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pv magazine corporate

Smart PV and storage – anytime for anyone

Four Challenges
Storage and digitalization help with the biggest hurdles to running a 100% clean power grid

A holistic approach
Charting a path to the necessary overhaul of the energy system

SPECIAL EDITION DEVELOPED IN PARTNERSHIP WITH HUAWEI

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Building a Fully Connected, Intelligent World

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Huawei: Powering ahead with innovation to get to net zero

Photo: pv magazine/Thomas Beetz

This is the sixth year in a row that **pv magazine** has partnered with Huawei to produce a special edition showcasing the latest solutions, technology and projects from this leading player in the global energy transition. There is an even stronger global consensus in 2022 to accelerate the energy transition away from fossil fuels and towards renewable energy and carbon neutrality.

In June 2021 Huawei established a new subsidiary, Huawei Digital Power Technology Co., to accelerate the move to low-carbon and zero-carbon energy systems. To do this, Huawei Digital Power is targeting five major industries: clean power generation, energy digitalization, green ICT power infrastructure, transportation electrification, and integrated smart energy.

But as the solar PV and energy storage projects profiled in this special edition make clear, Huawei's ICT track record has also brought more safety, efficiency and intelligence to such assets. This further reduces the levelized cost of electricity (LCOE) of solar PV, boosting the return of investment (ROI) in this asset class.

Intelligent solutions leveraging Huawei's deep ICT know-how are also fundamental to changing the way PV power plants integrate with the electricity grid. The ultimate goal is for grids to rely solely on renewable energy, but to get there, power electronics technology will have to replicate the way synchronous generators in conventional power systems stabilize the grid. Huawei is at the forefront of these developments. As Mr. Chen Guoguang, president of Huawei Smart PV Business, explains it, "[this solution] uses intelligent PV and storage collaborative control algorithms to realize synchronous characteristics to improve grid stability."

As we ramp up the share of renewable energy to 50% and more, we can also expect Huawei to continue to push the envelope when it comes to further lowering LCOE and the levelized cost of storage (LCOS). Optimizing the combination of high-powered bifacial modules and advanced trackers is one area to further improve yield and LCOE, and already last year Huawei unveiled a solution to address this potential. AI-powered intelligent O&M is surely another. On the LCOS side, pack- and rack-level optimization probably holds further potential and here too O&M costs can be reduced even further.

Solar PV has emerged as the low-cost leader in power generation all over the world and with the smart coupling of PV and BESS in a Smart PV Generator solution Huawei is showing the way to a future with zero carbon grids and much cleaner and friendlier environments.

We hope you enjoy this special edition and the potential of the technology and the solutions profiled in this edition to completely transform the way we engage with the flow of power and energy. The outcome will be a greener and more livable planet for all of us.

Eckhart K. Gouras, Publisher, pv magazine

Photo: Huawei

Digital Power Technologies

Carbon is solidly anchored into every corner of the global economy. Undoing this will require all stakeholder from information services to industrial production to mobility work together for the same goal.

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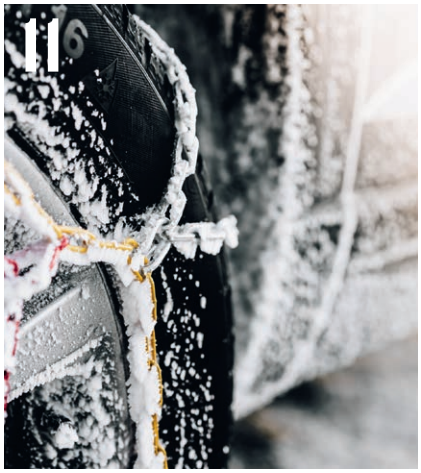

Photo: Huawei

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Four Challenges

It is not just political will or the lack of spending power that can hamper a speedy development toward 100% renewables. There are technical hurdles that demand solutions.

A smart way to disconnect

Smart technologies can cut through the noise of capacitors and transistors to make a difference between harmless oscillations in the system and the onset of a destructive blaze.

Maintain smarter, not harder

Solar power stations can be maintained from a control room. This does not only spare maintenance crews a trip into potentially bad weather but also saves big money.

Markets & Trends ▸

Applications & Installations ▸

Technology ▸

A holistic approach to energy digitalization

The path to a zero-carbon economy requires a fundamental overhaul of the energy system. In the future, power electronics will use algorithms and digitalization to enable the smooth supply of renewable power in every sector and every application. This means bringing a range of technical industrial fields under one umbrella, but Huawei recently took this step.

