

SUPERTRACK

WHITE PAPER

Smarter Algorithm - Real Application - Real Performance - Real Third-party Review

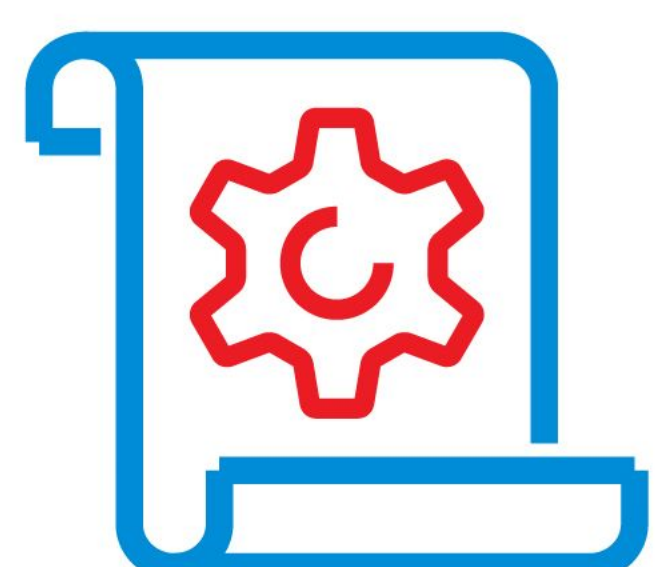
01 Executive Summary



Background

Achieving net-zero emissions has become an urgent goal as the world battles one of the most serious problems that faces the planet, climate change. Various countries have adopted net-zero emission-related policies to support the goal of limiting the global temperature rise to within 1.5°C above pre-industrial levels, as set out in the Paris Agreement of 2015. The construction of a clean, low-carbon, safe and efficient energy system is an important initiative to help achieve net-zero emissions. Photovoltaic power generation is an important component of renewable energy, and a report by the International Energy Agency forecast that by 2050, 90% of the world's electricity will be in the form of renewable energy, with about a third of the electricity coming from photovoltaic power generation.

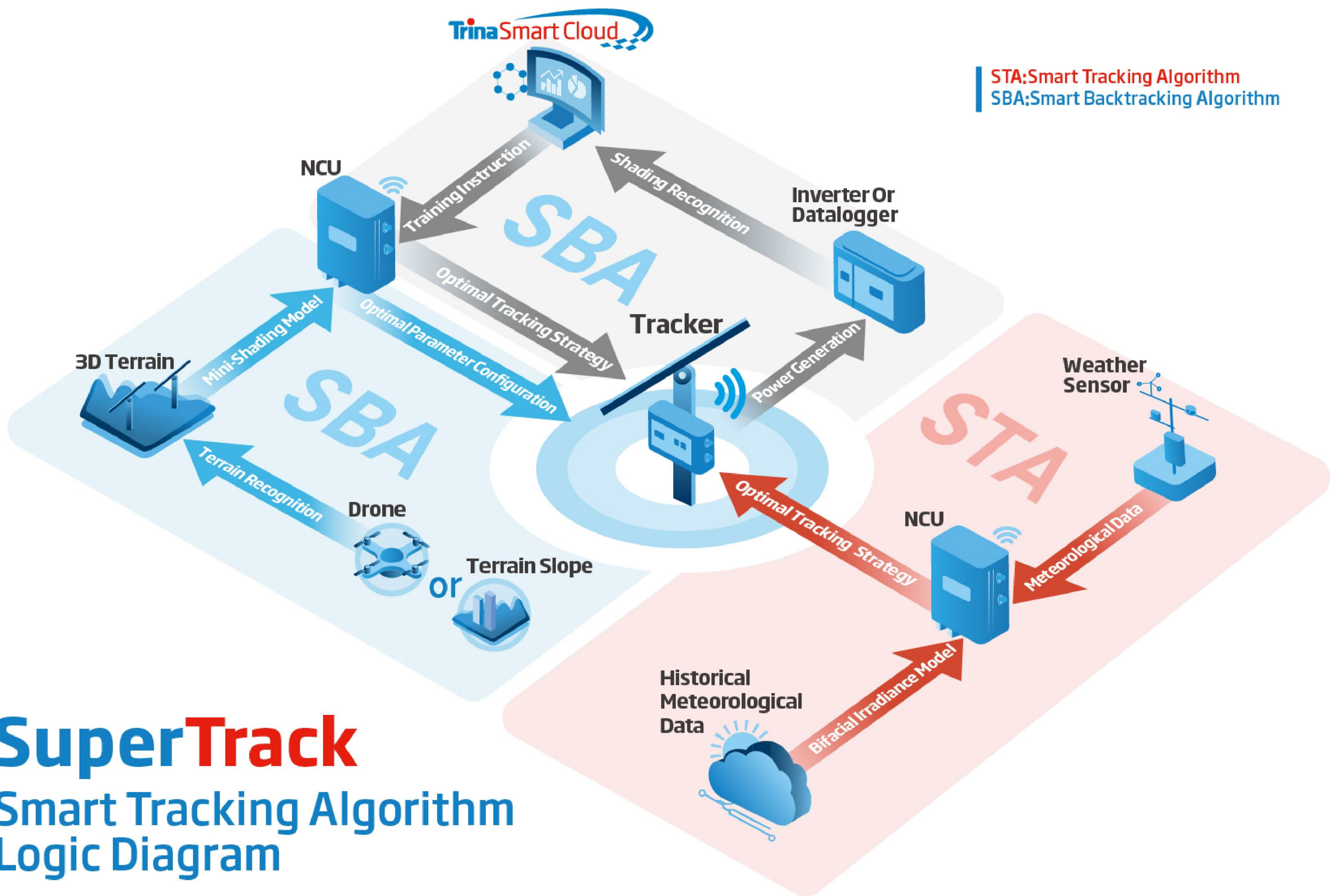
Photovoltaic tracking systems can adjust the angle of photovoltaic modules in real time, maximize the amount of solar irradiance, improve the rate of light use and improve power generation by more than 10% compared with that of traditional fixed mounting structures. It is the most direct and effective technological path to improve the efficiency of photovoltaic system, and its market share is increasing year by year.



SuperTrack Overview

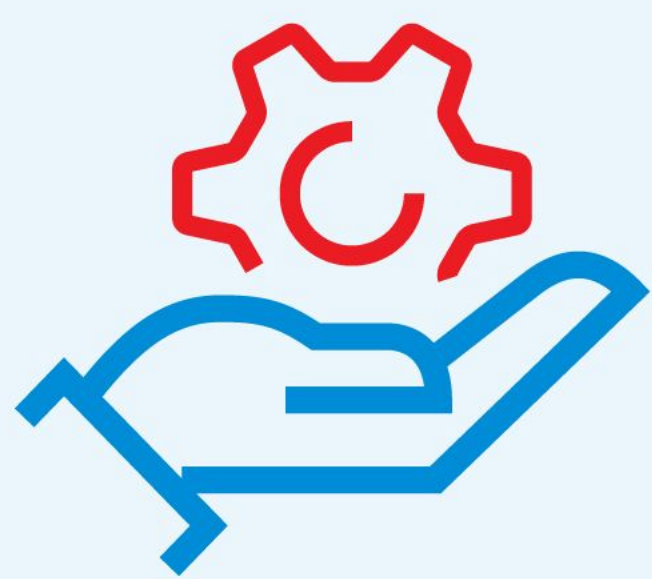
At present the tracking algorithm used in conventional tracking systems only considers high direct irradiance weather, flat terrain and monofacial modules receiving maximum irradiance. Most of the projects use bifacial modules, and there are terrain ups and downs and construction errors, resulting in shadow in the morning and evening backtracking phases, causing power generation losses. At the same time, under high diffused irradiance conditions (e.g., cloudy days), it continues to rotate based on the conventional tracking algorithm, which does not make full use of the diffused irradiance. Thus the conventional tracking algorithm does not make full use of the advantages of the tracker for power generation.

