White Paper on SDS Intelligent Joint Control Technology for Inverters and Trackers

Jointly issued by: National Energy Key Laboratory for Wind and Solar Simulation, Testing and Certification, China General Certification Center, and Huawei Technologies Co., Ltd.

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Preface

C urrently, the smart DC system (SDS), an intelligent joint control technology for inverters and trackers developed by Huawei Technologies Co., Ltd. (hereinafter referred to as "Huawei"), has entered the large-scale application phase. Entrusted by Huawei, China General Certification Center (CGC) has carried out a comprehensive review and verification of the SDS to verify its technical performance and application effect. Based on the review and verification results, the **National Energy Key Laboratory for Wind and Solar Simulation, Testing and Certification**, CGC, and Huawei jointly released the *White Paper on SDS Intelligent Joint Control Technology for Inverters and Trackers*. This white paper describes the development background, technical features, and application effects of the SDS in detail, helping the industry comprehensively and deeply understand the technology.

01

Technology Development Background

Continuously improving the efficiency of PV power systems is a sedulous pursuit in the industry. For this purpose, at the device end, the main goal is to improve the optical-to-electrical conversion efficiency of PV modules and reduce the energy loss of other devices. At the system end, the main goal is to increase the radiation received at the surface of the PV modules and reduce the efficiency loss.

In recent years, the efficiency improvement achievements at the device end are remarkable, but there is not much room for improvement.

The industry has shifted the focus on the system end. The application percentage of various technologies, especially the tracking technology, is increasing, aiming to improve the radiation received by the PV module surface. Figure 1-1 shows the application percentage of trackers in bases of the second and third phases of PV Forerunner, a PV demonstration project initiated by National Energy Administration, in China. The figure indicates that the application percentage of trackers increased significantly in the third batch of bases. In addition, according to the data released by GTM, the shipments of trackers in 2017, 2018, and 2019 increased by 34%, 36%, and 66% year on year. In 2019, the global shipment of trackers was about 35 GW.
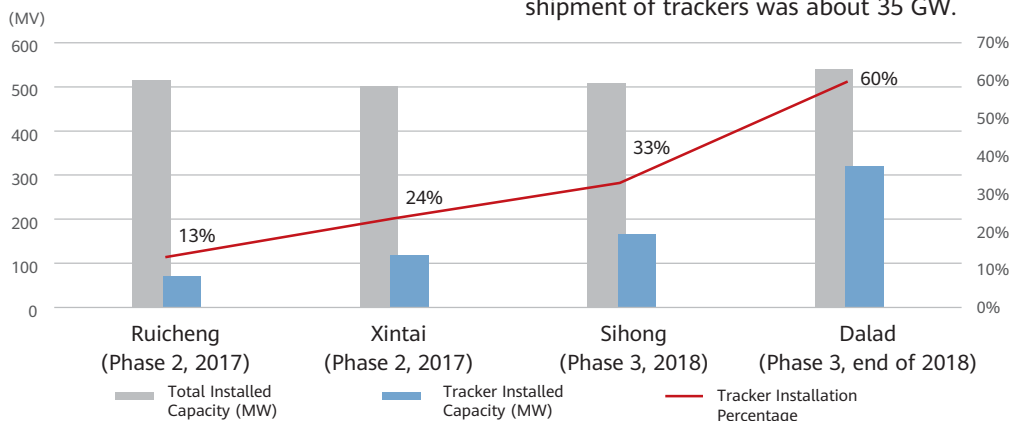

Figure 1-1 Comparison of application scale and percentage of trackers in the second and third batches of PV Forerunner bases (partially)

The trackers have been used for a long time, but the following issues may also exist in actual applications:

(1) Most tracking system algorithms are provided by the tracker manufacturer.

Traditional astronomical algorithms are used, in which the impact of terrain conditions, blocking in the morning and evening, and weather changes is not fully considered. Due to miscalculations of the optimum tracking angle, energy yield loss may occur in some time periods and in special weather conditions. Figure 1-2 and Figure 1-3 show the examples.
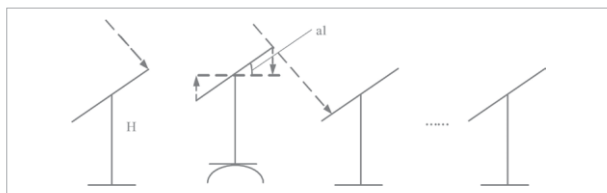

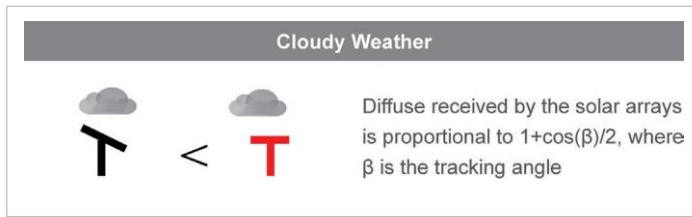Figure 1-2 Examples of shading between arrays in special areas and in the morning and evening

Figure 1-3 Difference of received radiation at
different angles on cloudy weather

(2) To solve the problems in common astronomical algorithms, the backtracking technology is used in the industry. However, the tracker angle control is relatively independent and is not associated with the I-V perception or change of the PV strings or control units. Therefore, refined adjustment or precise control cannot be implemented.

(3) In recent years, the power generation technology using the combination of trackers and bifacial PV modules has become one of the mainstream forms. This kind of system needs to dynamically adjust the control policy according to the change of external conditions. Figure 1-4 compares the daily cumulative radiation of the front and rear sides of a random 15-day period selected from the 3-month monitoring data of the CGC Inner Mongolia empirical research system (horizontal single axis and bifacial PV module power generation).

As shown in Figure 1-4, the ratio of the radiation received from the front side to that from the rear side varies greatly due to the weather. In special weather conditions, the daily accumulated radiation on the rear side is even higher than that on the front side. This means that the angle of the PV modules needs to be dynamically optimized and adjusted based on the weather conditions for the bifacial tracking power generation system, maximizing the control unit output.
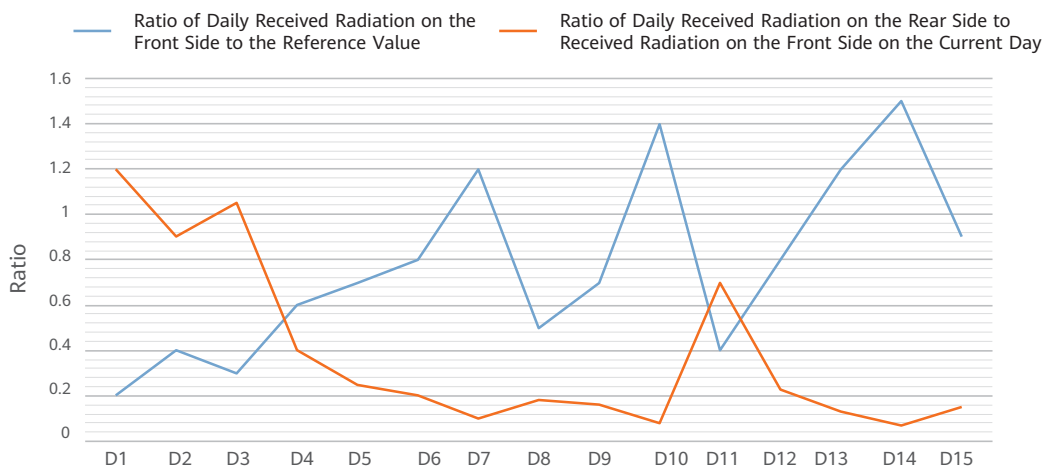

Figure 1-4 Comparison of daily accumulated radiation on
the front and rear sides (horizontal single axis)

As mentioned above, with the improvement of reliability and cost-effectiveness, the application percentage of the trackers, including the power generation technology using the combination of trackers and bifacial PV modules, will gradually increase.

