Racking And Trackers: Quality Issues in the Factory and Design Considerations

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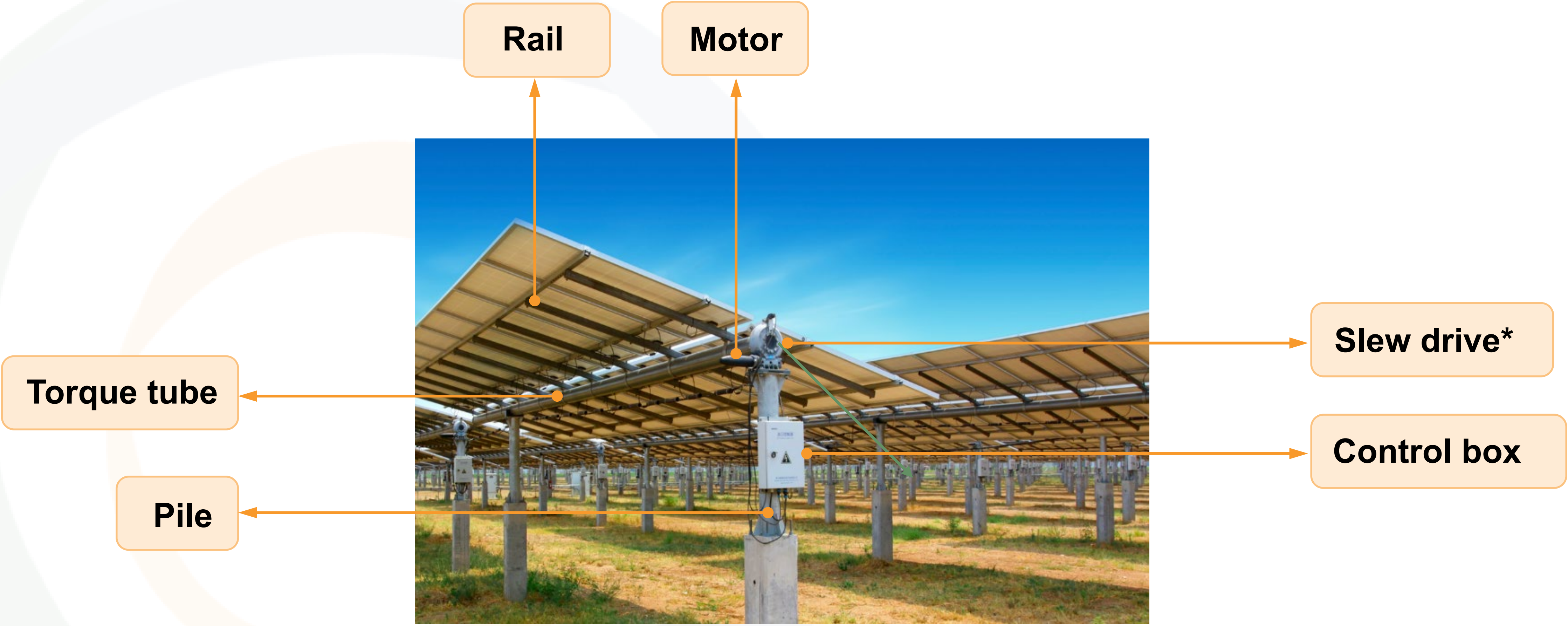
Pillars of Solar Success

Quality Assurance for PV Racking

Jörg Althaus, *Director QA & Engineering Services*

1. Core Components And Production Processes In PV Trackers
2. Typical Findings In Production
3. Case Studies
4. Inspection Methodology

Core Components Of a PV Tracker



*Some systems use linear or other actuators instead

Production Steps In Racking Manufacturing

12 Most Common Processes

1. Material Preparation

2. Forming

3. Punching

4. Drilling

5. Welding

6. Laser/Plasma cutting

7. Extrusion

8. Lathing

9. Milling

10. Painting

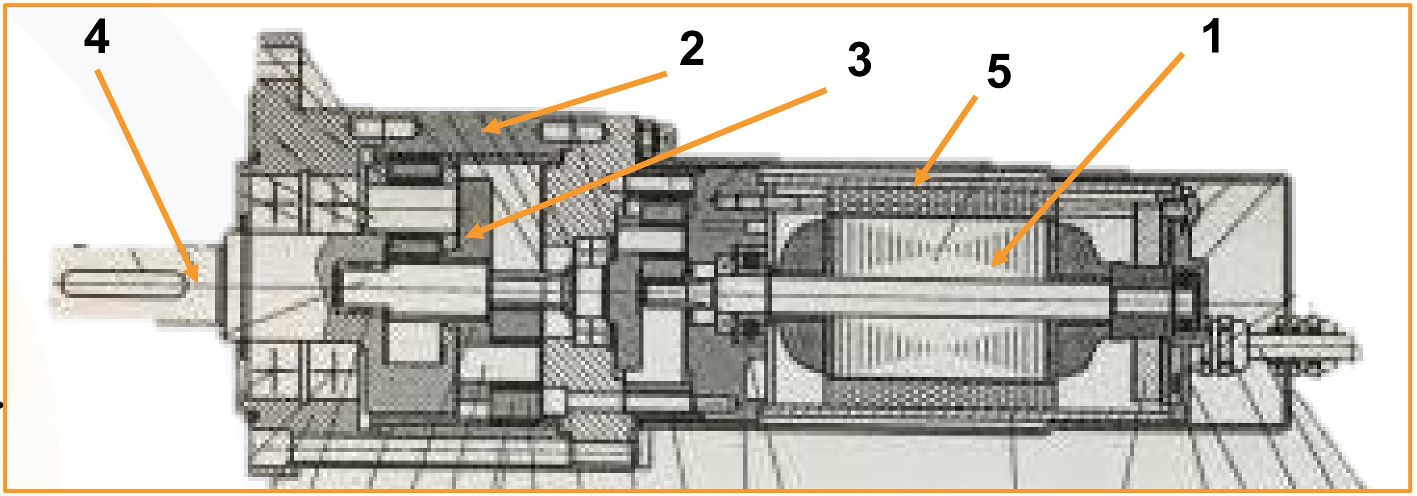
11. Bending

12. Galvanization

Due to product design and type specifications, racking production may include up to **50+ different technical processes**, of which each may require specific component customization and process modification.

The Motor

The motor unit of a PV tracker is made up of more than 60 components. Factories adopt different manufacturing processes and materials for each of these parts, resulting in added complexity.




1. Stator


2. Cover

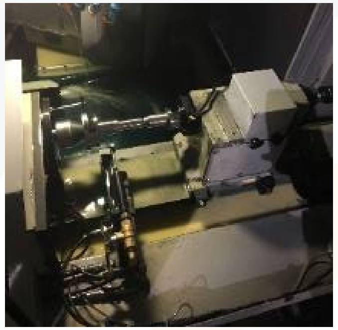

3. Planet Gear


4. Shaft


5. Rotor

The Motor

Most Common Processes


1. Machining


2. Wire Wrapping


3. Nitridation


4. Dimensioning


5. Immersion Painting


6. Coordinate Measuring


7. Assembling

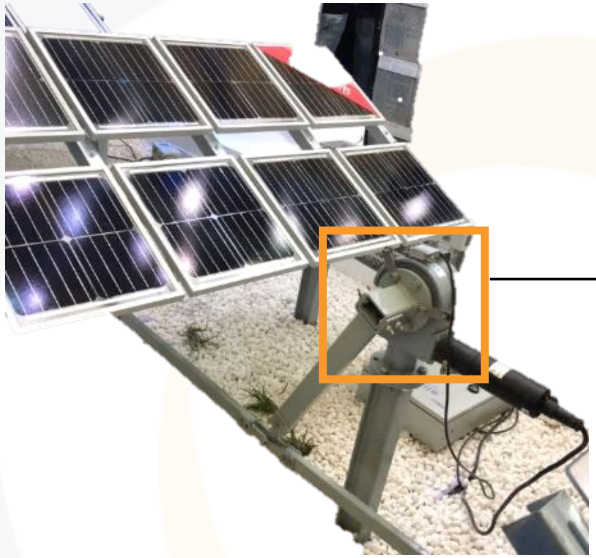

8. Safety Testing

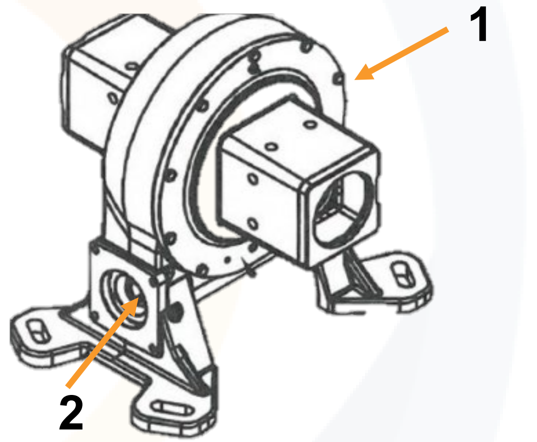

9. Noise Testing


10. RPM Testing

The Slew Drive

The slew drive is an intricate unit and serves as the joint between the motor and PV panels, but the slew drive manufacturing process is specialized, and any small defect can lead to severe rusting and systematic failure.