In response to the shortcomings of conventional tracking algorithms, Trinasolar has innovatively developed a smart tracking technology called SuperTrack, based on Trinasolar's exclusive patented technology and designed to optimize the power generation performance of the tracker. By accurately controlling the angle of the tracker, SuperTrack can maintain stable power generation output in complex weather and undulating terrain conditions, maximizing energy capture. This technology not only leads the digital development of PV trackers but also promotes efficient power generation and sustainable operation of PV power plants by improving system efficiency.



SuperTrack

Smart Tracking Algorithm Logic Diagram



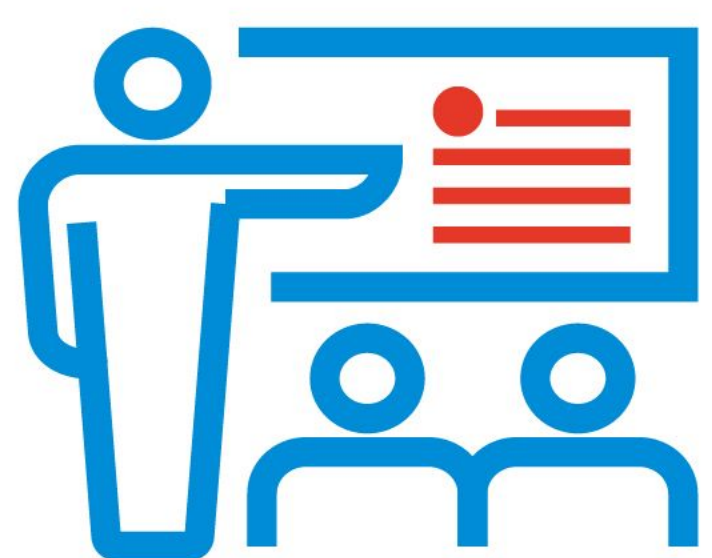
Highlights

SuperTrack makes full use of the tracker's maximum power generation potential to effectively increase power generation efficiency, with a gain effect of up to 8%, significantly reducing the cost of LCOE, providing customers with a more cost-effective solution, and effectively improving the project's return on investment. SuperTrack has been certified by third-party consultants such as SGS, UL Solutions and CGC to significantly increase the power generation efficiency of power stations.

02

About SuperTrack

Highly Reliable Tracker - Smart Software Platform - Professional Local Service



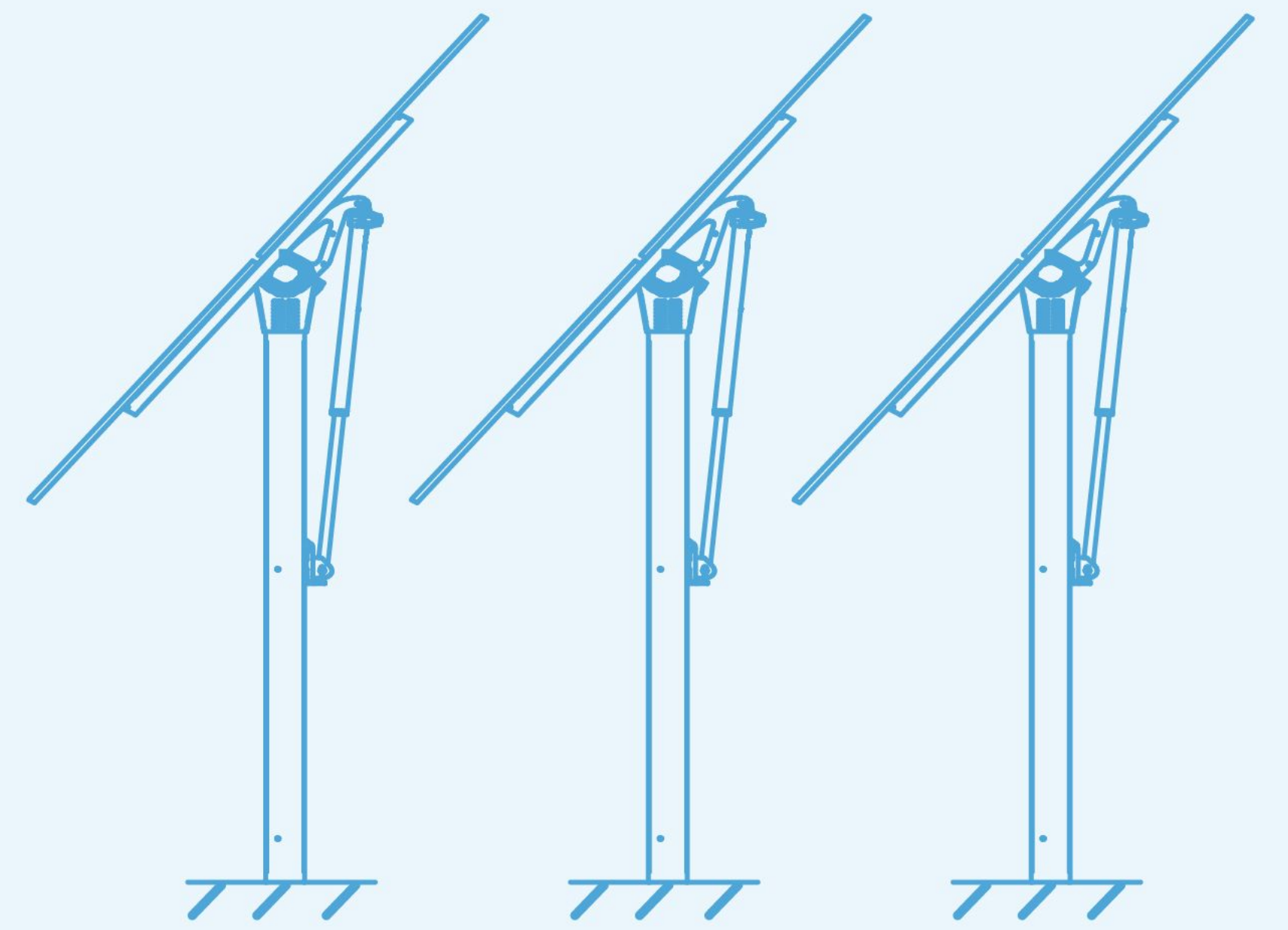
Release (May 2022)

In May 2022, Trinasolar unveiled SuperTrack, a breakthrough smart tracking technology, opening a new era of smart power generation. In July of the same year the power generation simulation and evaluation software SEB, which integrates SuperTrack functions, was launched online. The software helps users accurately evaluate the potential for power generation gains at the early stage of a project so they can fully understand the benefits of SuperTrack when making investment decisions.



Global Applications

Since SuperTrack was introduced, it has sold cumulatively up to 3.3 GW on four continents, boosting power generation by 92.4 million kWh per year, reducing carbon emissions by about 4.6 million tons and meeting the electricity needs of 15.4 million households.



