	纯Y轴塑性矩	25282.4630
形心离左边缘距离	60.0000	形心离右边缘距离	60.0000
形心离上边缘距离	60.0000	形心离下边缘距离	60.0000
主轴1	2632406.000	主轴1方向	(1.000,0.000)
主轴2	2632406.000	主轴2方向	(0.000,1.000)

截面几何参数表

A	1155.1216	Ip	5854787.5000
Ix	2927394.0000	Iy	2927393.5000
ix	50.3416	iy	50.3416
Wx(上)	43692.4478	Wy(左)	43692.4403
Wx(下)	43692.4478	Wy(右)	43692.4403
纯X轴塑性矩	26390.8783	纯Y轴塑性矩	26390.8783
形心离左边缘距离	67.0000	形心离右边缘距离	67.0000
形心离上边缘距离	67.0000	形心离下边缘距离	67.0000
主轴1	3553568.000	主轴1方向	(0.707,-0.707)
主轴2	2301220.000	主轴2方向	(0.707,0.707)

Theoretical Method

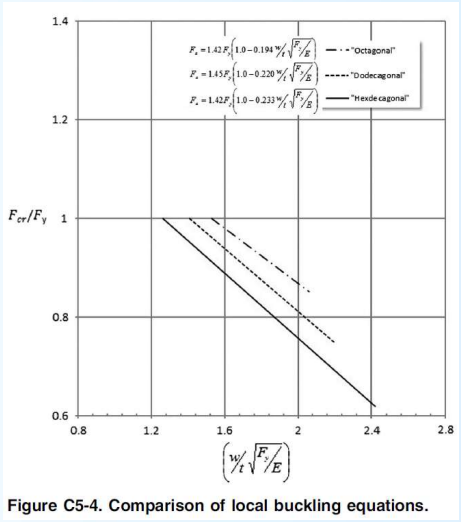


Figure C5-4. Comparison of local buckling equations.

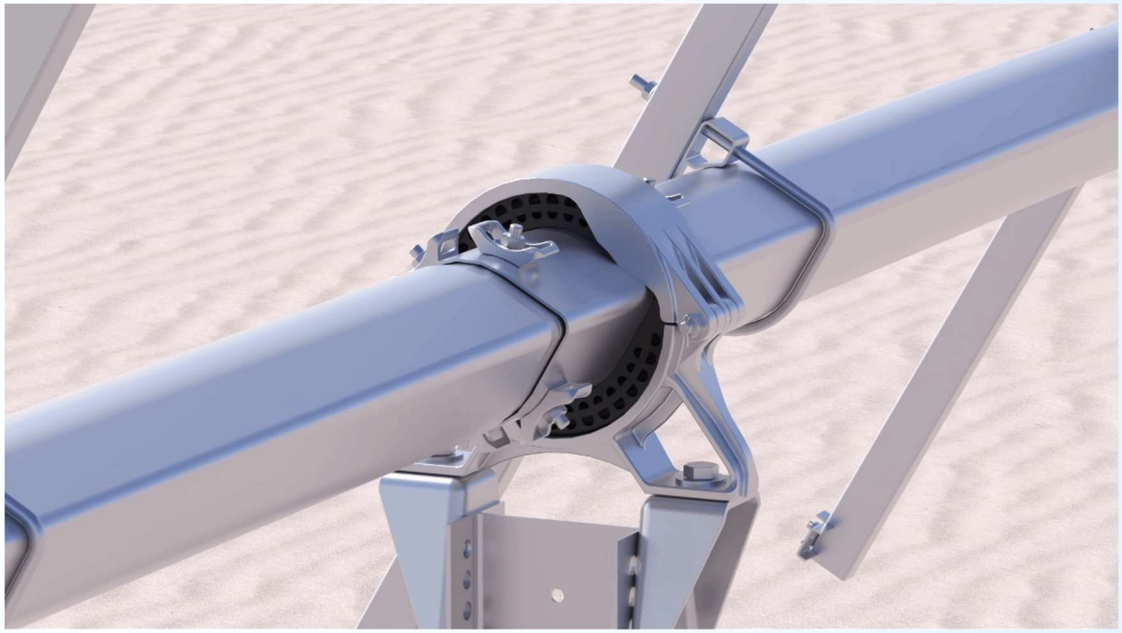
Core of Product Design

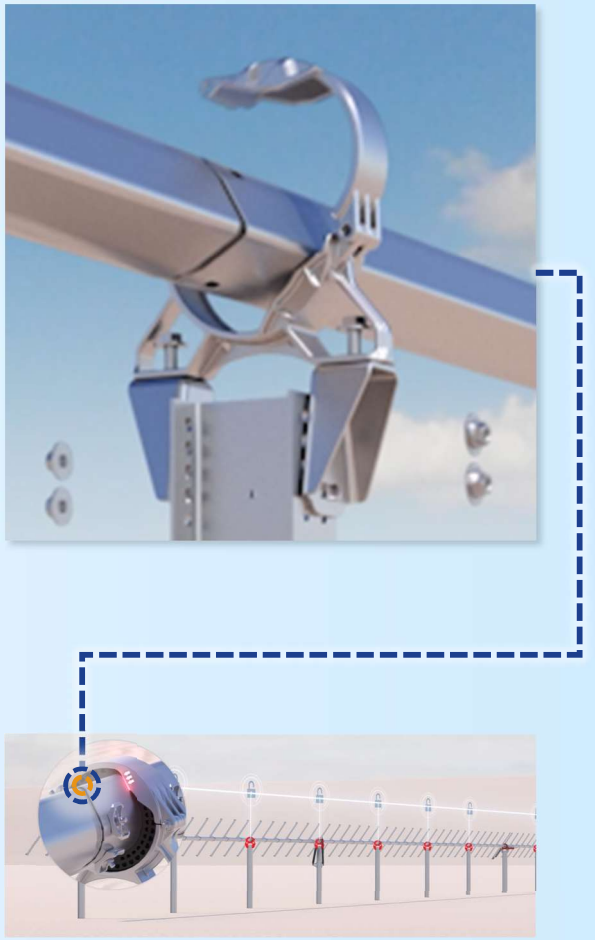
ESEEK Steady Highlights

Separable Bearing seat

→ The open-cover bearing housing ensures a tighter fit with the main shaft and bearings, reducing assembly clearance;

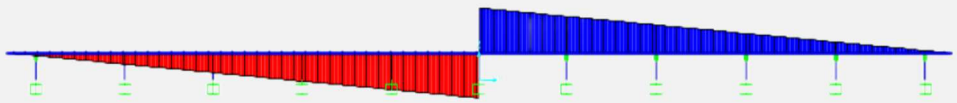
→ The polymer bearings feature a monolithic design, offering high stability.





Core of Product Design

Every Post Locking



Single Point Driven Main Beam Torque Diagram

Full Domain Self-Locking Structural Torque Diagram

Advantage-1

→ All columns and main shafts are fully locked, with torque evenly distributed

Advantange-2

→ Prevent the spread of vibrations from the bracket

Advantage-3

→ Avoid flutter or vortex-induced vibrations

Every Post Locking

→ Key structural points: Column (bearing) center and both end faces.

→ Manually control rotate to target angle; wait 30 seconds for system stabilization.

→ Precisely measure actual rotation angles of each photovoltaic module.

Fig.4: Target rotation angle 0°, south end component angle

Fig.5: Target rotation angle 0°, non-driven 1 component angle

Fig 6: Target rotation angle 0°, non-driven 2 component angle

Fig 7: Target rotation angle 0°, non-driven 3 component angle

Fig 8: Target rotation angle 0°, non-driven 4 component angle

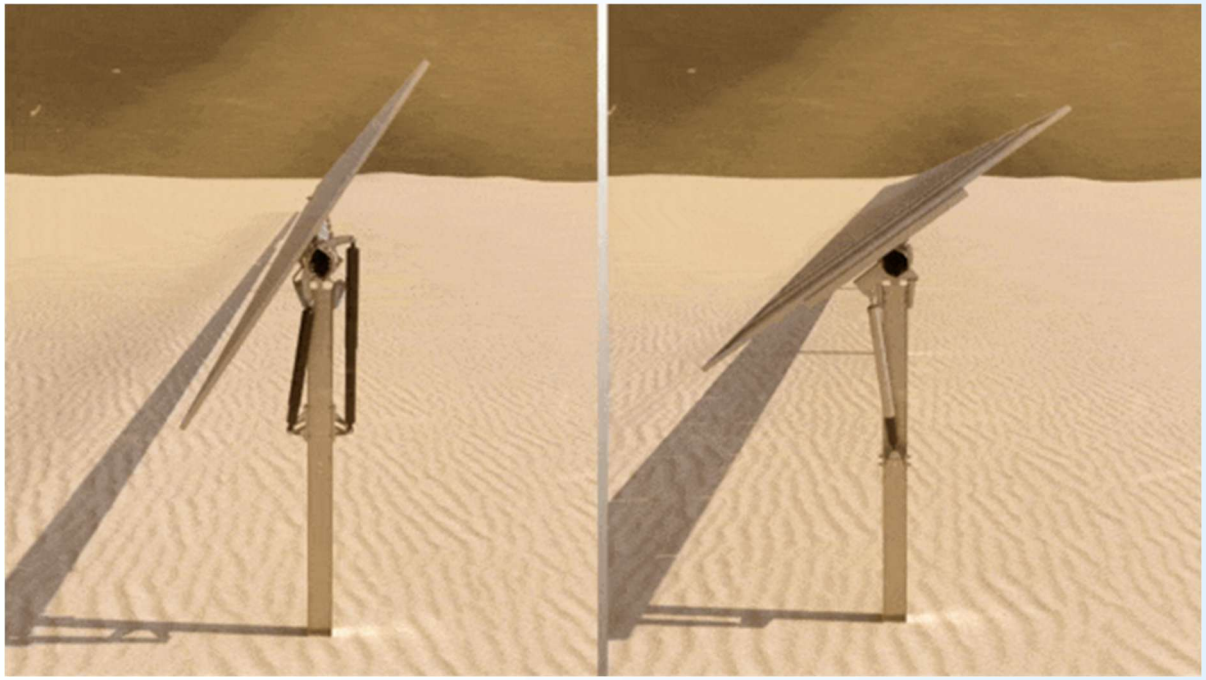
Fig 9: Target rotation angle 0°, non-driven 5 component angle

ESEEK Steady Highlights

Strengthen Damper

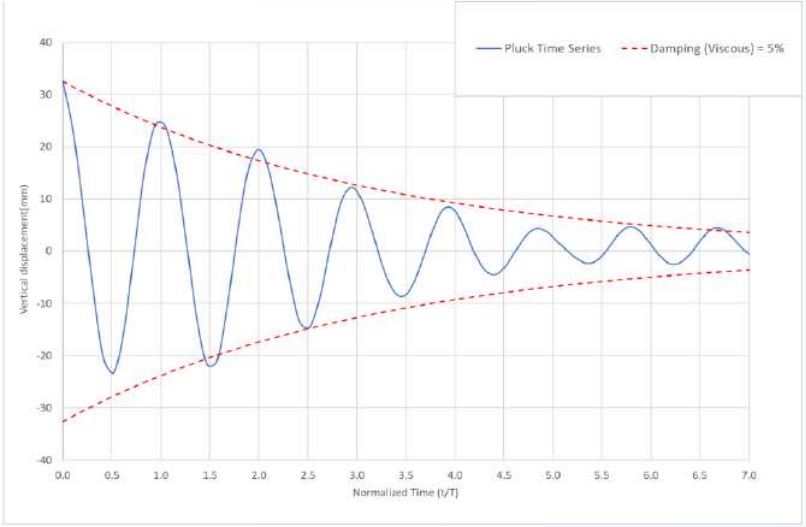
→ Axisymmetric damping design increase the damping ratio & Lower Vibration amplitude & Higher critical wind speed.

→ Larger angle of inclination & damping for wind protection provide better stability.