1. Cast housing

2. Worm gear

3. Gear

The Slew Drive

The slew drive is an intricate unit and serves as the joint between the motor and PV panels, but the slew drive manufacturing process is specialized, and any small defect can lead to severe rusting and systematic failure.

Back lash test

Gauging test

Salt spray test

Life-time test

Air tightness test

Jig inspection

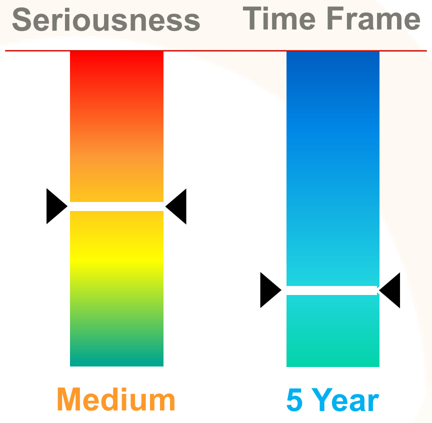
Painting thickness inspection

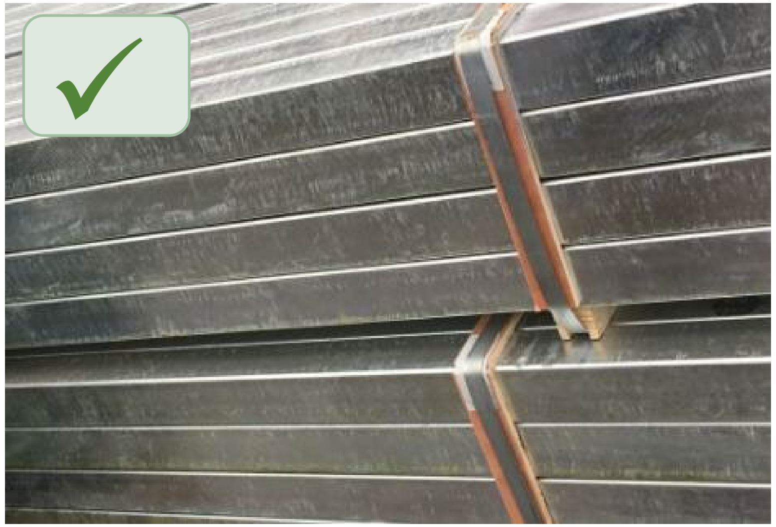
Dimension inspection

Typical Findings In Production

Critical Wet Storage Stain

- The weather resistance and mechanical properties of the torque tube will slowly decrease.

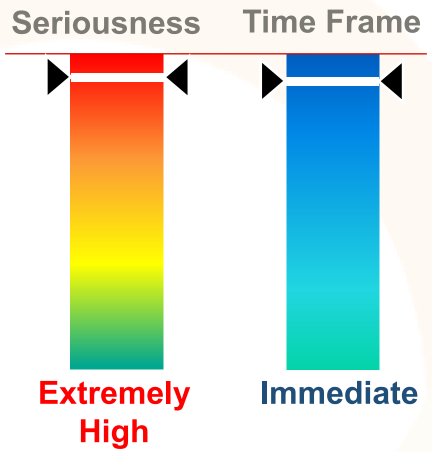




Typical Findings In Production

Hole Pitch Deviation

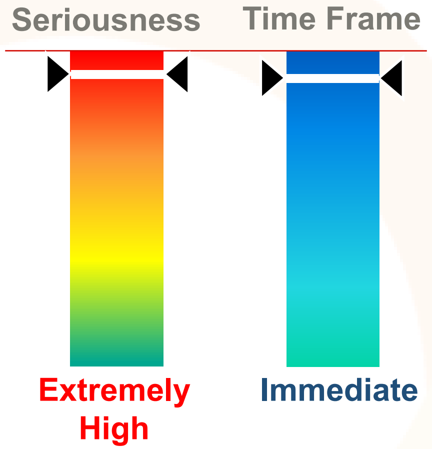
- Even slight imprecisions can lead to systematic failure at installation.

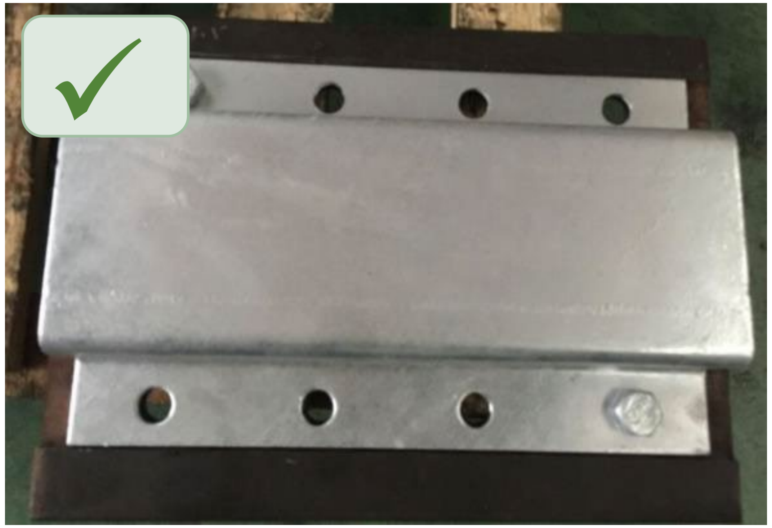


Typical Findings in Production

Excess Galvanization

- When excess zinc appears in a mounting or assembly hole, installation may fail, and workers can be under severe safety risk.

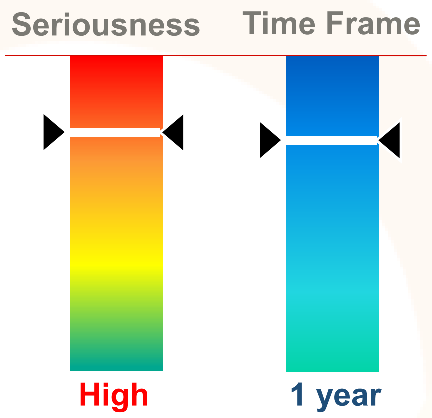




Typical Findings In Production

Rusting / Corrosion

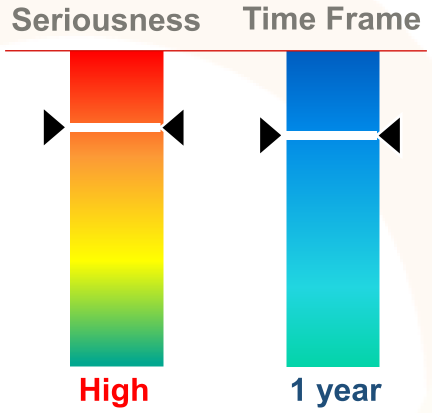
- Rusting decreases the mechanical strength of the system, possibly causing it to fail within few years.



Typical Findings In Production

Weak Coating or Paint Thickness

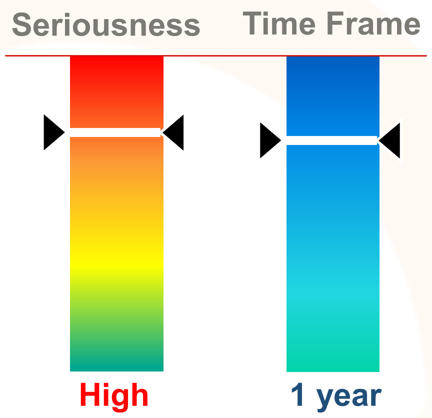
- System stability is compromised upon unqualified surface treatment (e.g. insufficient hot dip galvanization).



Typical Findings In Production

Welding Defect

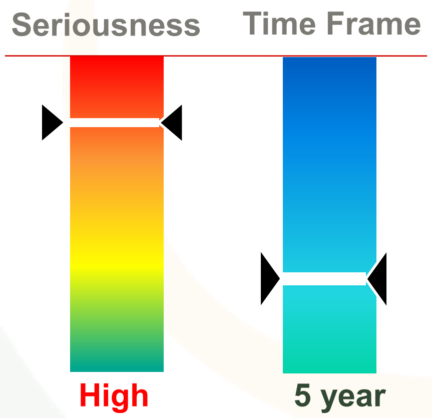
- Welding defects pose a major risk for the systems mechanical integrity.

