HUAWEI

2024 Smart PV Top 10 Trends

Continuous Innovation, High-quality Development, Accelerating PV to Become the Main Energy Source

January 2024

Foreword

As the world moves closer to carbon neutrality, the global PV and energy storage capacity additions of 2023 are expected to exceed 400 GW and 100 GWh, respectively. In China, utility-scale scenarios have diversified to include plateaus, deserts, wastelands, and agrivoltaics. As a result, market space has significantly increased and the PV and energy storage sector has continued to grow rapidly. Energy storage system (ESS) has become a key to renewable energy development. Integrated with ESS, PV is rapidly shifting from a supplemental energy source to a dominant one.

According to the International Renewable Energy Agency (IRENA), global installed PV capacity is expected to reach 5200 GW by 2030 and 14,000 GW by 2050, making it the primary energy source.

However, along with the opportunities during the process, there are challenges that must be addressed by the industry.

Grid Connection Challenges

PV systems, from utility-scale to commercial and industrial (C&I) and residential scenarios, are growing fast. However, stable grid connection and longer-term reliability require hardware and software capabilities of power electronics.

Operation Challenges

As the scale of power plants increases, the requirements for lifecycle operation and management are also getting higher. The connection of a massive number of distributed sites requires simpler and more efficient management by using cloud, AI, and intelligent capabilities.

Safety Challenges

Safety needs to be considered from the perspective of the entire power system, not just the equipment itself. In the meantime, we need to raise the requirements on the safety and stability of the user-end power supply and improve the end-to-end safety capability of the system.

To address the preceding challenges, Huawei releases the 10 trends to support the high-quality development of the PV industry.

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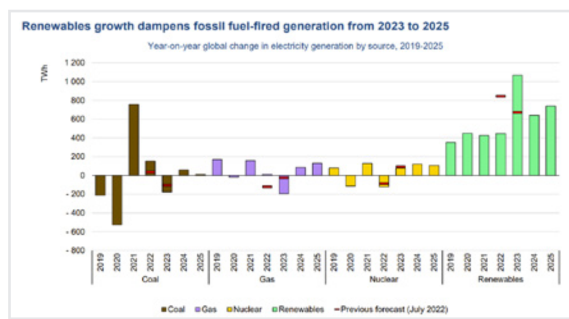
Trend 1

PV & ESS is Becoming Stable Power

Background

According to statistics, in 2023, the new installed PV capacity worldwide has exceeded 400 GW. According to Electricity Market Report 2023 released by the International Energy Agency (IEA), renewables will dominate the growth of global electricity supply over the next three years, and PV power will play an important role. In the past, PV power was restricted by factors such as the Levelized Cost of Electricity (LCOE). Therefore, it was used as a supplementary energy source and accounted for only a small proportion of the total power supply. Over the past three years, with the exponential growth of PV systems around the world, the share of PV in power supply keeps increasing. Especially against the backdrop of PV+ESS convergence and grid parity of PV+ESS systems, PV/ESS systems have evolved from a supplementary energy source to a stable energy source, and have the potential to become a primary energy source over the next three years.



Comparison of annual power generation changes of different types of energy sources

Trend

PV+ESS has evolved from a supplementary energy source to a stable energy source, and will become a primary energy source. The driving factors are as follows:

In terms of business as the costs of PV modules and ESSs continue to decrease, the LCOE of PV systems has decreased by more than 60% in the past three years. As the price of lithium carbonate decreases sharply, the Levelized Cost of Storage (LCOS) of ESSs has decreased by more than 70%. As a result, PV+ESS power becomes commercially viable in more scenarios and grows even faster.

In terms of technologies with the accelerated convergence of PV+ESS and the wide application of new materials and technologies, the power supply stability of PV+ESS systems is significantly improved. For example, the application of third-generation semiconductors, such as silicon carbide and gallium nitride, significantly improves the efficiency and reliability of power components. The safety design of PV+ESS systems is also developing rapidly. From AC safety to DC safety, from hardware safety to software safety and information security, from passive safety to active safety, a multi-node and multi-dimension safety net is being built. The grid-forming energy storage technologies make it possible for power grids to integrate a high proportion of renewable energy. In addition, the GWh-level PV+ESS grid forming capability has been proven in real-world projects.

Application

Huawei has participated in the 400 MW PV + 1.3 GWh project in The Red Sea Project (TRSP), Saudi Arabia. It is the world's largest microgrid energy storage project and has been successfully delivered in October 2023. TRSP is a milestone in Saudi Vision 2030. It is also the world's first new city that is 100% powered by PV+ESS (gensets are used only for emergency power backup). Once completed, the new city can receive millions of tourists from all over the world every year. This project makes many impossibles possible. First, in terms of economy, the LCOE of the PV+ESS microgrid is lower than US$0.1, which is less than 1/3 of the genset power supply cost. This is in line with Saudi Arabia's goal of achieving green and sustainable development. In addition, thanks to the intelligent control algorithm, Huawei's PV+ESS system can achieve a maximum PV-to-ESS power ratio of 2:1. With the same energy storage capacity, more PV modules can be connected, greatly reducing the system LCOE. In contrast, conventional solutions often use products of different vendors and can achieve a maximum of PV-to-ESS power ratio of 1:1 to prevent PV power from be charging into ESSs in case of anomalies.

In terms of power supply stability, Huawei's grid-forming technologies can be used to build an independent and resilient power grid. The microgrid for TRSP is the world's first GWh-level application of the grid-forming energy storage technologies. To achieve stable supply of 100% renewable energy, Huawei participated in the architecture design of the entire power grid and repeatedly verified the architecture with the world's largest (8.8 MW) PV+ESS off-grid test platform based on powerful simulation modeling capabilities. A series of new technologies are used to safeguard the brand-new city that emerges in the desert, such as GWh-level black start and off-grid continuous fault ride-through. TRSP is not only a shining star in Saudi Vision 2030 but also a milestone in the development of green civilization.

The Red Sea project in Saudi Arabia: 400MW + 1.3GWh

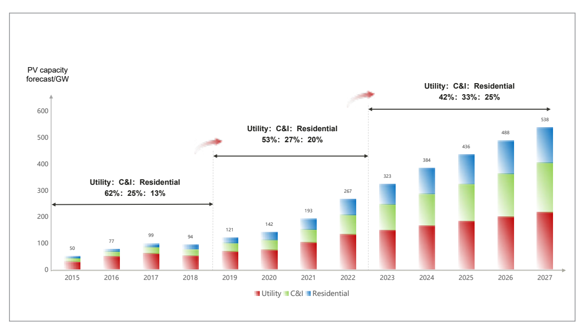
Trend 2

Tens of millions of power plants management

Background

In 2023, the new installed PV capacity exceeded 400 GW and the new installed energy storage capacity exceeded 100 GW, and the numbers are still increasing rapidly. PV& ESS has become an important way for countries around the world to achieve the carbon peaking and neutrality goals. According to the International Energy Agency (IEA), cheaper PV modules, higher PV adoption rate, and policies that encourage large-scale deployment will catalyze higher growth in all major markets, including China, the European Union, the United States, and India.

From 2022 to 2027, the proportion of new distributed PV installations worldwide is expected to increase from 47% to 58%, surpassing that of centralized PV plants and becoming an important incremental market in the renewable energy field. However, plants with tens of millions of devices and the integration of an increasing proportion of renewables will have greater impact on the power grids. To address the challenges, it is crucial to build a digitalized and intelligent network for efficient and intelligent scheduling of power generation, transmission, distribution, and consumption and for the integration of multiple energy sources.



Forecast of the growth trend of global PV new installation

Trend

Management of ultra-large-scale PV plants Using cloud-native fully distributed technologies, tens of millions of PV & ESS devices can be connected to the management system in minutes for intelligent management, and smooth capacity expansion and big data analytics are supported. The new intelligent energy management system integrates renewable energy devices, advanced sensing, information and communication, signal control, and energy storage technologies to form a smart energy network with tens of millions of interconnected and collaborative energy nodes, to better support the safe, reliable, and efficient operation of the power system.