Core of Product Design

Pluck Test



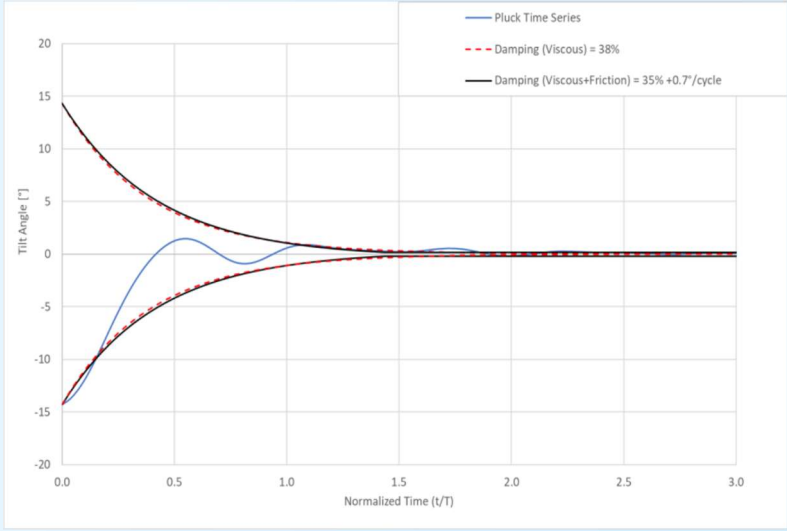
Heaving mode pluck time history

CPP WIND ENGINEERING CONSULTANTS

DRAFT REPORT 21402 ADD07
14 NOVEMBER 2025

Jiangsu Evershine 1P Pluck Test Review

Single-drive system

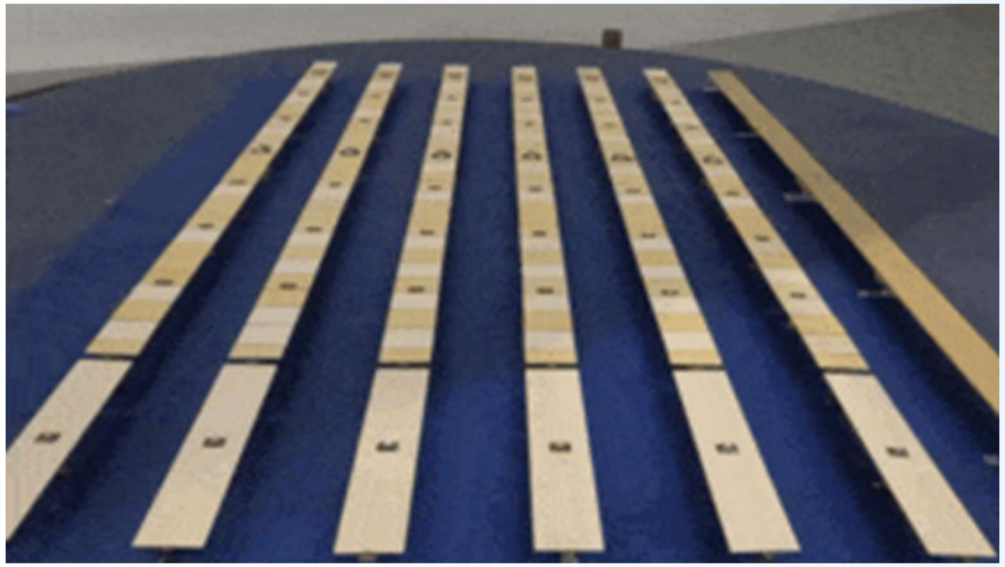


Torsional mode pluck time history

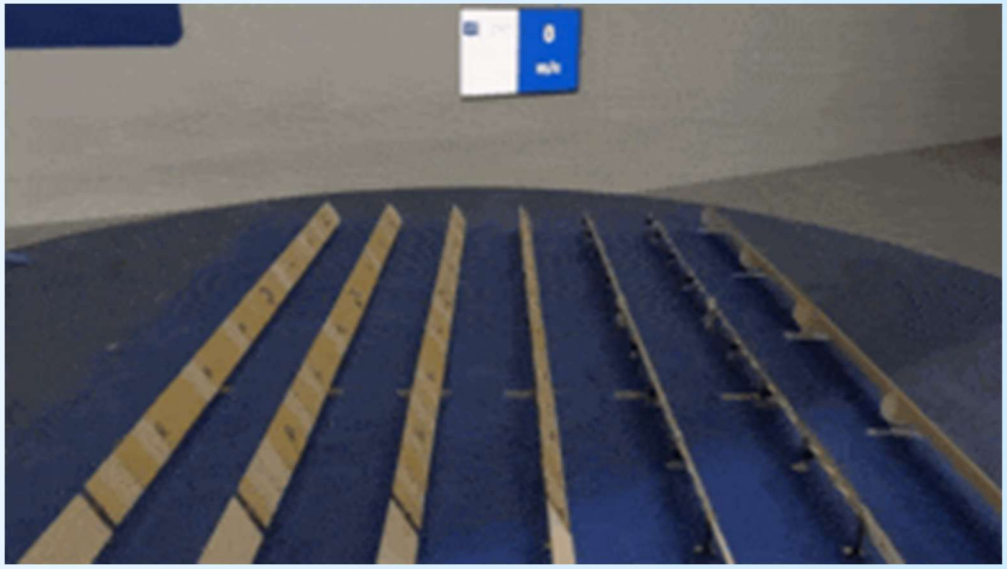
ESEEK Partnership with CPP

Verification and Validation - CPP Wind Engineering Consultants

- → For the 0° tilt case the lowest critical wind speed was observed at 47 m/s (3-second gust at 10 m).
- → At higher tilts, ±30° and ±60°, no significant angular deflections (more than 30° peak-to-peak) were observed during the test, up to a maximum wind tunnel speed of 69 m/s (3-second gust at 10 m).



No Self-locking Mode



Every-post Self-locking Mode

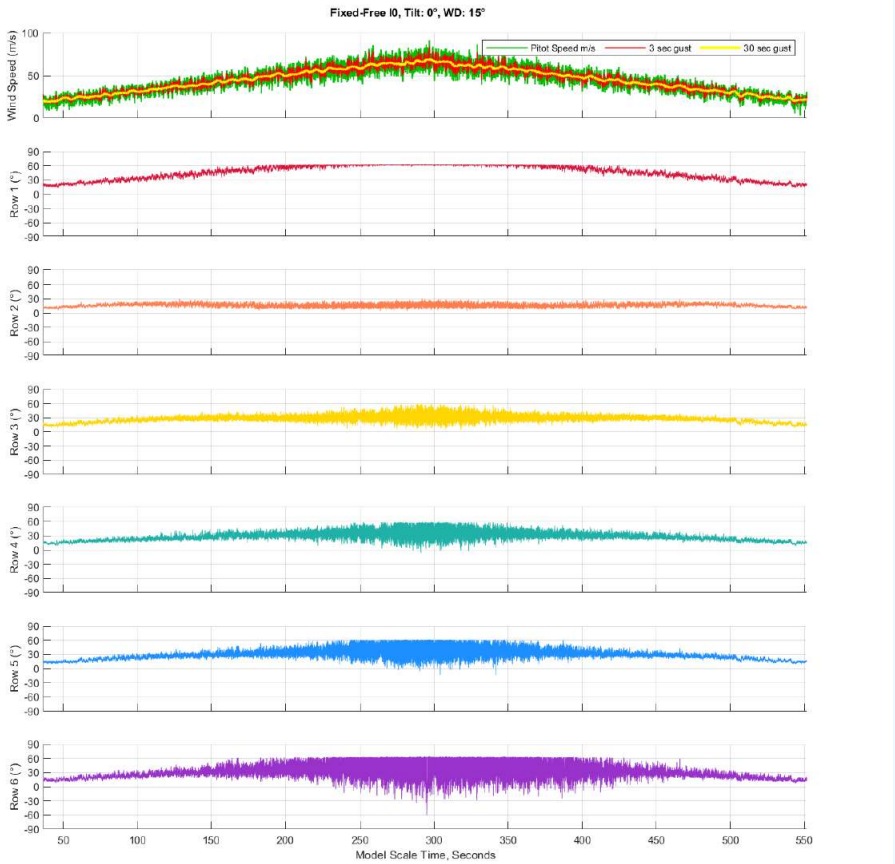


Figure 6: Model Scale Time， Seconds

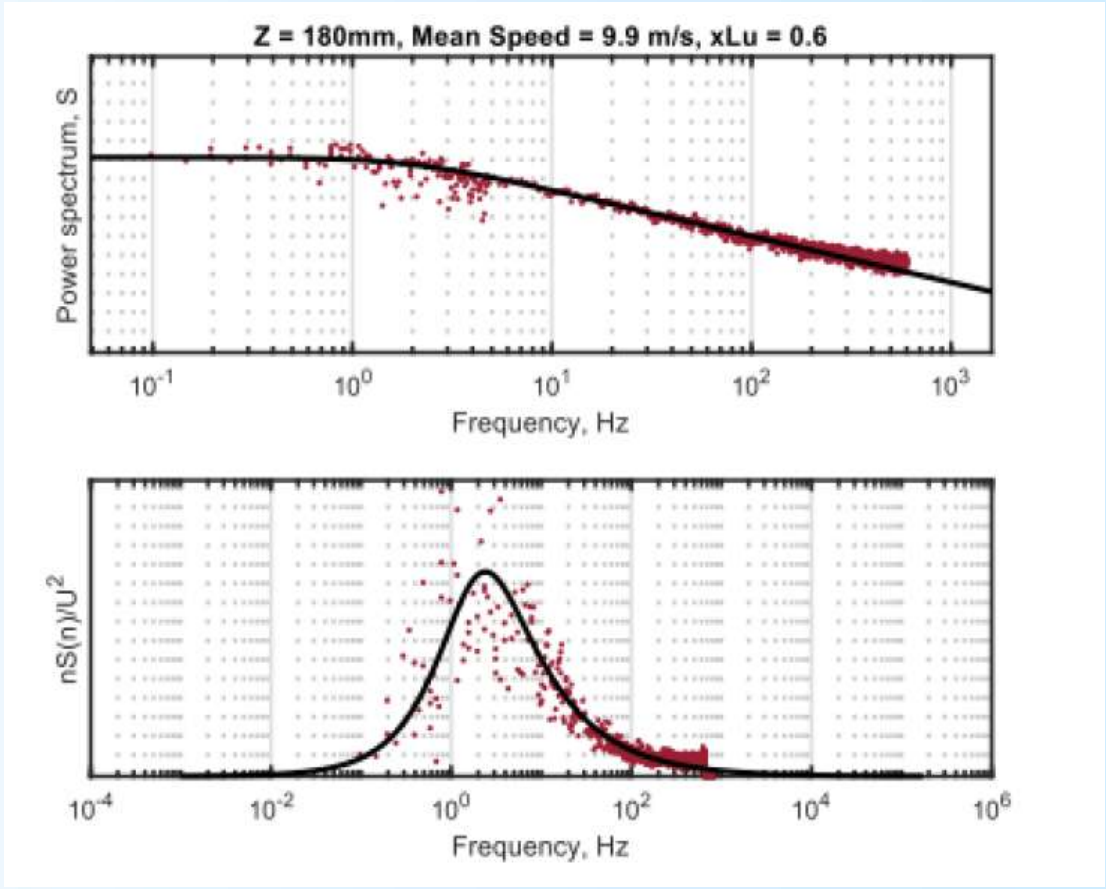


Figure 7: Turbulent Energy Spectrum at the turntable

Wind tunnel test examples for the Jiangsu Evershine 1P system (at various tilt angles) are shown. The critical velocity (Ucr) is represented by the black bounding curve, indicating the minimum threshold for safe motion under peak winds.

Critical Wind Speed Calculation

1P Tracker Section	30° Peak-to-peak (3-second gust at 10 m) (m/s)	
	Minimum measured Ucr	Bounding curve Ucr
Tilt	Fixed-Free span	
-60°	86	77
-30°	81	73
0°	48	41
30°	82	74
60°	87	78

- At 60° tilt, Ucr=78 m/s
- At 0° tilt, Ucr=41 m/s
- Smaller torque tube twist angle
- More stable and less vibration
- **Binary Stow**

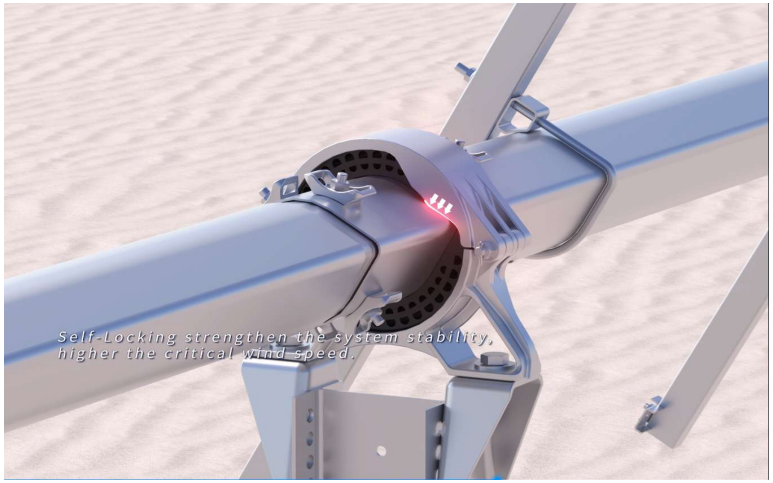
$$U_{cr\,b} = U_{cr\,a}\frac{S_a}{S_b}$$