SUPERTRACK

03

Complex Terrain Optimization

Challenges & Conventional Solutions

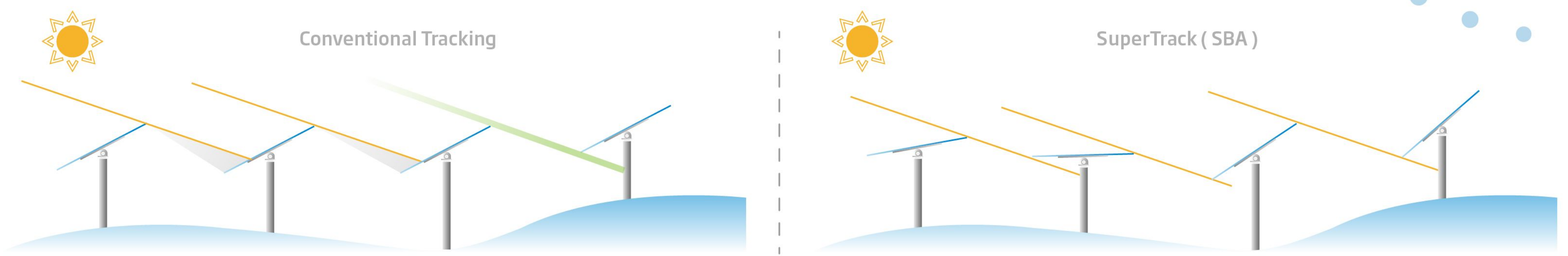
PV tracker project increases year by year, and with the continued development of land resources, flat terrain is becoming more and more scarce. In practical engineering, because of terrain undulation and installation errors and other impacts, there is a height difference between rows. If the conventional backtracking algorithm is still applied, it will result in inter-row shading during the backtracking phase, resulting in power generation losses. In high direct irradiance weather, instantaneous generation power loss can be up to 40%. Terrain undulation not only produces an east-west height difference, but with the north-south height difference as well. There is seasonal variation in shading, and it is impossible to eliminate year-round



shading by considering only the seasonal shading for optimization. At the same time, based on the power generation characteristics of the half-cut module, in certain settings the IAM loss due to eliminating shading may be greater than the power generation loss due to partial shading. This means there is a large optimization space for the tracking algorithm for complex terrain.

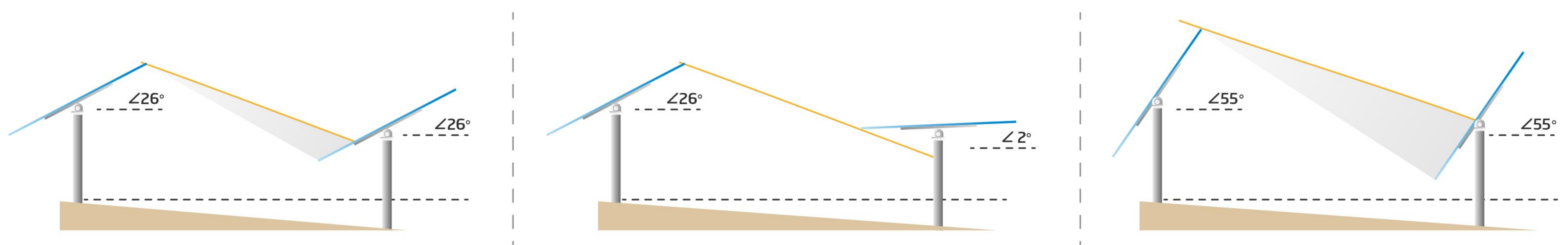
Smart Backtracking Algorithm (SBA) uses system operations data for optimization perturbation training and/or sensing technology to identify shading and to construct 3D terrain models. Based on the power generation characteristics of modules, it employs machine learning algorithms, optimized slope angle model and mini-shading model to iteratively determine the optimal backtracking angle groups for maximizing annual power generation. This approach effectively improves power generation during the backtracking phase, achieves terrain recognition and backtracking angle optimization in complex topographies, and makes the most of the power generation advantages of tracking systems.

The difference in tracking angles between conventional tracking arrays and SuperTrack arrays on complex terrain



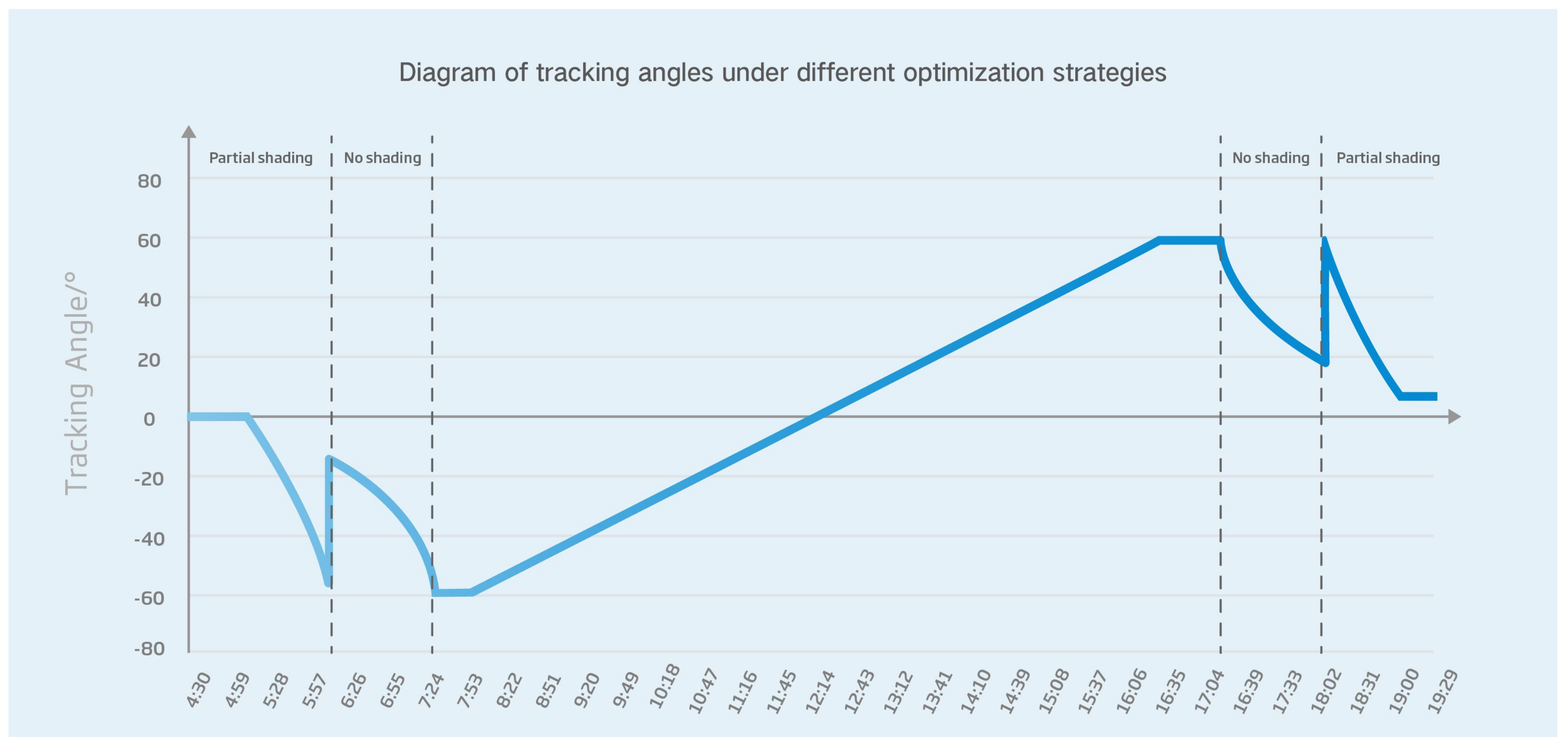
At the same time, considering the height difference between the rows in the east-west and north-south directions, the optimized slope angle model is used to follow the azimuthal changes of the sun's rays throughout the day, simulate the shading situation in different seasons, and compute the optimized slope angle clusters in different seasons, to ensure that the loss of shading is minimized for the entire period.

Comparison between the solution of reducing the angle to avoid shading and the solution of increasing the angle to allow partial shading



For different terrains the Trinasolar mini-shading model is used to simulate the optimization effect of no shading and partial shading, combined with IAM loss, to compare the irradiance loss due to the angle reduction with the power generation loss caused by partial shading, and based on the principle of maximum overall power generation, different optimization strategies are used for different periods to determine the optimal backtracking angle.