To solve the issues in the application of the trackers, the big data and AI technologies are used to optimize the inverter and tracker control linkage, further improving the increase effect of the trackers. This has become one of the development directions of the tracking technology.

02

Technology Description

Figure 2-1 and Figure 2-2 show the SDS block diagram, and logical block diagram of algorithm design and angle optimization, respectively.

Figure 2-1 SDS block diagram

Figure 2-2 Logical block diagram of algorithm design and angle optimization
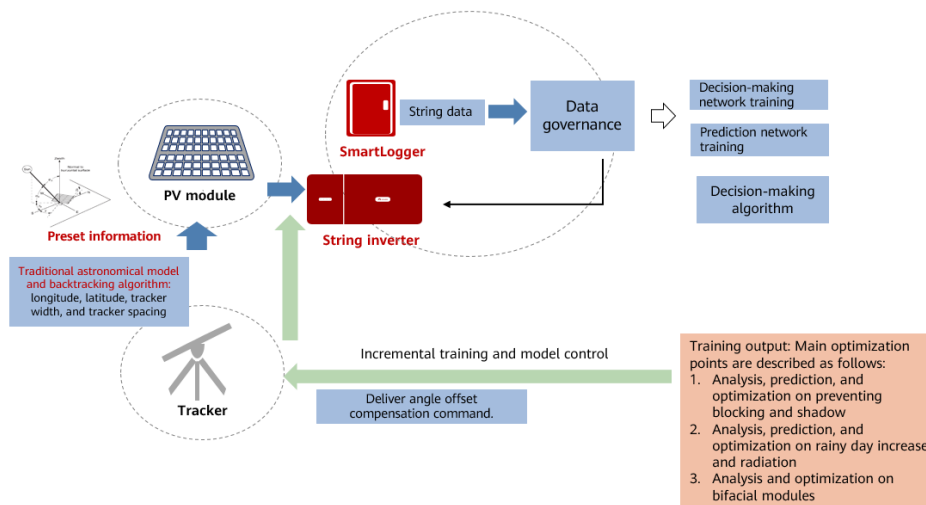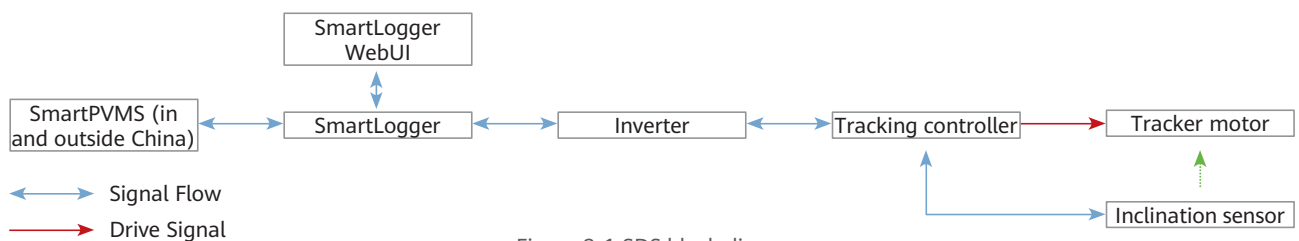
The SDS technology developed by Huawei has the following features:

(1) The inverter is linked with the tracker control system and performs closed-loop control to ensure that the system runs with the maximum radiation volume received by PV modules and optimal power output.

(2) No additional sensor device is required. AI technologies are used to automatically detect shading and weather changes and automatically optimize and control the tracking angle, eliminating manual operations and experience dependence.

(3) The inverter integrates the tracker communication and power supply functions and the tracker power supply cables and communication cables are reduced thanks to MBUS.

03

Technical Review and Application Effect Verification

To deeply understand the status and application effect of Huawei SDS, entrusted by Huawei, a CGC verification team was established to comprehensively verify and evaluate Huawei SDS from February to May, 2020.

Figure 3-1 shows a block diagram of the verification and evaluation process and contents.
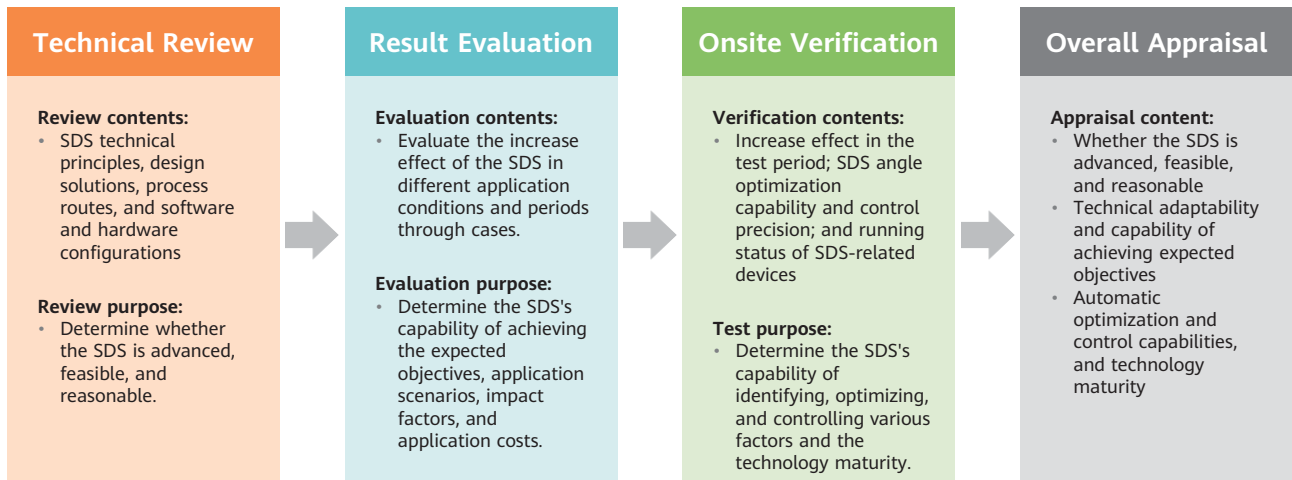
Technical Review	Result Evaluation	Onsite Verification	Overall Appraisal
Review contents: • SDS technical principles, design solutions, process routes, and software and hardware configurations **Review purpose:** • Determine whether the SDS is advanced, feasible, and reasonable.	**Evaluation contents:** • Evaluate the increase effect of the SDS in different application conditions and periods through cases. **Evaluation purpose:** • Determine the SDS's capability of achieving the expected objectives, application scenarios, impact factors, and application costs.	**Verification contents:** • Increase effect in the test period; SDS angle optimization capability and control precision; and running status of SDS-related devices **Test purpose:** • Determine the SDS's capability of identifying, optimizing, and controlling various factors and the technology maturity.	**Appraisal content:** • Whether the SDS is advanced, feasible, and reasonable • Technical adaptability and capability of achieving expected objectives • Automatic optimization and control capabilities, and technology maturity

Figure 3-1 Block diagram of the verification and evaluation process and contents

3.1 Technical Review

The SDS technology developed by Huawei is applicable to monofacial and bifacial power generation systems in tracking mode. This technology takes into account the factors that affect the maximum utilization of solar resources and the optimal power output under different time points, weather, topography, and installation conditions. By using the AI technology, the energy yield of the tracking system is further improved through the I-V perception of the inverter and the linkage and closed-loop control with the tracker control unit.