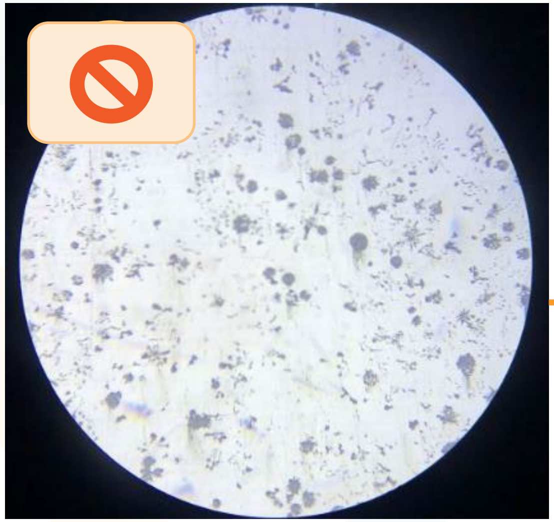


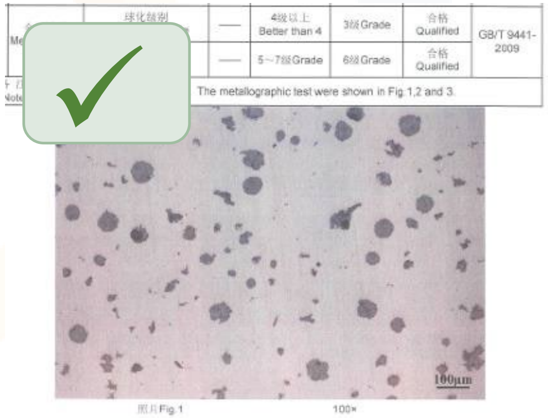
Typical Findings In Production

Metallographic Test Failure

- Metallographic tests can identify issues in the widely used casting material quality.
- Nodulizing grade and graphite size in ductile iron, as shown in the figure on the right, will lead to system failure and component damage.





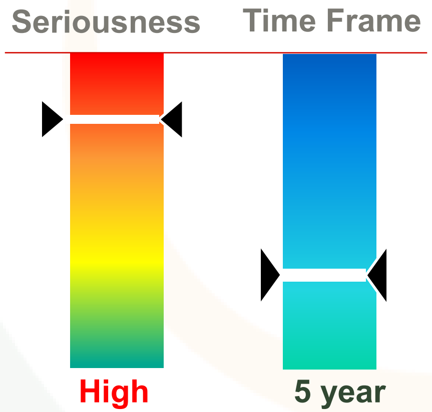


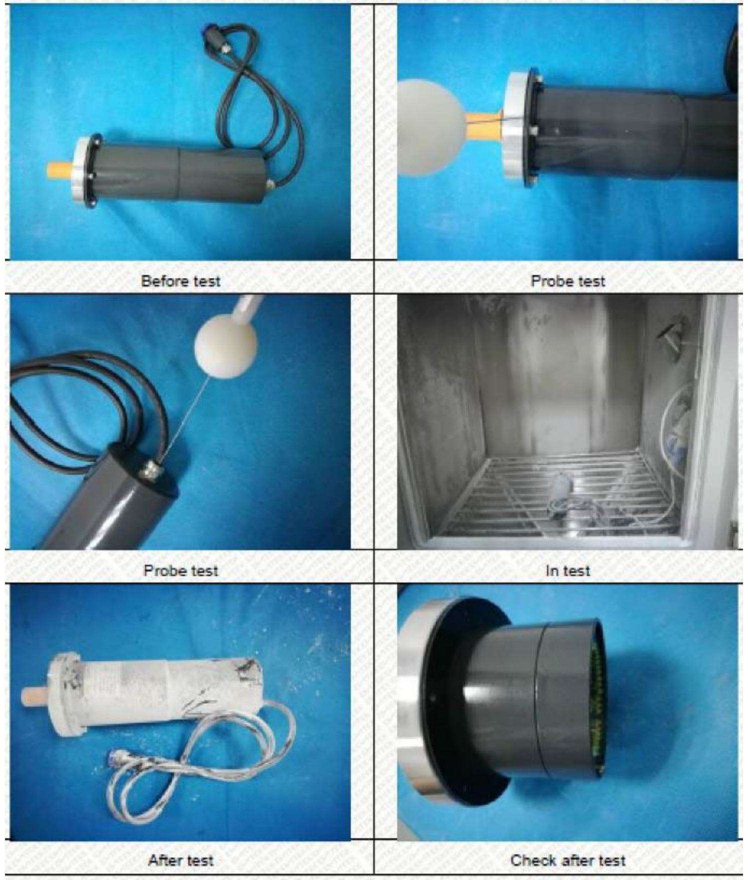
Typical Findings In Production

IP Protection Failure

- Improper IP (ingress protection) will accelerate wear and tear of the unit and cause internal oxidation.

- Moisture ingress will allow corrosion to happen and shorten the systems lifetime.

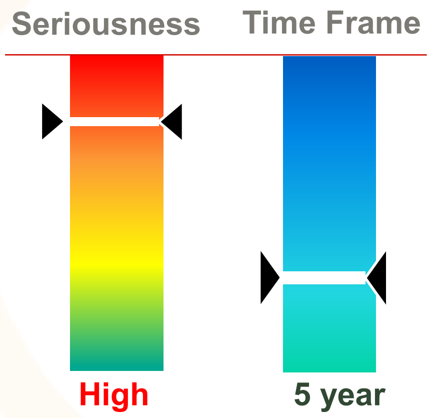


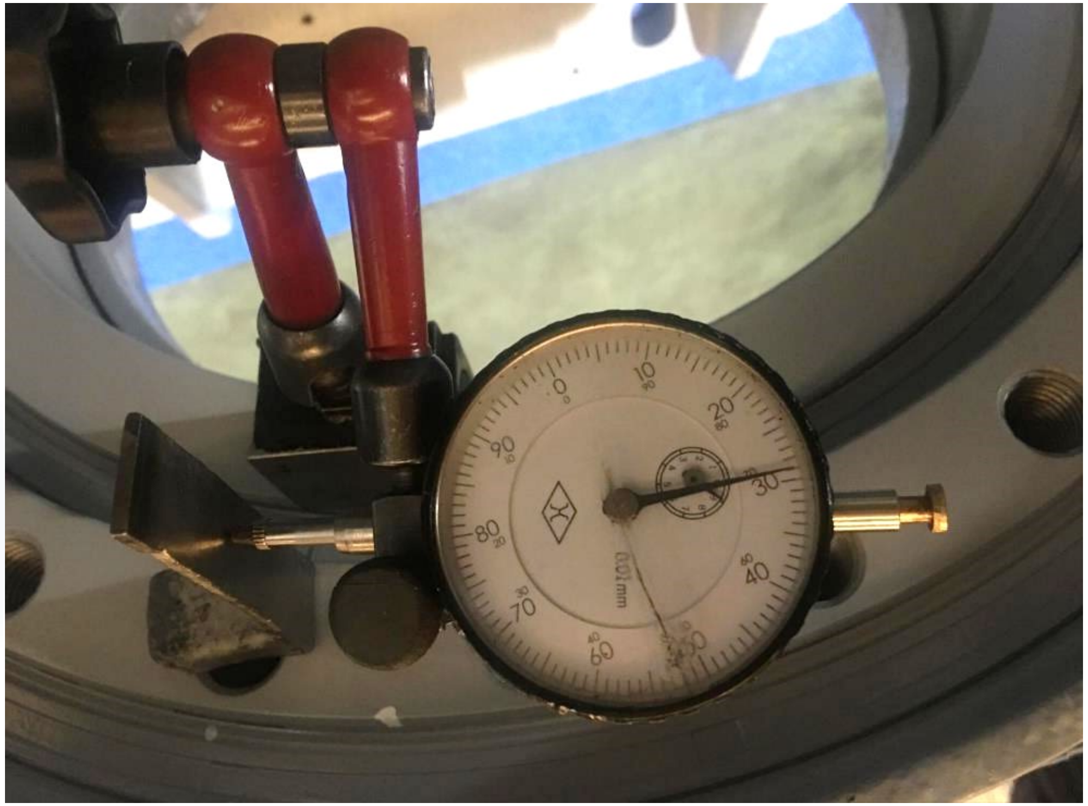


Typical Findings In Production

Backlash Test

- Backlash test is performed to check tracking precision.
- Low tracking precision seriously affects the systems power production.

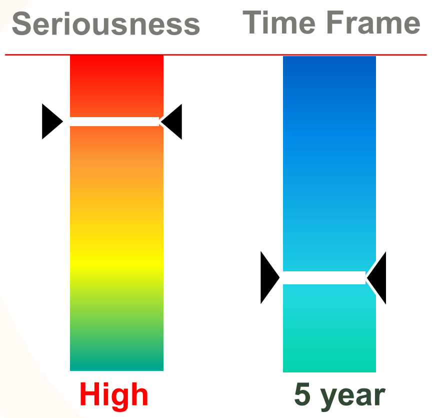




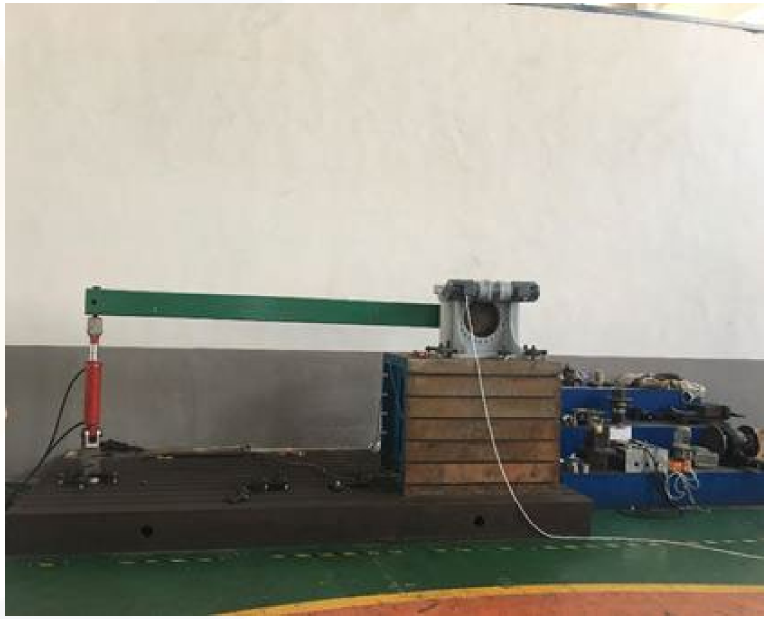
Typical Findings In Production

Load / No Load Test

- Load / no-load test is performed to prevent slew drive failure which can cause fatal system failure.