Diagram of tracking angles under different optimization strategies



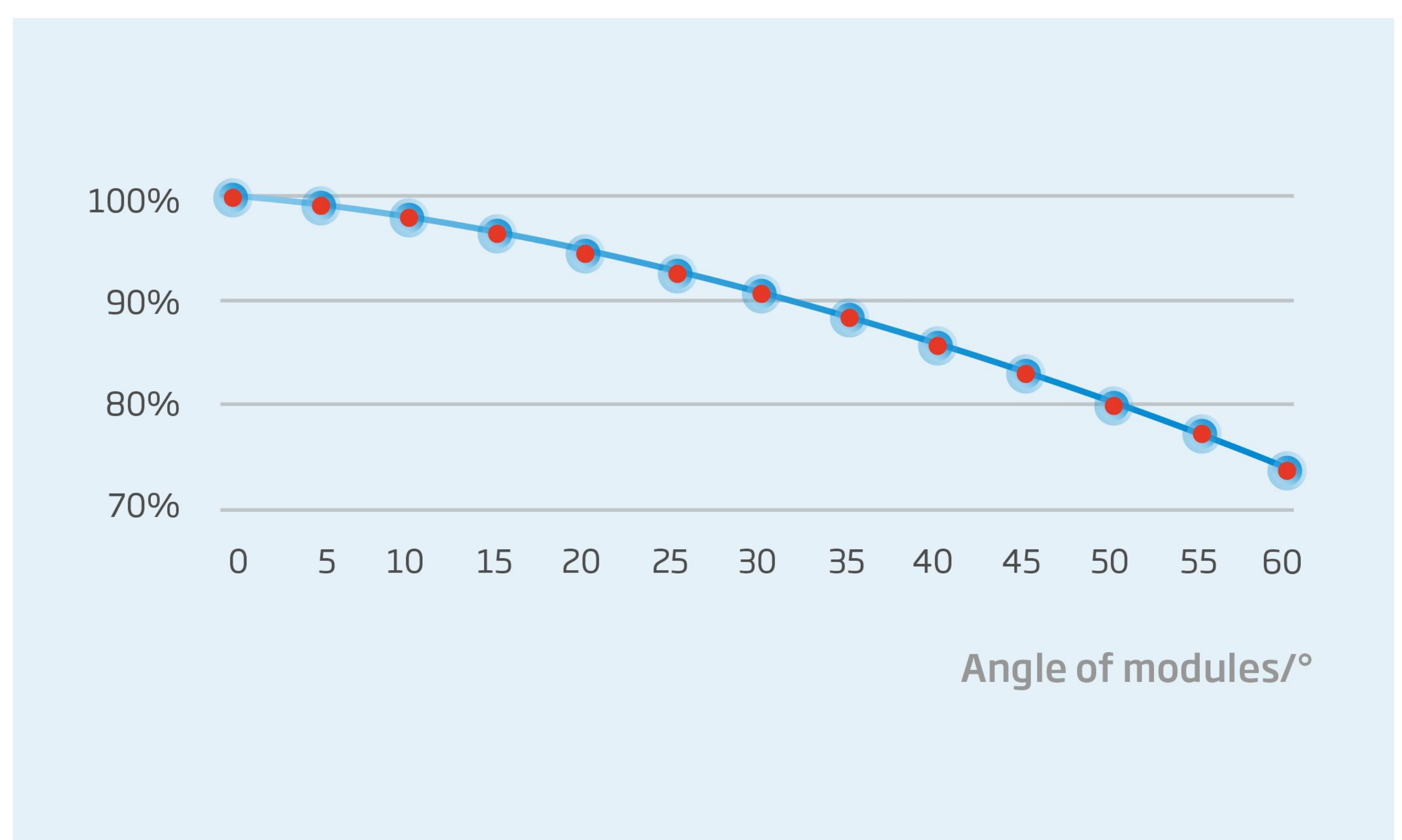
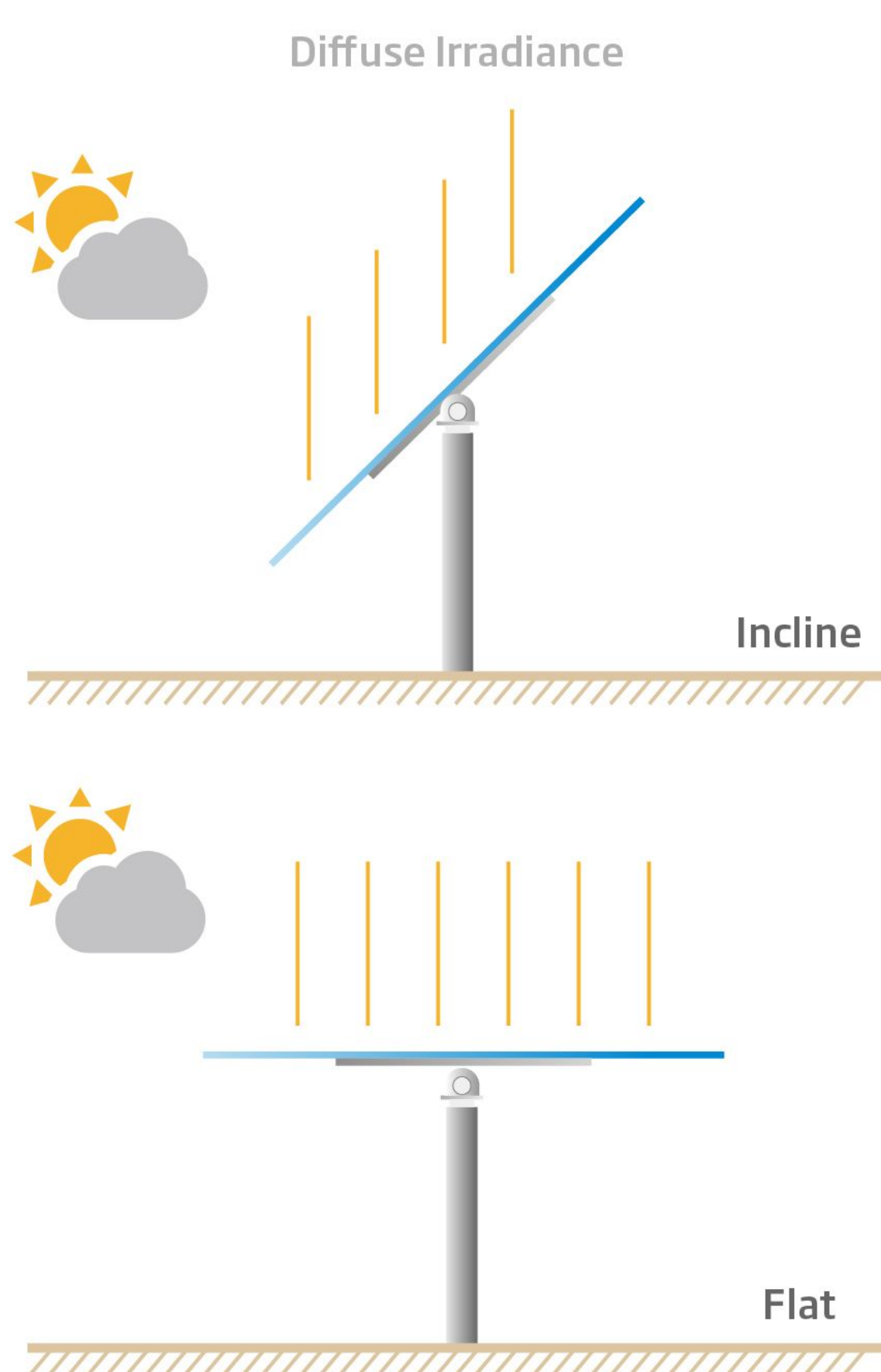
04

High Diffuse Irradiance Weather Optimization

Challenges

The real weather state includes high direct irradiance (sunny days), and high diffuse irradiance (cloudy and rainy days), with more cloudy and rainy days in some areas, which can account for more than half the year. Under the irradiance model, in high diffuse irradiance weather the diffuse irradiance received on the front side of the module gradually decreases with the increase of the module tilt angle, and, as shown in the figure, the diffuse irradiance received by the module flattened is higher than that received by the module with tilting angle, and the larger the module tilting angle is, the larger the difference is. Conventional tracking algorithms do not take into account the weather and only rotate as sunny days, and this fails to make full use of the diffuse irradiance in high diffuse irradiance weather.