Collaborative scheduling of generation, grid, load, and storage and multiple energy sources By 2030, the global renewable energy power generation capacity will be tripled. Intelligent scheduling and management of ultra-large-scale power plants are the core capabilities. Deep integration of energy and information technologies is the trend. Leveraging advanced big data, AI large models, and IoT communication control technologies, resources such as PV plants, energy storage systems (ESSs), adjustable loads, electric vehicles (EVs), and power grids can be aggregated to implement efficient collaboration between power supplies, power grids, loads, and ESSs, systematically improve dynamic balance of the power system, and maximize energy resource utilization.

Open ecosystem Home energy management is developing rapidly in Europe. Up to now, more than 1.1 million households in Europe have deployed multi-energy home energy management systems. Therefore, providing open northbound interfaces for ecosystem cooperation has become a trend in the industry. Based on the northbound capability, intelligent prediction and optimization as well as power trading capabilities can be combined to maximize benefits in the power trading market by using collaborative scheduling of plant inverters, ESSs, power grids, and smart loads.

Application

Huawei FusionSolar SmartPVMS–Intelligent Management of Tens of Millions of Plant Devices

By 2023, Huawei FusionSolar SmartPVMS has achieved unified, efficient, and stable access and management of over 5 million devices in Europe. Based on the distributed technology of cloud-native architecture, it makes comprehensive use of technologies such as IoT, big data, and artificial intelligence, and can carry out operation monitoring, intelligent diagnosis, efficient scheduling, and intelligent diagnosis. It connects to more than 15,000 weather stations around the world to predict energy yields accurate to 1 hour.

Low-Carbon City in Longgang, Shenzhen–China's first leading project of zero-energy-consumption stadium-type buildings

The International Low-Carbon City Convention and Exhibition Center in Longgang District, Shenzhen, China uses Huawei Digital Power's "Energy Cloud Network + Smart PV+ESS" solution to build China's first nearly zero-energy venue, equipped with 1.1 MW PV and 2 MWh ESS. Multiple energy synergies and complementarities can be achieved through the intelligent energy management system. The PV system, charging network, energy communication controller, smart lights, and smart cooling products can be collaborated to achieve flexible scheduling of power generation, transmission, distribution, and consumption and maximize energy utilization. According to the characteristics of low-carbon buildings, Shenzhen International Low-Carbon City will produce 1.27 million kWh of green electricity each year, reducing carbon emissions by 606 tons (equivalent to planting 31,000 trees). The campus becomes a benchmark for low-carbon campuses.

The International Low-Carbon City Convention and Exhibition Center Longgang, Shenzhen, China

"Energy Cloud Network + Smart PV+ESS" solution

Trend 3

Full-Lifecycle Intelligence

Background

While the installed capacity of PV & ESS power plants is increasing, power electronics and digital technologies are increasingly integrated. As early as the end of 2021, the Smart PV Industry Innovation and Development Action Plan (2021-2025) jointly released by the five departments of the Chinese government provides guidance in terms of intelligent design, integration, and O&M. With the continuous evolution of digital and intelligent technologies, technologies such as 5G, AI, cloud computing, big data, and the IoT have experienced exponential development. Managing watts with bits has been widely accepted in the industry. PV & ESS plants are experiencing digital transformation. Intelligent monitoring, O&M, and management tools, such as the digital operation platform and drone inspection system, are used to improve the O&M efficiency and reliability of PV plants. However, against the backdrop of high-speed construction, multi-energy complementation, and collaborative scheduling, both centralized and distributed PV & ESS power plants face pressures in terms of efficiency, quality, and revenue, requiring full-lifecycle intelligence.

Trend

Digital and intelligent technologies will play a key role in the entire lifecycle of power plants, including planning, construction, maintenance, and operation.

In the plant planning phase drones, satellites, and robots are used for survey to throughly evaluate the surrounding environment of the plant, improve the survey quality and efficiency, and assist in PV plant site selection, design, and decision-making. Especially for distributed power plants, obstacles on complex rooftops can be identified using drone and satellite images to accurately determine the PV installation capacity. The plant design tool can automatically design distributed plants, including 3D rooftop modelling, module layout and cable connection design, and device selection. By analyzing the historical power consumption, the tool can intelligently recommend the ESS configuration proportion and provide an ROI report. The overall planning time is halved.

In the plant construction phase the large area, remote site, a large number of construction personnel and materials, and tight construction schedule pose great challenges to the monitoring of the construction progress and quality. Because site surveillance has not been completed in the construction phase, drones equipped with HD zoom cameras become mobile "supervisors". The reality modelling technology is used to intelligently compare the onsite status with the design drawing to determine whether the construction is in progress as scheduled. The video can be used to intelligently detect whether the module tilt angle and pile foundation positions meet the requirements, reducing quality problems by 40%. Anomalies, such as improperly piled materials, workers who do not dress as required, and unexpected fires can be intelligently identified to ensure onsite safety.

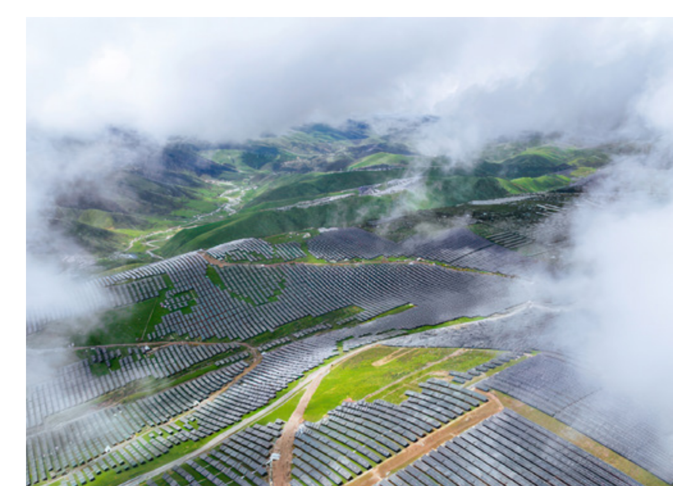
In the plant maintenance phase Currently, intelligent power plant O&M is widely used. It can implement functions such as power generation performance analysis, charge and discharge management, cell coefficient of variation analysis, fault diagnosis and location, alarm, and troubleshooting suggestion. The accumulated plant data will lead to predictive maintenance in the coming years. By establishing an AI fault model, you can predict the device status trend and indicate possible risks in the future, facilitating prompt site inspection, rectification, and spare parts delivery. At the same time, as the plant scale becomes larger, intra-plant road network modeling and navigation will be applied on a large scale to quickly locate faults. The old and new functions combined can make O&M intelligent and 70% more efficient.

In the plant operation phase Intelligence will make outstanding contributions to revenue improvement during plant operation. For centralized plants, AI large models will further improve the accuracy of short-term and ultra-short-term PV output power prediction and the efficiency of PV & ESS collaboration. It can not only reduce PV curtailment, improve consumption, but also reduce penalties caused by inaccurate forecast. For distributed plants, high-precision prediction is achieved not only in power generation, but also in power load prediction. AI can accurately predict power demand to properly plan and allocate PV and ESS resources, and maximize benefits in the complex power trading market.

The intelligence throughout PV & ESS plant lifecycle enables high quality, high efficiency, and high revenue, improves the reliability and stability of PV & ESS plants, and facilitates the development and application of renewable energy.

Application

Located at an altitude higher than 4000 m on the Sichuan-Tibet Plateau, the Kela PV project alongside the Yalong River covers an area of 16 square kilometers. To put this in perspective, that's 80 China National Stadiums. With more than 2 million PV modules, the plant has an installed capacity of 1 million kW. The Kela PV plant and the Lianghekou hydro plant can supplement each other, and the hydro-solar project is a world-class benchmark energy base on a plateau. From this project, Huawei FusionSolar and Yalong River Hydropower Development Co., Ltd. set up a joint innovation center to work with partners to do research on key technologies to address the pain points and difficulties in PV plant construction, O&M, and operation, enabling intelligent PV plant operations. By building a digital base, Huawei uses technologies such as high-precision ultra-short-term power prediction, drone-based modeling, digital twin, and Smart Co-Diagnosis System to implement all-domain sensing, precise prediction, and refined control, building a large, easy-to-manage, safe, and leading intelligent base.