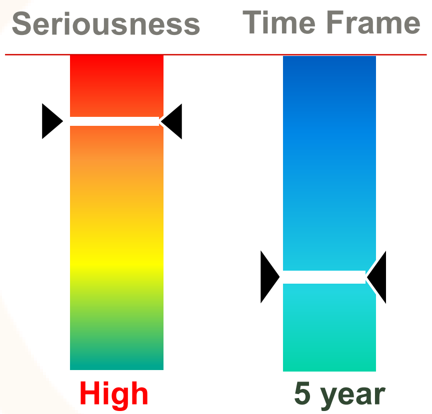
In house testing



Typical Findings In Production

Hardness Test

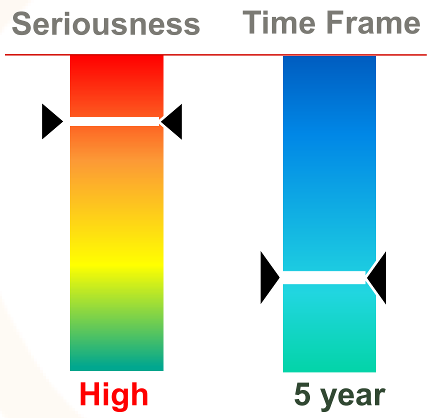
- Hardness test is done to prevent failure of the slew drive and secure the lifetime of the system.

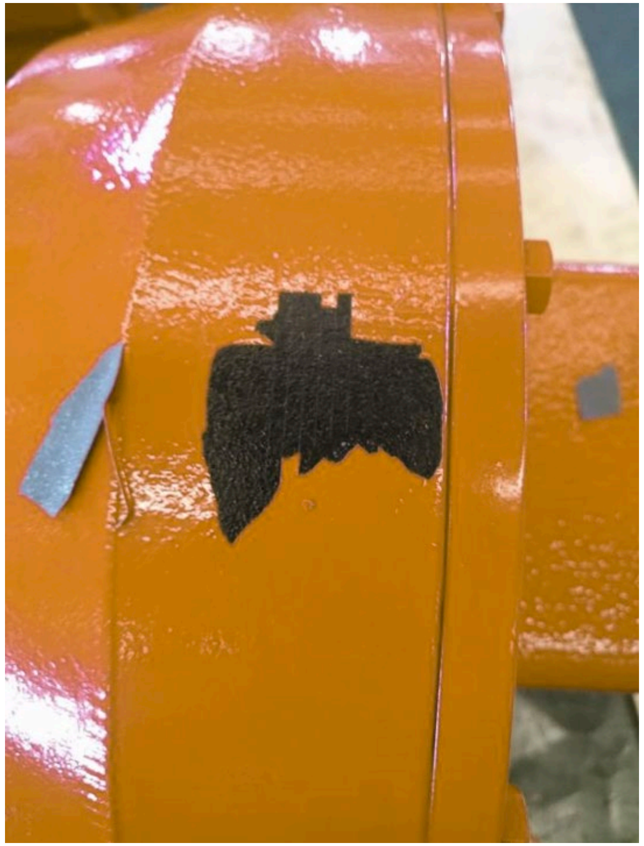


Typical Findings In Production

Adhesive Test

- The adhesive test is performed to check the coating / painting durability.
- Failure will cause oxidation of the components and affect the functionality and lifetime.





Case Studies

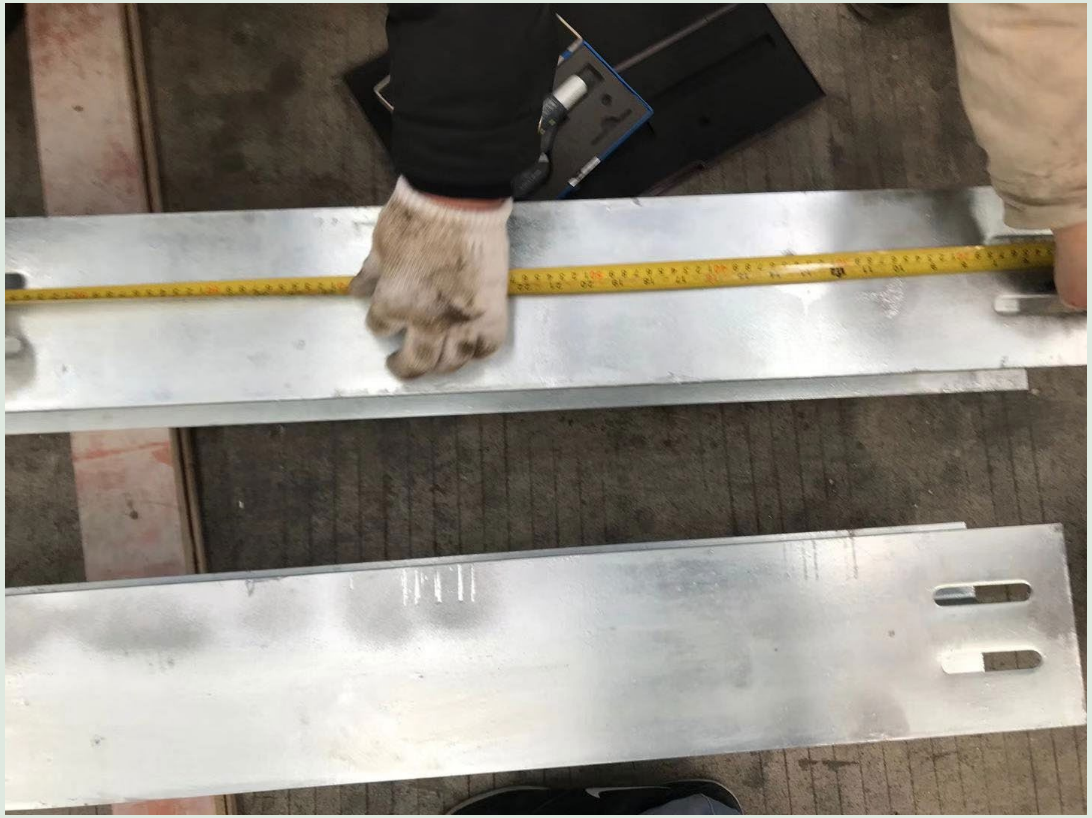
Client	Undisclosed
Product type	Tracker
Component:	Post
Supplier /Factory	Undisclosed / China
Project size	190 MW
Project dates	December 2019
Found in	PSI
Issues	Dimension Deviation

Summary: Critical deviation was found on one out of five samples of posts. The hole pitch of post was offset leading to issues during installation on site, making it unable to install the actuator.

Action: The batch was rejected by CEA, avoiding unqualified material being shipped.

Effect: Save labor cost and project delays.

Dimension inspection for post:



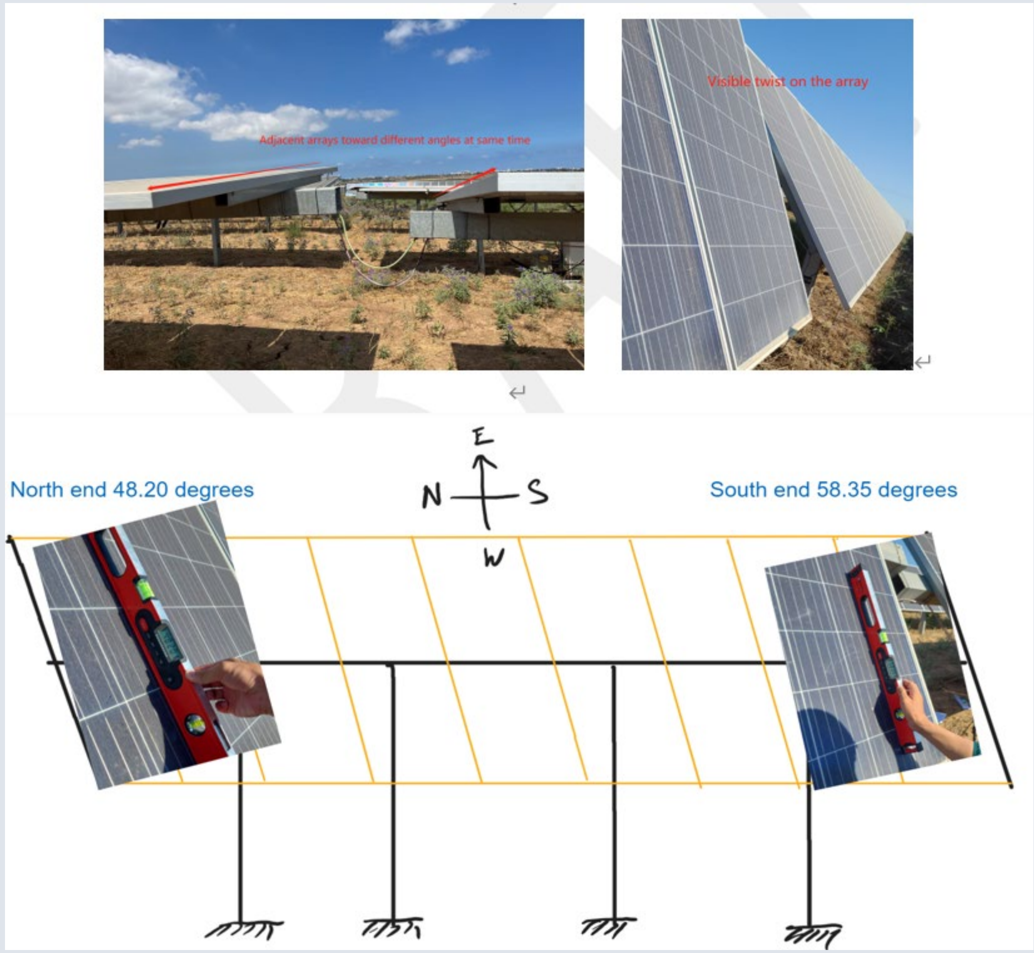
Case Studies

Client	Undisclosed
Product type	Tracker
Component:	Torque tube, actuator, control box
Supplier /Factory	Undisclosed / EU
Project size	8 MW
Project dates	August 2023
Found in	On-site inspection
Issues	Twisted tubes, leakage, rusting

Summary: Various critical issues were found on site leading to malfunction of the system. Torque tubes twisted, actuators leaking, structural surface rusting and motor failures. No initial QA was done.

Action: A findings report helped the client prepare a claim. Lab testing was suggested for further evidence.

Effect: Tracking failure, component breakdown, loss of production.



Quality Assurance for Racking Systems

Inspection Methodology

Pre-Production	Production Monitoring	Pre-Shipment	Container Loading
• Factory Audit • Factory certification (ISO, OHSAS, etc.) assessment • Product certification (UL, CE, etc.) assessment • Drawing / installation manual / bill of materials (BOM) review	• Mill test certificate verification • Raw material test report verification • QA report verification • Production process monitoring • Equipment management monitoring • Instrument calibration	• Random sampling • QC optimized criteria • Visual inspection • Dimension measurement • Identification marking and traceability • Uniformity test • Packing verification	• Proper packing • Proper loading • Container and seal information • Correct products being shipped

CEA's **customized QA services** for various racking products are designed to cover the **entire production lifetime** and can be applied to any technical process to **minimize risk of failure**.

Summary

- Different designs of racking / tracking systems require different QA approach.

- Many different production processes and multiple factories involved.

- Complex processes require customized approach to QA.

- Many different process and material issues may cause shortened life-time.

Investment Confidence Through Design

Engineering of Utility Scale PV Trackers

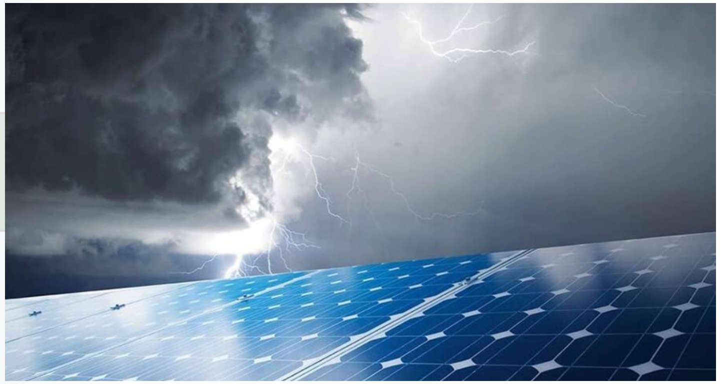
Nicholas Hudson, *Principal Engineer, Engineering Services*

Utility Scale Solar PV – Racking

Why Does Design Matter?

It is the first thing that goes in the ground

It is the foundation, and the skeleton of the entire system



It needs to last the entire life of the system

It is not modular, or plug-and-play

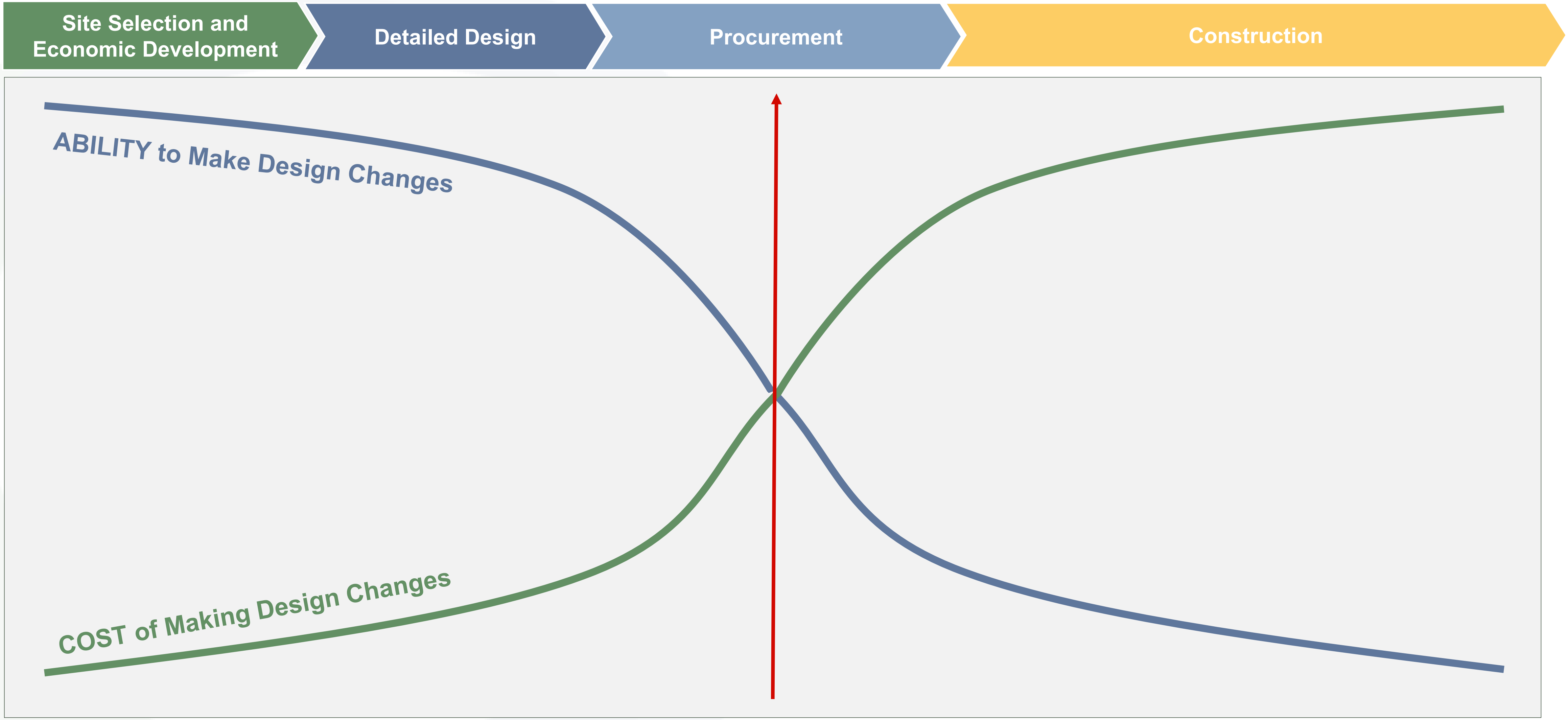
Elements of the Design Process

Major Phases

Site Selection & Economic Development	Detailed Design	Procurement	Construction
• High-Tech, Highly Automated • Low Precision • Economically Driven • Dictated by Owner & Developer	• Some Automation, CAD, Excel, PVSyst • High Precision • Code Driven • Dictated by Engineer	• Person-to-Person • Driven by Market • Dictated by EPC / Owner	• Low-Tech, Labor Dependent • Schedule Driven • Dictated by Contractor