In June 2021, Huawei established a new subsidiary, Huawei Digital Power Technology Co., to bring together its various solutions in the energy sector with the goal of accelerating the global energy transition. If we zoom out and look at Huawei as a whole the company it took the No. 44 spot in the Fortune Global 500 list last year with 2021 sales revenues of CNY 636 billion ($99.9 billion). Remarkably, Huawei ranks second among Fortune Global 500 companies in funds invested in R&D, devoting 22.4% of last year's revenues to research and development. About 54.8% of its 195,000 employees worldwide are in R&D. At the end of 2021 it operated 12 R&D centers in regions including China, Europe and the Asia Pacific. It also held more than 110,000 active patents across over 45,000 patent families.

Huawei devoted

22.4%

of last year's revenues to research and development

Huawei Digital Power serves one-third of the world's population across 170 countries and regions. Its leading solutions include the following five main areas: Smart PV, data center facilities, site power, mPower, and embedded power.

Smart PV has been leading the global photovoltaics market for six consecutive years in terms of gigawatts of capacity supplied. On the data center side Huawei's prefabricated data center solution has also led the global market for six years and its "smart module" design has led the Chinese market for seven years. Site power are solutions in the telecommunications sector to provide reliable power to mobile base stations and other telecoms infrastructure. Huawei is a pioneer in this area and its site power solutions have led the market for eight years since 2013 with deployments in over 170 countries and regions. mPower is a much more recent development focused on e-mobility. This platform seeks to accelerate the electrification of the automotive industry with an integrated power domain solution and charging infrastructure. Finally, embedded power constitutes a key platform for four sectors – consumer electronics, pan-industry, pan-IT, and pan-CT – to provide partners with digital and modular power solutions.

Five for zero

These five areas form the main highlights of Huawei Digital Power's portfolio with the overall mission of the company being to transition society from low carbon to zero carbon and help its customers achieve their carbon neutrality goals. Five major industries are targeted: green power generation, including on- and off-grid renewable energy generation and energy storage systems (ESS).

The second industry is energy digitalization with a particular focus on conventional power plants. These cannot be phased out immediately but need to become more efficient and also be integrated into the digital power system. Two areas form part of this industry: smart grids and digitalized power plants.

The third industry is squarely focused on the transition from internal combustion engine (ICE) vehicles to electric vehicles (EVs). Based on its established expertise in the traditional power supply field, Huawei further improves the transport experience with electric vehicles by leveraging converged innovations in digitalization and power electronics.

The fourth industry, green ICT infrastructure, has been mentioned already and this industry includes both data centers and site power. It is another area where Huawei can combine its decades long ICT expertise with its experience in delivering clean and smart energy solutions.

Finally, integrated smart power forms the fifth industry and this includes smart buildings, be they individual units or entire campuses. The focus is on managing both the clean energy generation

Photo: Huawei

Installing solar panels is just the tip of the iceberg for the energy transition. The next steps will require a high degree of technical and digital sophistication.

assets, like rooftop solar, and the local energy consumption, including heating and cooling, but also EV charging and other loads. Integrated smart power forms the basis to achieve low carbon or even net zero buildings and campuses.

By leveraging its long-standing expertise in digital and power electronics technologies, Huawei Digital Power integrates cutting-edge innovations on the watt level, as well as in the areas of thermal, energy storage, cloud, and artificial intelligence (AI). The goal is to achieve "Bit Manage Watt." It encompasses clean power generation, energy digitalization, green ICT power infrastructure, transportation electrification, and integrated smart energy, and collaborates with industry partners to accelerate carbon neutrality. Huawei has built a strong reputation in the ICT sector by developing various sensors, 5G, cloud systems and AI technology.

On the power electronics level, the global PV industry has become very familiar with key technologies used in Huawei's string inverters. Battery and cooling technologies are also critical to the further success of solar PV, especially in utility-scale installations in hot environments. If batteries are involved, then cooling is a key consideration both for the inverters and the ESS.