After the review, the verification team concludes that the SDS technology developed by Huawei complies with clear and specific technical principles, the technical solution is reasonable and feasible, the application cost is low, and the increase effect is obvious.

3.2 Long-Term Application Effect Verification and Evaluation

To verify the application effect of the SDS, two sample PV plants were selected from the PV plants where Huawei SDS technology was applied for demonstration, and were tracked for a long time. The two PV plants are located in Suixi County, Anhui Province (plant A) and Luchuan County, Guangxi Province (plant B) respectively. Plant A uses a bifacial horizontal single-axis tracking system, while plant B uses a monofacial horizontal single-axis tracking system.

Long-Term Application Effect Verification and Evaluation on Plant A

Figure 3-2 shows the PV plant panoramas, and Figure 3-3 shows the layout of the verification arrays.

Figure 3-2 PV plant panoramas
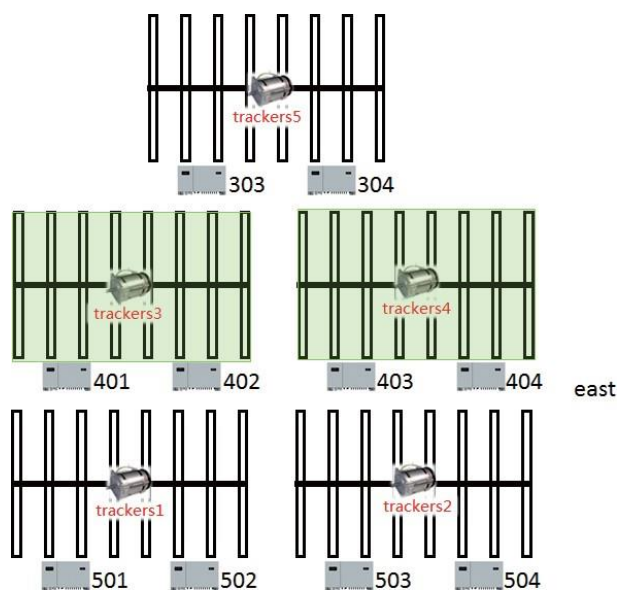
Note: The trackers of the inverters numbered 503 and 504 use the common algorithm, and the trackers corresponding to the inverters numbered 501, 502, 303, and 304 use the SDS algorithm. Inverters numbered 401, 402, 403, and 404 are not involved because they are installed in greenhouses and have different ground albedos.

Figure 3-3 Layout of the verification arrays

The project verification period is from July 2019 to June 2020. July 2019 is the performance deviation comparison test period between different arrays while the common algorithm is used. The differences of basic energy yields of arrays are collected as the reference baseline. The comparison and verification started in August 2019.

Figure 3-5 shows the monthly energy yield comparison of the arrays. Figure 3-6 shows the energy yield increase percentage of the SDS arrays after the performance deviation is corrected.

(kWh/kWp)

	July 2019 (History Baseline)	August 2019	September 2019	October 2019	November 2019	December 2019	January 2020	February 2020	March 2020	April 2020	May 2020	June 2020
SDS Algorithm (Average)	85.5	124.5	148.1	97.3	80.4	81.1	51.3	93.1	142.3	186.3	171.6	144.6
Common Algorithm (Average)	85.9	124.2	147.0	96.1	79.7	80.0	50.0	91.0	140.8	185.6	170.2	142.5

■ SDS Algorithm (Average)   ■ Common Algorithm (Average)
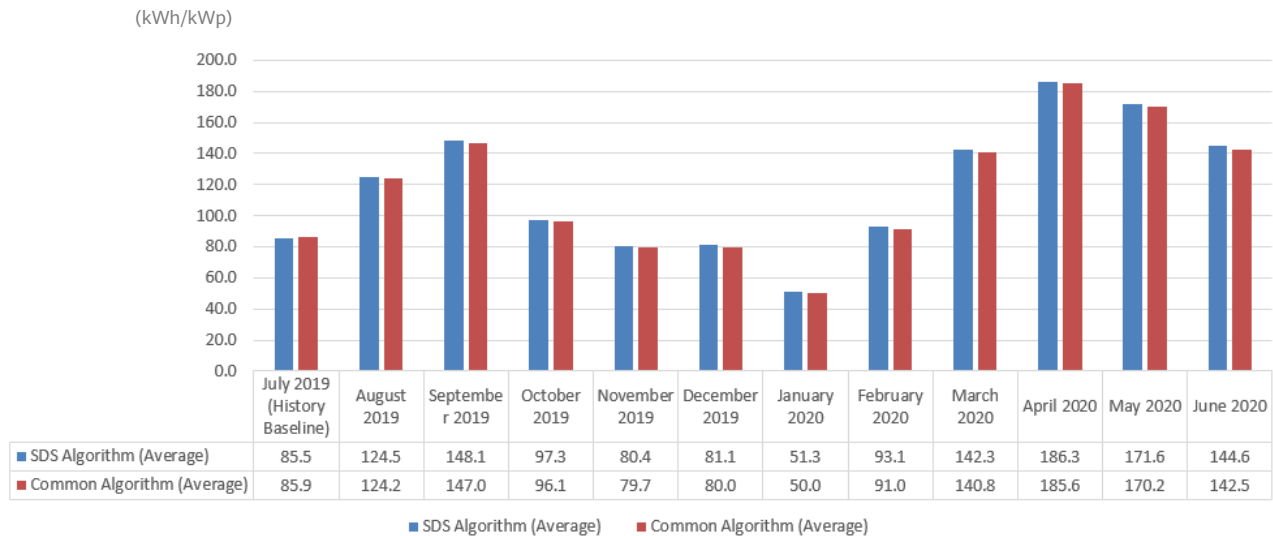
Figure 3-5 Comparison of specific energy per month between SDS arrays and common arrays

Calculation method for monthly energy yield increase:

Array energy yield after the SDS is used/Common array energy yield – Baseline energy yield difference before the SDS is used