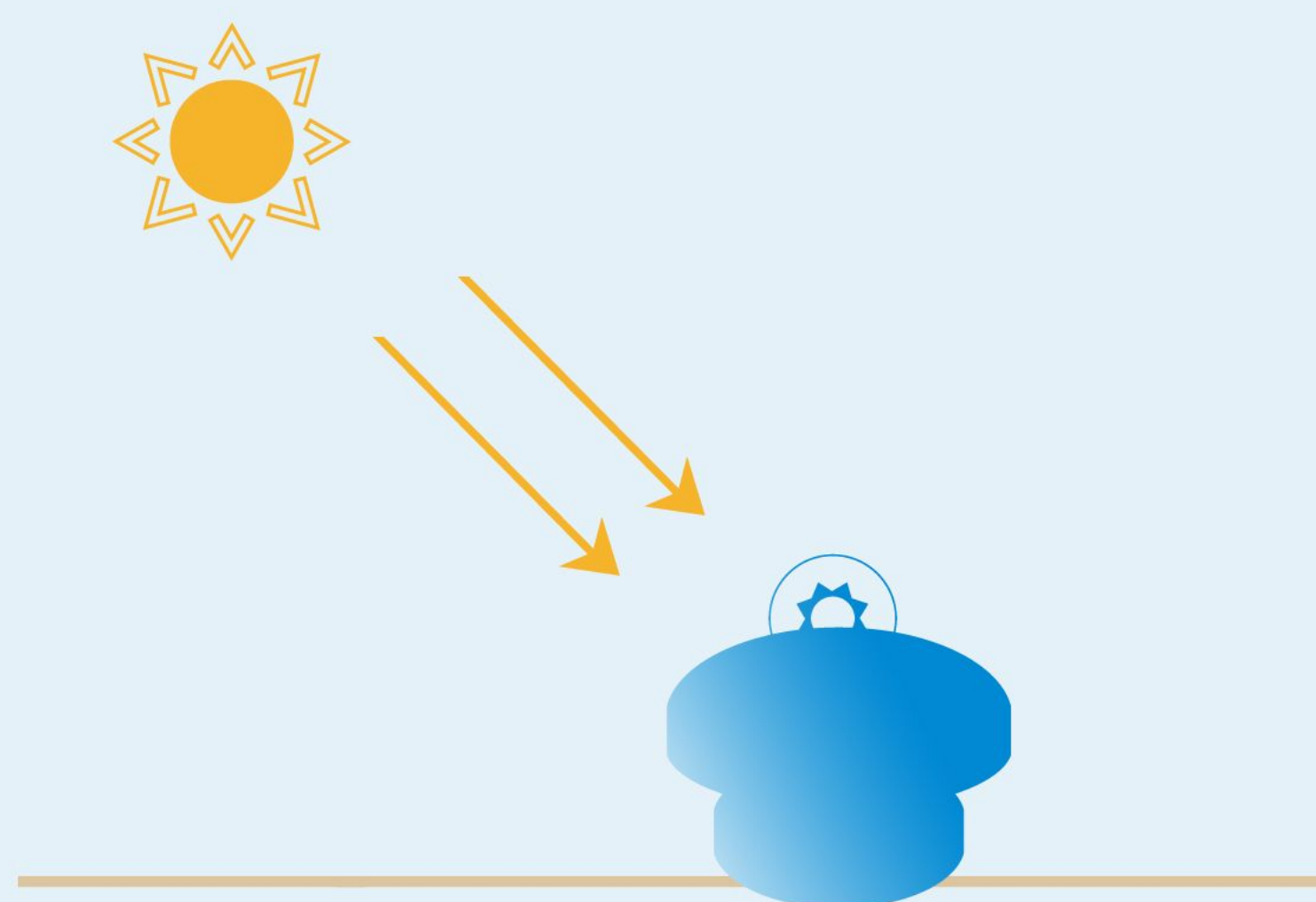
Diagram of diffuse irradiance received at different angles with the percentage difference in relative horizontal irradiance



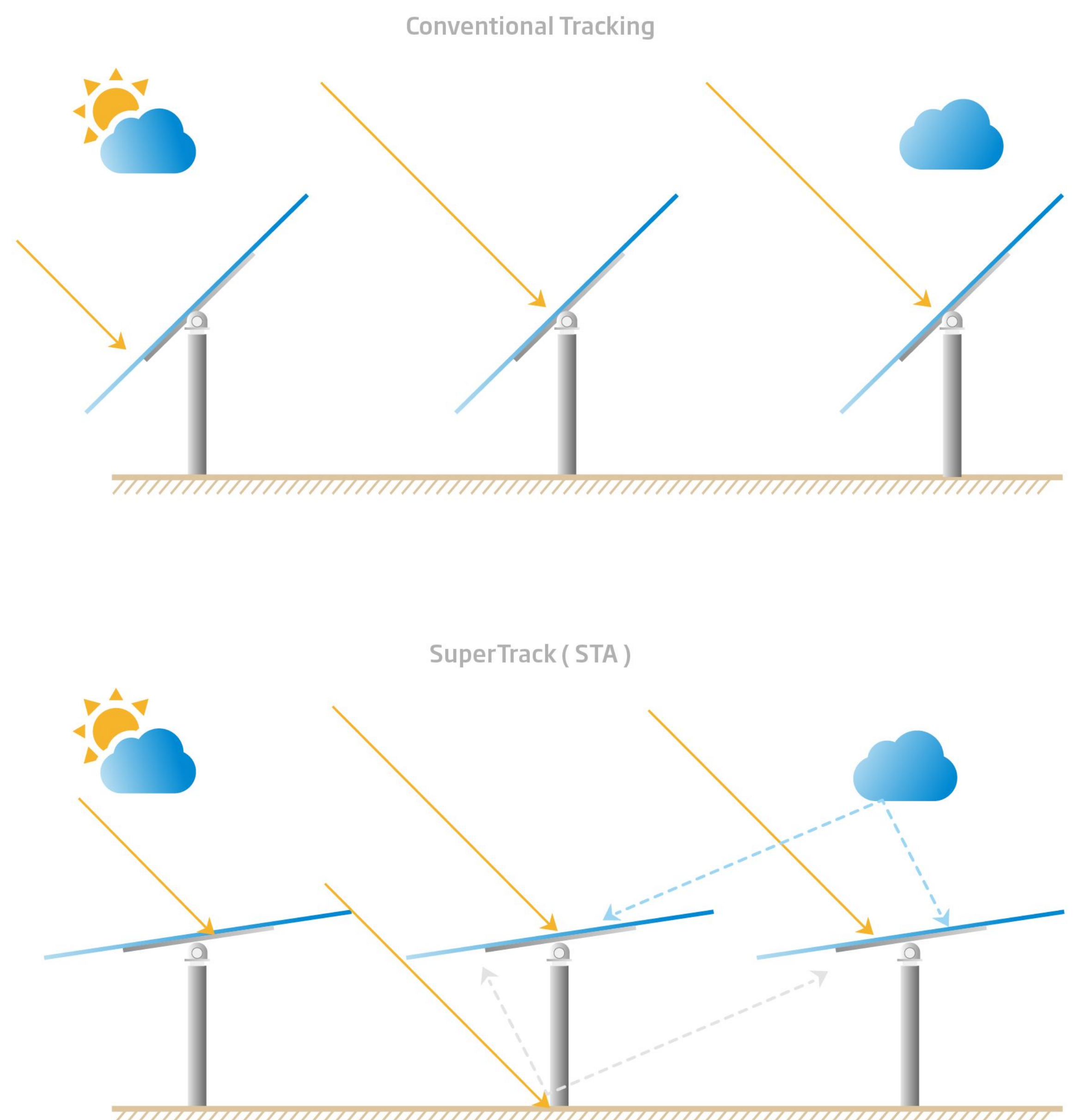
SUPERTRACK

Smart Tracking Algorithm (STA) relies on patented Bifacial Irradiance Model (BIM) to deeply learn the power generation characteristics of bifacial modules under the influence of many parameters, and dynamically optimizes the optimal tracking angle in real time according to meteorological and system operation data, so as to enhance the power generation in high diffuse irradiance weather.