Grid-friendly assets

Building on all these key components and platforms, the overarching objective is to enable more renewable power to move away from fossil fuels and decarbonize electricity grids. In regions with a high penetration rate of renewable energy, for example northwest China with a rate of over 40%, "grid friendly" applications are the only way to move forward. Huawei's latest FusionSolar Smart PV and Storage Solution complies with the strictest grid-connection standards in the world to enable grid friendly utility-scale installations. This includes the ability to handle a low short circuit ratio (SCR) at the interconnection point of at least 1.2 and complying with high- and low-voltage ride-through requirements. For example, for high-voltage DC power transmission lines in China, the active power fluctuation must be less than 10% for high-voltage ride-through and low-voltage ride-through.

To enable grids that are solely powered by renewable energy so-called "grid forming" technologies will be required. Huawei is at the forefront of these developments with its Smart PV Generator concept. As highlighted by Chen Guoguang, President of Huawei Smart PV Business, at last year's Huawei FusionSolar Smart PV & Large Scale Energy Storage Global Virtual Summit, "the PV and storage coordinated control algorithm turns the PV system from an uncontrollable and unstorable current source into a stable voltage source, creating the PV generator." Applying synchronous grid-forming technologies to renewable energy systems will enable even higher renewable energy penetration rates and ultimately grids that are 100% carbon-free.

Digital power technologies to reach carbon neutrality

Carbon neutrality will have an extensive impact on society – just as significant as the invention of steam engines, electricity, and computers. In fact, carbon-neutrality goals are no longer restricted to the energy and transportation industries, as achieving these goals will require the collective efforts of all countries, cities, enterprises, and individuals.

"ICTs have the potential to help industries reduce carbon emissions by 20%"

Carbon neutrality is a shared global mission. It's not a slogan. It's an action. It's the technologies, products, solutions, and services such as PV inverters and storage solutions, many people are working hard for. Individually, these products may not solve such a big challenge as climate change. Added up, however, the numbers could be way more staggering than we think. The International Energy Agency (IEA) estimated that renewable electricity generation would grow by 8% in 2021. Solar PV and wind are now slated to contribute two-thirds of the growth in renewables. Meanwhile, engineers at Huawei are also actively working toward a greener world.

'The Age of Resilience is now before us," said Jeremy Rifkin, leading economist and bestselling author. "How we adapt to the new planetary reality that faces humanity will determine our future destiny as a species."

Frankly, all of our futures depend on achieving carbon neutrality, which is a daunting thought. It's difficult to know where to begin. At Huawei, we start with the tech.

Carbon neutrality

Low carbon, electrification, and intelligence are the key to carbon neutrality, which relies on advances in science and technology to reduce energy consumption and carbon emissions, gradually decoupling economic growth from carbon emissions.

Globally, we are seeing three key trends. The first is the fourth industrial revolution, which is making our world smarter. The second we've already discussed, carbon neutrality is driving an energy transformation towards a clean, low-carbon, safe, and efficient energy system. And finally, we are seeing technology play an increasingly important role in clean energy.

Specifically, the third trend is the convergence of energy and information flows which will enable renewable energy to serve as the primary energy source in new power systems. Traditional power systems with limited digital automation and interactions will eventually be replaced by more efficient, digitalized, and intelligent alternatives capable of sensing and interacting.

Meeting demand

The levelized cost of energy (LCOE) of global renewable energy, such as PV and wind power, has decreased rapidly since 2018. It is now significantly lower than the cost range of fossil energy. This is the first step in renewable energy becoming the primary energy source. Renewable energy could meet 86% of global power demand by 2050, IRENA concludes. We will also see installed PV capacity increase from one Terawatt today to 8,5 TW, in 2050.

In terms of energy consumption, electric energy from cleaner energy mixes will gradually replace traditional fossil fuels. The usage of electricity will surpass oil by 2050, growing from 20% in 2017 to 49%. Manufacturing, construction, and transport are major industries that need to switch to electricity to go green. In addition, green buildings and campuses will be built using renewable energy, improving their energy efficiency.

While the increasing penetration rate of renewable energy and electric vehicles is positive for carbon neutrality, it also represents a huge challenge for the stability of conventional power grids as they need to shift from centralized to distributed power generation. To maintain their stability and reliability, intelligent collaboration and scheduling technologies must streamline power sources, grids, loads, and storage devices for peak shaving. This will improve energy effi-

Photo: Huawei

Digital industries and energy industry sectors will need to work in tandem for a clean, net-zero future.

ciency and grid stability, while reducing energy costs. Huawei will be an active player in the journey toward carbon neutrality. Through technological innovation, Huawei will help industries reduce energy consumption, accelerate the transformation of their energy mix, and make clean, stable, and affordable energy accessible to every business.