Trend 4

Grid Forming in All Scenarios

Background

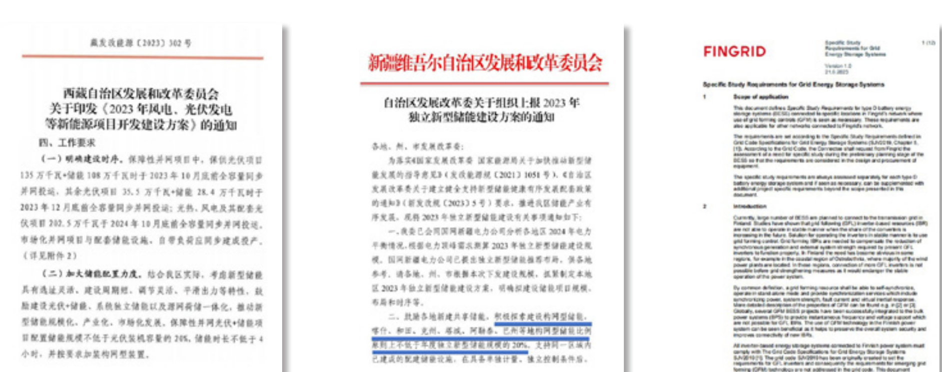
The new power system with new energy as the main source is crucial to achieving the goal of carbon peak and carbon neutrality.

Compared with synchronous units, renewable energy has a low controllability and rotation inertia. As the penetration rate of renewable energy increases, conventional renewable energy systems cannot proactively support the voltage and frequency like synchronous units when a fault occurs. As a result, it is increasingly difficult for conventional renewable energy systems to meet the requirements of new power systems, which brings great challenges to the safe and stable operation of the power system.

However, for the synchronous condenser solution, it not only has a higher initial investment and secondary investment (electricity fee) but also needs 24-hour manual attendance and regularly troubleshooting that leads to a higher O&M cost. Therefore, are there any other technical routes to help build new power systems?

Trend

The weak power grid problem caused by the integration of a high proportion of renewable energy has been widely recognized. The industry is exploring new technologies to solve this problem. As Huawei Smart PV released the grid-forming solution in the top 10 trends last year, the grid forming technology has garnered attention of the entire industry. For example, China's provinces such as Xinjiang and Tibet, and organizations and countries such as the European Union and Finland have released grid forming policies to support the development of the technology.



西藏自治区发展和改革委员会
关于印发《2023 年风电、光伏发电等新能源项目开发建设方案》的通知

四、工作要求

新疆维吾尔自治区发展和改革委员会

自治区发展改革委关于组织上报 2023 年独立新型储能建设方案的通知

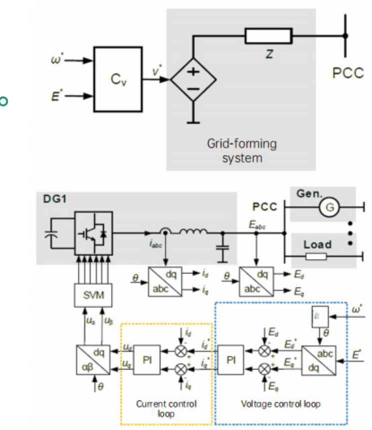
FINGRID

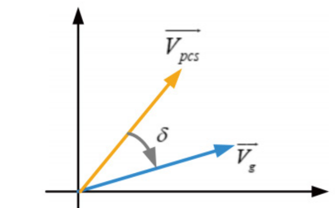
Specific Study Requirements for Grid Energy Storage Systems

The grid-forming solution involves the following technologies.

01 Voltage establishment technology

To imitate the voltage establishment process of synchronous units, the grid-forming solution converts the traditional current control to voltage control by inputting a given voltage and phase. Therefore, for the grid system, the grid-forming solution is a voltage source capable of voltage establishment.





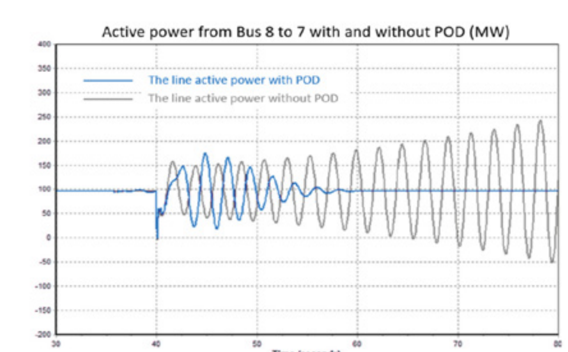
Basic control diagram of grid forming technologies

02 Virtual inertia support technology

The mechanical motion equation of synchronous units is imitated using control policies based on the virtual inertia J and damping coefficient D of the grid-forming solution. In this case, the PV and energy storage batteries can be compared to a prime mover, and the converter is equivalent to a generator. In this way, the two-stage model of synchronous units can be imitated. The frequency change of the system is usually caused by the impact of unbalanced power. In this process, the grid-forming solution also senses the effect of unbalanced power. Under the effect of unbalanced torque, the grid-forming solution actively and quickly injects electromagnetic power into the power grid to imitate the changes in the kinetic energy of the rotor and implement inertia support for the system. Different from those of synchronous units, the parameters of the power electronic equipment are less prone to hardware limitation. Therefore, the virtual inertia J and damping coefficient D of the grid-forming solution can be set flexibly to adapt to different operation scenarios and improve the frequency control of the system.

03 Power oscillation damping (POD) technology+adaptive virtual impedance technology

Generally, a power system stabilizer (PSS) is added to the excitation system of synchronous units to form an additional damping control to improve the system damping and suppress low-frequency oscillation. Based on this principle, the low-frequency POD technology is introduced to the power plant controller (PPC) to enable the grid-forming solution to have the PSS function of synchronous units and output additional damping control power. In this way, the low-frequency oscillation in the range of 0.1 Hz to 2.5 Hz can be suppressed. The following figure shows the simulation effect of low-frequency POD in PPC. To solve the subsynchronous/supersynchronous oscillation, Huawei Smart PV solution uses the adaptive virtual impedance technology to dynamically adjust the electrical characteristics of the plant through AI self-learning to match the power grid characteristics. In this



Power suppression effect of low-frequency POD way, the inverter and PCS can actively adjust their impedance and change the amplitude-frequency and phase-frequency characteristics of the output impedance to improve stability. This prevents power oscillation caused by insufficient damping in the subsynchronous/supersynchronous frequency bands. In this way, the oscillation in the range of 2.5–100 Hz can be suppressed.

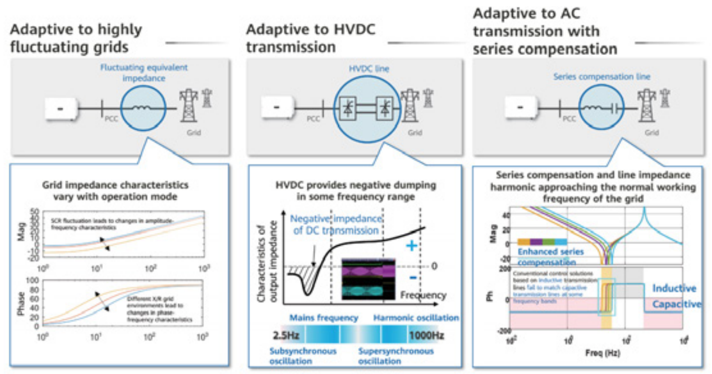
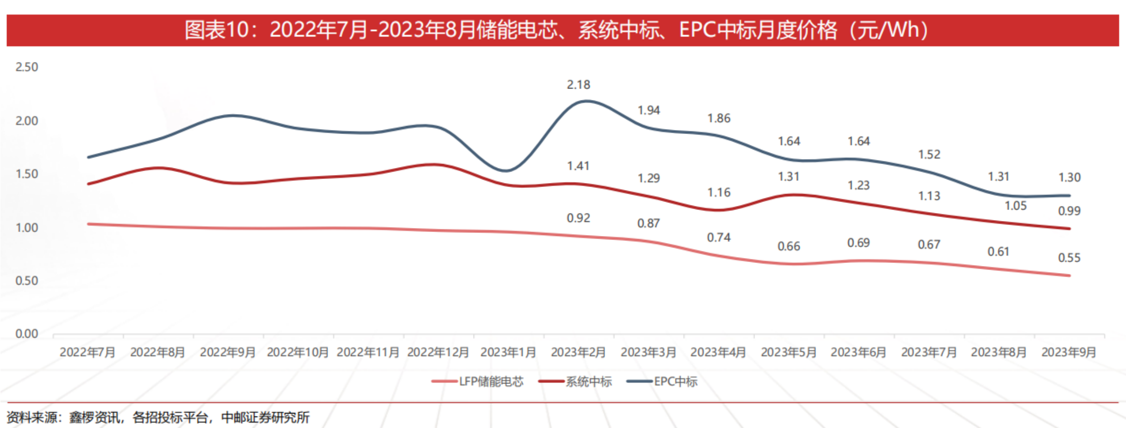


Figure 14 Adaptive virtual impedance technology

› Adaptive virtual impedance technology

Based on the preceding technologies, the grid-forming solution can support reactive current up to 3 times the rated current, equivalent rotational inertia of up to 20s, and wide-frequency (0.1–100 Hz) oscillation damping capability to ensure power grid stability (voltage, frequency, and rotor angle). From the perspective of capability, the grid-forming solution is equivalent to conventional synchronous unit solution.