Since the application of the patented technology in 2020, Trinasolar has taken the lead in using pyranometers to identify weather conditions on a large scale, laying the foundation for technological breakthroughs in the industry, and leading the industry in the use of pyranometers to determine weather conditions to optimize the PV tracking angle.



The difference in tracking angles between conventional tracking arrays and SuperTrack arrays on cloudy day



05

Industry Digitalization

Industry Trends

The global PV tracker market exceeded 90 GW in 2023 (Wood Mackenzie), representing an all-time high volume. Single-row trackers, which provide the greatest flexibility for advanced controls, made up 68% of all global shipments in 2023. The United States (36 GW) led all countries in demand, followed by Spain, Brazil, Saudi Arabia, and India.

Over the past several years, the tracker industry observed by Wood Mackenzie has seen the growing adoption of advanced control systems to address numerous performance issues, as these systems become increasingly important with the development of solar projects in sites characterized by more adverse weather conditions and challenging terrain.

A key differentiation between traditional tracker controls and these advanced software products is the use of machine-learning models to provide real-time, site-specific adjustments. For example, optimizing for diffuse generation will depend heavily on the types of clouds in the sky and the exact terrain beneath the modules. Intelligent software models that use iterative control loops and pattern recognition to adjust tracker angles, according to Wood Mackenzie, will improve generation compared to systems with pre-programmed instructions.

In order to execute these real-time commands, modern-day trackers must be equipped with tracker control units (TCUs) that communicate wirelessly with centralized network control units (NCUs) and a SCADA system. These devices also provide greater visibility into tracker equipment performance, enabling enhanced safety features and rapid maintenance alerts.

According to Wood Mackenzie, the use of trackers instead of fixed-tilt ground mounts can reduce a project's levelized cost of energy (LCOE) by an average of 14% in Europe and by 4% in the United States. Improvements to tracking algorithms and greater bifacial adoption will extend this advantage by an additional 1-2% over the next decade.

In addition to improving LCOE, advanced trackers will provide more generation during non-peak hours, which provides additional revenue per MWh-generated for projects participating in wholesale markets.

TrinaTracker Smart Control System

Trinasolar is also continuously innovating and developing in the field of digitalization in tracking systems, creating a unique smart control system, with the smart controller as the terminal carrier of the smart control system to drive the tracker to operate precisely and stably, and with the Trina Smart Cloud digital monitoring platform as the data processing center to monitor and control the tracker's operation status. Supplemented by the digital twin function 3D digital map, motor diagnosis and pre-warning function to achieve efficient operation and maintenance of the power station, the SuperTrack smart tracking algorithm acts as a decision-making center according to the different needs of the project site through two different ways to optimize the tracking angle in real time, to ensure the highest power generation efficiency. Building a three-dimensional digital solution integrating terminal, platform and algorithms, these components work in synergy to ensure high stability, efficiency and system performance.



06

Simulation Gain Evaluation

SEB Simulation Tool

The industry lacks smart tracking algorithm power generation gain evaluation software, and general simulation software does not fully support the simulation of smart algorithms, usually relying on experienced simulation engineers to repeat the modeling, correction and simulation, which is time-consuming

and expensive. To tackle this problem Trinasolar has innovatively created SEB Power Generation Simulation Software, which takes into account cloudy and rainy days and complex terrain, and simulates power generation gain of smart algorithms. Unlike with traditional simulation software, users need only input additional terrain information to obtain SuperTrack power generation gain evaluation.

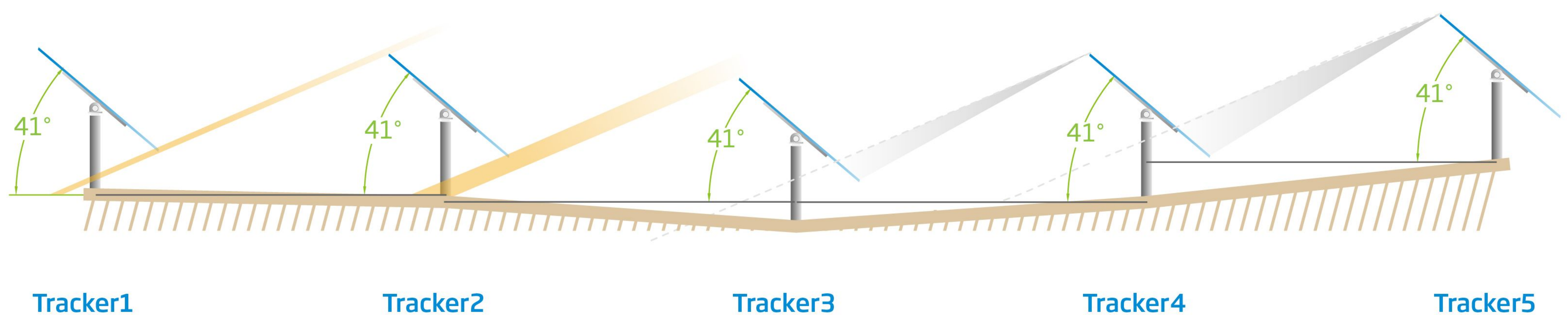
To verify the effectiveness of SEB we invited a globally renowned consultant to jointly simulate the power generation situation of a project site in Spain where there is undulating terrain and high diffuse irradiance weather. Trinasolar and the consultant simulated the power generation gain of the project using SEB and PVSyst, respectively, and the results of the two different evaluation methods were highly consistent. The power generation gain generated by SuperTrack will help further reduce LCOE and significantly improve customer's investment return.

Cooperation with PVcase

SuperTrack has received endorsements from numerous third-party consultants in the industry and has also partnered with the simulation company PVcase. For this joint work, typical uneven terrain was selected to compare and evaluate the optimization effects of SuperTrack and PVcase's upcoming terrain-aware backtracking algorithm.

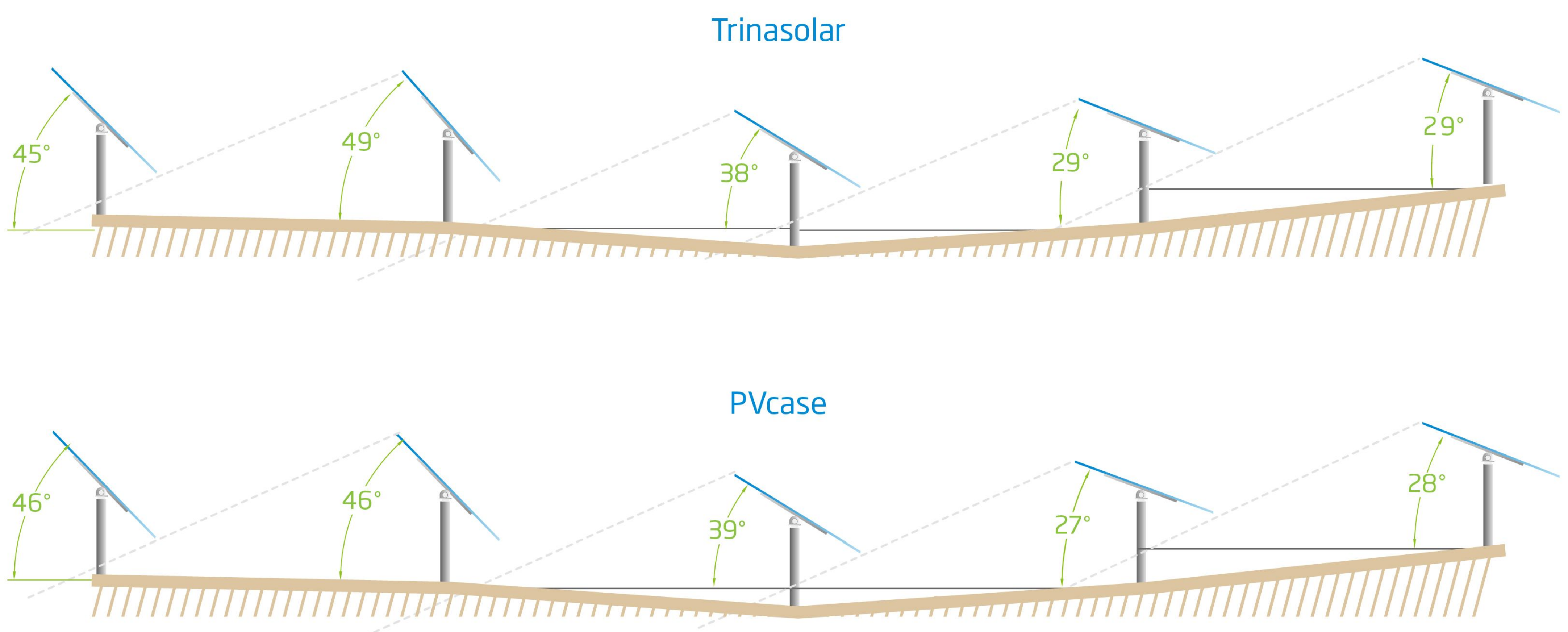
In this rugged terrain, shading occurs during both the morning and evening phases.