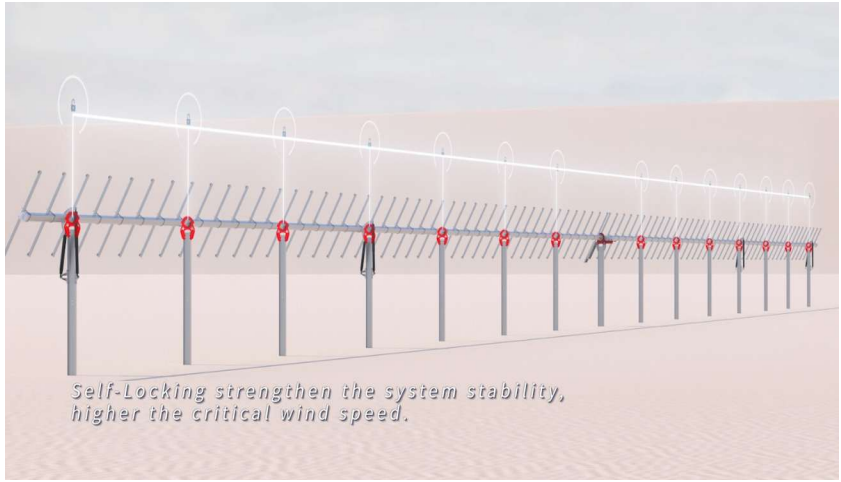
Flexible Span Length

$$U_{cr\,b} = U_{cr\,a}\sqrt{\frac{GJ_b}{GJ_a}}$$

Torsional Rigidity

ESET Every Post Locking





ESEEK Steady Highlights

Swaged Tube & No Special Tools

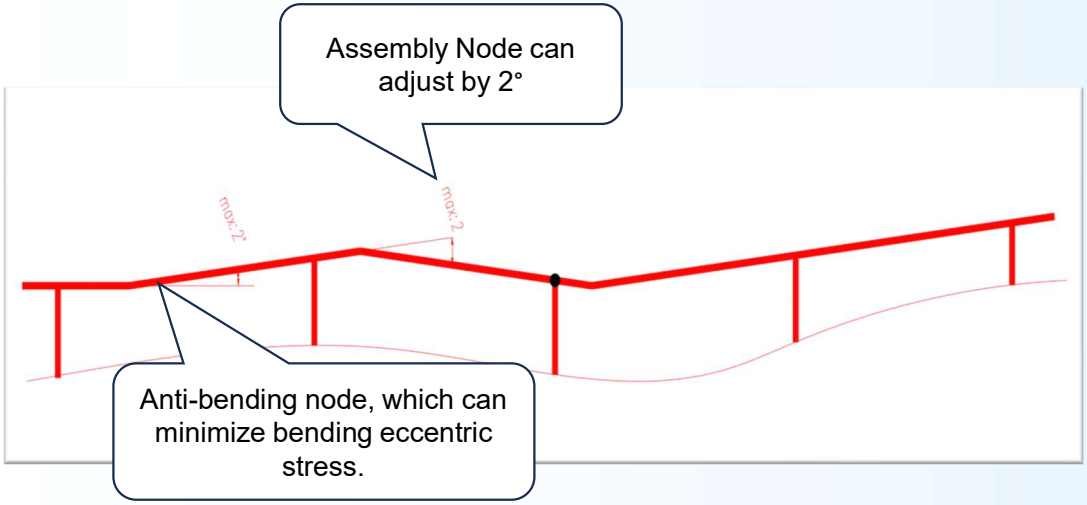
Removable Battery Slot

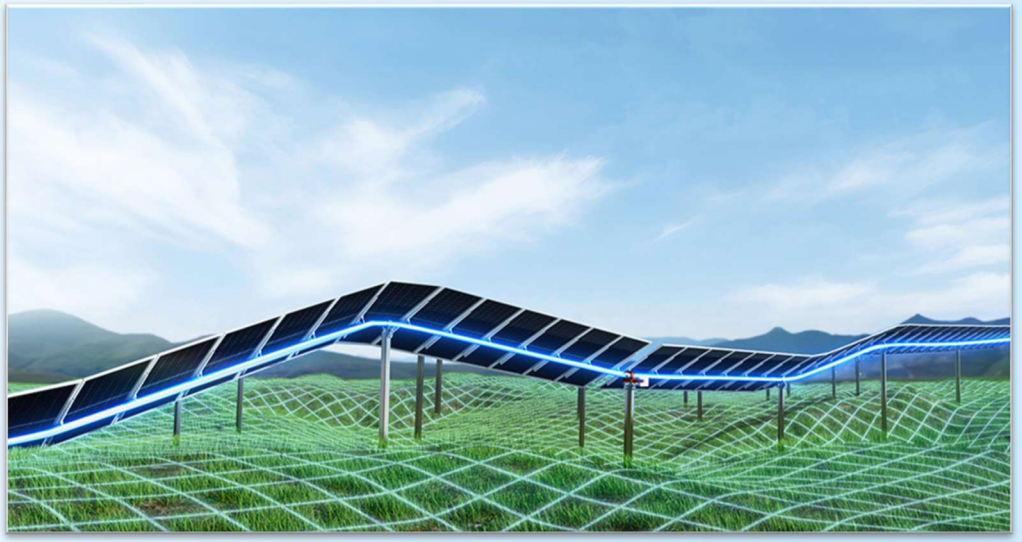
ESEEK System solution

Slope-adaptive - ESEEK-CLIMBER Terrain following system

→ A single diameter-reducing node can adjust by 2°;

→ Highly adaptable to uneven ground, reduces earthwork for leveling, minimizes environmental impact, and lowers project risks.



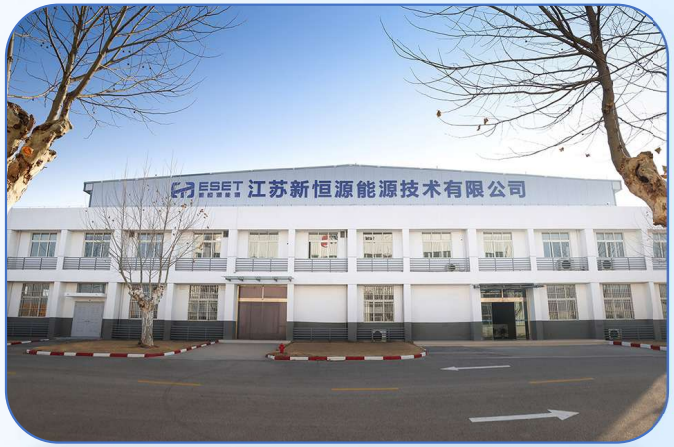


Certifications and Patents

CPP TUV UL SBP CE

FACTORIES

Production



Manufacturing

Manufacturing

FACTORIES

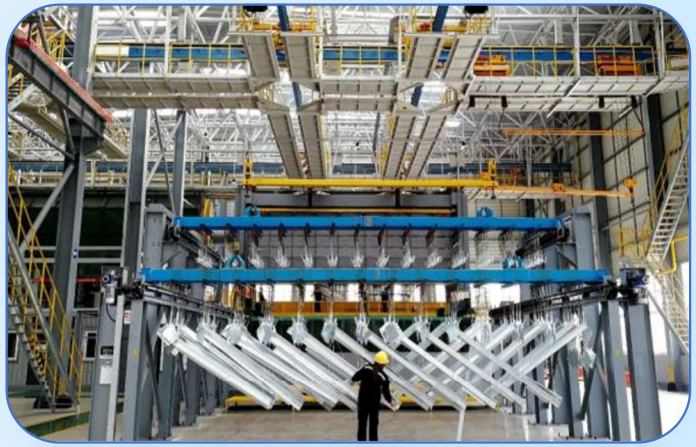
Zn-Al-Mg Production line

450,000 tons/year

Solar Structure Production Line

30 GW/year

Hot Dip Galvanizing Line



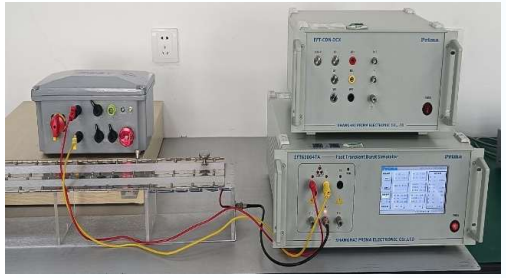
750,000 tons/year

QUALITY CONTROL

ESEEK Steady

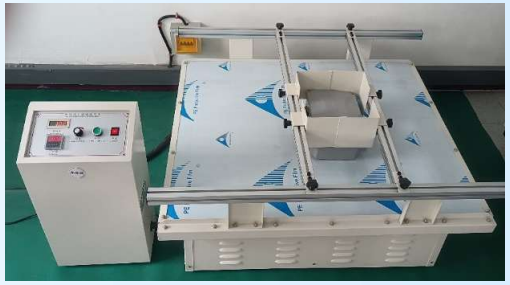
Verification and Validation - Prototype testing

→ Electrical Test for Control Systems.



Electrical Fast Transient/Burst (EFT/B) Test

Lightning Surge Test



Vibration test

High and low temperature test

Electrostatic Discharge (ESD) Test

Insulation Voltage Test

Module Compatibility Test

IEC 61215-2:2016 Static Mechanical Load test

Front

2nd Cycle

Front

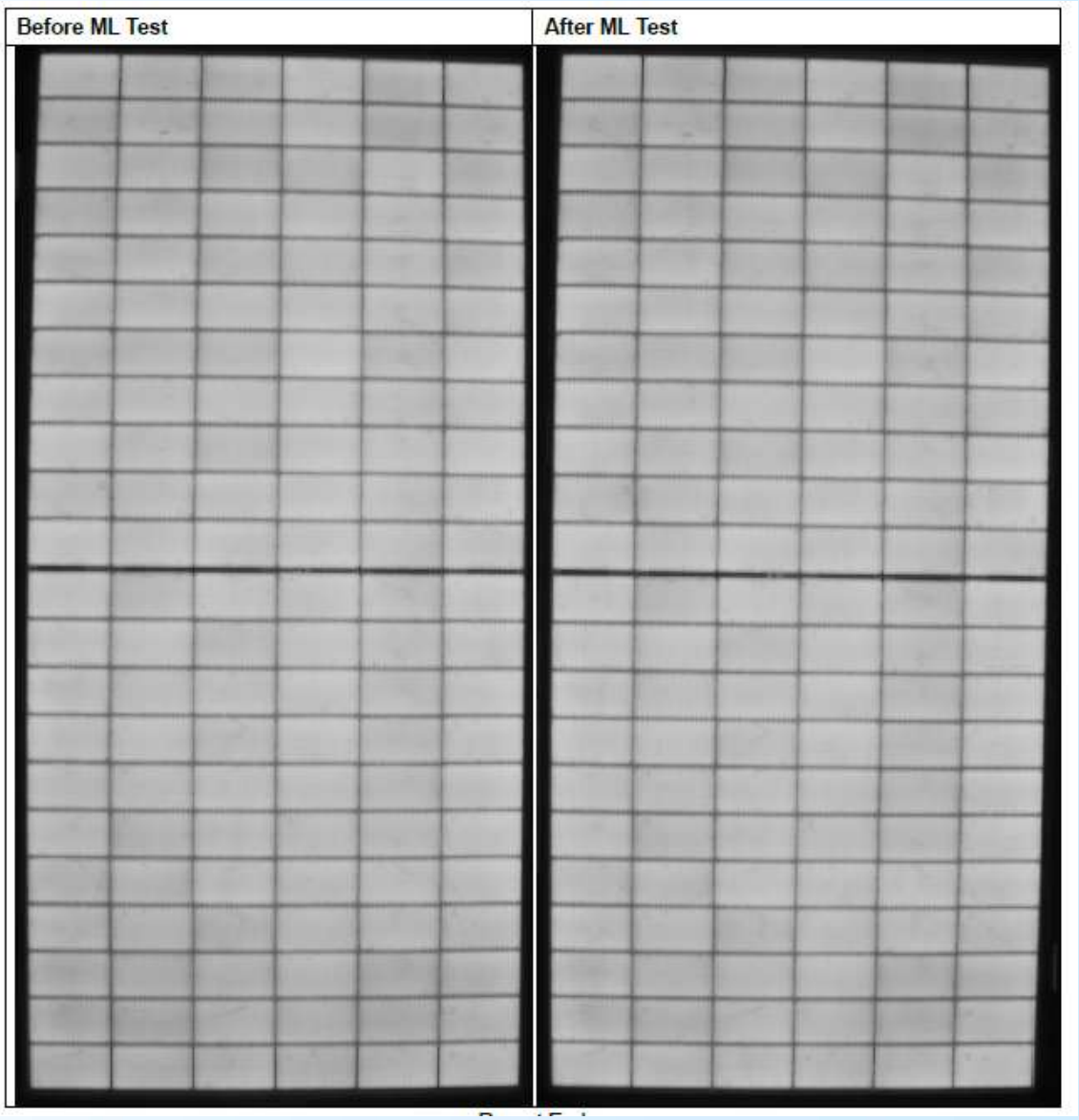
3rd Cycle

Module Compatibility Test

✅ **Passed:** Harsh Mechanical Load (ML) Testing.

✅ **Result:** No Cracks / No Frame Deformation.

✅ **Conclusion:** 100% Module Compatibility Guaranteed.