During the entire verification period, the energy yield of the arrays using the SDS algorithm increases by 1.50%. In January 2020 when there are many rainy days and scattering occurs frequently, the energy yield of the SDS arrays increases by 3.09%. In addition, in the months with the smaller the solar elevation angle and the greater the proportion of scattering light, the more obvious the increase effect.
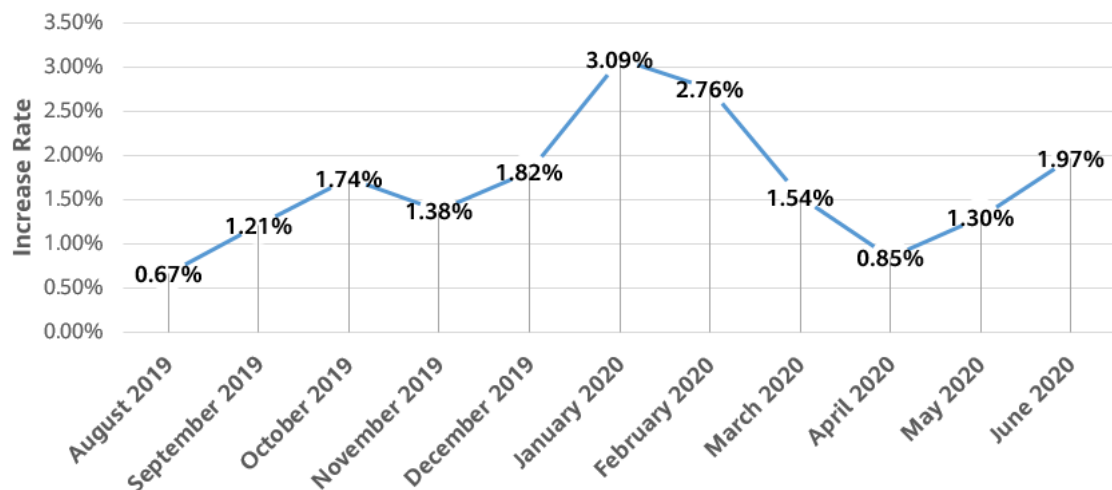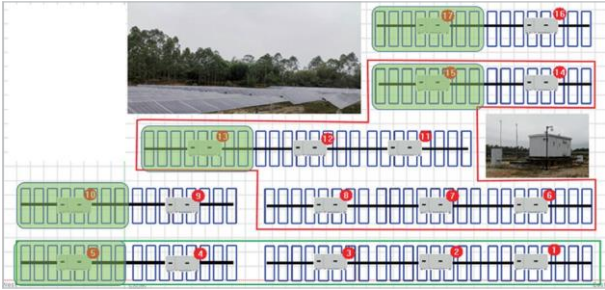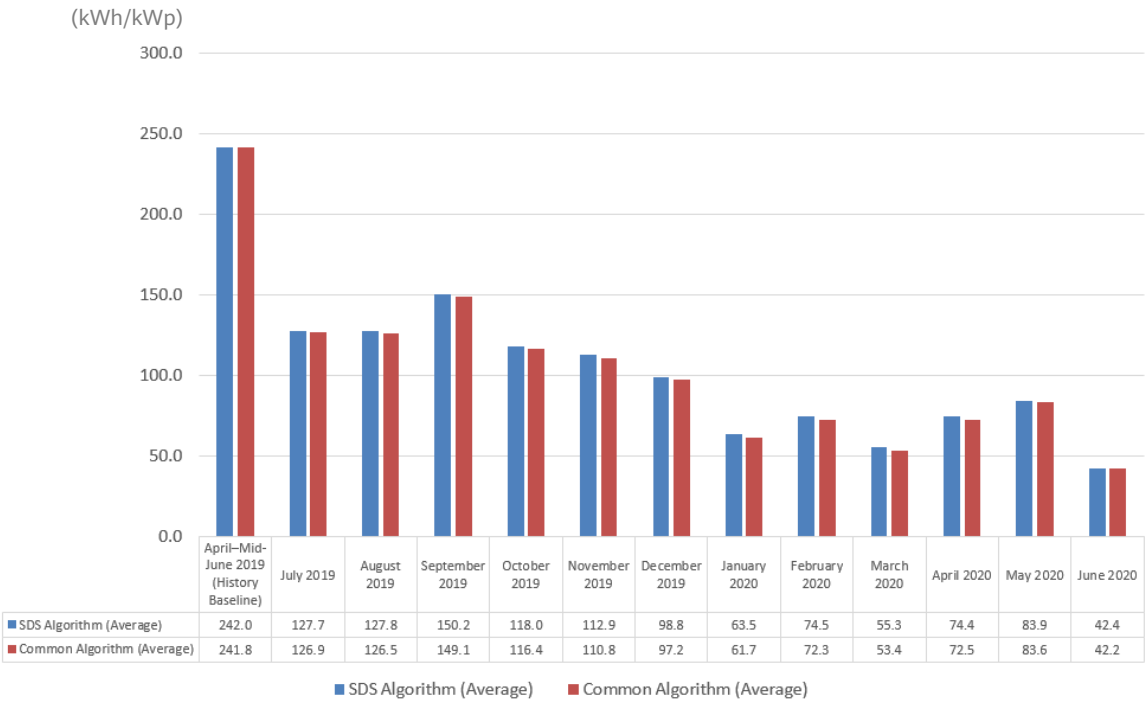
Figure 3-6 Monthly increase rate of the SDS arrays compared with the common arrays

Long-Term Application Effect Verification and Evaluation on Plant B

Figure 3-7 shows the PV plant panoramas, and Figure 3-8 shows the layout of the verification arrays.

Note: The trackers of the inverters numbered 1, 2, 3, 4, 9, and 16 use the common algorithm, and the trackers of the inverters numbered 6, 7, 8, 11, 12, and 14 use the SDS algorithm.

Figure 3-7 PV plant panoramas

Figure 3-8 Layout of the verification arrays

The project verification period is from April 2019 to June 2020. April to June 2019 is the performance deviation comparison test period between different arrays while the common algorithm is used. The comparison and verification started in July 2019.

Figure 3-9 shows the monthly energy yield comparison of the PV arrays. Figure 3-10 shows the energy yield increase percentage of the SDS arrays after the performance deviation is corrected.

(kWh/kWp)

	April–Mid-June 2019 (History Baseline)	July 2019	August 2019	September 2019	October 2019	November 2019	December 2019	January 2020	February 2020	March 2020	April 2020	May 2020	June 2020
SDS Algorithm (Average)	242.0	127.7	127.8	150.2	118.0	112.9	98.8	63.5	74.5	55.3	74.4	83.9	42.4
Common Algorithm (Average)	241.8	126.9	126.5	149.1	116.4	110.8	97.2	61.7	72.3	53.4	72.5	83.6	42.2

■ SDS Algorithm (Average) ■ Common Algorithm (Average)

Figure 3-9 Comparison of specific energy per month between SDS arrays and common arrays

Calculation method for monthly energy yield increase:

Array energy yield after the SDS is used/Common array energy yield – Baseline energy yield difference before the SDS is used