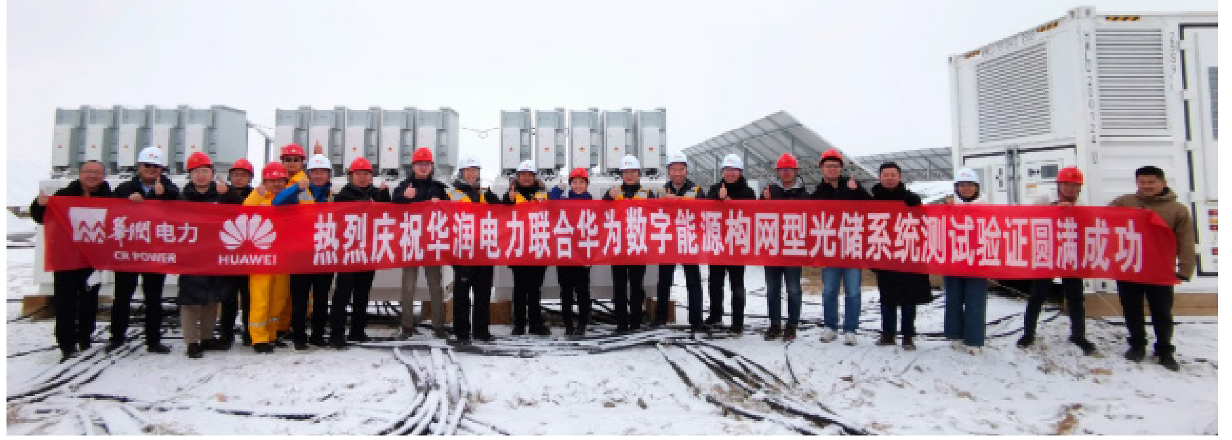
From the perspective of business value, with the further decrease in cell costs and the development of digital intelligent technologies and grid connection technologies, the grid-forming solution is more economical than the conventional synchronous unit + conventional energy storage solution, reducing the cost in the lifecycle.



Driven by policies, technologies, and business values, grid forming will be used in more scenarios, from utility-scale to C&I and residential plants, and from PV to wind and hydro power plants. This will increase the integration of all types of renewable energy and accelerate the development of a new power system dominated by renewables.

Application

Based on the grid-forming solution developed by Huawei, Huawei worked with China Resources Power on the continuous verification and demonstration of the research topics under the guidance of China Electric Power Research Institute and Qinghai Electric Power Research Institute in 2022, and completed the world's first grid forming PV & ESS system test at Gonghe PV plant in Qinghai in January 2023. The tests include parallel stability of the grid forming system, one-time and multi-time high/low voltage fault ride-through, primary frequency response (PFR), and inertia response tests. The tests fully verify that the grid forming renewable power generation systems are critical to support grids with a high proportion of renewable energy, marking a milestone in the development of renewable energy.



In September 2023, ACWA POWER, SEPCOIII, and Huawei jointly built the PV & ESS microgrid project for TRSP in Saudi Arabia. It is the world's largest PV & ESS microgrid project (400 MW PV and 1.3 GWh energy storage) and a key part of Saudi Vision 2030. TRSP will become the first city in the world that is powered 100% by renewable energy. The PV & ESS microgrid replaces conventional diesel generators to provide clean and stable power for 1 million people. The project helps Saudi Arabia build a global clean energy and green economy center, setting a great example for the world in terms of clean power supply with PV and energy storage.

In September 2023, under the guidance of China Electric Power Research Institute and Qinghai Electric Power Research Institute, Huawei and China Energy Investment jointly completed the world's first onsite testing of the grid-forming ESS for weak grids in the Golmud power plant in Qinghai. About 510 tests were performed, including steady-state response and transient response tests of grid at different short-circuit ratios (SCRs), and phase angle change, frequency change, impedance change, low-frequency oscillation, variable damping control, overload capability, and black start tests at different SCRs. It is the world's first testing of the electrical characteristics and specifications of grid-forming solution in weak grid scenario. It proves that Huawei's grid-forming solution supports both weak and strong grids to maintain grid stability, and can be used to integrate a high proportion of renewables and build a new power system.

Trend 5

Four-Dimensional Safety

Background

For the stability and fast development of new power systems dominated by renewables around the world, we need to ensure safety from multiple dimensions. Many organizations and vendors are also conducting research on this issue. However, they focus more on the basic safety of energy equipment, such as providing more protection and preventive measures and intelligent detection measures, to ensure the stable running of equipment. Some organizations study the security of new power system networks to ensure the security of plant information and prevent unauthorized access to or tampering with personal privacy data. However, these are not enough. We need to look for a solution from a higher dimension to ensure the long-term safety and stability of power systems.

Trend

To ensure the long-term safety and stability of power systems, Huawei implements a four-dimensional safety solution. The four dimensions are as follows

The first dimension

The first dimension is supply safety. By building a supply system for core plant devices and ensuring the security of plant-level and cloud-based systems, the safety foundation of new power systems is consolidated. The core devices refer to the key components. The long-term stable supply of such components must be ensured. The operating system of electric power systems is the basis for the stable operation of power plants. The system must be able to support update and upgrade throughout the lifecycle.

The second dimension

The second dimension is device safety. Based on power electronics and digital technologies, preventive diagnosis and refined management are implemented to ensure the safety of each device in the power system. Vendors take digital and refined measures to continuously improve the safety protection capability of devices, as well as the safety of connected dumb devices. For example, the combination of inverters and PV optimizers can not only detect device faults, but also detect cable arcing, grounding, and impedance and locate module faults to ensure the safety and reliability of each node.

The third dimension

The third dimension is network security. We need to build a secure and trustworthy network architecture and perform security certification from product-level to carrier-grade to ensure network reliability, availability, security, resilience, and achieve the framework safety of new power networks.

To ensure reliability, availability, and resilience of plants and prevent external attacks, the most important thing is to prevent unauthorized access to system information, ensure that personal privacy or sensitive data is not disclosed, and ensure that information is not modified or tampered with by unauthorized users, and take measures such as secure boot, digital signature, and centralized certificate management. However, such passive information protection cannot cope with the complex and changing network environments. Therefore, active security is also needed to improve the security and resilience of the power plant systems. For example, the system intrusion detection policies need to be adjusted in real time. After detecting a network security event or potential risk, the plant system can respond to the event promptly and take corresponding measures to quickly restore the functions and services to ensure service continuity.

In addition, the networking protocols of the management system are modularized to minimize the impact of external network attacks on the plant system and minimize economic losses.

The fourth dimension

The fourth dimension is power system safety by evolving from grid following to grid supporting and grid forming. From dispatching prediction and control to emergency recovery, digital enablement and intelligent interconnection between power grids must be implemented so that different energy sources can supplement each other by collaboration between power generation, grid, load, and storage. To ensure the safety of a new power system, we need to consider two aspects. First, we need to consider the safety of multiple energy sources on the power generation side, and the complementary allocation of hydro, solar, and wind energy sources to maximize the energy utilization. Second, we need to ensure the safety of the entire network architecture of the power generation, grid, load, and storage, including the power generation side, transmission side, distribution network, and load. The allocation mechanism, fault ride-through, and load requirements on power quality must be considered.