Structure Test

Loading Test

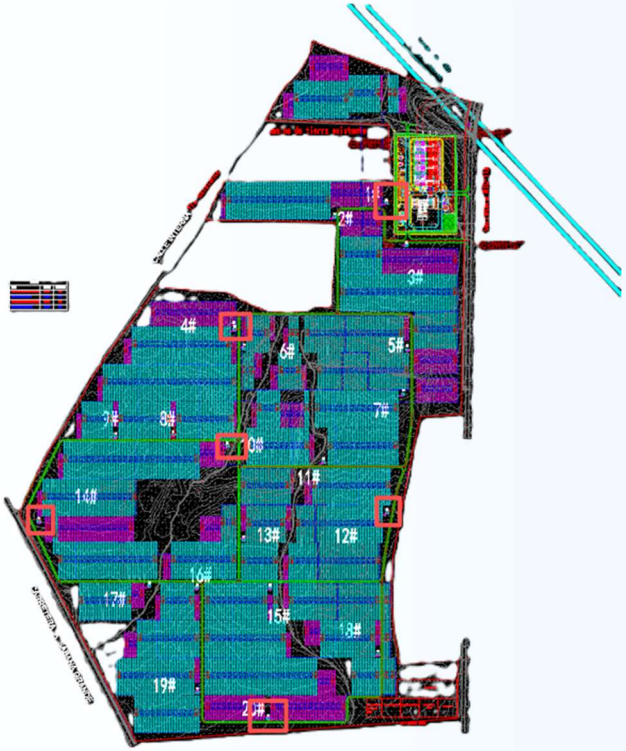
Structure Section Test 1

Torque Tube Loading Test

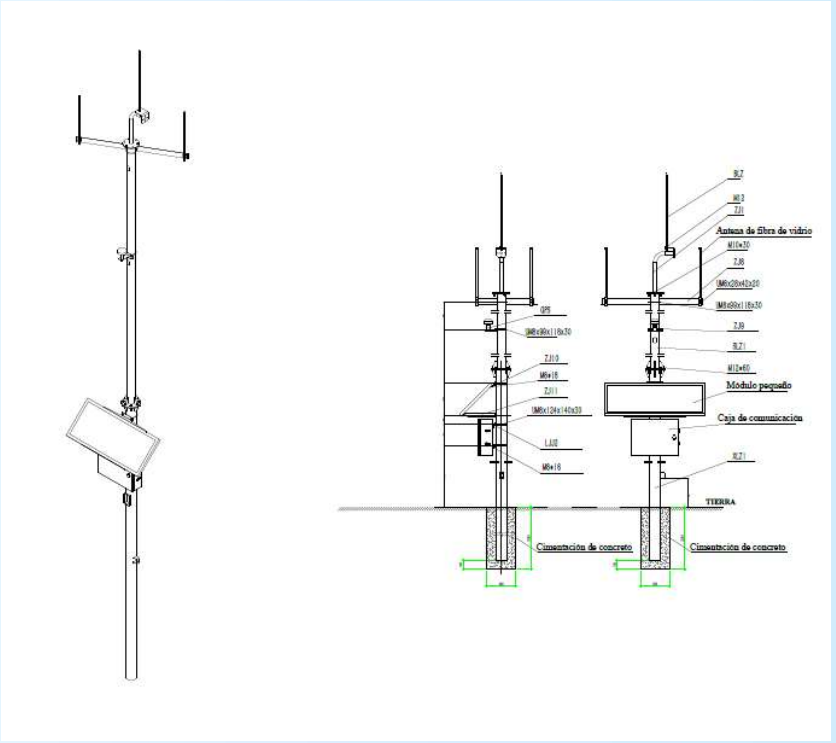
Structure Section Test 2

ESET Case Study

Case Study 1：Nicaragua 70MW Project



- Surrounding Meteorological Station Location
- Reinforced **Wind Monitoring Redundancy**



- 10m Weather station
- More accurate wind speed measurement

ESEEK Steady Highlights

Smart Tracking

→ NCU + TCU + SCADA

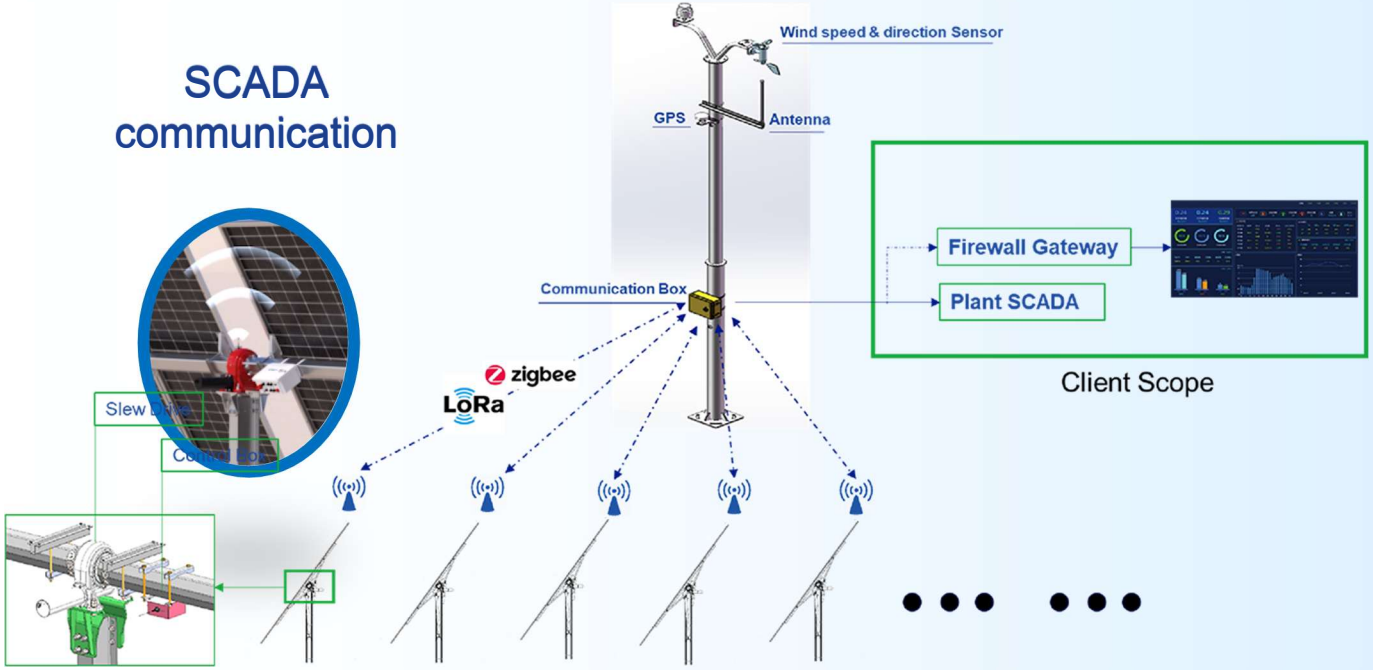
→ Lora / Zigbee communication

Wireless communication
with Lora / Zigbee
Easy installation

Power by
String / Self / AC
Lithium Battery Backup

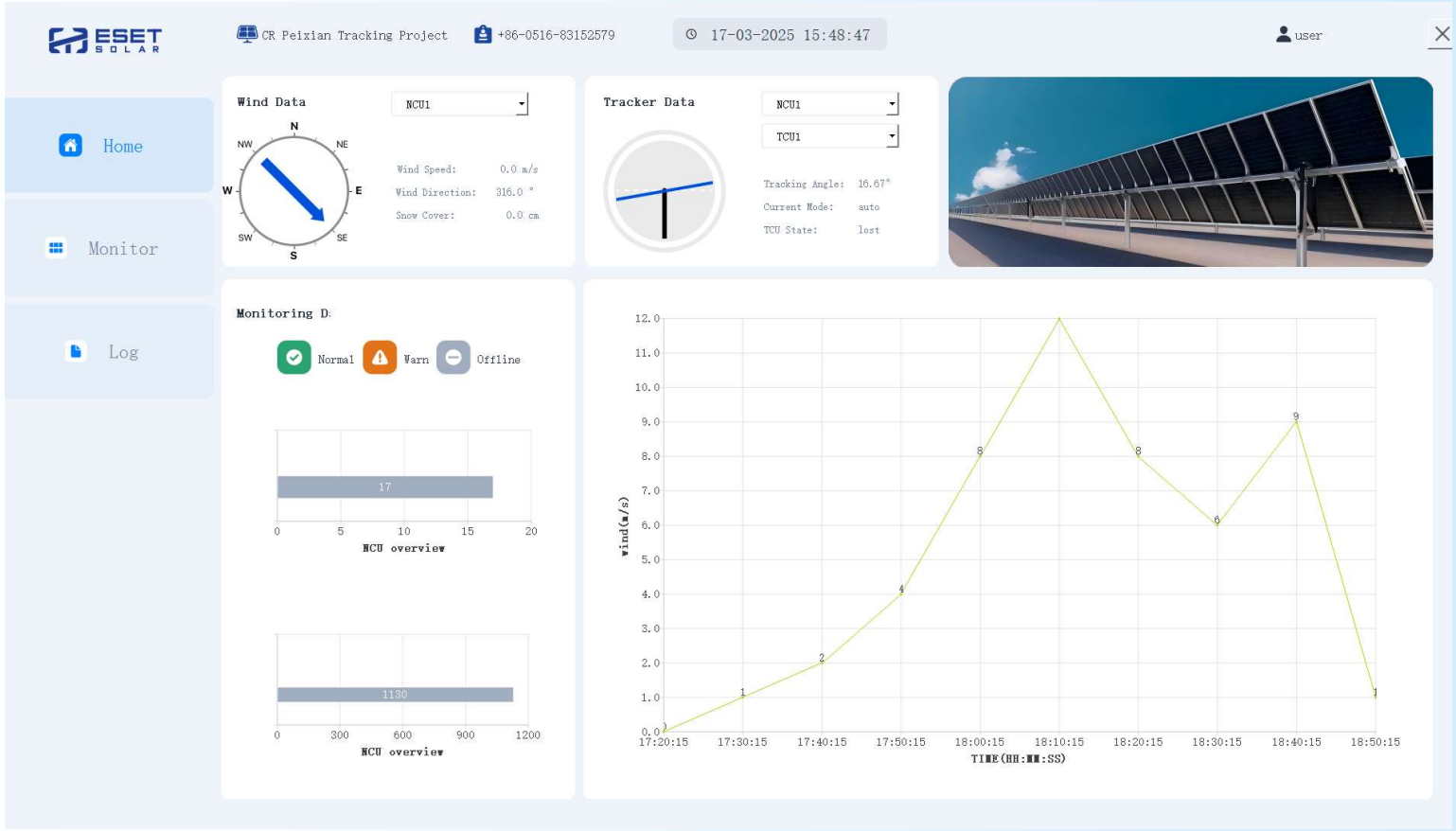
Astronomical Algorithm
Built-in inclinometer
Backtracking

SCADA
communication



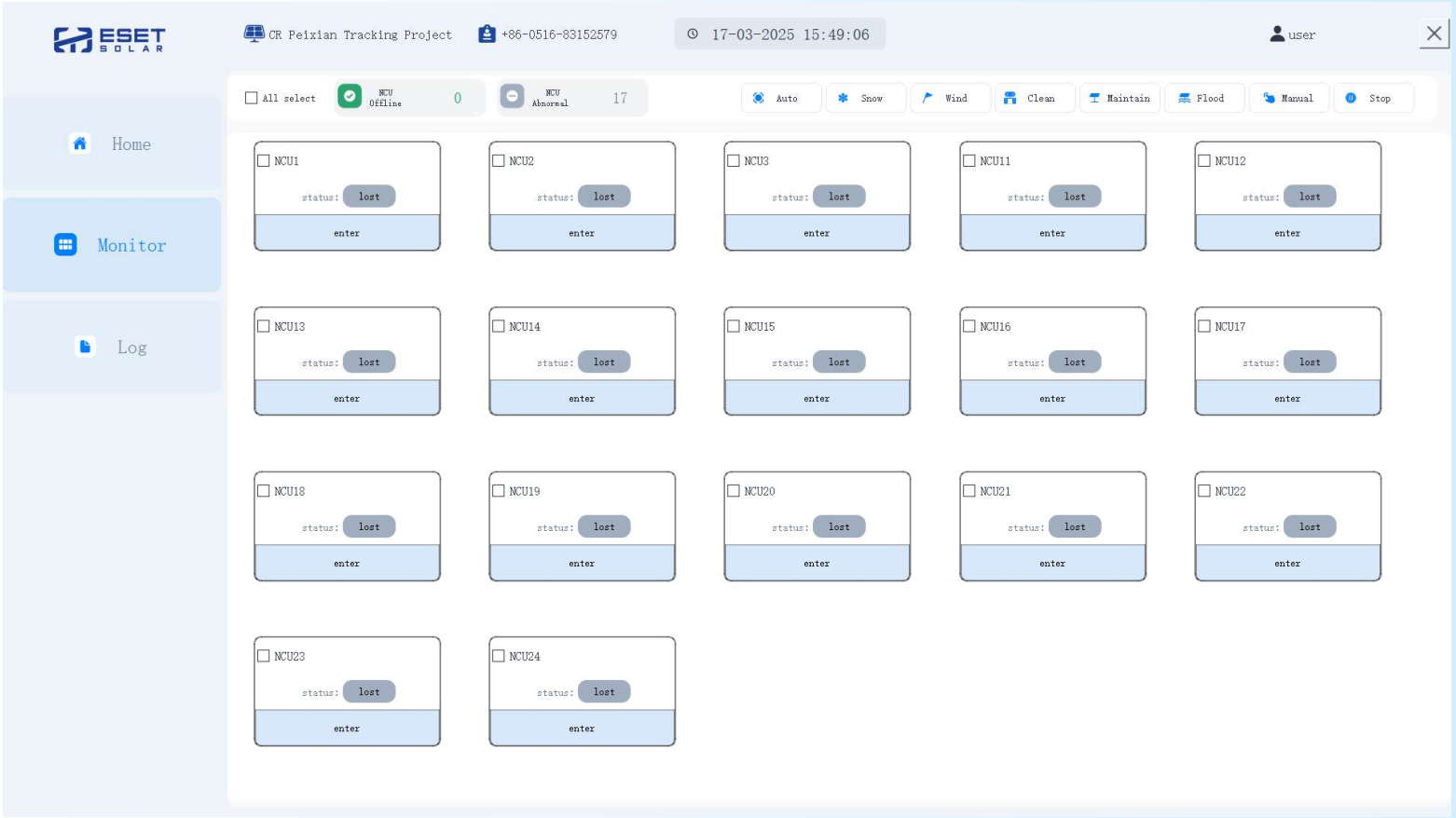
SCADA System-User Interface

SCADA Functions：
Home： Project Overview; Operation condition; Meteorological information; Block information.