During the entire verification period, the energy yield of the arrays using the SDS algorithm increases by 1.43%. In March 2020 when there are many rainy days and scattering occurs frequently, the energy yield of the SDS arrays increases by 3.58%. In addition, in the months with the smaller the solar elevation angle and the greater the proportion of scattering light, the more obvious the increase effect.
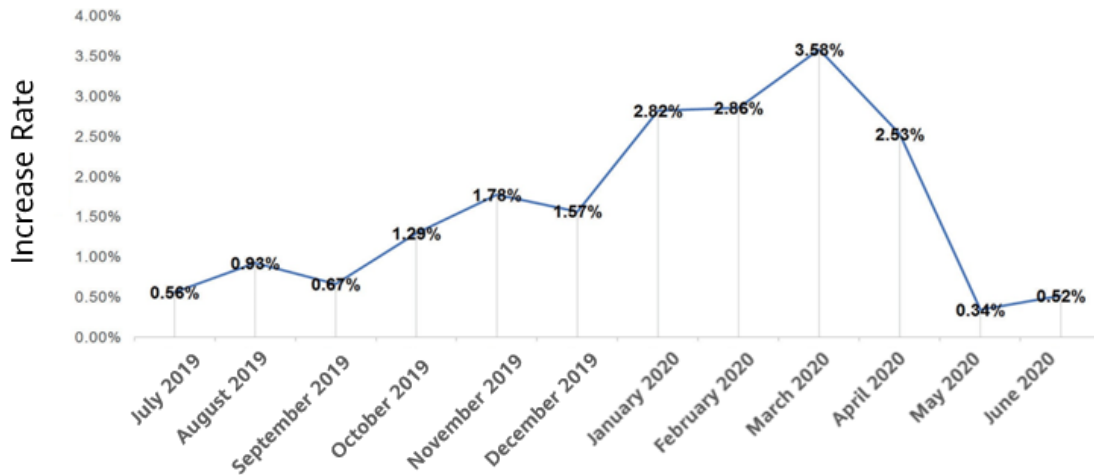
Figure 3-10 Increase rate

3.3 Onsite Verification

To further verify the increase effect and mechanism of the SDS, plant A is tested based on the relationship of "Angle – Radiation – Operating current – Output power". A detection team dispatched by CGC performed onsite comparison tests of the increase factors from September 16 to 23, 2020.

The onsite test scenarios include two weather conditions: sunny and rainy. The following figure shows the sample units selected during the test. The units marked in red are SDS units, and the units marked in yellow are common units. The comparison test data of motor 5 (SDS) and motor 2 (common) is used for scenarios 1 and 2.

Note: The greenhouse area is not involved.
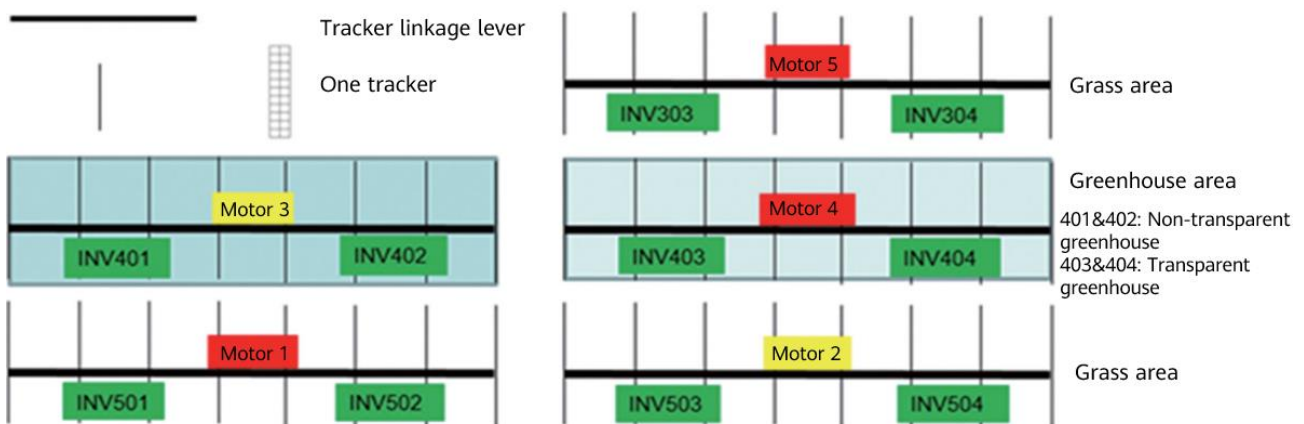
Scenario 1: sunny days

Verification focus: SDS control policy and effect for time-specific shading between arrays

Figure 3-11 shows the weather conditions of the current day and the inter-array and time-specific shading between common arrays.

Figure 3-11 Weather conditions and time-specific shading between arrays

Figure 3-12 shows the position of the irradiation sensor for monitoring.
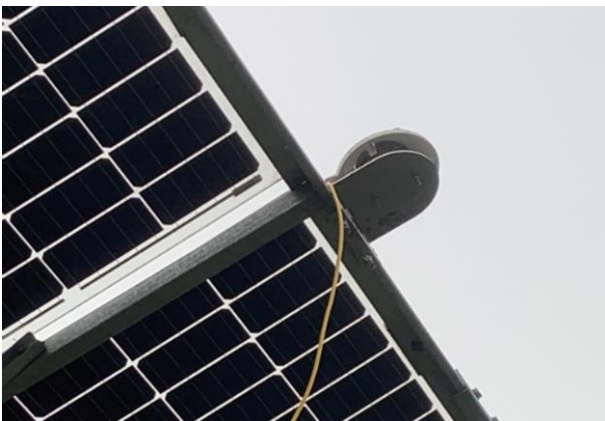
Figure 3-12 Position of the irradiation sensor