Illustration of the conventional tracking algorithm on typical undulating terrain



To deal with this SuperTrack simulated the optimal tracking angles during the backtracking period based on its core patented model. At the same time, PVcase drew on its extensive experience in energy generation simulations to assess the best tracking angles for the same period.

Comparison of optimized tracking angles between Trinasolar and PVcase under the same terrain



The result was that the optimal tracking angles simulated by both SuperTrack and PVcase were largely consistent, effectively minimizing power generation losses caused by shading. Through this collaboration, Trina and PVcase compared their independently developed smart algorithms, demonstrating that the highly consistent optimization results validate the rationality and effectiveness of their solutions for complex terrain.

07 Case Studies

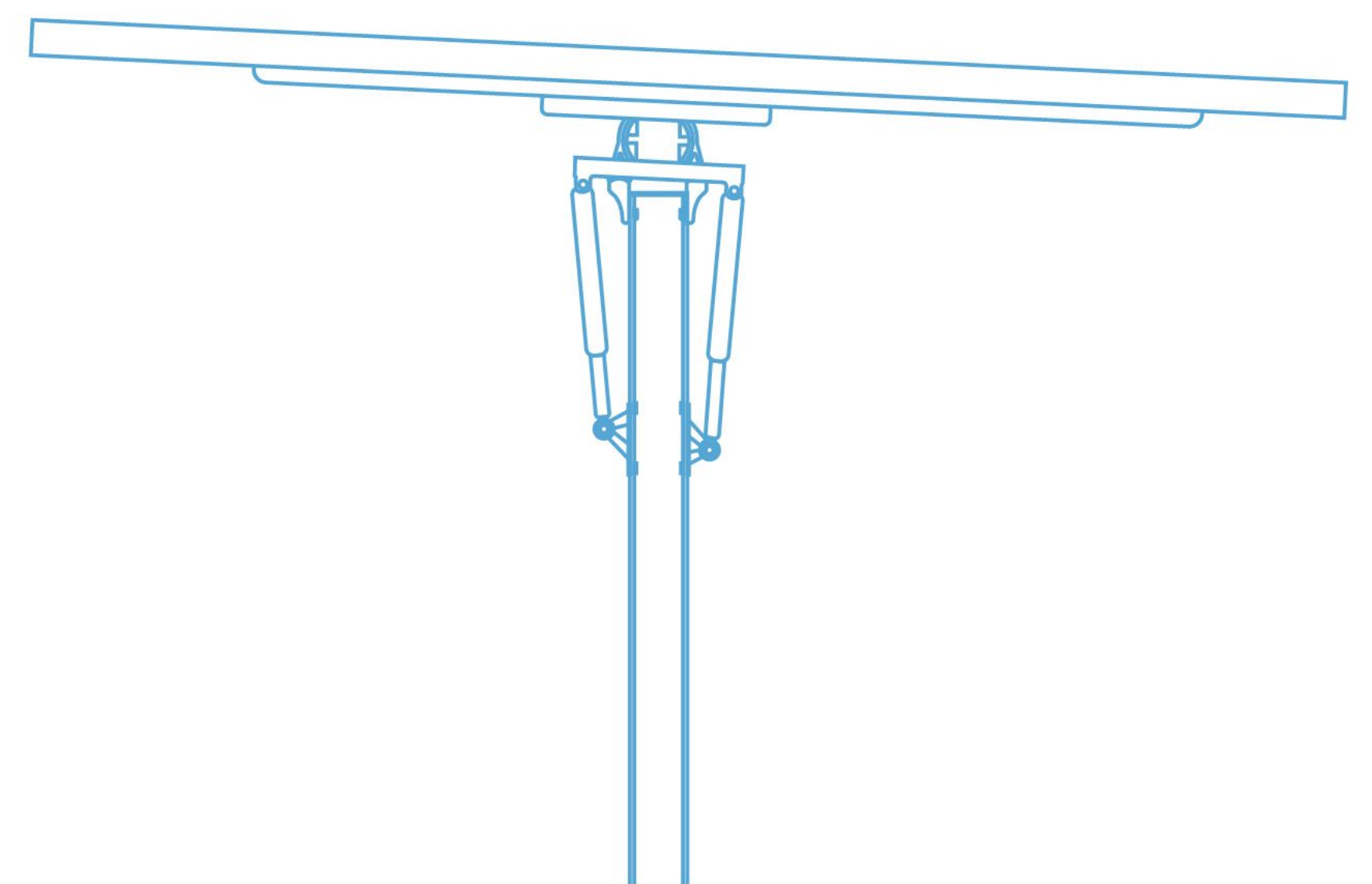
Shandong, China (Retrofit)

Located in the rugged, underutilized hills in Shandong Province, China, this project is set in demanding landscape. Despite the challenging accessibility, this strategic location is poised to make a substantial impact and drive operational efficiency.

For this project, Trinasolar provides an integrated smart control solution, which includes TCU, NCU, Trina Smart Cloud and SuperTrack smart tracking algorithm.

Some equipment failures led to communication interruptions, affecting many trackers and complicating troubleshooting. Trinasolar's self-developed smart control system, including TCU and NCU, replaced the faulty equipment. This system uses wireless communication and self-powered technology, reducing the need for cables and lowering costs. The 'broadcast + polling' strategy ensures efficient and stable communication. In addition, the operation and maintenance platform shares meteorological data, reducing the need for weather sensors and improving tracker reliability by avoiding power loss. Trackers continue operating normally during sensor maintenance, ensuring no energy yield is lost.

The project site is spread across difficult terrain, making manual inspections costly and time-consuming. Without a dedicated tracker monitoring system the O&M team struggled with delays in detecting and correcting issues, leading to energy yield losses. To deal with this we installed the Trina Smart Cloud platform, allowing the team to monitor and manage tracker operations in real-time. The system's features, such as data sharing, digital map and health diagnosis, ensure timely fault detection and efficient maintenance, significantly improving operational efficiency and reducing power generation losses.





The complex terrain at the start of construction resulted in significant shading issues between the trackers. To address the limitations of traditional astronomical algorithms we implemented the new smart tracking technology SuperTrack. This system eliminates or minimizes shading between the front and back rows of modules during backtracking and optimizes power generation in various weather conditions. As verified by SGS, SuperTrack delivered an additional 3.24% energy generation gain for the project from November 2023 to October 2024.

“We choose our tracker partner based on three key considerations: First, the partner’s strength and ability to provide stable after-sales service for years, second, its R&D excellence and ability to improve the overall energy yield of the power station, and third, the capability to offer remote real-time monitoring and reduce our overall O&M costs. That is why we chose to work with Trinasolar.”