Application

• Common Criteria (CC)

Huawei commercial inverters have passed the industry's first CC EAL3+ certification, leading the safety certification in the PV industry.

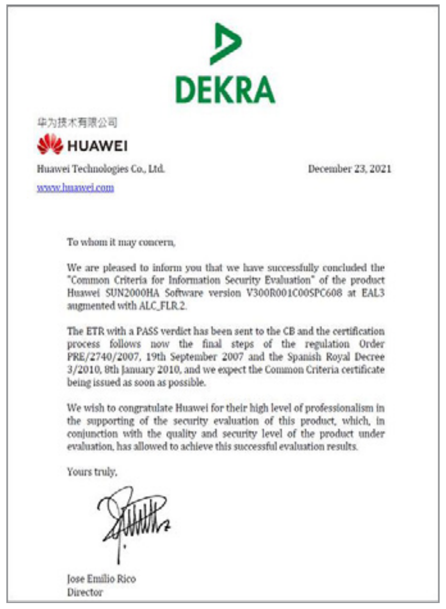
• Industrial cyber security standard IEC 62443

Huawei's network management system, SmartLogger3000, LUNA2000B (C&I ESS), and LUNA2000C (utility ESS) have passed IEC 62443-4-2 SL2 certification. The product development process has passed the highest level of IEC 62443-4-1 ML3 certification in the PV industry.

• Information security management system standard (ISO27001)

Huawei's information security management has passed the ISO27001 series certification.

The technologies and joint efforts of the industry and the whole society will help the PV industry build digital trust and achieve sustainable and healthy development.



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华为技术有限公司

HUAWEI

Huawei Technologies Co., Ltd. December 23, 2021

www.huawei.com

To whom it may concern,

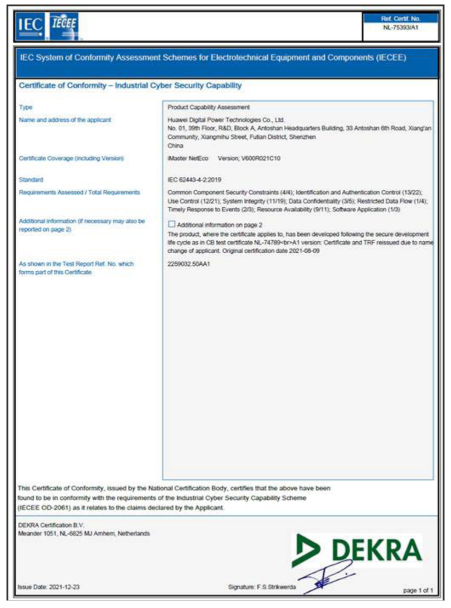
We are pleased to inform you that we have successfully concluded the "Common Criteria for Information Security Evaluation" of the product Huawei SUN2000HA Software version V300R001C00SPC608 at EAL3 augmented with ALC_FLR.2.

The ETR with a PASS verdict has been sent to the CB and the certification process follows now the final steps of the regulation Order PRE/2740/2007, 19th September 2007 and the Spanish Royal Decree 3/2010, 8th January 2010, and we expect the Common Criteria certificate being issued as soon as possible.

We wish to congratulate Huawei for their high level of professionalism in the supporting of the security evaluation of this product, which, in conjunction with the quality and security level of the product under evaluation, has allowed to achieve this successful evaluation results.

Yours truly,

Jose Emilio Rico
Director



IEC IECEE

Ref. Certif. No. NL-75393/A1

IEC System of Conformity Assessment Schemes for Electrotechnical Equipment and Components (IECEE)

Certificate of Conformity – Industrial Cyber Security Capability

Type	Product Capability Assessment
Name and address of the applicant	Huawei Digital Power Technologies Co., Ltd. No. 01, 39th Floor, R&D, Block A, Antoshan Headquarters Building, 33 Antoshan 6th Road, Xiang'an Community, Xiangmihu Street, Futian District, Shenzhen China
Certificate Coverage (including Version)	iMaster NetEco Version: V600R021C10
Standard	IEC 62443-4-2:2019
Requirements Assessed / Total Requirements	Common Component Security Constraints (4/4); Identification and Authentication Control (13/22); Use Control (12/21); System Integrity (11/19); Data Confidentiality (3/5); Restricted Data Flow (1/4); Timely Response to Events (2/3); Resource Availability (9/11); Software Application (1/3)
Additional information (if necessary may also be reported on page 2)	☐ Additional information on page 2 The product, where the certificate applies to, has been developed following the secure development life cycle as in CB test certificate NL-74789 A1 version: Certificate and TRF reissued due to name change of applicant. Original certification date 2021-08-09
As shown in the Test Report Ref. No. which forms part of this Certificate	2259032.50AA1

This Certificate of Conformity, issued by the National Certification Body, certifies that the above have been found to be in conformity with the requirements of the Industrial Cyber Security Capability Scheme (IECEE OD-2061) as it relates to the claims declared by the Applicant.

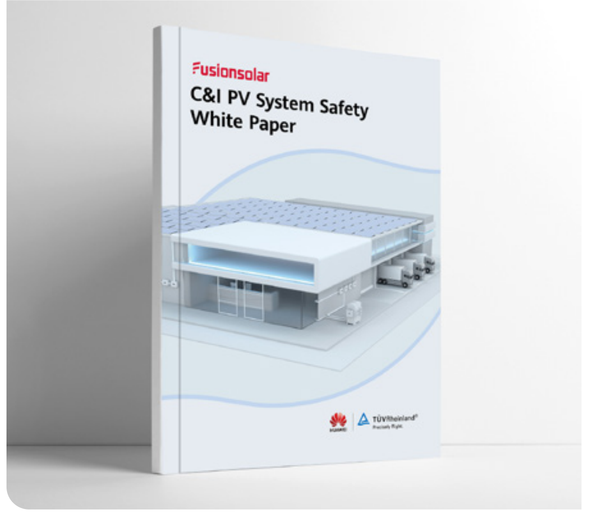
DEKRA Certification B.V.
Meander 1051, NL-6825 MJ Arnhem, Netherlands

DEKRA

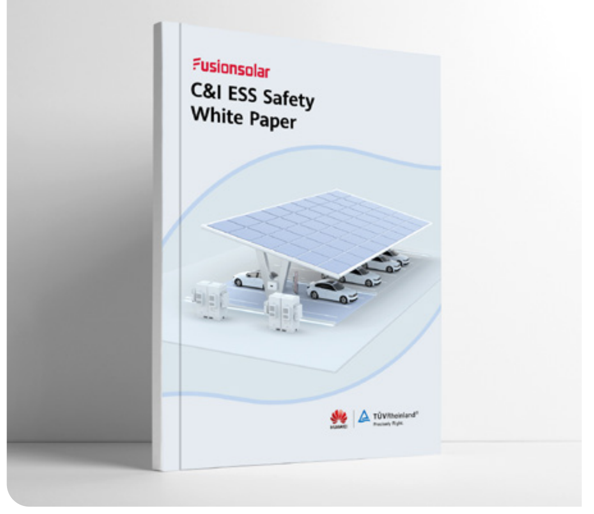
Issue Date: 2021-12-23 Signature: F.S.Strikwerda page 1 of 1

Commercial and Industrial PV Safety White Paper

C&I scenarios involve heavy assets and complex personnel management. However, from the perspective of the entire PV industry, the design and application of safety solutions for PV plants have not become a consensus. To achieve high safety and reliability of C&I PV systems, the entire industry needs to work together. Huawei and TÜV Rheinland jointly released a C&I PV safety white paper, which puts safety first during design and provides comprehensive protection for C&I owners by combining system safety design and industry-leading safety protection technologies. Huawei hopes to work with other industry players to continuously improve C&I PV safety standards, build 100% safe and reliable PV plants, facilitate low-carbon transformation in all walks of life, and build sustainable business.



