Solar PV-Energy Storage Empirical Test Platform

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PART 01

Research Background

Background

The development and construction of photovoltaic power stations in the world are fast, but relevant technologies are still being explored.

- The new equipment and materials with rapid development are all subject to laboratory analysis and evaluation, and there is no means and methods for site empirical test analysis;
- The instruments, methods, and precision required for on-line operation inspection and measurement and performance evaluation methods, equipment layout schemes required for the actual operation of the key equipment of large-scale grid-connected photovoltaic power generation system are still under research. The methods for data comparison analysis and performance evaluation on actual operation are restricted, resulting in it impossible to carry out scientific and effective evaluation on existing photovoltaic power stations.
- Therefore, it has become a global consensus to vigorously develop renewable energy and accelerate energy transformation by promoting clean and low-carbon energy.

The development potential of the photovoltaic + energy storage industry is huge. The construction of photovoltaic empirical test platform and the outdoor empirical test and inspection of PV and energy storage key equipment, products, and systems can provide scientific test and comparison data support for the actual application effect of new technologies, new products, and new solutions, and provide a scientific basis for the formulation of global industrial policies and technical standards, and are of great significance for promoting the technological progress and industrial development of PV industry.

Significance

Significance:

(1) Facilitating the construction of demonstration area for comprehensive application of renewable energy and energy storage

(2) Facilitating the transformation and development of energy resource-oriented cities

(3) Accelerating the reduction of tariffs of new energy

(4) Facilitating the construction of empirical test area under innovative development modes of new energy

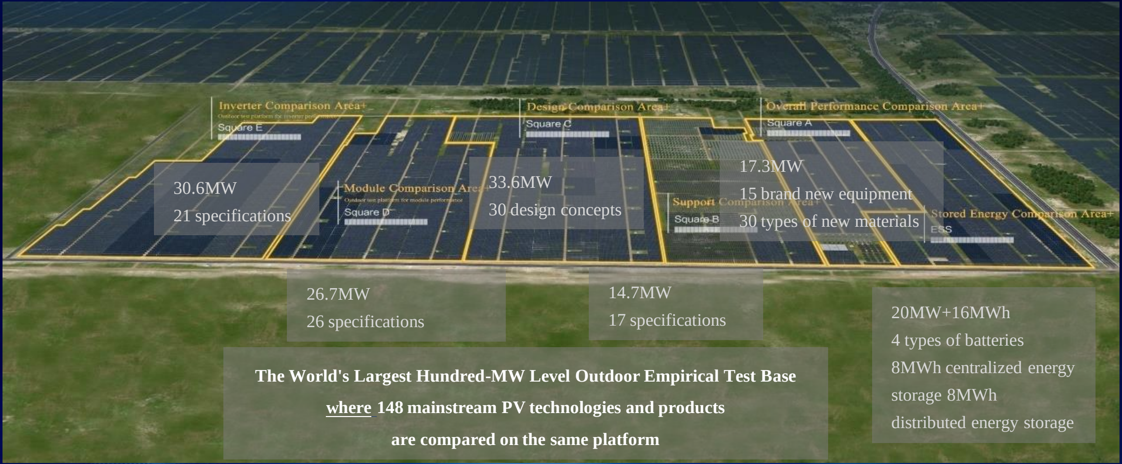
(5) Facilitating the empirical test of new technologies and products

(6) Facilitating research on demonstration effect of PV and ecological protection, PV and energy storage integration