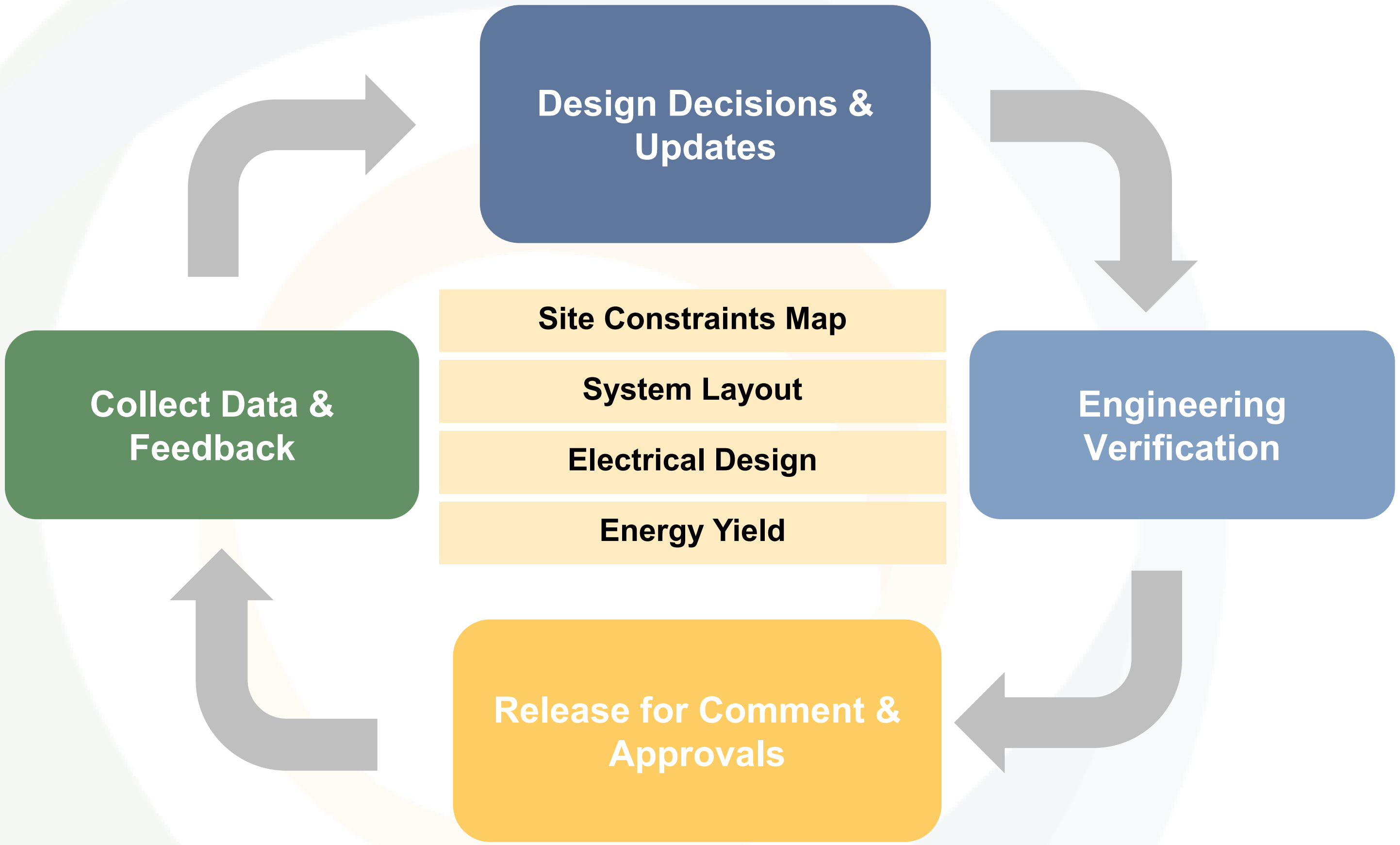
Effects of Design Changes

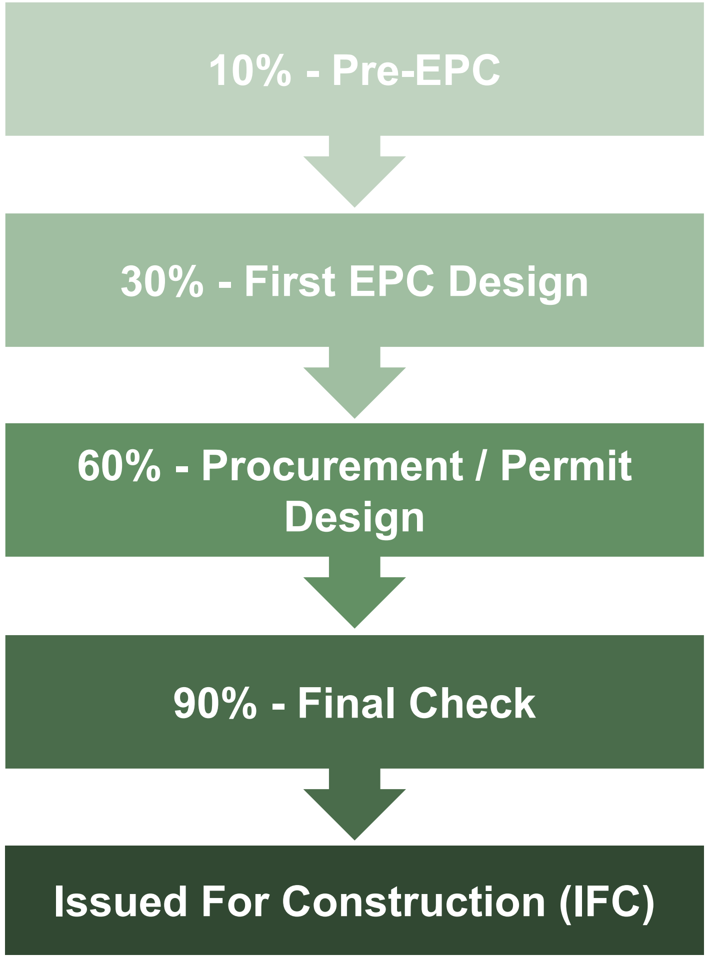
Benefits Of Front-loading Design Diligence



Design Cycle

At each stage, additional and refined inputs lead to improved design





Racking - Engineering Design Considerations

What are the specifications to consider?

	ENVIRONMENTAL	CODES	SITE	SYSTEM
Engineering Factors	• Temperature, Humidity, and Weather • Proximity to Corrosive Environment • Wetlands and Flood Zones	• Design Codes • Certification Requirements • Material Spec • Factor of Safety	• Site Slope • Tracking Algorithm • Power Source • Foundations • Attachment	• Accessibility for Maintenance • Row & Block Arrangement • Warranty & Maintenance • Modules
What Specification to Look For	• Operating Temp Range • Hail, Ice & Snow • Stainless, Aluminum, Galvanized, Painted • Min/Max Tube Clearance	• IBC, ASCE, NEC • UL, IEC • ASTM, AISC, ACI • Mechanical Load Capacity (Pa) • Wind Stow	• N-S & E-W Slope Tolerance • Algorithm Features • Self-Power, Battery Backup, Aux DC/AC Powered • Alternate Foundations	• Max Height Above Grade • Min/Max Row Length • Ground Coverage Ratio • Structural & Mechanical Warranty Period(s) • Module Compatibility List

The goal is not just to find any tracker that *can* work
The real challenge is, picking the ***best combination*** of equipment that will enhance the maximum performance and value from your site.

Interpreting A Datasheet

Which Factors Are Important To Compare?

STRUCTURAL & MECHANICAL FEATURES/SPECIFICATIONS

Tracker Type	Horizontal single axis (1 module in portrait)
Ground Cover Ratio (GCR)	Site configurable. Typical: 28-45%
Linked Rows per Drive Motor	Up to 32
Drive Type	Rotating gear drive connected by drivelines (no driveline or bearing lubrication required)
Array Height	Torque Tube Elevation: 54" standard, adjustable (48" min height above grade)
Tracking Range of Motion	+/- 52°
Terrain Flexibility (N-S)	Up to 8.5° standard (up to 15° optional)
Terrain Flexibility (E-W)	Up to 25° combined angle
Wind Protection	Autonomous passive mechanical system No sensors or grid power required to activate
Max Wind Speed	140mph (225 km/h) per ASCE 7-10 (3-second gust), higher wind speeds possible depending on project conditions
Operating Temp Range	Standard: -4°F to 140°F (-20°C to 60°C) Optional: -40°F to 104°F (-40°C to 40°C)
Materials	Pre-galv steel, HDG steel and aluminum structural members, as required.
Codes and Standards	Certified to UL 3703 and IEC 62817

MODULE COMPATIBLITY

c-Si Modules per Row (1500V DC)	Typical: 84-112 Maximum: 120
First Solar Modules per Row (1500V DC)	Series 6 Plus: 84-108 Series 7: 96-114
Modules Supported	Most commercially available, including framed or frameless crystalline, thin film, bifacial, and back rails
Module Attachment	Single fastener, high-speed mounting clamps with integrated grounding. Traditional rails for crystalline in landscape, custom racking for thin film and frameless crystalline and bifacial per manufacturer specs.