Commercial and Industrial ESS Safety White Paper



C&I ESS applies to scenarios such as factories, hospitals, shopping malls, and campuses. Compared with conventional power plants, C&I ESS plants involve more complex scenarios, more difficult fire fighting, and denser personnel and assets. Therefore, safety requirements on C&I ESS are higher. To help the industry better understand the safety design of C&I ESSs, Huawei and TÜV Rheinland jointly released the C&I ESS Safety White Paper to explore C&I ESS safety in terms of equipment, assets, and personnel and introduce future-oriented innovative technology paths to address the safety challenges.

Application in Yalong River Plant and TRSP

The safety of power systems must be ensured at architecture level. In the Yalong River Plant, multiple complementary energy sources and stable operation are also considered. In the microgrid for TRSP, the holistic safety of power generation, grid, load, and storage is considered and verified.

Trend 6

Cell to Grid BESS Safety

Background

The large-scale application of ESSs and the upgrade of safety standards require the safety from cell level to grid level. In recent years, the rapid development of energy storage technologies also brings a series of safety challenges. Safety accidents occurred from time to time. Some are caused by internal cell management, and some are caused by failed high/low-voltage ride-through (HVRT/LVRT). ESS is an important part of a new power system. Its safety must be designed from cell level to grid level across scenarios and dimensions, with effective management and control measures, to ensure the safety of the entire power system.

Trend

The ESS safety design needs to integrate power electronics, digital, thermal, electrochemical, and AI technologies to implement refined monitoring and management at the cell, battery pack, battery rack, ESS, and power grid levels to ensure ESS safety, efficiency, and grid forming capability.

› Cell to Grid BESS Safety

At the cell level

System specifications such as the number of cycles and efficiency have been paid more attention in the real project. However, as the cell capacity is increasing, the energy density of the system is increasing as well. This results the quality and performance of batteries have a great impact on ESS safety. To ensure battery safety, strict tests and quality control must be performed to ensure the safety and reliability of cells, which are the first line of defense.

At the pack level

Passive balancing is widely used in the industry to solve the inconsistency and uncertainty between cells. The battery packs must be protected by refined proactive control and shutdown capabilities to isolate faulty units promptly to minimize the impact and property loss.

At the rack level

The rack-level battery protection is implemented in both hardware and software. That is, the BMS active control and physical isolation using circuit breakers and fuses quickly disconnect faulty components in case of faults, such as short circuit and overcurrent.

At the system level

The ESS charge and discharge, consistency, and health need to be diagnosed from multiple dimensions. The AI technology is used to build a prediction model to identify risks and generate warnings in advance. At the same time, end-to-end protection measures after thermal runaway must be considered from multiple aspects to prevent further deterioration of the situation.

At the grid level

ESS plays a significant role to maintain grid stability. Therefore, it should not only focus on the safety of BESS and PCS, but also the issues in real grid operation need to be considered as well, such as wide-band oscillation, transient overvoltage, power quality deterioration, and stability issues of islanded PV & ESS system, and HVRT/LVRT. We need to use grid algorithms and technologies such as adaptive HVRT to support ESS grid forming and improve grid stability.

Application

In 2023, a 100 MW energy storage project in Hubei province in China used Huawei's battery risk warning function to implement cell-level fault warning. This function can identify more than 10 faults in advance, such as internal short circuits, abnormal temperature, and overcurrent. If an HVRT occurs during the ESS operation, the bus voltage can be dynamically adjusted based on the DC/DC+DC/AC dual-stage architecture of the ESS and the PCS adaptive HVRT algorithm to ensure stable active output. In addition, the battery voltage remains unchanged during HVRT, preventing energy backflow from the power grid to the ESS and ensuring the safe operation of the entire power plant.

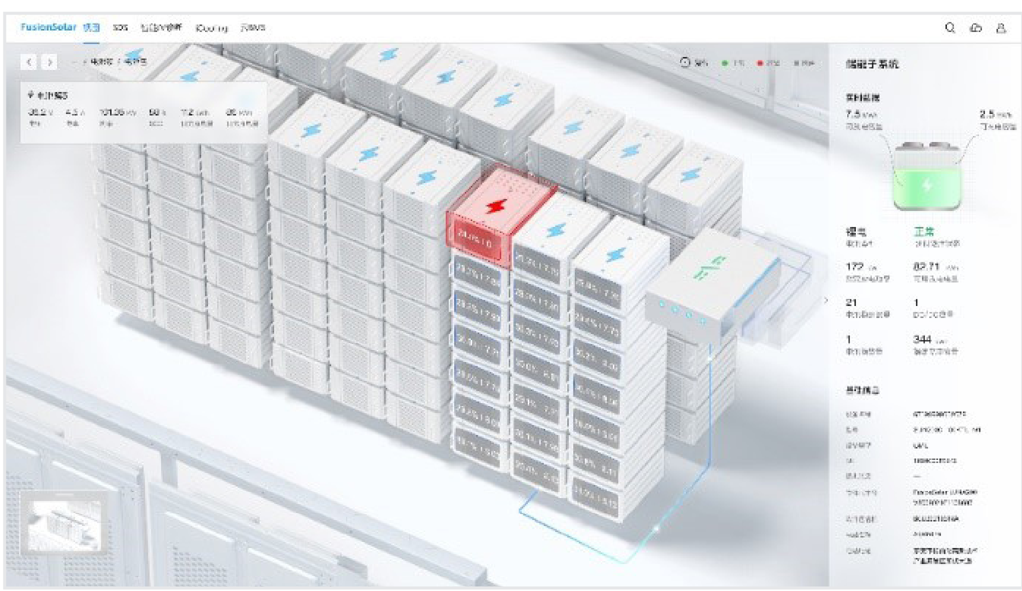
› BESS project in Hubei Province, China

Trend 7

MLPE and CLPE

Background

Driven by industry policies and technology advancement, distributed PV has witnessed vigorous development in recent years. However, with the rapid growth of the total installed capacity, the rooftop resources for large-scale PV installation become more and more scarce. We are facing challenges such as how to maximize PV installation on multi-pitched rooftops and rooftops prone to shading. In addition, distributed PV systems are mainly installed on rooftops, and safety risks related to high voltage on the DC side need to be addressed. Furthermore, as distributed PV plants are scattered, it is difficult to implement refined O&M and management relying on manual work.



› Cell-level management

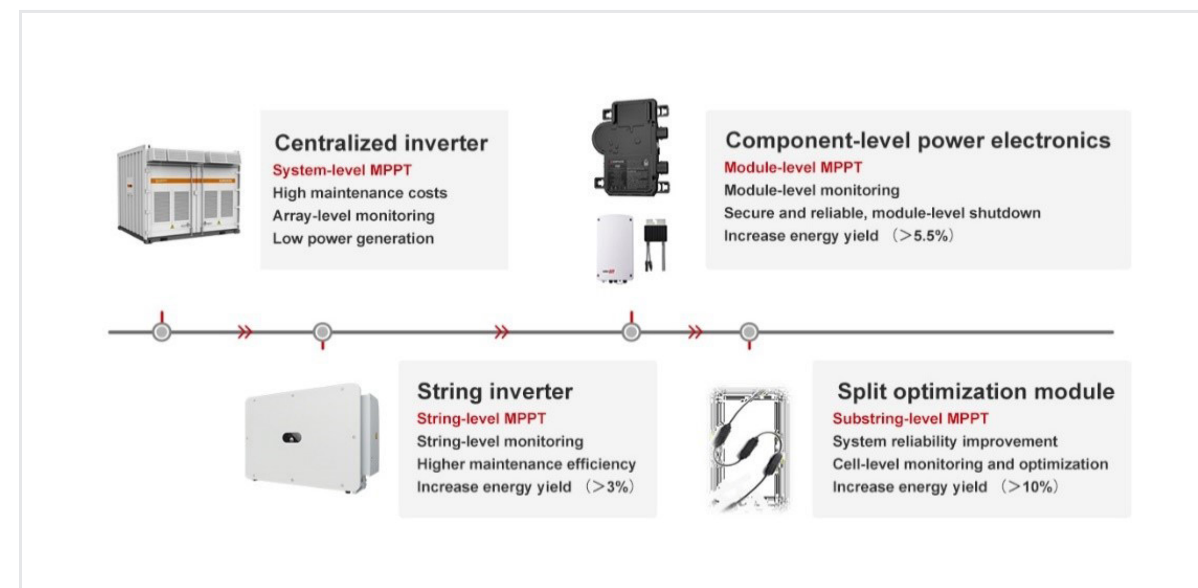
The gradual increase of the total installed capacity drives the market space of string ESS. In a lithium battery energy storage system (BESS), the lifecycle energy efficiency and system safety are the most important. With deep integration of power electronics, electrochemical, thermal management, and digital technologies in the energy storage field, the management granularity of the ESS has evolved from extensive management for centralized systems to refined management at the battery rack and pack levels.