PART 02

Innovative Research

Qinghai—Hundred-MW Level Photovoltaic Empirical Test Base

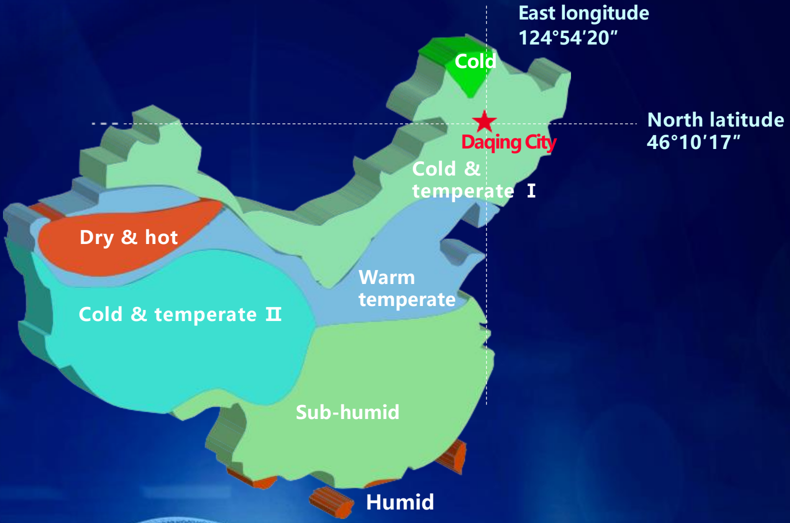


Daqing—Solar PV-Energy Storage Empirical Test Base

Cold & temperate climate

Flat land

High latitude



Daqing—Solar PV-Energy Storage Empirical Test Base

Four major functions:

◆ Basic and core empirical function

It is the basic and main function of the platform to carry out outdoor empirical test for PV and energy storage products.

The purpose is to carry out empirical comparison with laboratory data and manufacturers' data.

◆ Expanded experimental function

On the basis of product empirical test, outdoor experiments are conducted on new technologies and latest products of PV and energy storage to promote technological innovation and industrialization promotion and application.

Daqing—Solar PV-Energy Storage Empirical Test Base

Four major functions:

◆ Public and open testing function

Openly soliciting testing products and solutions for PV and energy storage for various objects such as designers, developers, manufacturers, etc.According to the needs of the industry, under the guidance of the relevant authorities to provide testing services.

◆ Market-recognized certification function

On the basis of continuous improvement of the empirical experiment function, enhance the market recognition, seek the support of relevant national management departments, promote the testing and certification of solar and energy storage products in due course, and create a market-recognized solar and energy storage product standards.

Platform Planning

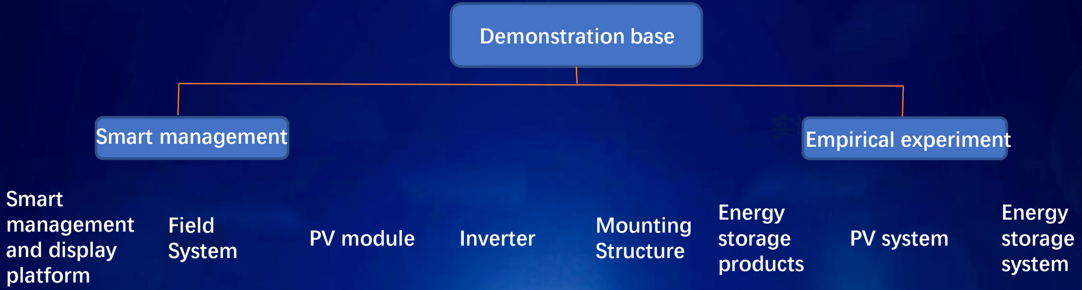
The platform is planned uniformly, implemented by stages and completed in five years. About 640 empirical test schemes were planned and arranged, and the converted scale is about 1050 MW.

At least 100 empirical test schemes are arranged every year to carry out demonstration, experiment, detection and certification for new technologies, new products, new materials and new design schemes.

Each year, 6 empirical test comparison areas are set up according to the technical progress of the year. Each area adopts the unified zoning coding principle. The number of each area is: X (I, II represent the empirical test area) -202x (represent the years).

Platform Phase I

- In the first phase, there are 6 comparison areas and 161 demonstration experiment schemes.
- 4 product demonstration areas: photovoltaic modules, inverters, mounting structures, energy storage products
- 2 System demonstration experiment Areas: photovoltaic system, energy storage system



The platform was approved in December 2020, started construction in April 2021, started operation in November of the same year, and started empirical work in January 2022.