Figure 3-13, Figure 3-14, Figure 3-15, and Figure 3-16 show the trend of changes of SDS array and common array tracker angles, irradiance on the tilted surfaces (front + rear sides), and array output power in different time periods based on the monitoring results within 18 days (whole days).
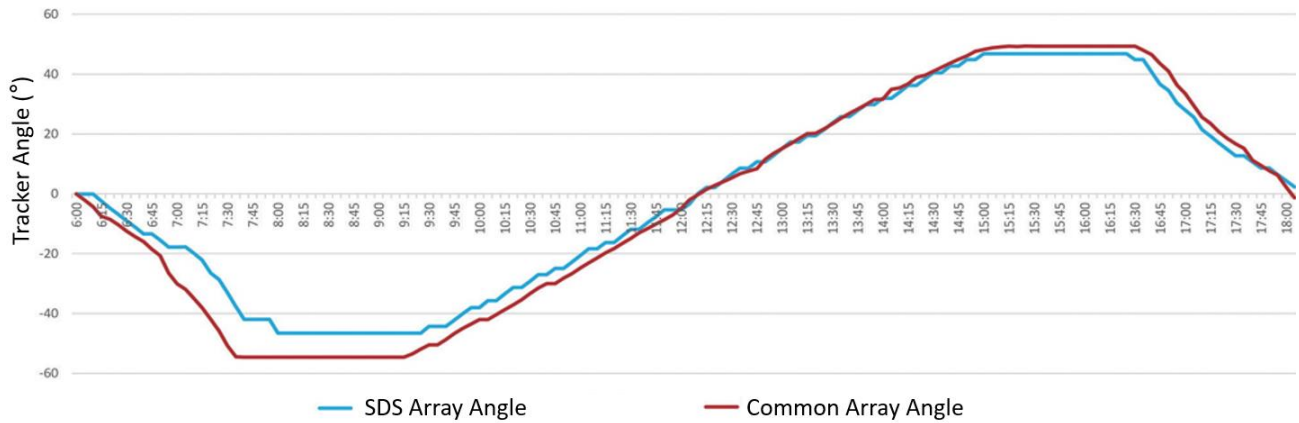
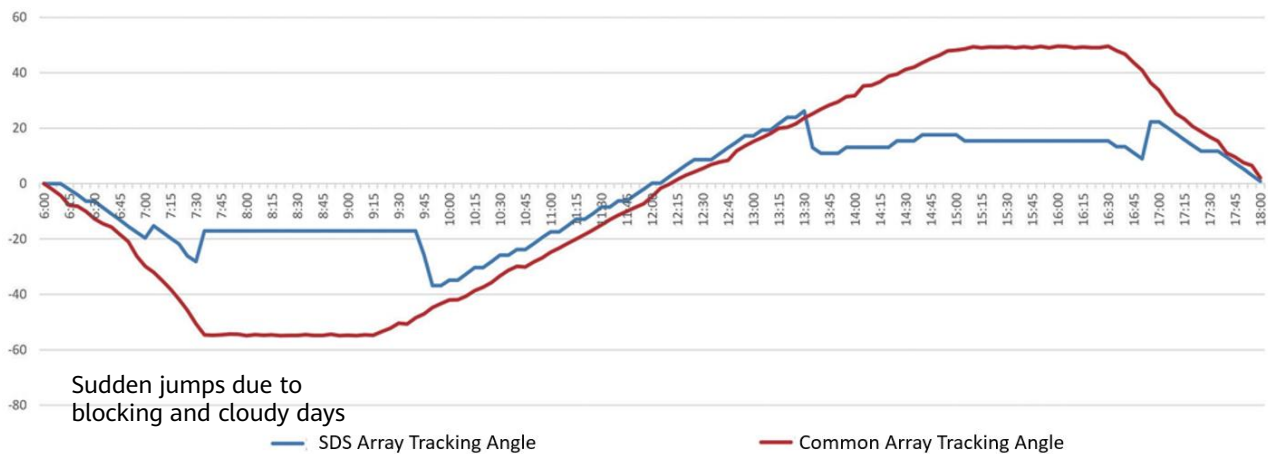Figure 3-13 Comparison of tracker angles
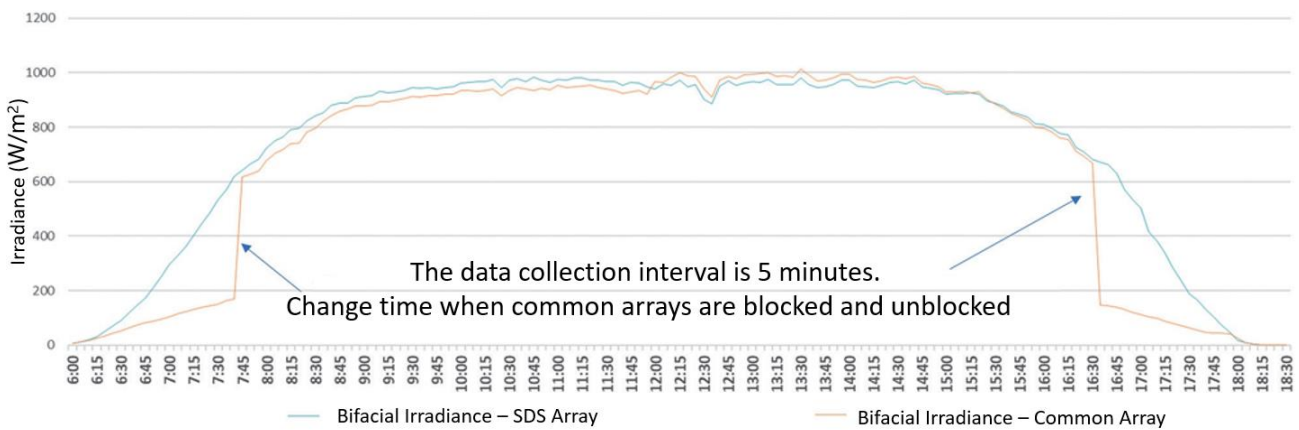
Figure 3-14 Comparison of irradiance between SDS arrays and common arrays (front + rear sides)
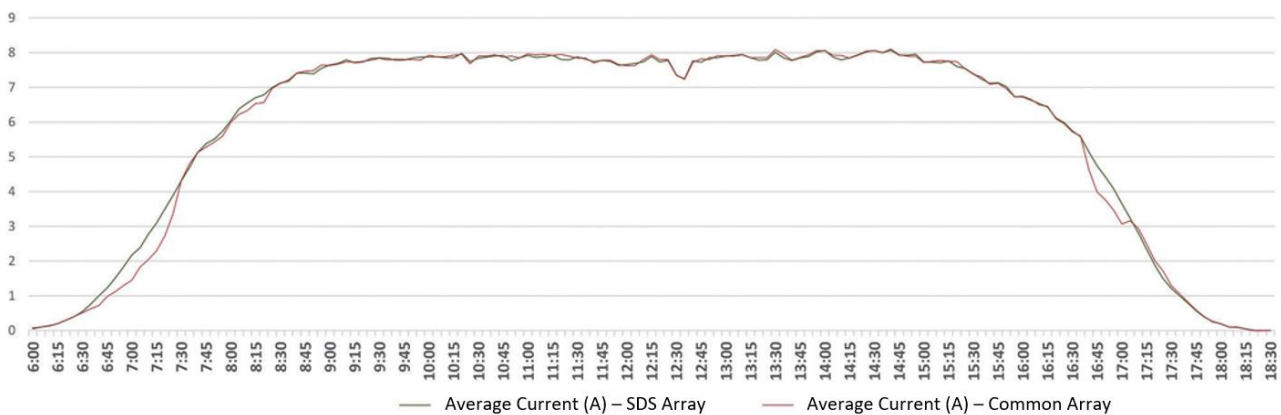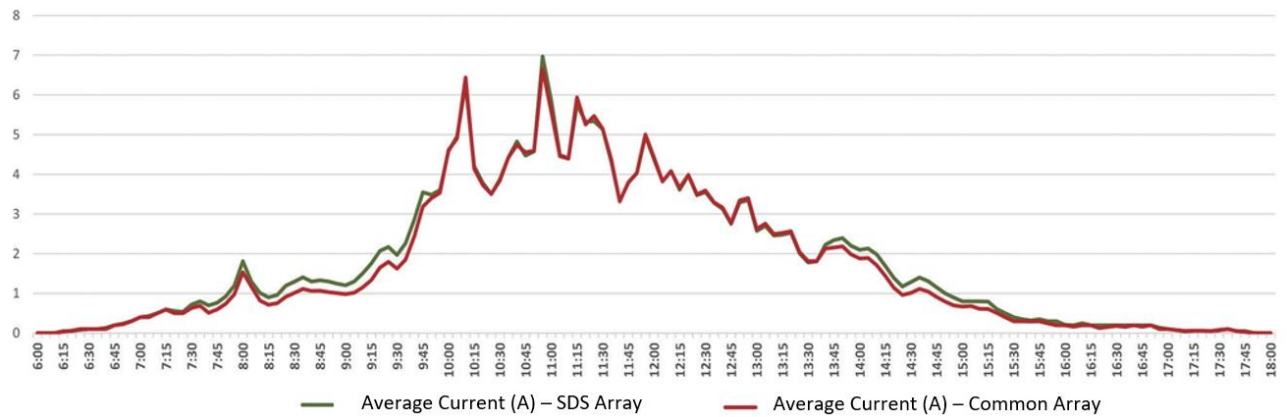
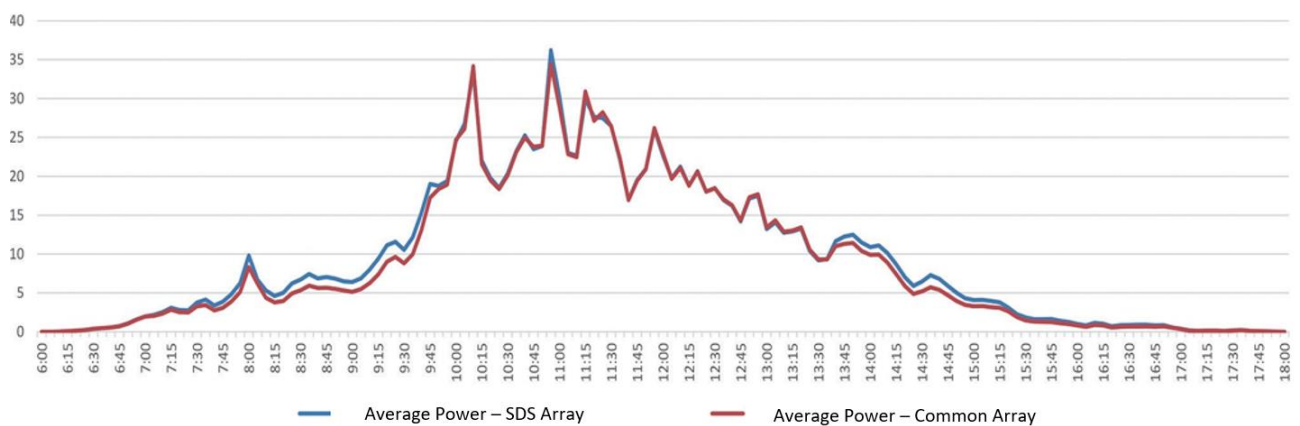Figure 3-15 Comparison of the operating current (average value) between SDS arrays and common arrays
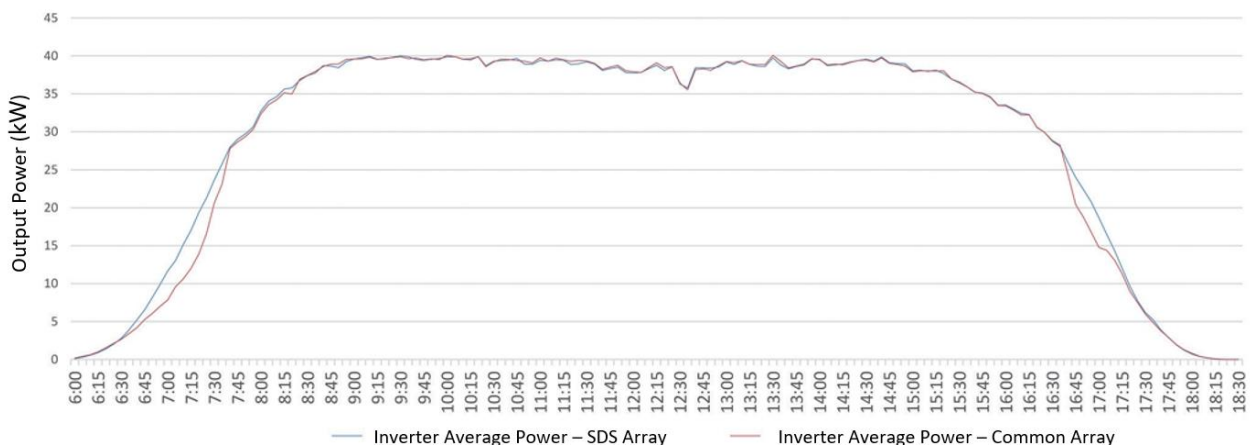
Figure 3-16 Comparison of inverter average output power between SDS arrays and common arrays