Therefore, we need to further improve the power generation, storage, and O&M efficiency of distributed PV, ensure power consumption safety and efficiency, and implement refined management and O&M through innovative technologies.

Trend

In a PV system, module-level power electronics (MLPE) refer to power electronic equipment that can perform refined control on one or more PV modules, including micro inverters, power optimizers, and disconnectors. MLPE brings unique values such as module-level power generation, monitoring, and safe shutdown.

In recent years, PV rapid shutdown (RSD) standards have been released and implemented in various countries. The US's NEC 2020B stipulates that the system should be shut down within 30s in an emergency. The European VDE-AR-E 2100-712 safety standard has been enforced. Australia's AS 5033:2020 and Thailand's EIT Standard are also being implemented. As more customers attach importance to features such as safety and high energy yield, the market value of MLPE is further explored. Therefore, its market acceptance and market share increase rapidly. Take the power optimizer as an example. The annual shipment of power optimizers has exceeded 20 million worldwide. Looking back on the development path of PV power electronics, we can see a trend from central inverters to string inverters. The system-level maximum power point tracking (MPPT) is upgraded to the string-level MPPT, improving the energy yield by more than 3%. In the future, string inverters will evolve toward optimizers to achieve module-level optimized power generation and monitoring. The energy yield and safety of the PV system will be further improved.



› History of PV power electronics

Similar to PV systems shifting towards MLPE, lithium BESSs are set to develop towards smaller management granularities. Cell-level power electronics (CLPE) implement refined management for cells and detect and warn about safety risks in advance to improve ESS throughput and facilitate the trading in the power market, such as VPP frequency regulation. Currently, the traditional battery management system (BMS) can only aggregate and analyse limited data, and it is almost impossible to detect faults and generate warnings in the early stage. Therefore, BMS needs to be more sensitive, intelligent, and even predictive. This depends on the collection, computing, and processing of a large amount of data, and AI technologies to find the optimal operating mode and make forecasts.

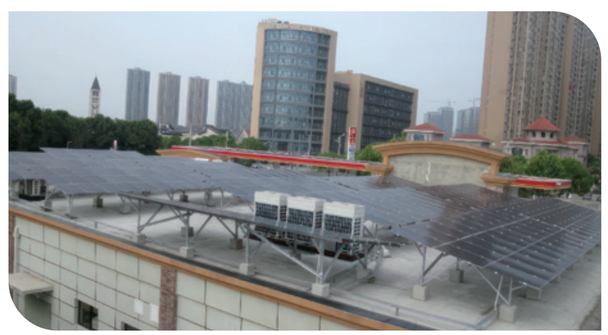
Application

The 300 MW whole-county rollout of distributed PV in Xiangcheng County, Xuchang City helps revitalize the local economy. The PV system in Kuzhuang Middle School adopts the full optimizer configuration, which has the following features:

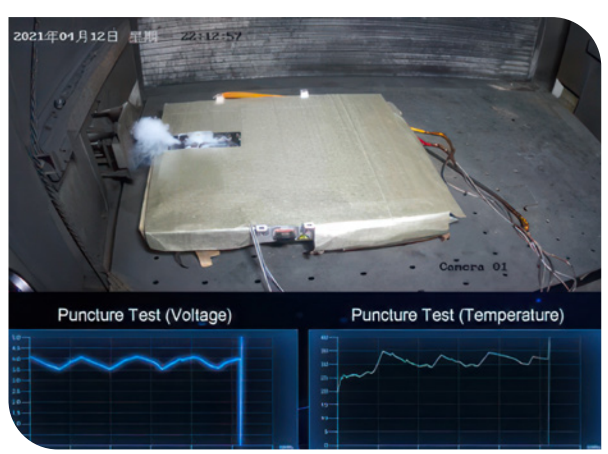
- Compliance with the NEC 2020 safe shutdown standard and all-round safety protection for power consumption,

- Efficient and intelligent power generation and 25.9% higher installed capacity than traditional solutions, greatly improving the space utilization and aesthetic appearance of rooftop PV modules. In addition, the optimizers can effectively reduce series-parallel mismatch loss and increase the energy yields in the first year and throughout the lifecycle by 6.65% and 9.7%, respectively.

In terms of safety, Wuhan built the first "highly safe gas station" of China National Petroleum Corporation. The system adopts the full-configuration optimizer solution, which can quickly shut down the rooftop voltage to 0 V and shut down the PV module output in case of emergency, allowing firefighters to rescue and fully meeting the strict safety requirements of the gas station.



The cloud BMS solution uses a large number of voltage, current, and temperature sensors deployed in the ESS to collect massive data and migrate the data to the cloud. Based on AI algorithms and models, the solution can effectively monitor the battery cell status and forecast the trend. In the battery nail penetration test, a steel needle with a diameter of 1 mm is used to simulate a derivative internal short circuit. The cloud BMS can implement hour-level battery cell thermal runaway warning to avoid causing greater losses. The cloud BMS technology has been reliably verified in electric vehicles with larger data volume and higher timeliness requirements.



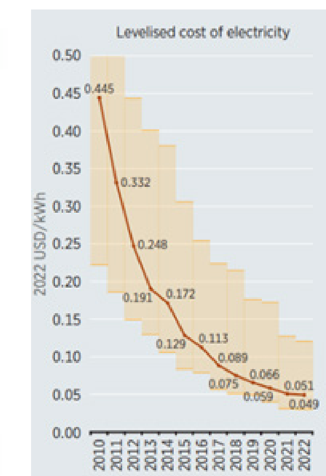
Puncture test for LFP cells

Trend 8

High Voltage and Reliability

Background

According to statistics released by the International Renewable Energy Agency, the global weighted average levelized cost of electricity (LCOE) of PV plants fell by 89% from US$0.445/kWh in 2010 to $0.049/kWh in 2022. On the premise that IEC standards are met, PV inverters are designed to continuously improve the DC/AC voltage level to reduce the LCOE of the systems. Emerging PV technological innovations accelerate the reduction of LCOE. PV will replace traditional energy at a faster pace.



LCOE Trend of PV Plants

Trend

AC/DC voltage increase

The reduction of LCOE for PV systems depends to a large extent on the continuous increase of voltage.

The voltage on the DC side of an inverter system has increased from 600 V to 1000 V and then to 1500 V. The corresponding voltage on the AC side has gradually increased from 270 V and 380 V to 800 V. PV technological innovations raise the DC and AC voltage levels, accelerating the reduction of LCOE for PV systems. Meanwhile, high-voltage development will reduce cable loss and improve the performance ratio. It is estimated that PV plants will evolve toward higher voltage in the future, exceeding 1500 V on the DC side and 1000 V on the AC side.

Reliability improvement

The system reliability will be further improved to cope with the impact of higher voltage.

The high-voltage trend will not only result in LCOE reduction to the PV industry, but also pose new challenges to the reliability of PV systems.

Device reliability Based on previous research, continuous innovations will be carried out by using new materials and components to facilitate the stable operation of devices such as PV inverters in high-voltage scenarios.

System reliability As the system voltage rises, risks will increase accordingly. Reliability of individual devices cannot ensure the stable operation of the whole system. It is estimated that in the next three to five years, bipolar high-voltage architecture and system-level safety protection capabilities will be used to ensure that PV systems run reliably for a long term.

Application

In June 2023, the 1 GW Kela PV Plant Phase 1 alongside the Yalong River (altitudes: 4000–4600 meters), was connected to the power grid. Located in Ganzi, Sichuan Province, China, this project is the world's largest and highest-altitude hydro-solar hybrid power plant. The PV plant uses Huawei's 1500 V DC Smart PV Controllers. In the frigid and high-altitude area, electrical safety risks are high as the thin air would weaken the insulation strength of electrical devices and low temperatures would compromise the device reliability. Up to now, more than 3000 Huawei Smart PV Controllers have been operating stably there to deliver over 2 billion kWh of clean electricity every year, proving that both the devices and systems are reliable enough to tolerate the impact of high voltages.