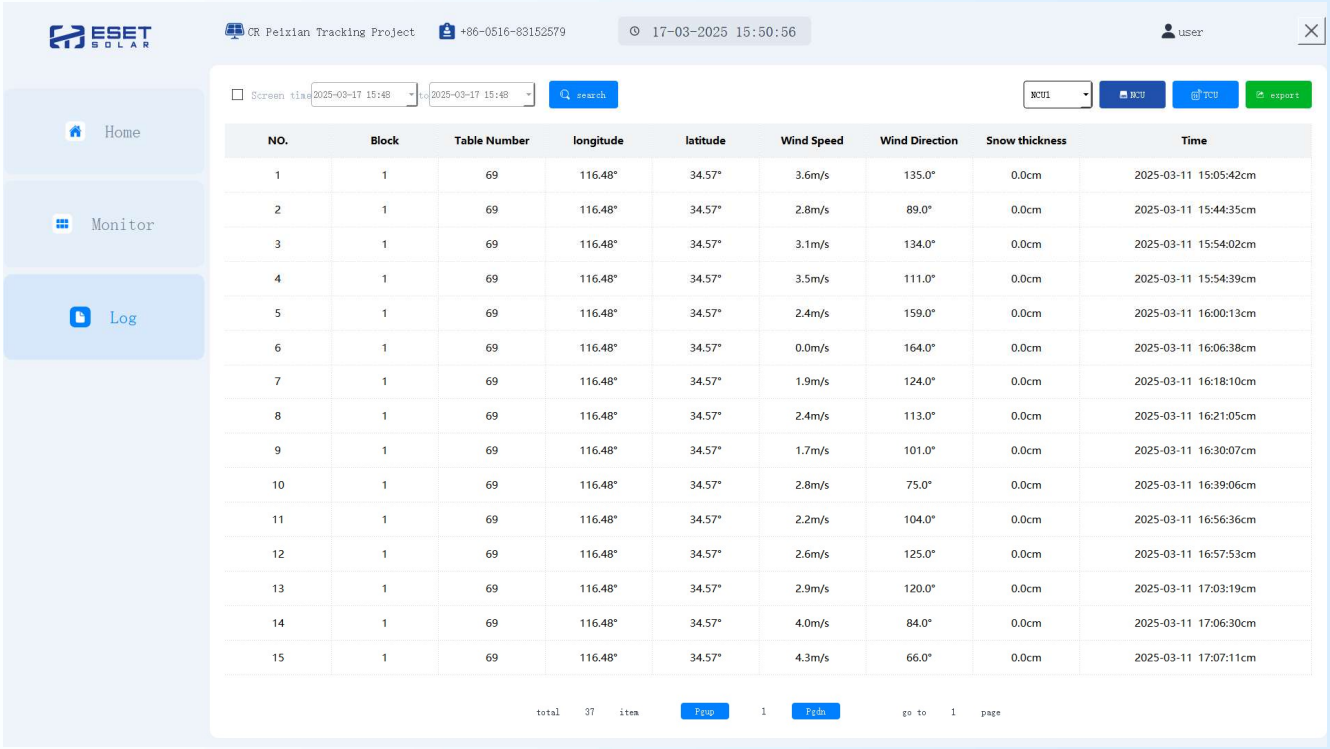
SCADA System-User Interface

Monitor: Display the operating status of each block; View block information; Send control instructions

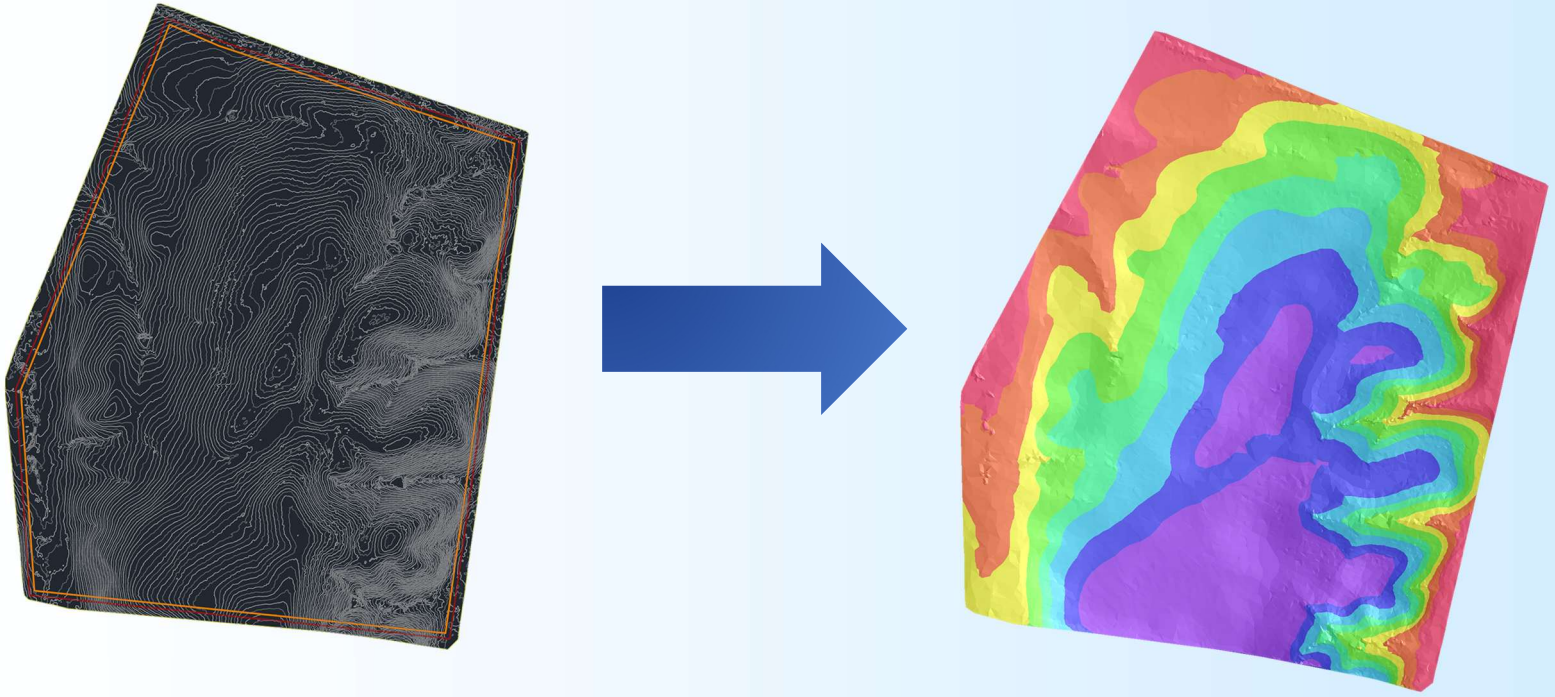


SCADA System-User Interface

Log: View the past operation status



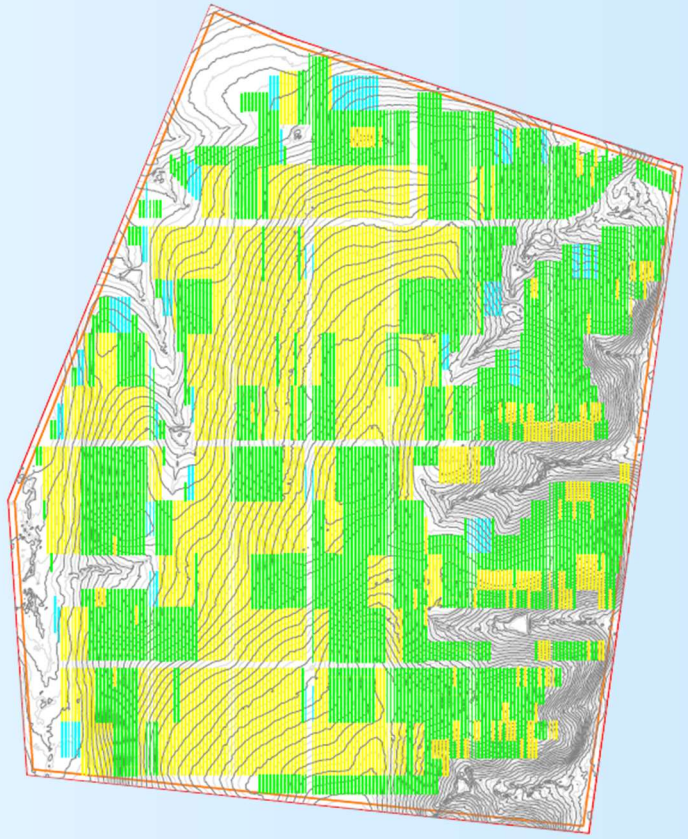
Case Study 2



- Full site detailed slope analysis
- Create a 3D model based on contour points.

Case Study 2

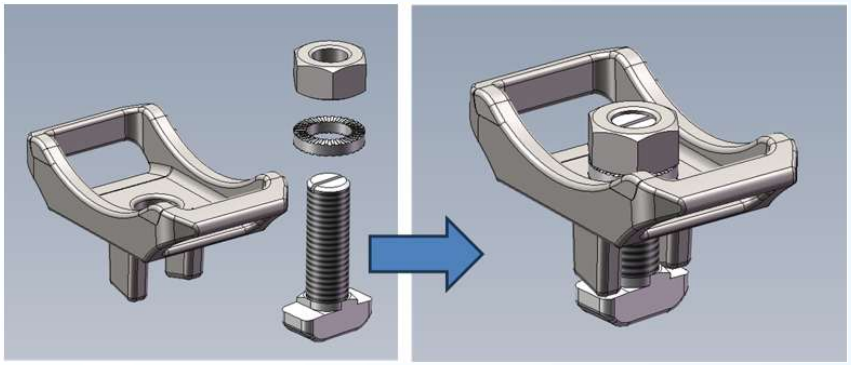
- Specific layout arrangement according to slope analysis
- Cut&fill analysis to obtain earthing volume (optional)
- Post location table

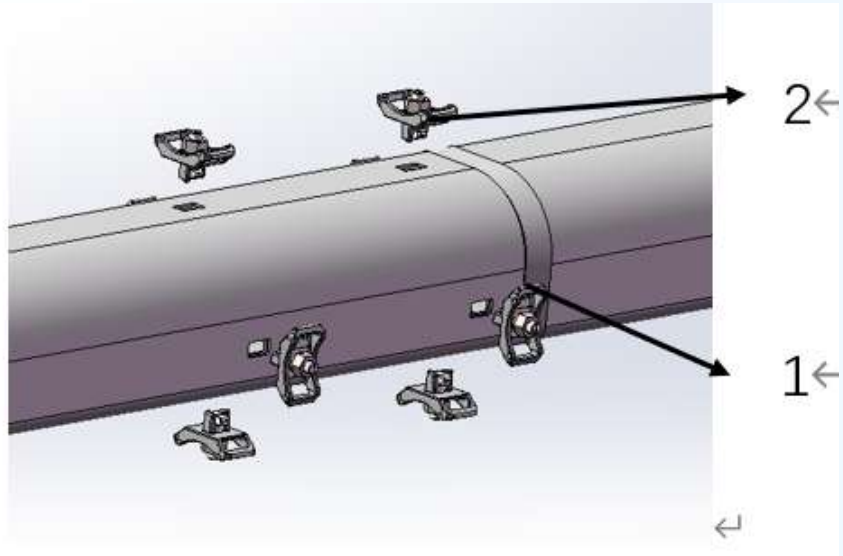


Cut/Fill Report

	Name	Elevation after balancing	2D Area (m^2)	Cut (m^3)	Fill (m^3)	Net (m^3)	
1	Melo	Varied	2140876.646	3431.76	3430.956	-0.804	<Fill>
Total			**2140876.646**	**3431.76**	**3430.956**	**-0.804**	<Fill>