Demonstration & Testing Scheme

Conducted hundreds of market researches and technical exchanges with domestic and foreign equipment manufacturers, scientific research institutions, testing institutions, industry associations, etc., and held more than 20 program demonstration meetings and expert consultation meetings

I-2021 Area Module	II-2021 Area Inverter	III-2021 Area Structure	IV-2021 Area Energy Storage Products	V-2021 Area Energy Storage System	VI-2021 Area Solar PV System
Manufacturers: 14 Modules types: 29	Manufactures: 6 Inverter types: 10	Manufactures: 7 Structure types: 21 Design&testing Schemes: 66	Manufactures: 7 Battery types: 8	6 kinds of energy storage system schemes	42 kinds of solar PV system schemes
Technical Route: P-PERC / N-TOP Con / N-HIT / N-IBC / Perovskite **Sizes:** 210/182/166/162/158 **Cell Packaging:** Half/ 3Cut/ Triangular Ribbon **Module Versions:** 110/120/132/144/150/1556	**Technical Route:** Centralized Distributed Strings **Different Devices:** Domestic IGBT / Carborundum Devices **Power (kW):** 175 / 196 / 225 250 / 3125 / 3250	**Structure Type:** Fixed structure with different angle / Fixed structure with regulable angle / Flat single-axis / Inclined uniaxial / Biax / Vertical single-axis / Fexibility / All dimensions **Schemes:** Height/Angle/Spac areae/ Layout / Pnom /Area	**Energy Storage Type:** Lithium ternary/ Lithium iron phosphate / All-Vanadium redox flow / Lithium Titanate / Supercapacitor / Flywheel * 2 / Hybrid Capacitor	Hybrid Energy Storage System Singular Battery Energy Storage System	Fixed Structure+ Various Inverters + Various Modules **Total : 34 Schemes** Flat Single-Axia + Stings Inverter+ Various Modules **1 Scheme** Fixed Structure+ Stings Inverter+ Various Modules **1 Scheme** PERC 182 + Srings+ Various Structures **Total : 6 Schemes**

Empirical Test Scope

- The demonstration and experiment of equipment combines vertical and parallel comparisons
- Vertical verification on whether the empirical results of the equipment in different outdoor application scenarios and operating environments meet the indicators and parameters guaranteed by supplier
- Parallel verification and comparison on the real performance of each equipment in different application scenarios and operating conditions

Modules

Compare the measured power, efficiency, degradation rate, temperature characteristics, spectral characteristics, weak irradiance performance, material aging characteristics with laboratory data, as well as the power generation characteristics in different application scenarios and different typical weather conditions of modules in outdoor conditions

Inverters

Compare the measured efficiency, MPPT tracking efficiency, overload capacity, IGBT operating temperature, fault duration, fault power loss, start-stop time, power quality, etc., with laboratory data, as well as the power generation characteristics in different application scenarios and different typical weather conditions of inverters in outdoor conditions

Mounting Structures

Compare the outdoor empirical power generation characteristics, irradiation characteristics, back-side reflectivity, power losses due to accumulated snow and dust, LCOE, etc. in different application scenarios and different typical weather conditions with the theoretical calculation results. The failure rate, tracking accuracy and tracking strategy are compared for the tracking system

BESS

Verify the applicability of different energy storage technologies in severe cold and high latitude regions, including the cell voltage consistency, temperature coherence, battery DC system efficiency, battery system (including PCS) efficiency, attenuation rate, cycle counts, depth of discharge, auxiliary power consumption, etc.

Empirical Test Scope

- The solar PV empirical test area focus on the solar generation system with test on overall integrated performances of different modules, mounting structures and inverters under real operating conditions.
- The BESS empirical test area is equipped with a solar+ BESS power generation system with 100% solar PV and energy storage equipment, which could meet the peak and frequency regulation demand of the power system.

Solar PV System

With modules, inverters and mounting structures as the basic comparison elements, and by researching and verifying various combination of different modules, inverters and mounting structures, the actual operating conditions and parameter tests of the solar system are carried out to verify the performance indicators of equipment under various operating conditions.

BESS System

Through the joint control of the solar and BESS system, the solar power generation characteristics, as well as the active support and output regulation capabilities of equipment can be improved, so that the solar+ BESS power station could be self-regulated, safer and stable, and gradually become one of the main power supply resources for the new power system, reducing the rotating reserve capacity of power system and realizing peak & frequency regulation on power supply side.

Test Equipment

Resources

7 *Categories*

19 *Types*

Test data

Environment

Electrical Performance

Mechanical properties

Test Equipment

One main and two auxiliary public weather stations

1 main weather station and 2 weather sub-stations, installing meteorological equipment such as all-sky camera equipment, irradiometer, UV irradiator, spectrometer, automatic solar tracker , Crystalline silicon reference wafers, etc., to collect and analyze the solar resources and environment of the platform in real time.