New system

Huawei's Institute of Strategic Research forecasts that renewable energy will account for more than half of all energy produced in 2030, half of all vehicles sold will be electric, and electric transport will become the norm. Within this context and in the next decade, ICTs have the potential to help industries reduce carbon emissions by 20%.

To position renewable energy as the primary energy, new power systems will integrate digital and physical systems to optimize energy and service flows using data. Data will be a core production element for streamlining power sources, power grids, loads, and energy storage. It will make power generation visible, measurable, and controllable. Power grids will be controlled by a coordinated cloud and edge system, and power consumption will be supported dynamically by pooling a massive number of resources.

In the digital industry, Huawei will pursue four "green" directions, focusing on innovation and open cooperation.

Four green directions

Integration: We will continue to integrate leading power electronics technologies with digital technologies, converging energy and information flows to manage watts with bits. This will promote the digital transformation of the energy industry.
Clean power system: We will develop a clean power system using primarily renewable energy sources. This synergy of power sources, grids, loads, and energy storage will help renewable energy replace fossil fuels.
Electric vehicles: Electric transport users are still concerned with charging convenience, mileage, and safety. To ensure a good user experience, Huawei will build a converged, simplified, safe, reliable, and intelligent electric power solution. We will also develop charging and swapping network solutions that integrate PV power generation and storage to interact with users, vehicles, charging stations, roads, and networks.
Green data centers: ICTs are consuming more and more energy. By 2025, data centers and telecom sites will consume 950 and 660 billion kWh (3% and 2% of global electricity consumption) per year, respectively. Huawei will build zero-carbon, efficient, and intelligent green ICT infrastructure solutions for data centers and telecom sites.

Storage, consumption

In the power generation field, Huawei was one of the first companies to launch a smart solution, starting with inverters, which function as intelligent sensors for PV arrays and collect information from each string. This innovative solution fully digitalized PV plants. In 2021, Huawei further integrated smart PV and new ICTs to build a comprehensive, intelligent, and all-scenario PV plus storage solution. The solution significantly reduces LCOE and transforms PV from grid following to grid forming, making PV a primary energy source. By December 2021, Huawei's digital energy products and solutions had generated 482.9 billion kWh of green electricity, saved 14.2 billion kWh of electricity, and prevented 230 million tons of carbon dioxide emissions, equivalent to planting 320 million trees.

The smart PV solution has been used in more than 70 countries. For example, China's Ningxia and Shandong provinces have the world's largest agricultural-solar plant and fishery-solar plant, respectively. These have become local showcases of environment protection. On September 30, 2020, Huawei helped the world's largest PV plant (2.2 GW) connect to the grid.

Such clean energy bases are not only showcasing green energy, but are also accelerating the transformation toward a low-carbon energy mix. PV power can play an important role in the rural economy. For example, it can enable energy independence in agricultural production. Moreover, surplus power can be sold to the grid to increase farmers' incomes. Businesses are also benefiting from PV power – it both reduces costs and makes companies more sustainable. PV also has significant synergy potential with agriculture, fishery, and animal husbandry to increase income, improve the environment, and combat desertification, bringing economic and environmental advantages.

In the ICT infrastructure field, operators also see carbon neutrality as an important strategic goal. However, going green is a substantial challenge. Operators often receive power devices as auxiliary devices of telecom equipment, which increases both energy consumption and OPEX. To address these issues, Huawei offers five solutions for target digital power networks, including simplified sites, equipment rooms, and data centers, as well as ubiquitous green power and a comprehensive smart power cloud. From zero-carbon power generation to zero-carbon homes, transportation, data centers, and campuses, Huawei's efforts are actively contributing to creating zero-carbon cities and eventually a zero-carbon planet.

Global partners

Huawei digital power integrates power electronics technologies with IoT, big data, and AI to minimize power generation costs, maximize bits transmitted per watt consumed, support the increasing computing power of data centers, and enable green transport for everyone.

