

The rise of intelligent PV tracking

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The global solar industry is entering a new phase. For more than a decade, utility-scale PV growth was primarily driven by falling module prices, rapid deployment and economies of scale. Today, the conversation is shifting. As solar power becomes one of the dominant pillars of global electricity generation, investors, developers and asset owners are increasingly focused not only on installed capacity, but on operational performance, resilience and long-term yield.

This shift is fundamentally changing expectations for PV tracker systems. Trackers have long been among the most effective methods for increasing energy yield in utility-scale installations. By following the sun throughout the day, they reduce cosine losses and increase effective irradiance compared with fixed-tilt arrays. In most growth markets, single axis trackers are now the default for utility-scale projects.

Yet the rapid scaling of solar projects is exposing the limits of conventional tracker control strategies. Plants are becoming larger, more geographically distributed and increasingly located in difficult environments, including sloped terrain, mixed land use and weather-volatile regions, where operational complexity can create entirely new challenges.

As a result, the industry is beginning to ask several important questions:

- Can traditional astronomy-based tracker control systems still maximize yield under real-world operating conditions?
- How can AI-driven optimization improve performance under dynamic factors such as diffuse irradiation, cloud movement and uneven terrain?
- With cybersecurity, resilience and operational efficiency becoming central concerns, what role will intelligent tracker control play in the next generation of PV infrastructure?

The answer is becoming increasingly clear across the utility-scale solar sector: tracker control is evolving from a relatively simple positioning mechanism into an intelligent, data-driven operational platform.

Solutions such as Gantner.trackIQ represent this next generation of technology, combining machine learning-based optimization, advanced analytics and cybersecurity-focused architecture with industrial-grade engineering developed and manufactured in Germany.

The limits of conventional tracker control

Traditional tracker systems are typically based on static astronomical models. Using Solar Position Algorithms (SPA), they calculate the theoretical position of the sun purely from time, date and geographic location. Under ideal conditions, this works very well.

Real-world operating environments are rarely ideal.

Cloud cover changes everything. The balance between direct and diffuse irradiation can shift within minutes and with it, the optimal tracker angle. Terrain adds a second layer of complexity: small elevation differences between rows create partial shading, mismatch losses and inverter MPPT inefficiencies. Wind, temperature and humidity bring further mechanical and electrical effects. Conventional open-loop control cannot respond to any of this, because it has no feedback from what is actually happening in the plant.



At the same time, the economic environment for utility-scale solar is becoming more demanding. Falling margins, highly competitive Power Purchase Agreements (PPAs) and tighter investor expectations are putting pressure on operators to maximize performance throughout the full operational lifetime of an asset.

At this scale, the economics are unforgiving. Even low single digit yield improvements can materially affect a project's Internal Rate of Return and across gigawatt-scale portfolios, a 1 to 2% yield gain can translate directly into significant additional revenue over a 25-year operational lifetime.

The gap between theoretical optimization and real operating conditions is therefore no longer a technical curiosity. It has become a material driver of project economics.



AI-driven optimization: from static rules to adaptive intelligence

Machine-learning-supported optimization is fundamentally changing how tracker systems operate. Instead of relying solely on predefined astronomical trajectories, control systems continuously adapt their operating strategy based on changing environmental inputs, combining historical patterns, live measurements and forecast data to determine the optimal tracker position at any given moment.

Gantner.trackIQ processes multiple inputs in parallel: direct and diffuse irradiance, satellite forecasts of wind, hail and diffuse radiation, cloud movement, terrain geometry and live system performance data. Based on these inputs, tracker angles are adjusted

dynamically, reacting to real conditions rather than following a fixed daily path.

A particular focus is diffuse-light optimization. Conventional tracking aims primarily at direct sunlight, but in regions with variable weather, diffuse radiation can contribute a substantial share of total yield. Optimizing module orientation for both direct and scattered light raises energy production without additional hardware, effectively turning software into a yield driver.

As extreme weather events become more frequent and harder to predict, the ability to fuse forecast data with live measurements and adjust the array in seconds is becoming a key operational capability. It is what separates a plant that actively protects its yield from one that simply rides out the conditions.

Terrain variability is becoming a defining challenge

Terrain variability is emerging as one of the most important operational challenges in modern utility-scale PV development. Even relatively small elevation differences between tracker rows can drive partial shading, mismatch losses and inverter MPPT inefficiencies that meaningfully reduce overall plant performance.