Real-time online measurement device

Online IV tester, temperature sensor, Crystalline silicon reference wafers, inverter monitoring box, power meter, etc. are installed on the modules, sink box, inverter and box transformer respectively to realize real-time monitoring and analysis of the whole system and loss of each section from modules to box transformer PV power plant throughout the day.

Test Methods

Combination of online + offline + lab testing

The online test system is mainly used, offline test and lab test are combined to achieve mutual calibration of accuracy and complementary testing.

Combination of public test + special test

Layout of public test equipment to ensure consistent test data, and according to the data analysis needs of each comparison area, layout the corresponding special equipment.

Consistent test conditions

Using a uniform standard set-up ， Insure consistent test boundary conditions and representative test data.

Test data continuity

The required test equipment is determined based on data analysis needs and designed with redundancy to ensure data continuity.

Lab test equipment

Inverter Sidewinder

Online IV Tester

Portable EL tester

Data Collection and Cleaning

Source of data

All data comes from the high-precision test equipment and system installed on the platform, and the test equipment is regularly calibrated by a third-party authority to ensure the authenticity of the collected data.

Frequency of collection

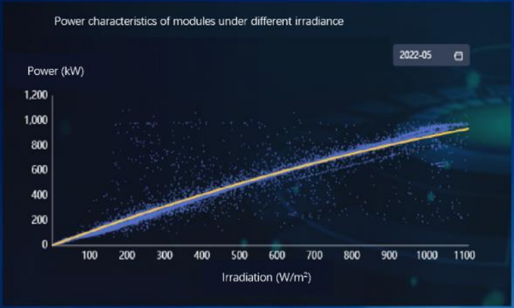
The frequency of data collection is in second, and the clocks of all test equipment are synchronized to ensure consistent data time.

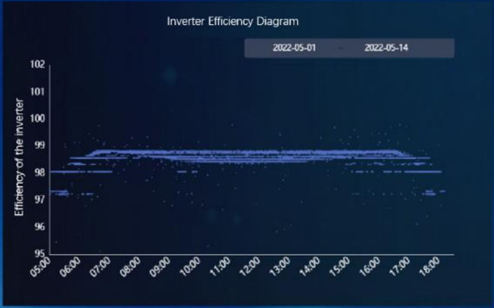
Data cleaning

Use threshold judgment, zero drift data judgment, horizontal data comparison, multi-dimensional data verification, etc. to judge and ensure the validity of the data.

Data Analysis

- Established more than 40 analysis models such as irradiation, temperature, spectrum, backside irradiation ratio, attenuation, etc. and more than 150 automatic analysis reports
- Real-time data collection, real-time online analysis, and automatic generation of analysis reports





PART 03

Achievements

Empirical Results Analysis

Different application scenarios (Different reflect, temperature scenarios), Different typical weather (Sunny, cloudy) 24 dimensions, the content was analyzed in combination with the empirical test comparison area, conduct empirical data comparisons, output 432 comparative data in total in the first quarter

Empirical analysis of power, temperature, voltage, power generation and other characteristics, formed 134 performance index charts.

Module Empirical Test area

- Different technical routes of modules
- Different sizes of cell modules
- Different versions of modules,etc.

Empirical analysis of inverter efficiency, temperature, overload capacity, start-stop time, power generation and other characteristics, formed 42 performance index charts.

Inverter Empirical Test area

- Different technical route of inverters
- Different manufacturers of inverters,etc.

Empirical analysis of irradiation, occlusion, emissivity, power generation and other characteristics, formed 152 performance index charts.

Mounting structures Empirical Test area

- Different types of mounting structures
- Different floor space
- Different ground heights
- Different separation distance,etc.

Empirical analysis of operating current, power, inverter efficiency, start-stop time, power generation and other characteristics, formed 104 performance index charts.