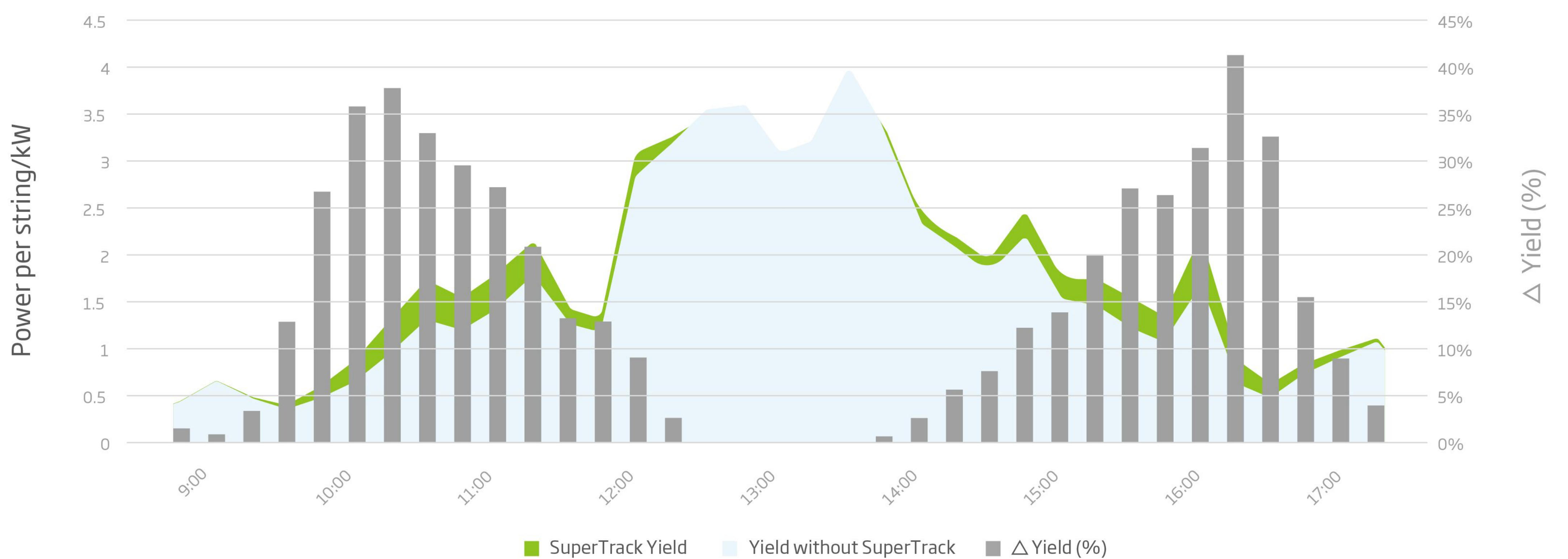
–The power station operation and maintenance company



Campiña, Spain

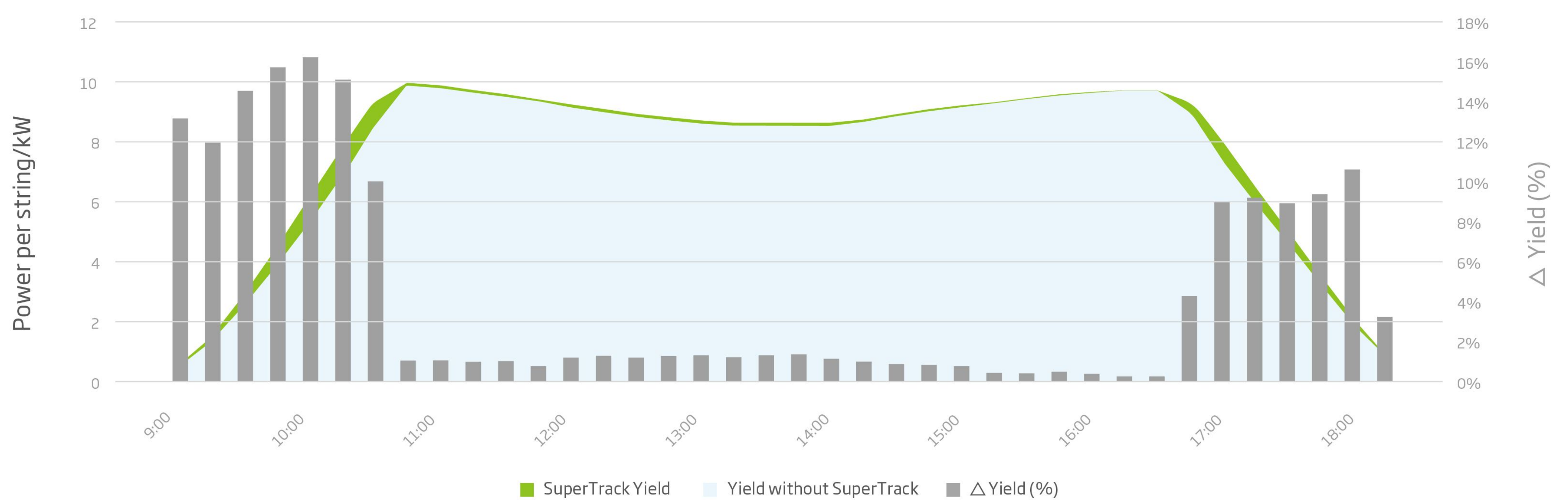
The empirical power plant has total installed capacity of about 11 MW and uses a single-axis tracking system. Since August 2023 some arrays have operated with a conventional tracking algorithm, while comparison arrays have employed the SuperTrack smart algorithm. SuperTrack algorithm optimizes tracking angles for high diffuse irradiance weather and backtracking angles, increasing the collection of diffuse irradiance under such conditions and reducing shading losses caused by uneven terrain. By March 2024 the overall power generation gain had reached 2.21%, with a gain of 9.15% on typical cloudy days and 2.87% on typical sunny days.

SuperTrack Boosting Solar Performance - Typical Cloudy Day (October 31st)





SuperTrack Boosting Solar Performance - Typical Sunny Day (January 24th)



UL Solutions has verified the demonstration setup and power generation data, recognizing the power generation gains achieved by SuperTrack.



“Our independent review of the Campiña experiment data shows a 2.21% positive bias towards the SuperTrack test group.”

–Ding Yifeng, Renewables, Software & Advisory, China Country Lead



Tongchuan, China

The empirical station is located in Tongchuan, Shaanxi province, China, and uses bifacial modules and a single-axis tracking system.

The comparative experiment began in May 2020, with some arrays still using conventional tracking algorithms and comparison arrays integrating the SuperTrack smart algorithm. The shading ratio of the arrays was about 33%. The tests were conducted continuously for a year, showing that the power generation of the smart algorithm arrays was improved by 3.06%. CGC monitored the empirical project throughout the process, validating the accuracy and effectiveness of the data and recognizing the advances and reliability of SuperTrack.

Comparison of the equivalent power generation hours and power generation gains for different months in the Tongchuan project



Actual photos of shading scenarios during the backtracking phase: comparison between conventional tracking arrays and SuperTrack arrays.



Real-life images of the uneven terrain at the Tongchuan project site show shading and light leakage issues in conventional tracking arrays. The SuperTrack arrays optimize backtracking angles for each row based on the terrain conditions, effectively avoiding shading while minimizing light leakage, thereby improving power generation during the backtracking phase.

Comparison of SuperTrack arrays and conventional tracking arrays on a typical cloudy day



On cloudy or rainy days, conventional tracking arrays continue to rotate based on traditional astronomical algorithms. In contrast, SuperTrack arrays adjust the tilt angle of the tracker according to weather conditions, positioning it at a smaller angle to capture more diffuse irradiance and improve power generation. On typical cloudy or rainy days the daily power generation gain can be as much as 12.86%.



Leading the way
in smart PV and energy storage solutions

Trinasolar



*TrinaTracker reserves all the right for
the final explanation

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