CONTROL SYSTEM DETAILS

Baseline Solar Tracking Method	SANDIA's Ephemeris Model
Control Electronics	SmarTrack™ Controller Site Data Controller 6X Motor Controllers
Communications	MODBUS TCP
Backtracking	Yes (Optional terrain adaptive backtracking with SmarTrack)
Diffuse Light Response	Optional with SmarTrack
Night-time Stow	Yes (configurable)
Tracking Accuracy	+/- 2°
Motor Type	2HP, 3 Phase, 480V AC

INSTALLATION, OPERATION, AND MAINTENANCE

Annual Power Consumption (kWh per 1 MW)	Approximately 310 kWh per MW
PE Stamped Structural Calculations & Drawings	Yes
On-site Training and System Commissioning	Yes
Connection	100% bolted connections. No drilling, cutting or welding on-site or in-field fabrication
Scheduled Maintenance	None required
Module Cleaning Compatibility	Robotic, Tractor, Manual
Warranty	10 years structural; 5 years drive and controls components

ENVIRONMENTAL FACTORS

CODE FACTORS

SITE FACTORS

SYSTEM FACTORS

Modules	Supporting Type	Most commercially available, including frameless crystalline and thin film
Civil	Slope Tolerance (N-S)	7% standard, can go to 15% special order
	Slope Tolerance (E-W)	15% Tracker follows slope (Y/N) Yes
Structural	Drive Type	Robust linear actuator stainless steel & aluminum
	Piles per MW	450/MW typical
	Operating Wind Load	105mph(Std) / 130mph(Premium 1) / 150mph(Premium 2) / 175mph(Premium 3)
	Snow Load	5psf(Std) / 20psf(Premium 1) / 40psf(Premium 2) / 60 psf(Premium 3)
	Tracking Range (Std)	45°, 52° Tracking Range (Premium) 60°
	Pile Sections	G235 galvanized steel (or HDG option) roll formed standard posts, HDG wide flange option also available
	Pile Size (Interior) & (Exterior)	6" X 6" roll form shape or W6x7 or W6x9 or W6x15 wide flange
	Motor Foundation	6.5" x 8" roll form hat or W6x15 or larger wide flange
	Standard Embedment	5 - 7 ft Flood Plain Allowance Up to 6 feet
Design	Module Configuration	1 up in portrait for crystalline, FSLR Series 6, 2 up landscape for Bifacial, 3 to 4 up landscape FSLR Series 4
	Modules per Table	Up to 340 ft. (for example 10272 cell crystalline)
	Module Attachment	SpeedClamp™ or Bolts available for bottom mount frame modules or clamps for glass on glass modules
	Ground Coverage Ratio	0.25 to 0.65
	Rows per Drive	1 drive per tracker(table), distributed drive system
	Powering System	Onboard solar module with battery or wireline power
	Compliance	UL 2703 / 3703
	Ground Clearance To Module	2 ft
	Min / Max Ground to Top of Pier	51" typical / ground clearance + 51" + 9" adjustment range
	Backtracking	Yes, although can be turned off as requested (I.e.for FSLR modules)
	Temperature Range	-20° C + 48° C
	FCC 3rd party design verified	Compliant with FCC guidelines
Self Perform	Specialty Tools Required	No
	Mechanical Installation	Available
	Max offload for deliveries	As per customer requirement
Electrical	Tracking Method	Time and location based algorithm
	String Design	Compatible with any string size
	Cable Supports	Free hole punching as per customer requirement
	Linear Actuator Motor	24 volt DC
	Controller Box	Zigbee® wireless communications, 24v solar panel and battery or wireline power
	Control System	Master to Node: Zigbee® wireless communications Master to SCADA/DAS: MODBUS communications
	# of Motors	28 to 52 / MW depending on panel wattage and loading conditions (35 for typical conditions)
	1000V System or 1500V System	Both
	Grounding Method	Tracker structure is part of grounding path per UL 2703
	UL Listed Assembly	UL 2703 / UL 3703
	NEMA Ratings	IP66 stroke tube end /67 waterproof motor end (NEMA 3x/4 equivalent)
	# Weather Station	1 per 6 MW typical
	Monitoring System	Web portal interface available Compatible with all standard third party monitoring vendors
	Snow & Flood Sensors	Move panels to optimum location for weather events
	Backup Power	Solar module and battery providing integrated backup - 3 days
O & M	Warranty	5 year drive & control, 10 year structural standard, 10 /20 also available
Shipping	Max load	45,000 lbs. per truckload 5,000 lbs. maximum bundle size 2,900 lbs. or other maximum as requested by customers
	Shipping Containers or flatbeds	Flat beds for structure, dry vans for hardware
	# Trucks per MWdc	2.76 typical
Commissioning	Backfeed required?	No, Generator for power to master as alternative

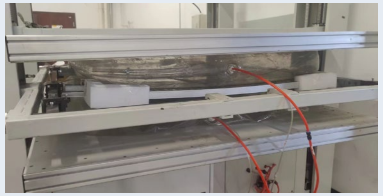
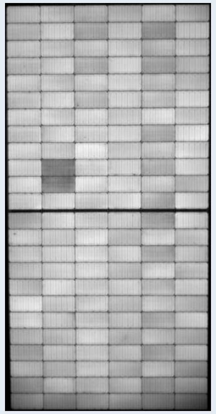
Beyond The Datasheets

What to look for in the module and tracker combination

	INTERNATIONAL CERTIFICATIONS	COMPATIBILITY TESTING	EXAMPLE CALCULATIONS	HAZARD MITIGATION STRATEGY
Look for these things	• UL 1703/2703/3703 • IEC 62817, 61215	• Compatibility Letter, counter-signed by racking and module manufacturers • Test records available showing test conditions and outcomes	• Wind and Seismic Loads • Snow Loads • Factors of Safety • Degree of Stress	• Wind, Snow, Hail Stow • Passive vs Active Stow • Time to Stow • Intervention Required to Stow • Algorithm Performance
What to do if lacking?	• Request latest certifications for your region • If unavailable, then combination may not be compatible	• Request specific test records to support mechanical load certification • Hire 3rd party testing lab to perform specific analyses • If unavailable, consider certified loads as unconfirmed	• If advanced wind tunnel study from 3rd party firm (RWDI, CPP) is not available, proceed with caution • Request higher Factor of Safety (1.5 min) • Request higher code Risk Category design	• Usually, these options are not factors which can be easily changed • Ensure the tracker hazard mitigation strategy aligns with your desired operations and company resources • Ensure tracking features align with module technology

Module & Tracker Testing

How to ensure the assembly is up to the load

	ML [Static] Mechanical Load	**DML** Dynamic Mechanical Load	**EL** Electro-Luminescence	**Current** and **Power** Measurement
What it is Used For	• Overall static pressure from all hazards (wind, snow, ice, etc). • Service deflections under loading • Elastic / Yield performance	• Repetitive loading cycles • Flexibility and durability of elastic performance • Accelerated life-cycling	• Before/After identify invisible cell cracks • Identify dead cells and activated diodes	• Before/After to show power degradation • Identify current leakage and potential • Quantifies energy, economic, and safety impacts
What does it Look Like?	 	 		

Design Issues - Environmental

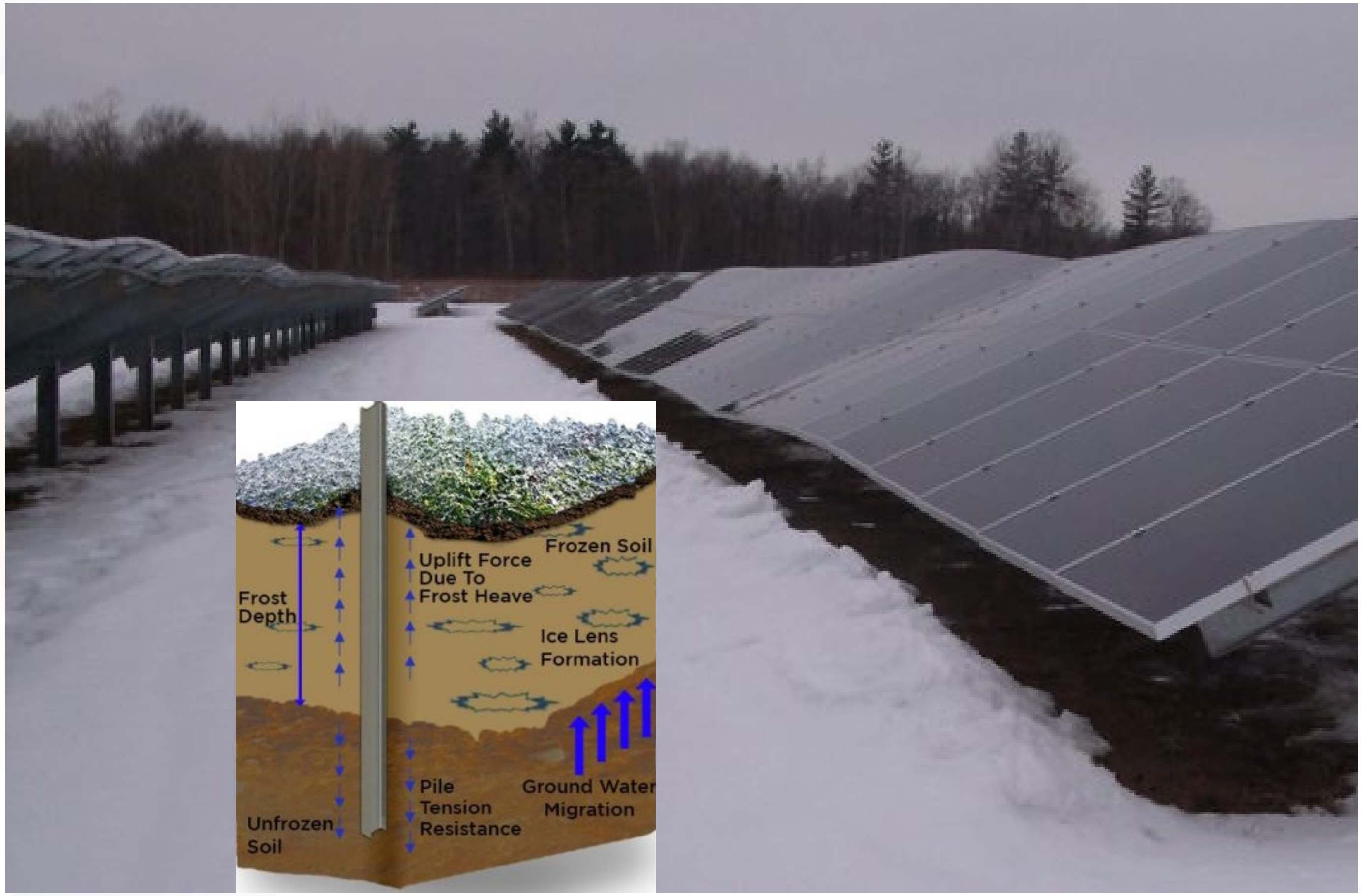
What can happen when it goes wrong?