PV-System Empirical Test area

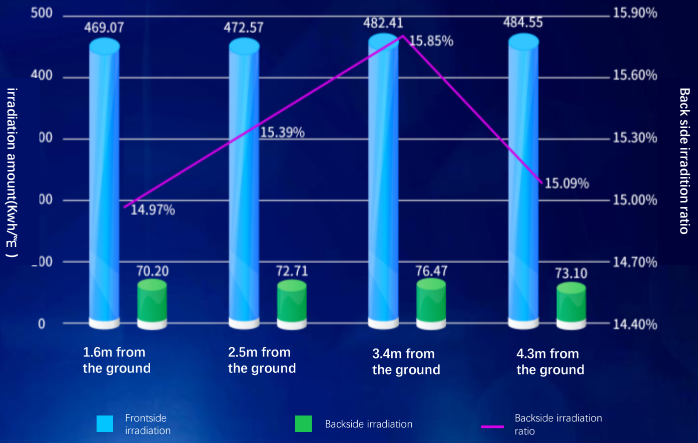
- Different modules match same inverters
- Same modules match different inverters
- Different modules match different inverters,etc.

Empirical Results Report

- Detailed empirical experimental technical results reports (quarterly, semi-annual and annual)
- Externally published reports on the results of empirical experiments (quarterly, semi-annual and annual)
- Produce special empirical data analysis reports for different user needs

Meteorological Empirical Results - Percentage of backside irradiation at different heights

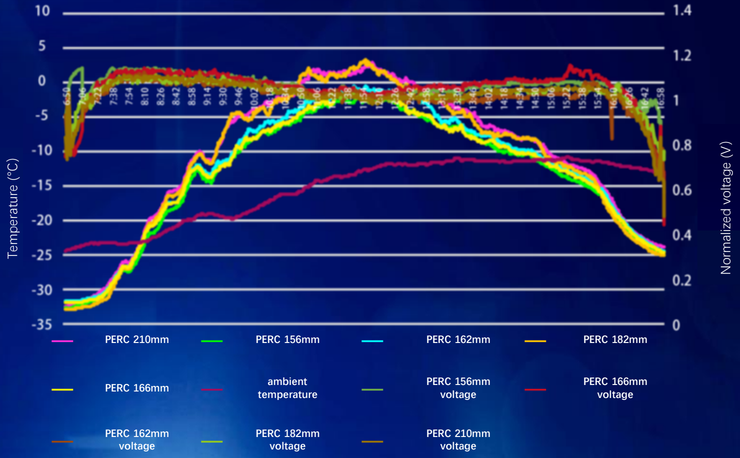
- Horizontal four-row arrangement (irradiometer height from the ground are 1.6m, 2.5m, 3.4m, 4.3m)
- The percentage of backside irradiation of each row was 14.97%, 15.39%, 15.85% and 15.09%
- There were differences in the percentage of backside irradiation of each row at different heights from the ground



Module Empirical Results - Module Operating Temperature and Operating Voltage

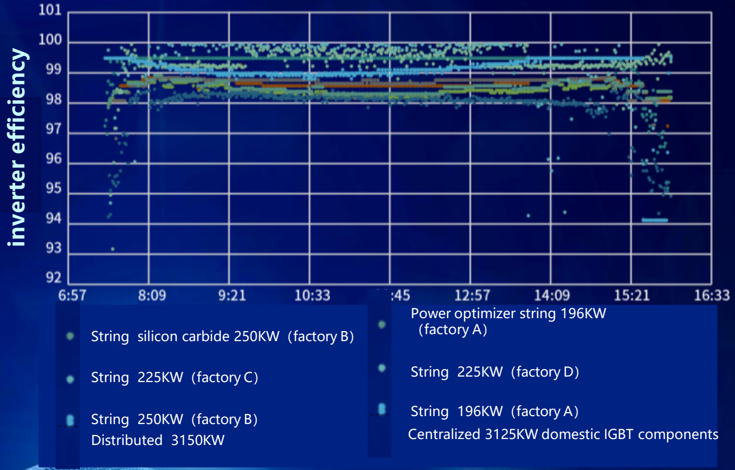
- The operating temperature of modules of different sizes is not very different, and the operating temperature of 210-size modules is slightly higher

- The operating voltage of different sizes of modules in the low temperature environment in the first quarter is higher than the nominal voltage



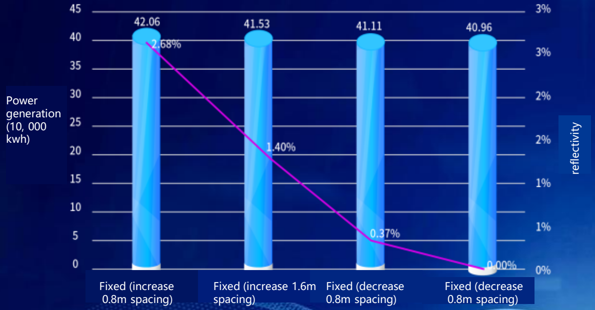
Inverter Empirical Results - Inverter Efficiency