United, we can achieve anything. Peak carbon emissions and neutrality goals require the collective efforts of every player in the industry. Huawei will continue to promote its open cooperation strategy and work with partners throughout the industry to save our planet. pv

By December 2021, Huawei had generated about

482.9 billion kWh

of green electricity

Building a future-oriented power system

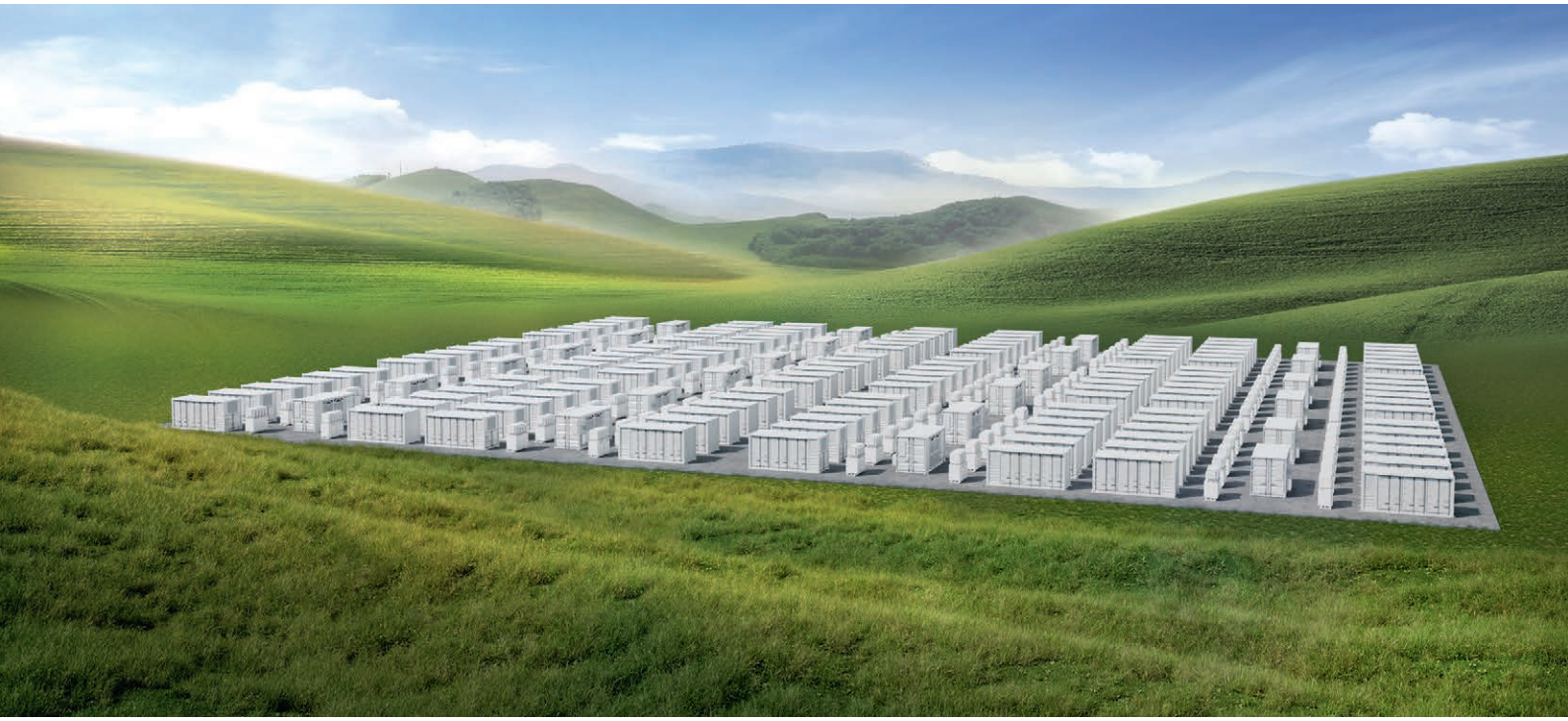
Around the world, power systems are set for a complete overhaul, replacing the old fleet of conventional power stations with zero-carbon emissions options. This transition will require the use of storage systems, as such technologies can help with a range of challenges. What are the technologies, solutions and applications that will matter in the future?

Huawei's participation in the world's largest micro-grid project underscores its status as a global leader in the use of battery storage. In March, the group's Huawei Digital Power unit signed an agreement with Ghana-based solar developer Meinergy to provide 500 MWh of battery storage capacity for a 1,000MW solar installation in Ghana. The project, set for completion in 2023, will showcase Huawei's unparalleled ability to turn PV projects into grid-friendly assets.