Case Study 2





Pre-assembled T bolts for torque tube connection

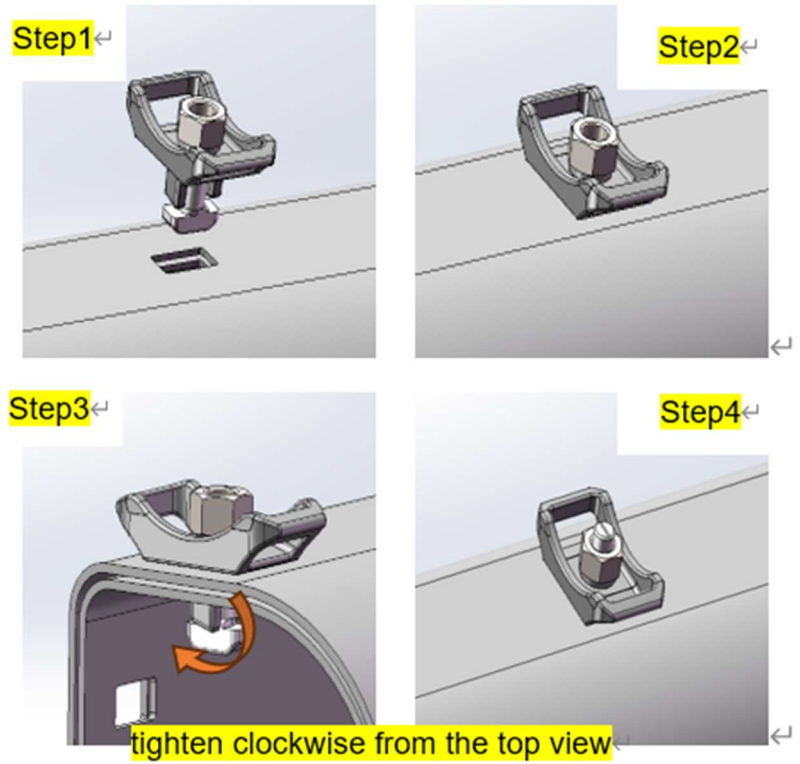
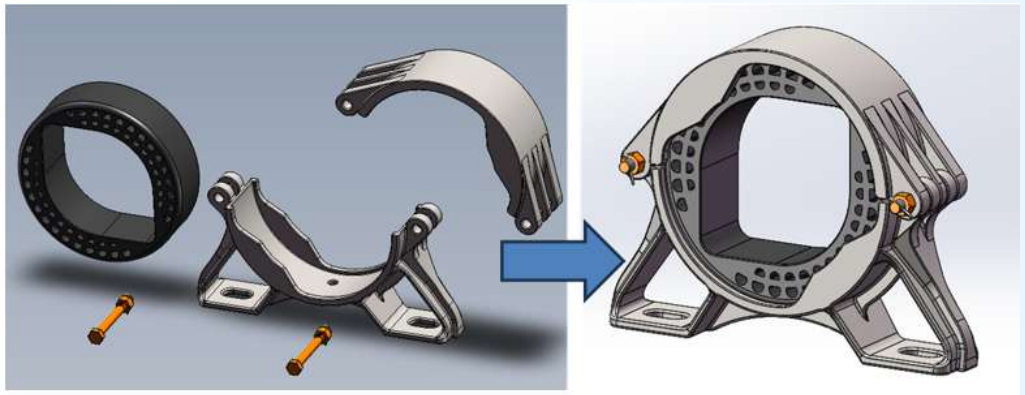
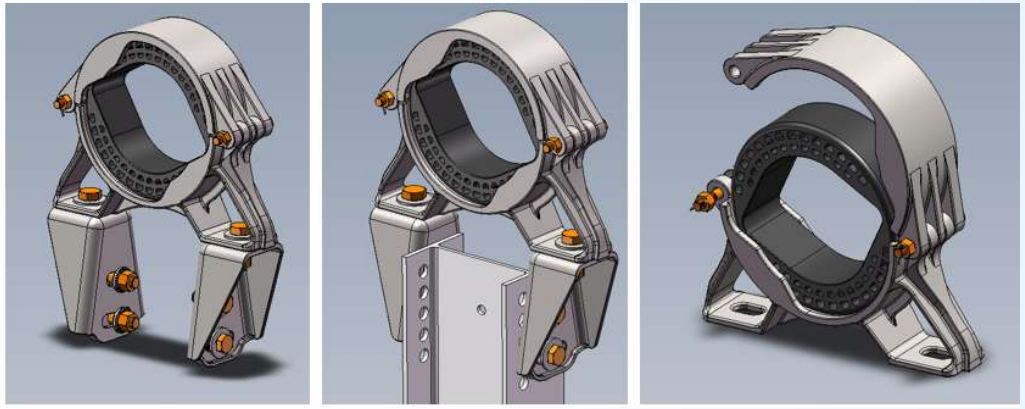
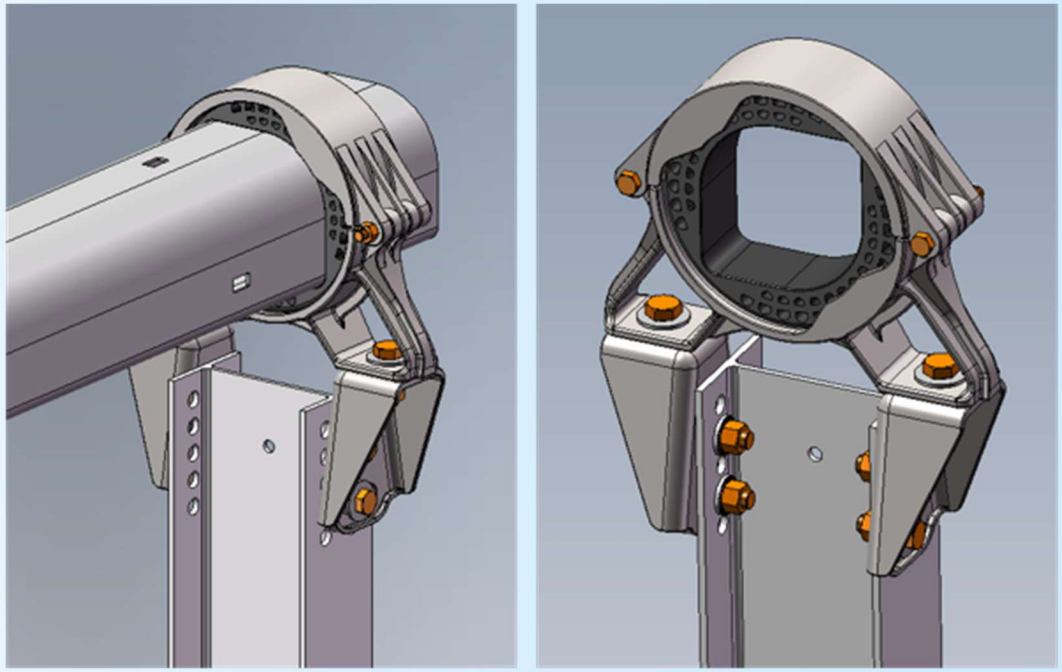


Figure 4.2: Installation diagram of carriage bolts

Case Study 2







Pre-assembled bearing housing

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THANKS

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W: www.esetsolar.com

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Wind Tunnel Testing of ESET Steady

Surfing extreme winds: How 'Every post self-locking' trackers eliminate torsional risks

15th June 2026

Parsa Enshaei

penshaei@cppwind.com

Who We Are

- *Structural engineering + aerodynamics:*
  - Variety of structures:
    - Tall buildings, Stadiums, Bridges, Data centers, Landmarks and Monuments, Airports, etc.
  - **Utility-Scale Solar Sites**
- *Offices around the world:*
  - US, Australia, Canada, Malaysia, India, UAE
- *Four wind tunnels:*
  - 2 in Colorado, 1 in Sydney, 1 in Kuala Lumpur

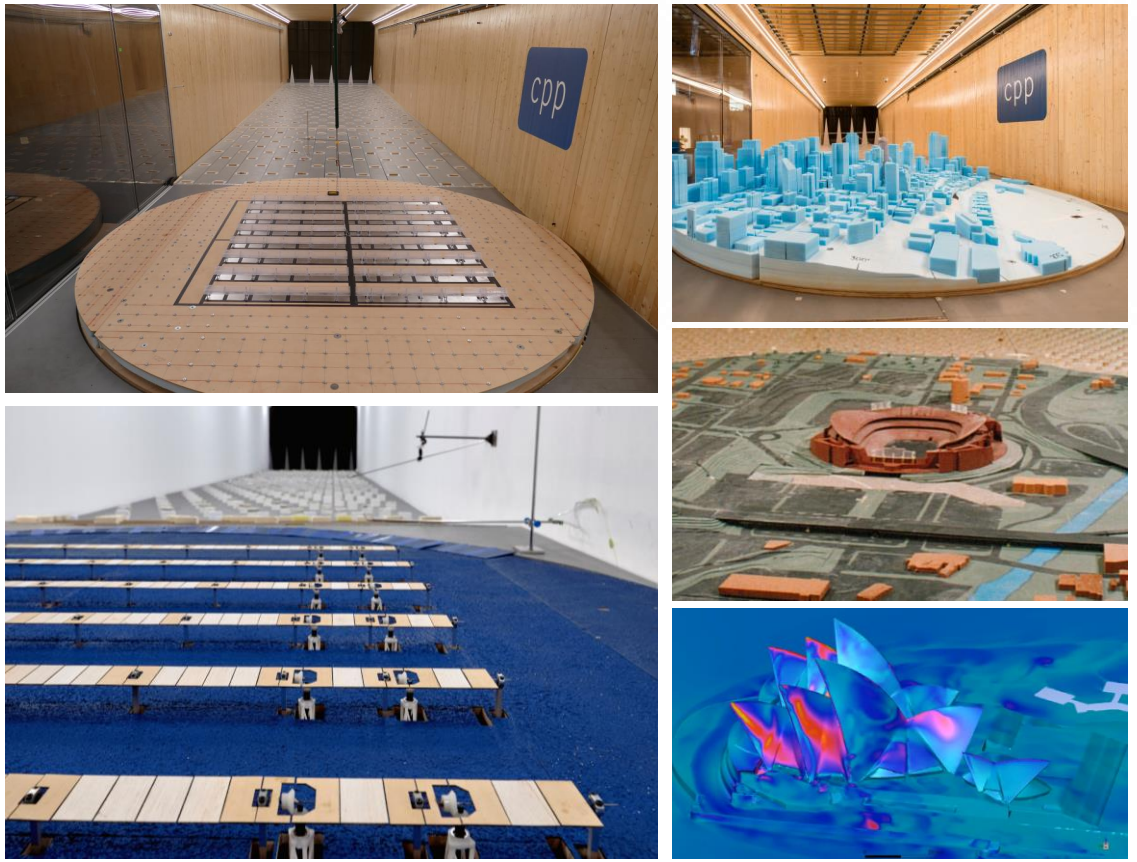
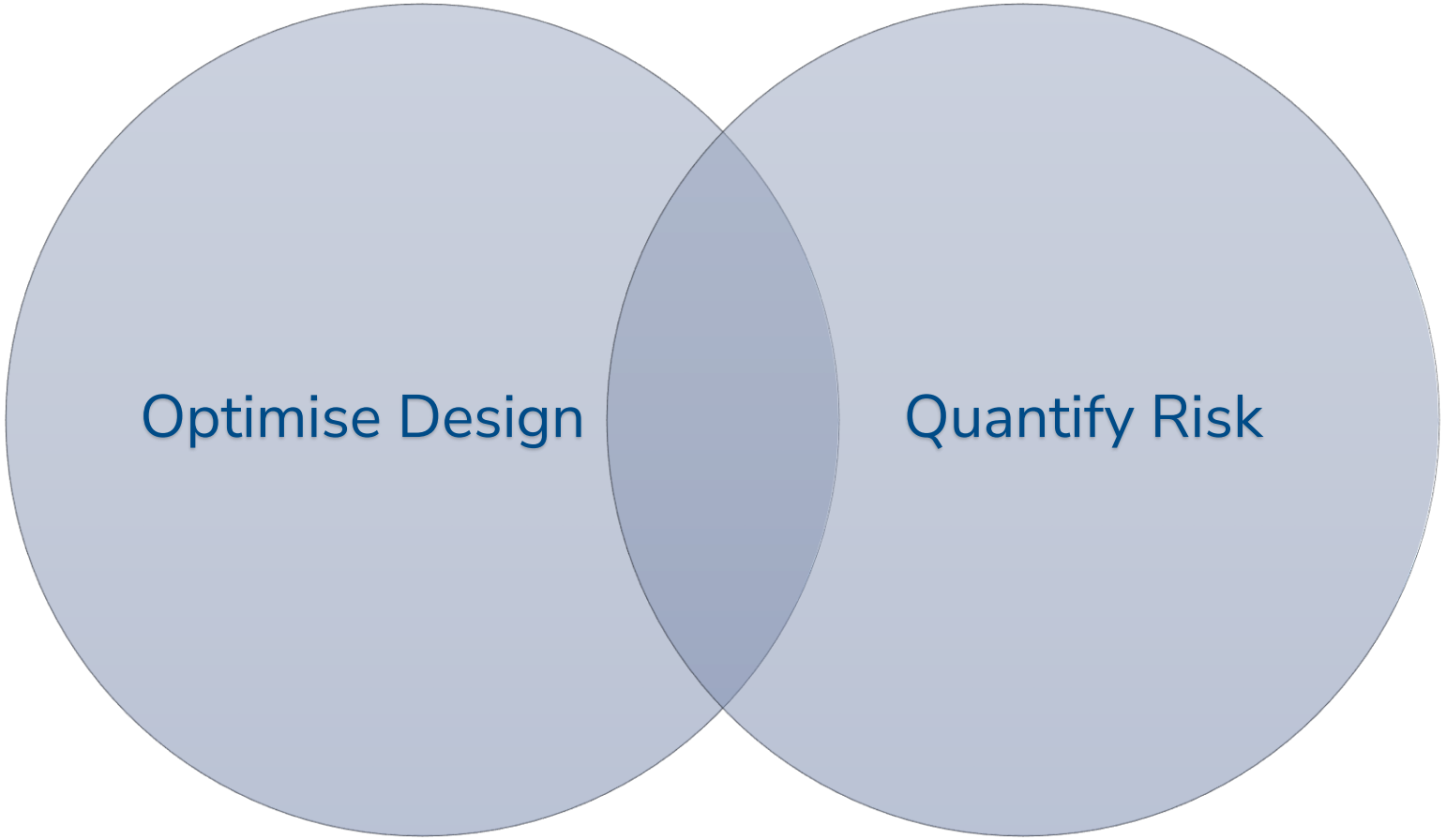