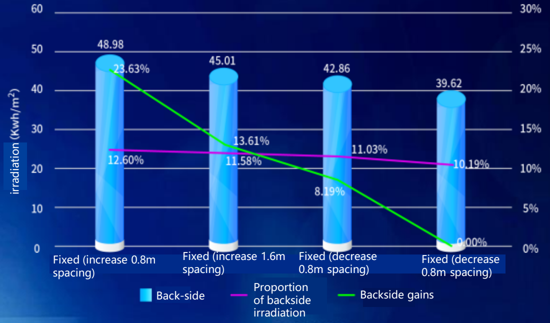
- The inverter efficiency of different technical routes is more than 98.5%, which is basically consistent with the manufacturer's laboratory data
- The inverter efficiency of string inverters is slightly higher than centralized and distributed inverters



Mounting Structures Empirical Results - Power generation and irradiation of fixed mounting structures at different space

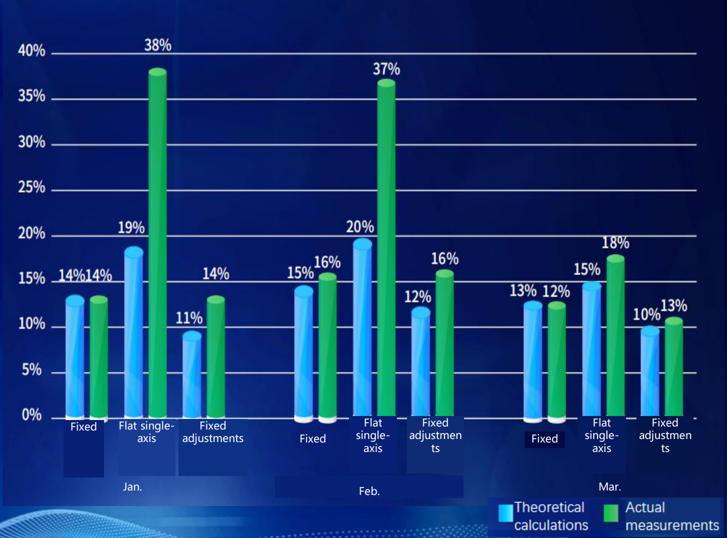
- Increasing the spacing of subarrays helps to improve the power generation of per megawatt of subarrays. And the power generation per megawatt after increasing the spacing by 0.8m is 2.68% higher than that by decreasing the subarray spacing by 1.6m in the first quarter.
- Backside irradiation and proportion of backside irradiation is different at different spacing. The larger the overall spacing, the higher the proportion of back-side irradiation





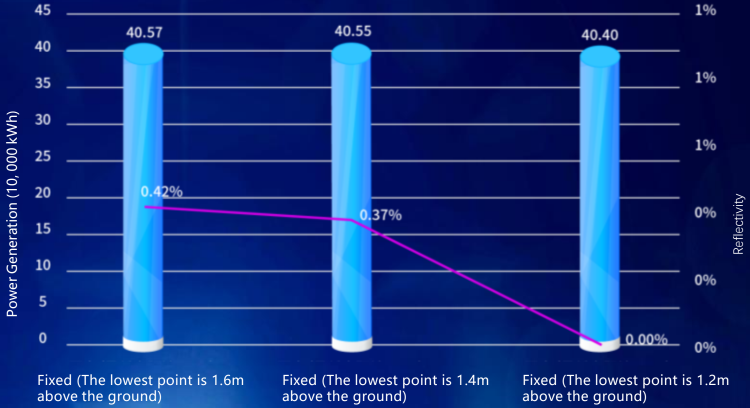
PV system Empirical Results – Theoretical calculations and actual measurements

- The difference between the measured backside irradiation gain of the Mounting Structure and the theoretical backside irradiation gain is large. With the large-scale application of tracking Mounting Structure, a set of software for calculating the power generation on the back of tracking Mounting Structure should be developed.