As shown in the preceding figures, **the SDS avoids inter-array shading by adjusting the tracking angle in the morning and evening. Compared with common arrays, in a corresponding time period, the irradiance on the tilted surfaces, branch average operating current, and array output power of the SDS arrays are improved, and changes of different parameters are highly consistent. This indicates that the SDS can improve the received irradiance on the tilted surfaces by optimizing the tracking angle in sunny weather conditions, thereby improving the operating current of the PV strings and the output power of the arrays.**

Figure 3-17 shows the comparison of the accumulated energy yields of inverters on the current day between SDS arrays and common arrays. According to the statistics, **the energy yield gain rate of the SDS arrays is 1.58% on the whole day. The energy yield gain rate is 6.86% from startup time to 9:00, and is 11.69% from 16:30 to shutdown time. This indicates that the energy yield gain is mainly reflected in the morning and evening in sunny days.**
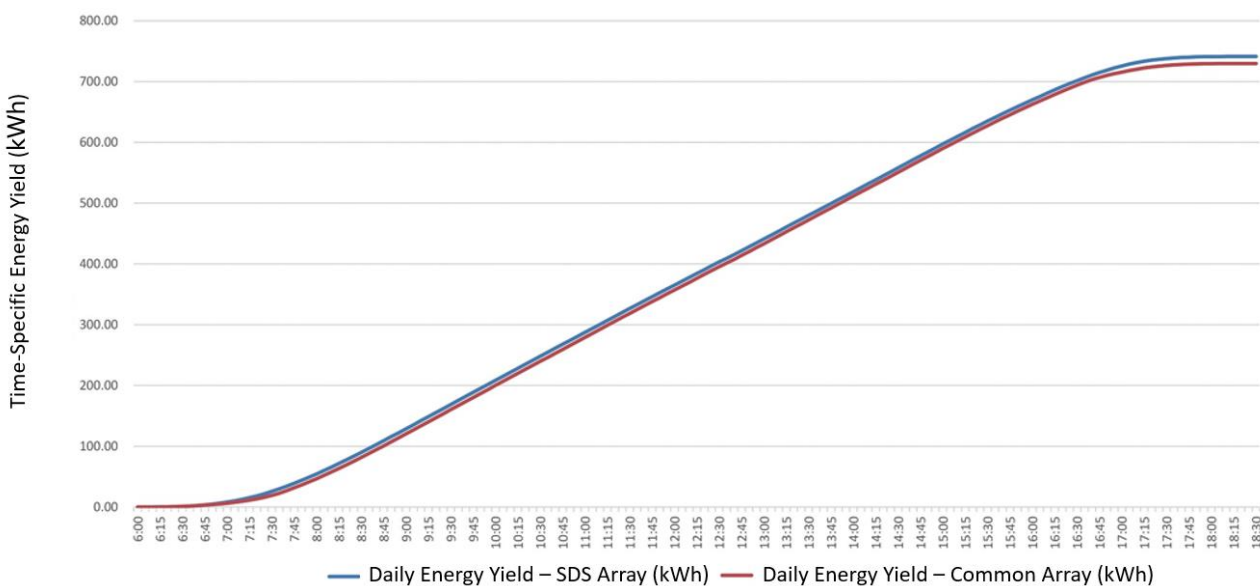
Figure 3-17 Comparison of accumulated energy yields between SDS arrays and common arrays

Scenario 2: rainy days or days when scattering frequently occurs

Verification focus: control policies and effects of the SDS on this kind of weather Figure 3-18 shows the weather of the current day.