Frost Jacking

Moisture Heaving

Can Be Caused By

- Insufficient Pile Length & Depth
- Poor Site Drainage
- Water-Retaining Soils
- High Water Table



Design Issues - Environmental

What can happen when it goes wrong?

Corrosion

Can Be Caused By

- Missing Corrosion Study
- Poor Material Quality Control
- Poor Site Drainage & Grading
- Landscaping Management

Design Issues - Loading

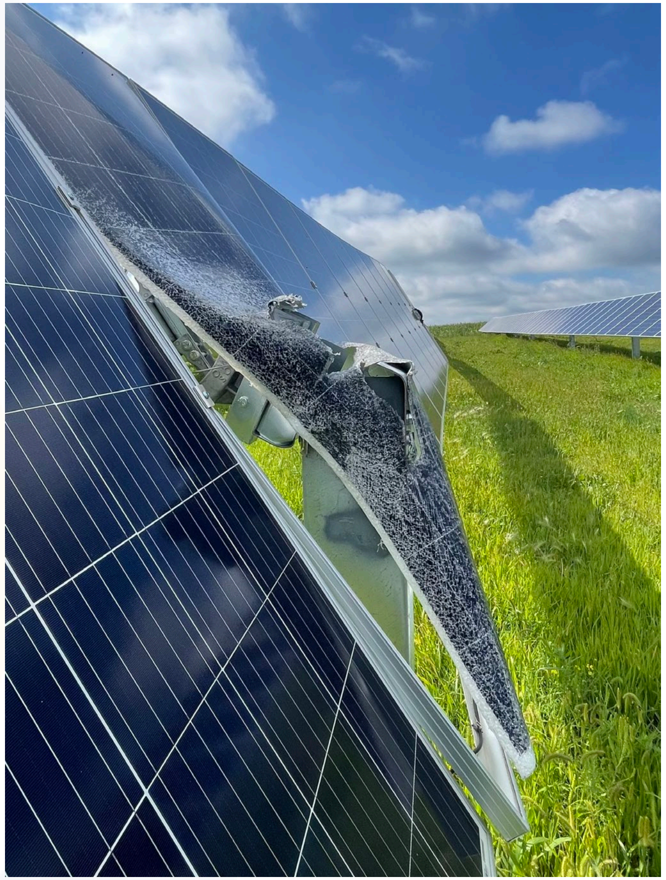
What can happen when it goes wrong?

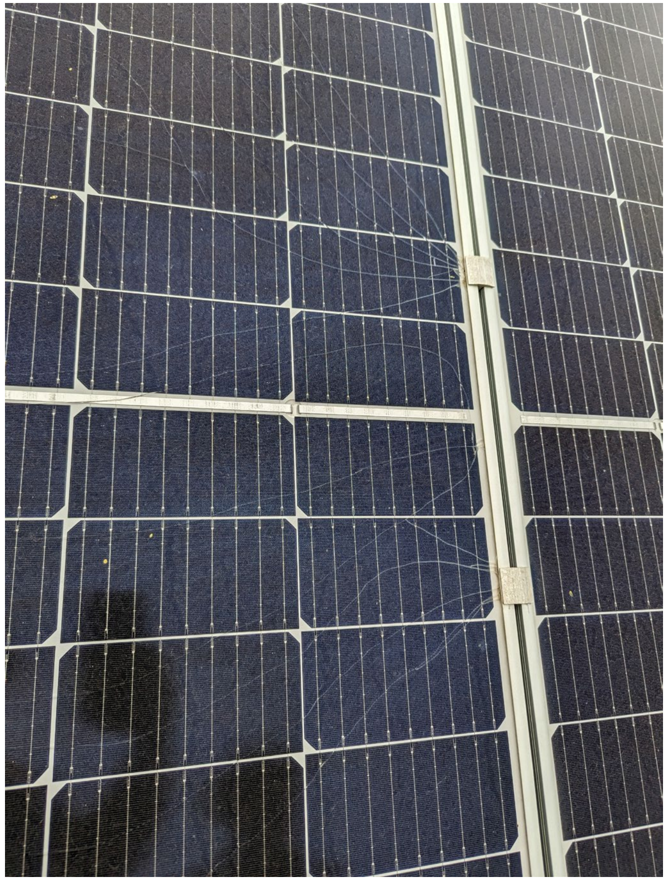
Mechanical Failure

Excessive Wear

Can Be Caused By

- Insufficient Material Strength
- Code Calculation Errors
- Insufficient Factor of Safety
- Incorrect BOM Specification
- Mechanical Binding





Design Issues - Site

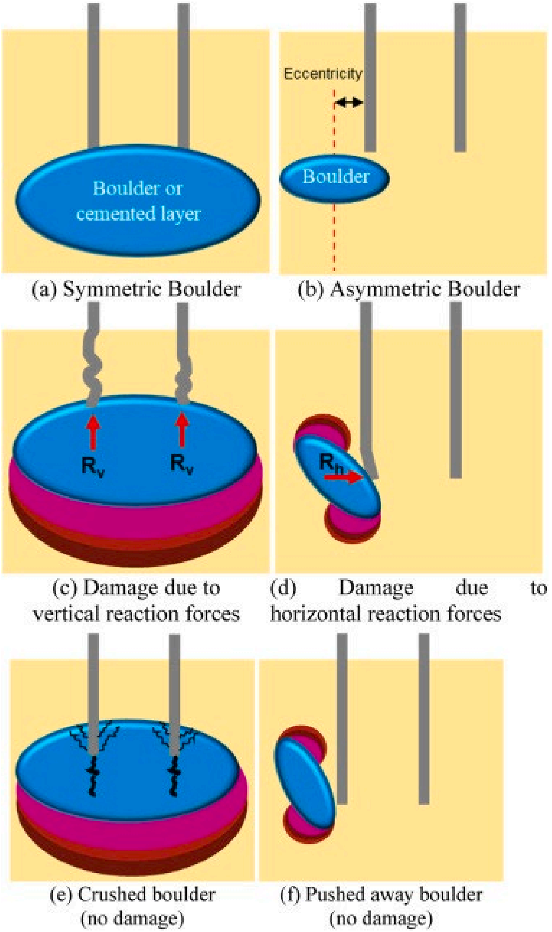
What can happen when it goes wrong?

Erosion

Pile Refusals

Can Be Caused By

- Insufficient Site Studies
- Insufficient Erosion Protection
- Insufficient Ground Cover & Vegetation
- Poor Grading Design
- Lack of Pre-Drilling



Design Issues – Hazard Mitigation

What can happen when it goes wrong?

Hail Strike

Snow Drift

Can Be Caused By

- Insufficient Code Study
- Incorrect BOM Specification
- Poor or Slow Stowing Performance
- Lack of Warning
- Backup Power Failure

Design Issues – Hazard Mitigation

What can happen when it goes wrong?

Dynamic Wind Failure

Can Be Caused By

- Insufficient Code Study
- Incorrect BOM Specification
- Poor or Slow Stowing Performance
- Lack of Warning
- Backup Power Failure
- Lack of advanced Wind Tunnel study

Summary - Design

- Early design decisions are the easiest to make and the most impactful to project success

- Engineering precision and detailed specifications are needed to ensure the best performance and durability

- When information is lacking, ask for more data, or obtain it yourself. Especially concerning the compatibility of modules and racking

- Failures are costly, but avoidable, if following best design practices.

Thank You

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