Mounting Structure Empirical Results - Power generation of fixed mounting structure at different heights from the ground

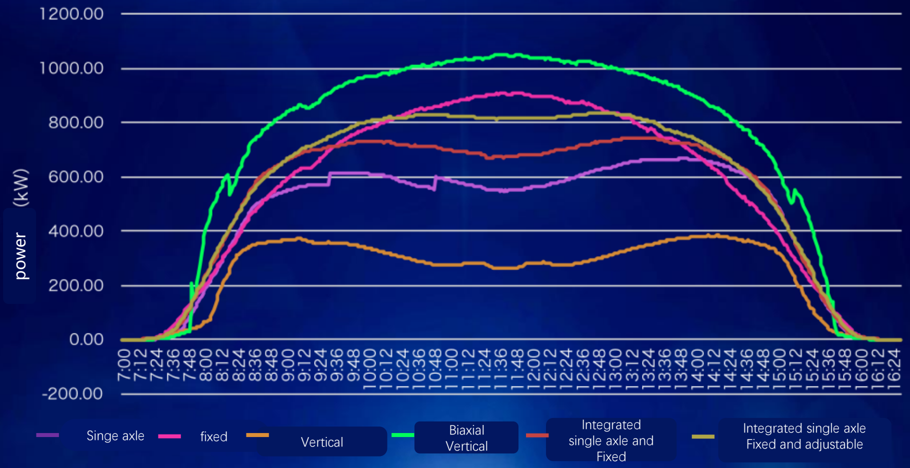
- **When the distance above the ground is 1.6m, the power generation is the highest,** which is respectively 0.05% and 0.42% higher than that at 1.4m and 1.2m.



Mounting Structure Empirical Results - Irradiation of fixed-mounting structure at different heights from the ground

- **Minor difference of frontside irradiation with different height**
- **Larger difference of backside irradiation with different height. The lower the height from the ground, the smaller the backside irradiation and the lower the backside irradiation ratio**

Solar System Empirical Results - Solutions for different types of mounting structure combinations



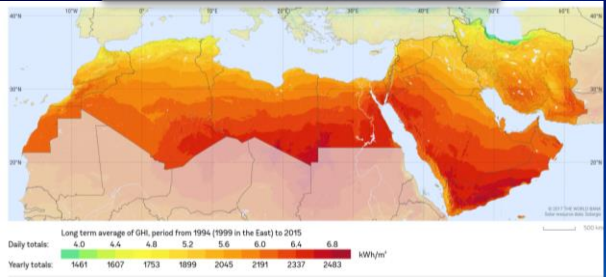
Solar System Empirical Results - Solutions for different types of mounting structure combinations

- Different power-output curve of the combined solutions
- Combined solutions lead by fixed-mounting structure, the result is a parabolic curve with single peak
- Combined solutions lead by flat single-axis with tracking, the result is a saddle-shaped curve with double peak
- Combined solutions lead by dule-axis with tracking system, the result is a flattened parabolic curve, the generation increased by 20% and MAX peak power-output increased by 15% compared with fixed-mounting structure
- Combined solutions with different mounting structures in the same array, the result is a flattened parabolic curve with single peak or flattened saddle-shaped curve with double peak, the generation increased by 3% and MAX peak power-output reduced by 9% compared with fixed-mounting structure

PART 04

Future Perspective

Feasibility of Developing Empirical Test Platform in Countries of League of Arab States



Good Resource Endowment and Great Development Potential

- The Arab League countries are rich in light resources and have great development potential;
- The Arab League countries are rich in land resources, and the scale of the Project can be considered to be hundred-MW level, thus providing a professional field empirical platform for the Arab League countries;
- The empirical experimental platform can focus on the world's most advanced photovoltaic technology and verify it in the Arab League countries, which is of great significance.

Significance of Developing Empirical Test Platform in Countries of League of Arab States

- It is suggested to build demonstration projects in the UAE and Saudi Arabia and other suitable countries or regions recommended by the Arab League to promote the research on regional photovoltaic technology innovation;
- The research results of demonstration projects are well representative and replicable in the Arab League countries and regions;
- Through long-term test and inspection, the system application comparison and research are carried out on various products, equipment technology and economic indicators to promote the improvement of technical products, optimize design, guide equipment selection, improve efficiency and reduce investment cost.

Thank you for your support!

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