Yalong River 1GW Keda PV Plant @Sichuan Province

On September 30, 2020, the world's largest single-site PV plant — 2.2 GW ultra-high voltage (UHV) PV plant built by Huanghe Hydropower and Huawei — went live in Hainan Prefecture, Qinghai Province. The plant is 3100 m above sea level and has 9216 Huawei Smart PV Controllers running stably in this harsh environment. The total availability hours of the Smart PV Controllers exceed 20 million hours, and the availability reaches 99.999%. This plant supplies 5 billion kWh clean electricity to Zhumadian, Henan Province through the Qinghai-Henan DC power transmission line over a distance of 1500 km.

Hainan 2.2GW High DC PV Plant @Qinghai Province

Trend 9

High Frequency and Density

Background

Driven by industry policies and technology development, distributed PV has been booming in recent years. Along with the rapid growth of the total installed capacity, PV systems have been deployed on or designed for a great number of suitable rooftops. Many air conditioner outdoor units or communications devices may be installed on the rooftops, resulting in complex conditions for PV deployment. Smaller inverters with a higher energy density are essential to make full use of the limited spaces on numerous C&I or residential rooftops. In addition, PV optimizers are often adopted on complex rooftops. It is now a new development direction in the industry to provide more economical and reliable optimizer solutions for installers.

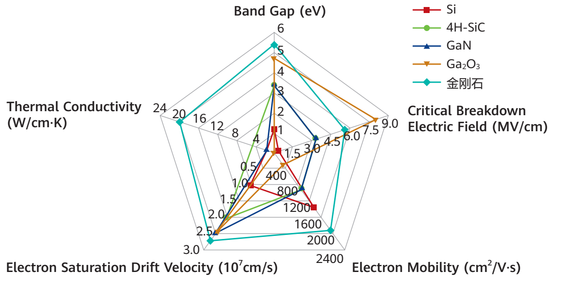
Complex rooftop

Trend

A combination of third-generation semiconductors and digital technologies will continuously increase the power density of power electronic converters, which is set to improve the quality and efficiency of PV systems. As the power of individual devices increases, the unit cost will be continuously diluted and decreased thanks to the marginal effect. However, lower power will result in larger device size and heavier weight, especially for distributed power plants. Consequently, installation, construction, and O&M will become increasingly difficult, which will increase the costs. We believe that PV devices will evolve toward high frequency and high density in the future.

The increase of power density is not just about higher power, but requires upgrade of many technologies, including material science, heat dissipation technology, and engineering technology. Third-generation wide-bandgap semiconductor materials represented by silicon carbide (SiC) feature small on-voltage drop, high temperature tolerance, high voltage resistance, and low loss. They can be used in conjunction with high-frequency magnetic technology

Semiconductor characteristics



to boost the overall operating efficiency of switch devices while reducing the overall loss. With high-frequency application at the device level, the energy density of the product will be significantly improved. Driven by technological innovations such as efficient heat dissipation and integrated drive technology, it is estimated that there will be a 30%, 50%, and 10% increase in energy density respectively for PV inverters, optimizers, and energy storage devices in the next three to five years. In this way, the quality and efficiency of PV devices will be raised to a higher level.

Application

In response to the call for carbon neutrality, Shanghai intensifies efforts to promote the high-quality development of PV applications and related industries by encouraging PV deployment wherever conditions permit. A batch of "PV+" projects have been implemented to drive the green energy transition and low-carbon development of industries across the city. For example, Shanghai Xinguo Power Technology Co., Ltd. rolled out a distributed 1 MW rooftop PV project to accelerate green and low-carbon transformation.

Project highlights

01

1.The energy yield increases by 32.3%, helping the company approach energy self-sufficiency and reduce costs by leveraging the time-of-use pricing mechanism.

02

Safe and reliable clean energy is available to alleviate power shortages, reduce power load, cut carbon emissions, and help build a green factory.

Shanghai Xinguo uses the 50 kW inverter + optimizer solution. The next-generation inverters used in the solution provide 20% higher energy density than the old 50 kW inverter solution, allowing the installer to install certain inverters in narrow spaces. In addition, thousands of next-generation optimizers are installed in the 1 MW PV plant, helping the owner gain more economic benefits. Module-level rapid shutdown and monitoring increase the safety and reduce O&M costs for the PV plant.

Trend 10

High Power Quality

Background

With the rapid development of PV & ESS, PV has become a stable source of electricity. As such, technological progress and breakthroughs should be accelerated to further reduce costs and improve efficiency in order to develop a stable, reliable, economical, and efficient alternative for traditional energy sources. High power quality will be a development trend in the next three to five years. Behind the trend lies two driving forces. First, new power systems are developing rapidly, with an outpouring of renewable energy. Second, high-tech industries are growing at a faster pace, requiring an increasing number of intricate and precision electrical devices that are sensitive to power quality issues and in urgent need of high-quality power. With such insights, we propose the concept of "high power quality" and aspire to provide more stable and reliable clean energy.

Trend

Global IEC standards, pan-European standards, and Chinese national standards all will continuously raise their requirements on power quality.

Harmonic

The existing standards require that the THDi be less than 5%, and the industry average is less than 3%. Huawei uses an intelligent harmonic algorithm to reduce the THDi to below 1%, thereby improving the power supply quality and ensuring safe and economical operation of power systems. In the future, the upper limit of THDu will need to be reduced from 5% to 3%.

EMC design

EMC design: The industry requires that EMC be raised from Class A to Class B in both EMI and EMS designs. While the product power is increased, the electromagnetic interference shielding capability needs to be improved to enhance the power quality and reliability.

Reactive/ Active power response

Reactive/Active power response: The C&I markets set rigid compliance requirements for the power factor. To make full use of electrical equipment, save electric energy, and reduce energy loss, the reactive/active power response needs to be accelerated from seconds to milliseconds.

Application

Centurary

Policies have been set to control the volume and intensity of energy consumption and to promote the market-oriented electricity price reform in Jiangsu Province. Against this backdrop, Huawei FusionSolar and Centurary Technology Co., Ltd. worked together to build an 8 MWh energy storage plant (phase 1) and a 1.6 MW PV plant. The project makes Centurary the first private enterprise that has achieved PV & ESS integration in Jiangsu.

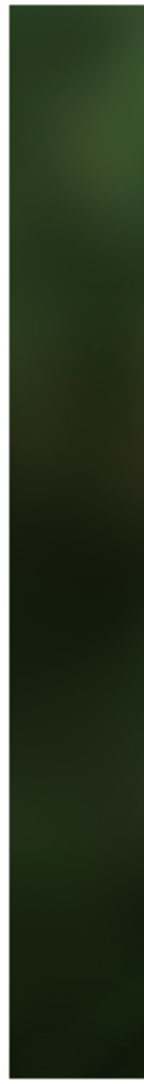
High power quality quickens Centurary's pace in building a modern energy management system, reduces the comprehensive energy consumption of its products, and ensures the continuity of green production.

Yinghua

Guangdong Yinghua Electronic Materials Co., Ltd. worked with Huawei FusionSolar to build a distributed Smart PV demonstration project. The first 4 MW C&I PV system equipped with optimizers in northern Guangdong is deployed on the rooftops of the multi-functional building and the factories of phases 1 and 2. The project covers a total area of about 38,000 square meters and provides the total installed capacity of 4.65 MW. The estimated annual energy yield will reach 5.13 million kWh, which is equivalent to saving around 25,000 tons of standard coal and reduces more than 62,000 tons of carbon dioxide emissions. Huawei FusionSolar 50 kW inverters, 1100 W one-to-two optimizers, and SmartPVMS are used in the system.

Summary

With the convergence of 5G, cloud, and AI, we will embrace a green world where all things will be sensing, connected, and intelligent. In the transformation, Huawei is willing to work with global customers and partners to promote high-quality industry development. Combine PV and energy storage, make green PV a main energy source for every home and business.



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