Figure 3-18 Weather

Figure 3-19, Figure 3-20, Figure 3-21, and Figure 3-22 show the trend of changes of SDS array and common array tracker angles, irradiance on the tilted surfaces (front + rear sides), and array branch

operating current (average value), and array output power in different time periods based on the monitoring results within 21 days (whole days).

Sudden jumps due to blocking and cloudy days

— SDS Array Tracking Angle   — Common Array Tracking Angle

Figure 3-19 Comparison of tracking angle between SDS arrays and common arrays
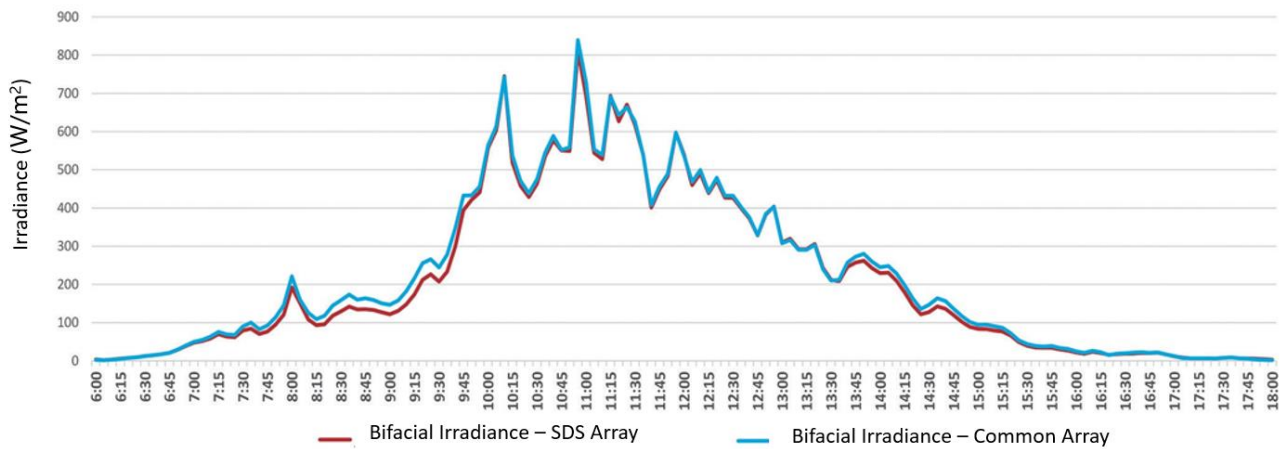
Figure 3-20 Comparison of irradiance on the tilted surfaces (front + rear sides) between SDS arrays and common arrays

Figure 3-21 Comparison of the operating current (average value) between SDS arrays and common arrays

Figure 3-22 Comparison of the inverter power (average value) between SDS arrays and common arrays

As shown in the figures, **the SDS optimizes and adjusts the tracking angle for all time in rainy days or days when scattering frequently occurs. Compared with common arrays, the irradiance on the tilted surfaces , branch average operating current, and array output power of the SDS arrays are improved in multiple time periods, and changes of different parameters are highly consistent. This indicates that the SDS can improve the received irradiance on the tilted surfaces by optimizing the tracking angle in this kind of weather conditions, thereby improving the operating current of the PV strings and the output power of the arrays.**

Figure 3-23 shows the comparison of the accumulated energy yields of inverters on the current day between SDS arrays and common arrays. According to the statistics, **the energy yield gain rate of the SDS arrays is 5.10% on the whole day. Compared with common arrays, the energy yield gain ratio of the SDS arrays is increased in multiple time periods.**
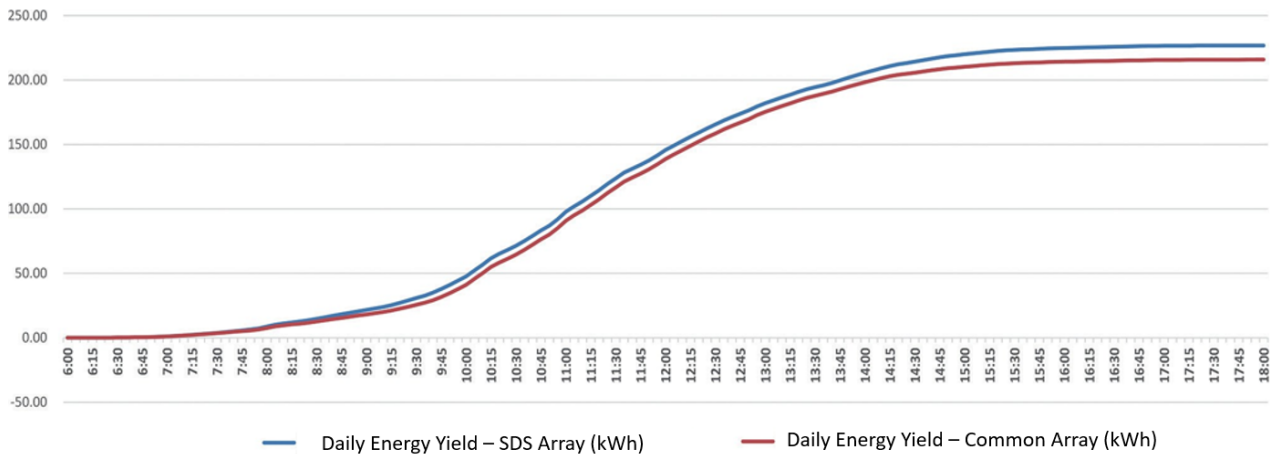
Figure 3-23 Comparison of the accumulated energy yields of inverters between SDS arrays and common arrays

3.4 Overall Appraisal

Based on the technical review and verification results,

(1) The SDS technology developed by Huawei has been verified for a long time and has entered the large-scale application phase. It can be widely used in PV power systems that use trackers. This technology makes full use of the core function of the inverters. The solution used is designed based on the logical framework of "comprehensive monitoring or perception of environment and operating parameters – Optimal tracking angle – Maximum and balanced received radiation – Optimal output parameters". The closed-loop control with the tracker control unit solves the deficiencies in the prior art, and further improves the technical efficiency of the trackers.

(2) The technical solution adopted by the SDS is scientific and reasonable, and has obvious operation effect. According to the comparison and verification results of the two sample plants in the past year, the SDS increase rate reaches 1.50% and 1.43% respectively. Based on the short-term comparison test results, the SDS can implement the design function of automatic monitoring or perception, and automatic optimization and control. The control and operation effects meet the expectation, especially in the early morning, evening, and special weather conditions.