Figure: *CPP services across different sectors*

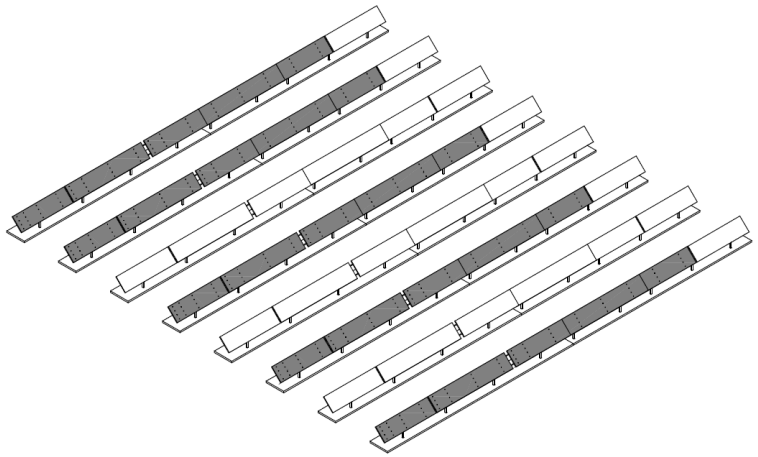

Optimise Design
Quantify Risk

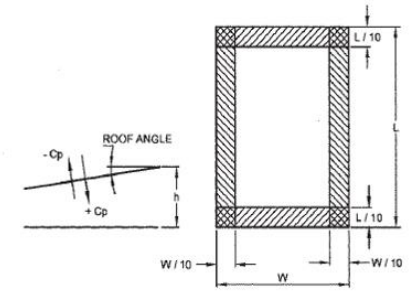
Wind-Induced Risk

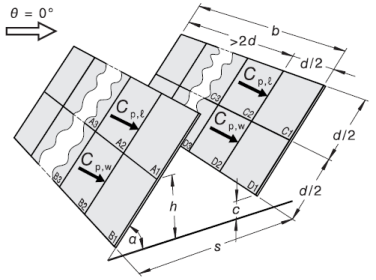
***Figures**: Solar mounting failures reported on social media*

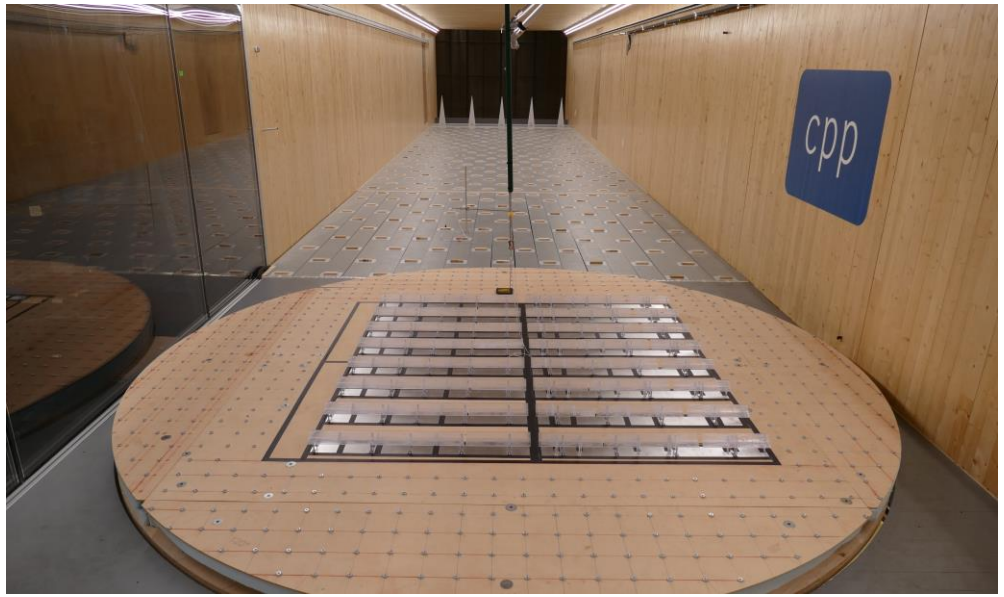
Pressure Tests

- *Assumed-static analysis for forces and moments*
  - Assumes vibration or deflection isn't significant enough to alter the aerodynamics
  - Not accurately covered in wind codes









***Figures**: Pressure testing of solar trackers*

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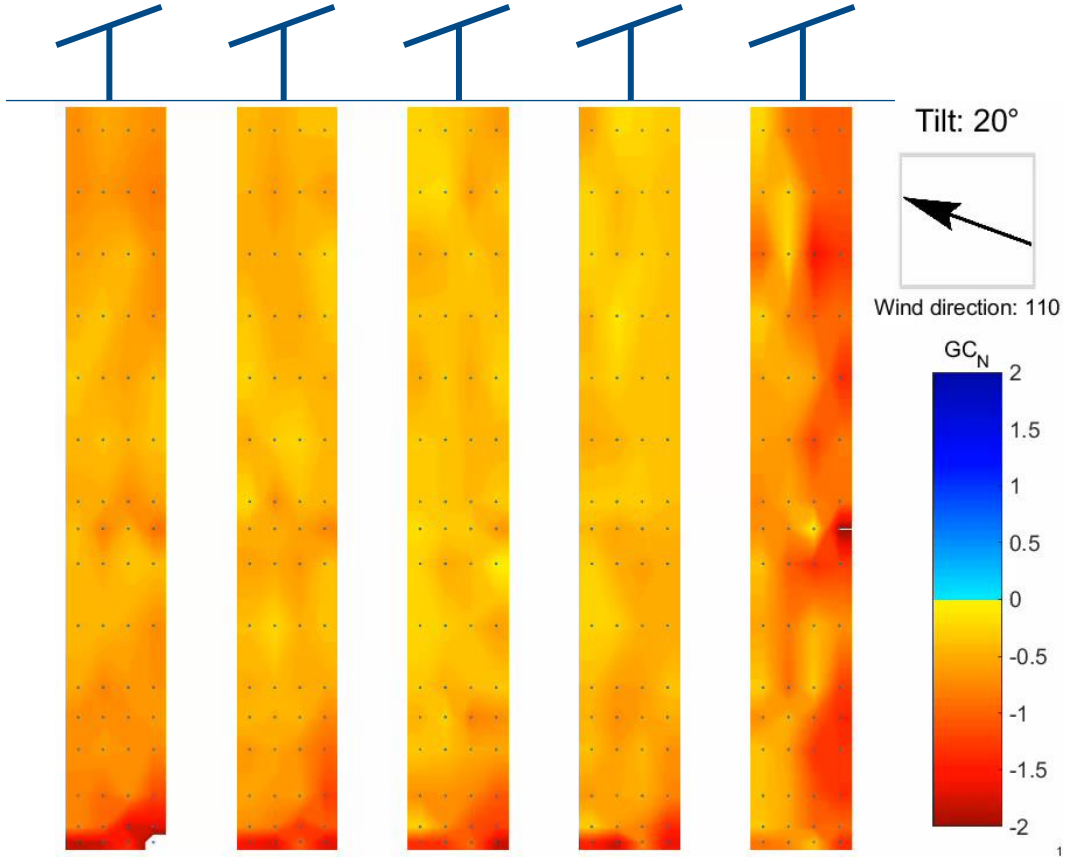
Pressure Fluctuations

- *Variation with Location and Geometry*
  - Sample case of leading edge up at 20° during a cornering wind
  - Several tilts, heights and row spacings are considered
  - Inter-row and gap effects clear

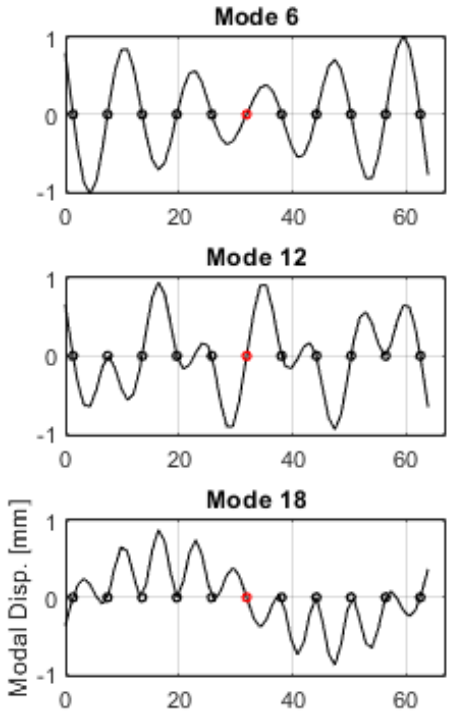


Figures: *Peak pressure locations on the system in uplift*

Advanced Dynamics Analysis

- *Dynamic (resonant) effects can amplify loads*
  - Advanced structural analysis
  - Verified damping levels

Video: *Heaving motion of trackers (Social Media)*



Figures: *Snapshot of pluck tests on the ESET system (middle) and heaving mode shapes (right)*

Torsional Instability

Video: *Tracker array experiencing torsional instability (LinkedIn)*

Figure*: Aftermath of damage incurred:*

Top*: At the Oakey 2 site in October 2018 (pv magazine, 2020)*

Bottom*: South of Spain (Valentin et, al, 2022)*

Aeroelastic Models

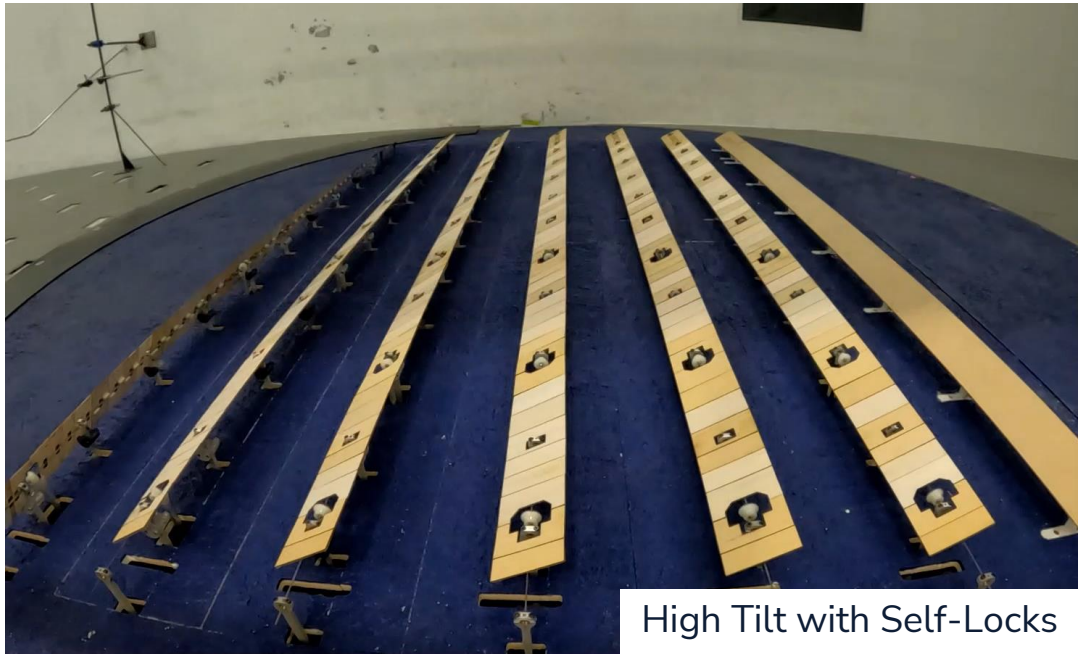
- *Scaled model that moves like the full-scale system in torsion*
  - Tracker geometry
  - Torsional stiffness and mass moment of inertia
  - Damping
  - Self-locks

***Figures**: ESET Torsional Instability Aeroelastic Models*

Aeroelastic Instability Testing

- *Guidance in defining the stow strategy and design wind speed*

Low Tilt

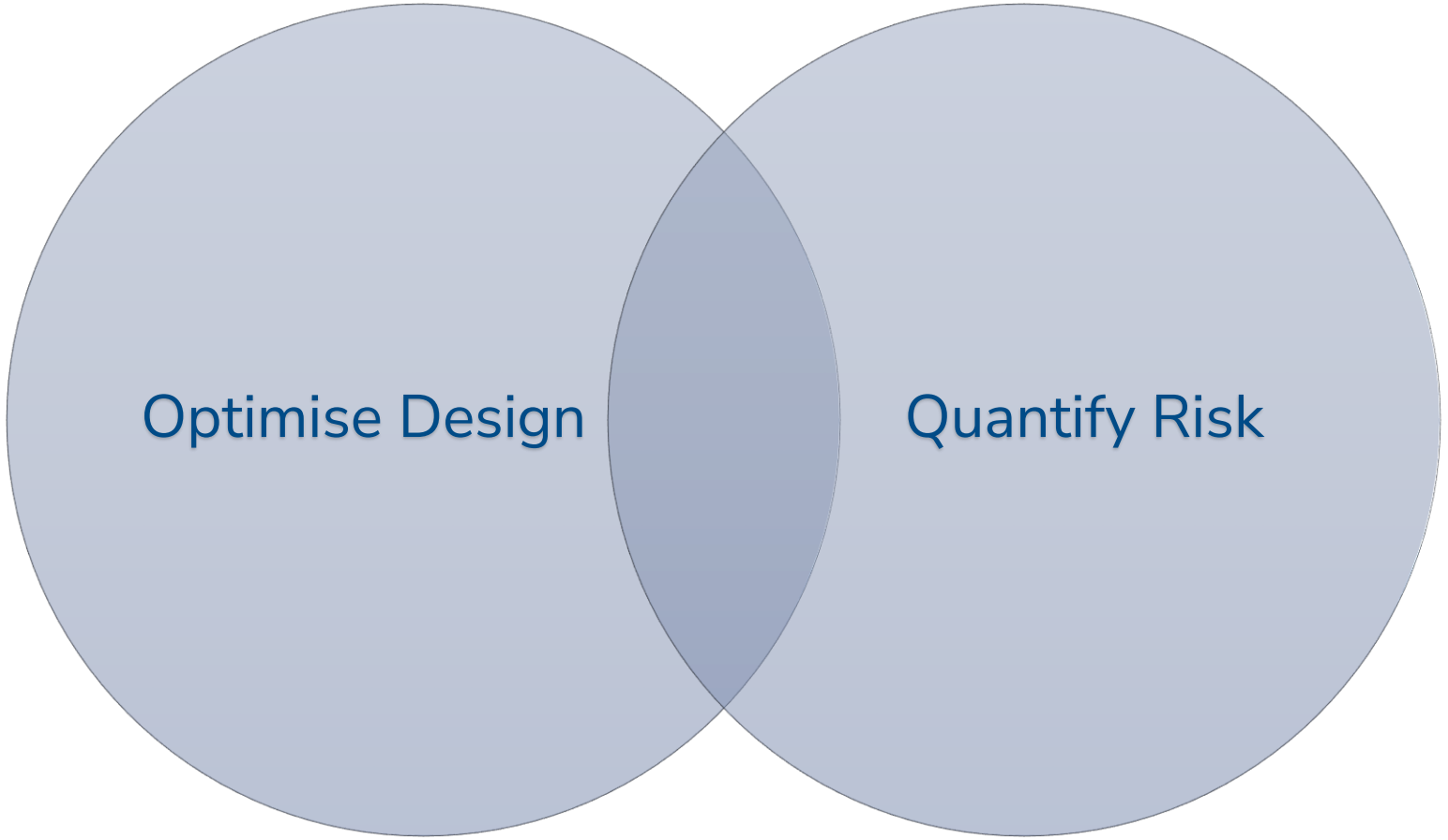


High Tilt with Self-Locks

***Videos**: Torsional instability tests of wind tunnel models*

Overview

- *Step by step engineering*
  - ✓ Assumed-static loads
  - ✓ Advanced dynamics analysis
  - ✓ Torsional aeroelastic testing
  - ✓ Site-specific analysis…