With prime flat land scarce in most growth markets, the next generation of utility-scale projects will increasingly be built on sites once considered marginal. Tracker control has to follow.

Adaptive terrain tracking calculates optimal angles row by row rather than applying

uniform motion across the array, using full 3D backtracking that incorporates CAD-based row positions and elevation data. Advanced backtracking goes beyond simple geometry by combining real-time measurements with predictive methods to refine the strategy continuously. Crucially, all algorithms run locally on an onsite control unit, ensuring reliable operation even where connectivity is limited, and keeping the plant independent of external infrastructure.

Cybersecurity is becoming a core infrastructure requirement

As solar power becomes a critical national infrastructure, cybersecurity expectations are rising rapidly across the renewable energy sector. For asset owners managing portfolios across multiple jurisdictions, cybersecurity has moved from an IT concern to a board-level risk.

Regulations such as the European NIS2 Directive and the Cyber Resilience Act (CRA) are redefining operational requirements for industrial control systems, including renewable energy infrastructure. Tracker controllers, gateways and monitoring systems are no longer isolated devices: they are increasingly part of the connected infrastructure that asset owners must secure, monitor and manage.

Modern control platforms, therefore, need encrypted communication, secure remote access for configuration and firmware updates, certified information security management (ISO 27001) and over-the-air update mechanisms aligned with NIS2 and CRA. Data sovereignty matters just as much: operational data should remain with the operator, supporting regulatory compliance and the tighter audit trails that institutional investors

increasingly demand across renewable portfolios. Gantner.trackIQ has been developed with these requirements in mind.

Resilience and operational continuity under extreme conditions

Climate related operational risks, high winds, hailstorms, flooding and snow events are increasing in both frequency and severity. Asset owners increasingly expect resilience to be built into the control layer itself, not bolted on afterwards.

Modern tracker control, therefore, has to go beyond yield optimization alone. The control loop itself takes responsibility for protecting the plant: instead of relying on manual intervention or external safety systems, the plant decides autonomously when to take the array out of harm's way, stowing ahead of incoming wind, repositioning to shed snow, or moving into a protected state when a hail or flood event is forecast. Events that previously meant hours of unplanned downtime are increasingly handled by the plant itself, protecting both yield and physical assets.

From data to insight

Modern PV plants generate vast volumes of operational data, but value is only created when that data becomes actionable insight. Advanced analytics, streamlined commissioning workflows and continuous remote diagnostics together provide fleet-wide visibility, surfacing trends, inefficiencies and anomalies across multiple sites, and identifying unusual performance patterns early, before they become unplanned downtime.

The result is continuous optimization, lower O&M cost and consistent performance over the full installation lifetime, increasingly a baseline expectation in utility-scale operation, not a premium feature.



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Proven at scale

This combination of technologies is no longer theoretical. Solutions of this kind have been deployed in monitoring, control and analytics roles in more than 53 countries, including Europe's largest 650 MW solar park and the largest installations to date in Denmark, Angola, Poland, Spain, Latvia and Ireland. One project in Chile alone runs more than 6,000 individual tracker control units on a single DC-powered, 2.4 GHz wireless mesh network, operational evidence that intelligent, machine-learning-supported tracker control is already meeting the reliability and scalability requirements of utility-scale deployment.

From tracker control to intelligent PV infrastructure

Modern PV plants are evolving into highly interconnected digital energy systems that demand adaptive optimization, predictive operation, cybersecurity, fleet-wide analytics and long-term operational resilience. Intelligent tracker control is becoming a foundational technology layer of this environment rather than a standalone subsystem.

Returning to the three questions the industry is asking: conventional astronomy-based control will not, on its own, deliver the yield, the resilience, or the security profile that the next generation of utility-scale PV demands. Machine-learning-based optimization closes the gap on yield under dynamic conditions. Architectural openness and certified cybersecurity close it on resilience and asset-owner risk. Integrated commissioning, monitoring and analytics close it on operational efficiency over the full plant lifetime.

As the global solar industry continues to scale, intelligent tracker control is no longer a competitive advantage for a few advanced operators; it is becoming a fundamental requirement for the next generation of utility-scale solar infrastructure.

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