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Thank You

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PV Tracker Risk Analysis

An Independent Engineer's perspective

Dipl.-Ing. Max Dinkelaker

PV Magazine Webinar, 15.06.2026

- *sbp sonne* founded in 1980 by Prof. Jörg Schlaich and Rudolf Bergermann as part of specialist consultancy *schlaich bergermann partner*

  Stuttgart – Berlin – Hamburg – New York – Sao Paulo – Shanghai – Paris – Madrid – Los Angeles - Riad

- areas of expertise
  - **PV - Technology** development & -design consultancy,
  - **CSP - Technology** development / -licensing,
  - independent **structural reviews**, checking engineering and certification
  - interdisciplinary **engineering services**

- third-party reviewer for > 60 GW single-axis PV tracker since 2016
  for owners, developers, insurance companies, system OEMs





Evolution of single-axis tracking technology

	Previously	Nowadays
Typical Project Size	5 - 25 – 50 MW	600 – 1000 - **3000 MW** …
PV Tracker Layouts	1P → 3L → 2P → 1P + 2P	**1P** .. 2P
stow-tilt	dominantly -15° < 0° < 15°	diverse **- 60° < - 45° < 0° < 45°< 60°**
Drive	central-/mono-drive	multi-drive / multi-locked
Design Innovation	homogeneus designs for most tracking systems (square TT, …)	Innovative, individual designs, broad diversity of solutions (TT sections, dampers vs locks, module brackets, purlins, …)
Wind Tunnel Test	code-based approach Basic WTT: Static & Dynamic	adv. WTT: Static, **adv. Dynamics & Aeroelastic**
Mechanical Tests	unusual for the market, basic testing	market standard practice, **advanced testing**, sbps customized testing requirements

→ constant design development
→ constant innovations to improve structural, electrical, economic performance enable growth and technology maturity

Anatomy of modern tracking systems

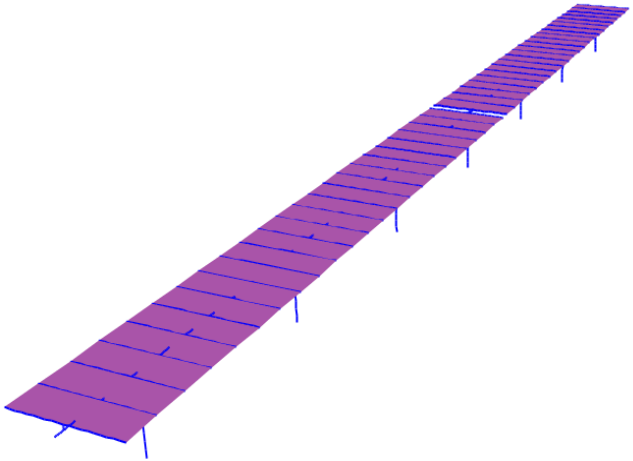
- PV-Tracker shall be considered **both - static and moveable** structures

- PV-Trackers are **highly optimized** through advanced physical testing (static/dynamic/aero-elastic WTT, damping, mechanical load tests)

  → structural stiffness decreases, various degrees of freedom
  → high deformations & dynamic behavior to be considered

  → **advanced analysis method**s are mandatory
  → interaction between **system response** (stiffness) and **loading** (i.e. wind) needs to be considered at all design stages / analysis steps

- PV-Tracker / Solar Structures being developed as *products* but implemented in specific *site-conditions*, thus detailed adaption engineering is required.



Key Design Challenges

Each tracker in a different location/site is a new tracker!

A tracker previously designed & reviewed for a different site, *does not mean less efforts!*

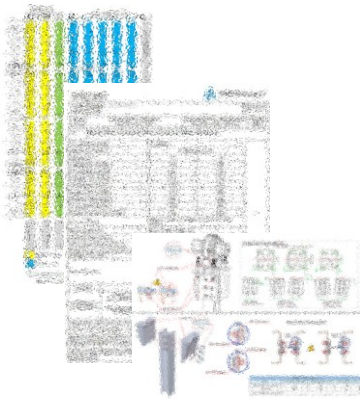
- local wind conditions
- applicable local code(s)
- soil conditions
- specific OTS criteria
- small changes in a tracker (structural) design can cause cascading consequences

- trend towards *modular, multi-drive tracker assemblies* leads to more individual/unique project designs

Consequences

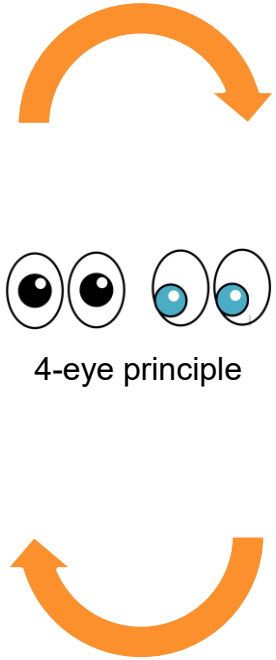
- Design Criteria between **Code(s) – OTS – OEM project design** must be reviewed for consistency individually for each site/project/phase
- Focus on implementation of Wind Tunnel Testing: application, processing, adaption to project parameter
- Analysis models must be customized and benchmarked for each projects individually

Review of above criteria are independent from previous reviews for “similar” projects!



Design

- Documentation
- Load assumptions
- Analysis
- Results
- Verification



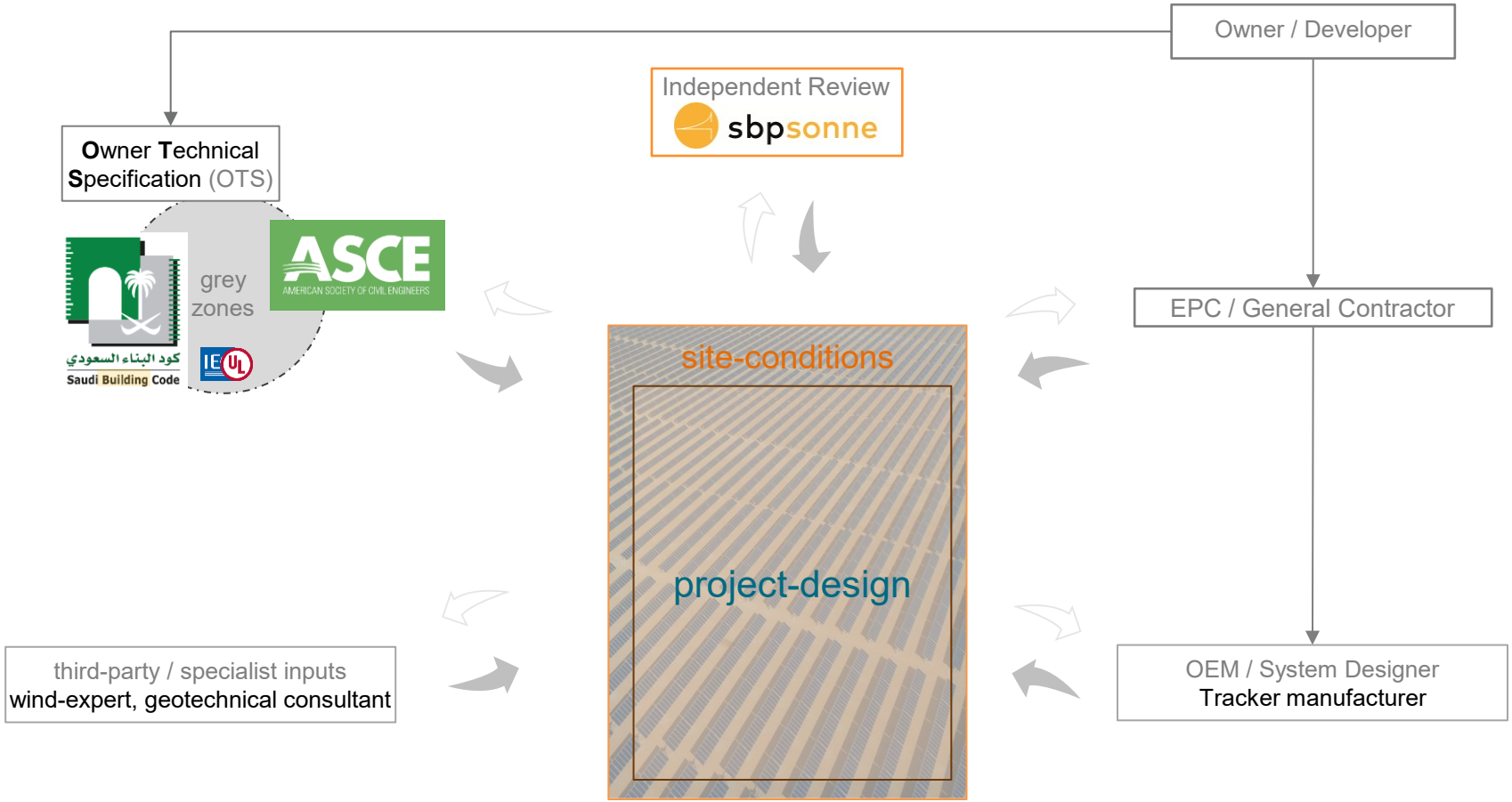
4-eye principle

Checking

- ‘Global’ Safety Concept considerations
- Reference Calculations
- Feedback and Confirmation

independent
separating
ensuring

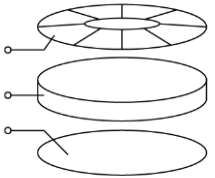
from technical and economic conflicts
design and checking
design support, education and quality through dialogue



Design Reviews

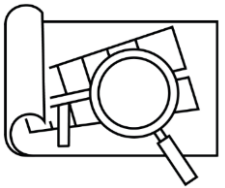
- regulations: adapting Building Codes to specific characteristics of PV plants
  i.e. size-effects, stiffness criteria, serviceability criteria

  understand – challenge – analyze – refine

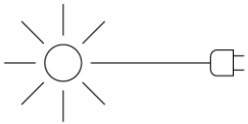


- optimization / customization / site-specific designs and control strategies are *industry-standard*
  i.e. WTT-implementation and applicability

  Every design review is unique – attention to the details!



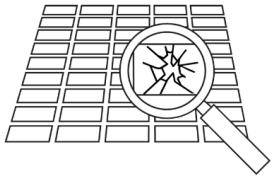
- Structural and mechanical malfunction or failure influence electrical performance of plant.
  Reliability of structural components in utility-scale PV plants is essential for resilient energy-supply.



Incident Investigations

- sbps observes accumulation of PV-Trackers damage incidents in recent years – *pre-dominantly systems designed before 2020*.

- main root-cause(s)
  - high-wind events, exceeding code provisions
  - ‘blank spots’ in structural design, i.e. in-sufficient aero-elastic stability, construction-sequence design, -stow strategy
  - in-sufficient site adaption
  - control / communication system outages
  - incompatibility tracker-to-module



- magnitude of damages/failures significant
  - module breakage
  - primary steel structure failure
  - assembly failure and cascading array collapse

What can we learn for the future to reduce development risks

Specification
Refining code regulations where necessary – relaxing where possible!
Bespoke, site-specific load criteria based on advanced analysis and research.

Systems
Product development must be followed by detailed adaption engineering.
Resilient system design beats optimization and cost-savings.

Approval
Comprehensive, third-party checking of structural and electro-mechanical systems – before execution

Monitoring
Holistic QA during construction, commisioning, operation and maintenance.
Tracking weather, control and structural data on-site, estimating short- and long-term trends

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Surfing extreme winds: How 'Every-post self-locking' trackers eliminate torsional risks | Q&A

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Senior Editor
pv magazine

Frank Wang
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Integrating heat pumps for smart solar self-consumption

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Marian Willuhn
Senior Editor
pv magazine

Thank you for joining today!