However, the Ghana deal is just the latest step in Huawei's rise as the world's leading purveyor of grid-friendly solutions. The contract underscores its solid track record for cost-effective, value-added consulting services, such as modeling and simulations for large-scale micro-grids and off-grid power systems. The message is clear: Huawei FusionSolar's smart string energy storage system is set to turn PV into a primary energy source in the future.

"The key to building a future-oriented power system based on renewable energy is the integration of digital and power electronics, technologies" said Fang Liangzhou, CMO of Huawei Digital Power, at a virtual summit in July 2021.

Huawei has built this reputation on more than 10 years of experience in energy



Big batteries could be tied together to power stations, in order to form the backbone of future power systems. Batteries offer stability to the grid, but Huawei's battery control algorithms ensure stable operation of the actual batteries.

Photo: Huawei

storage R&D, with more than 8GWh of lithium batteries shipped for a range of applications, including utility-scale PV plants and residential applications. And experience breeds expertise – a point clearly illustrated by the company's projects in West Africa.

For example, it has provided its smart string energy storage solutions to ensure smooth PV output and reduce the impact on the grid with several solar projects in Ghana, in cooperation with local EPC specialist Meinergy. In March 2022, Huawei FusionSolar agreed to provide Meinergy with a complete set of smart PV and ESS solutions for a 1 GW utility-scale PV plant backed by 500 MWh of battery storage capacity in Ghana.

Grid-friendly assets

The intermittent and fluctuating nature of PV makes storage critical for grid connection, safety and stability. Huawei pairs advanced power electronics with digital technologies to drive digital transformation in the energy industry. Fang notes a number of challenges facing traditional storage systems, but Huawei's smart string modular design refines storage system management via battery pack-level and rack-level optimization. The list of control algorithms is topped with short-circuit diagnosis at the cell level, smart rack control and fault isolation at the rack level and multi-level linkage at the system level.

Rack-level optimization means all racks are simultaneously fully charged or discharged, avoiding parallel mismatch and enabling phased battery deployment. The Huawei Smart String ESS allows each rack to be fully charged and discharged via a smart rack controller. This facilitates automatic SoC calibration via the BMS through the voltage method. Huawei's smart rack controllers also mean the calibration of a single battery rack does not affect other racks – old and new batteries can be mixed, allowing for phased deployment.

Pack-level optimization improves the charge and discharge capacity by 6%, while rack-level optimization offers a 7% improvement, Fang said. Huawei's innovative distributed heat dissipation architecture extends battery lifespans, while intelligent technologies such as AI and cloud-battery-management-systems are critical to ensure the safe operation of storage assets.

"Huawei pairs advanced power electronics with digital technologies to drive digital transformation in the energy industry"

Industry benchmark

Ghana's PV and storage project will pioneer the safe, stable operation of PV and storage-based power systems, while ushering in a new era of grid parity. Huawei will also show how its solutions can withstand extreme environments, high temperatures, high humidity, and high salinity.

With regard to grid-friendliness, Huawei's advanced technologies offer many benefits. Its grid-forming algorithm solves problems related to parallel cross currents in systems with multiple voltage sources, black starts, and power oscillation damping. This allows systems to switch between grid-tied and off-grid modes, and adapt to extra-low voltage power grids and electrical power grids, while supporting a wide short-circuit ratio range.

Huawei uses power electronic technologies to overcome inconsistencies in lithium batteries. It uses refined management to maximize battery charge and discharge capacity, while supporting the mixed use of old and new batteries for easy maintenance and replacement.

It also offers four layers of safety protection, including cell-level AI internal short-circuit detection, pack-level proactive safe shutdown, rack-level overcurrent protection and fault isolation, and system-level intelligent fire extinguishing linkage protection. Huawei's Smart String ESS Solution helps grids to maintain stability in the face of high temperatures, high humidity, and high salinity. Aside from some hydro-capacity, the Ghana power grid is dominated by oil and gas-fired power generation, while synchronous generators feature voltage sources that support independent grid integration, with rotational inertia and reliable frequency and peak regulation capabilities to maintain grid stability.

However, PV and conventional energy storage are current sources and can't be grid-independent and stabilize the grid. Huawei's grid-forming algorithm therefore enables PV and energy storage systems to become reliable voltage sources for a stable grid. The system also has equivalent rotational inertia and maintains grid frequency stability with the primary frequency regulation capability. This will be crucial in the complex grid environment of the Meinergy project in Ghana, but Huawei's Smart String ESS with grid-forming algorithm can support both extremely weak and strong grids.

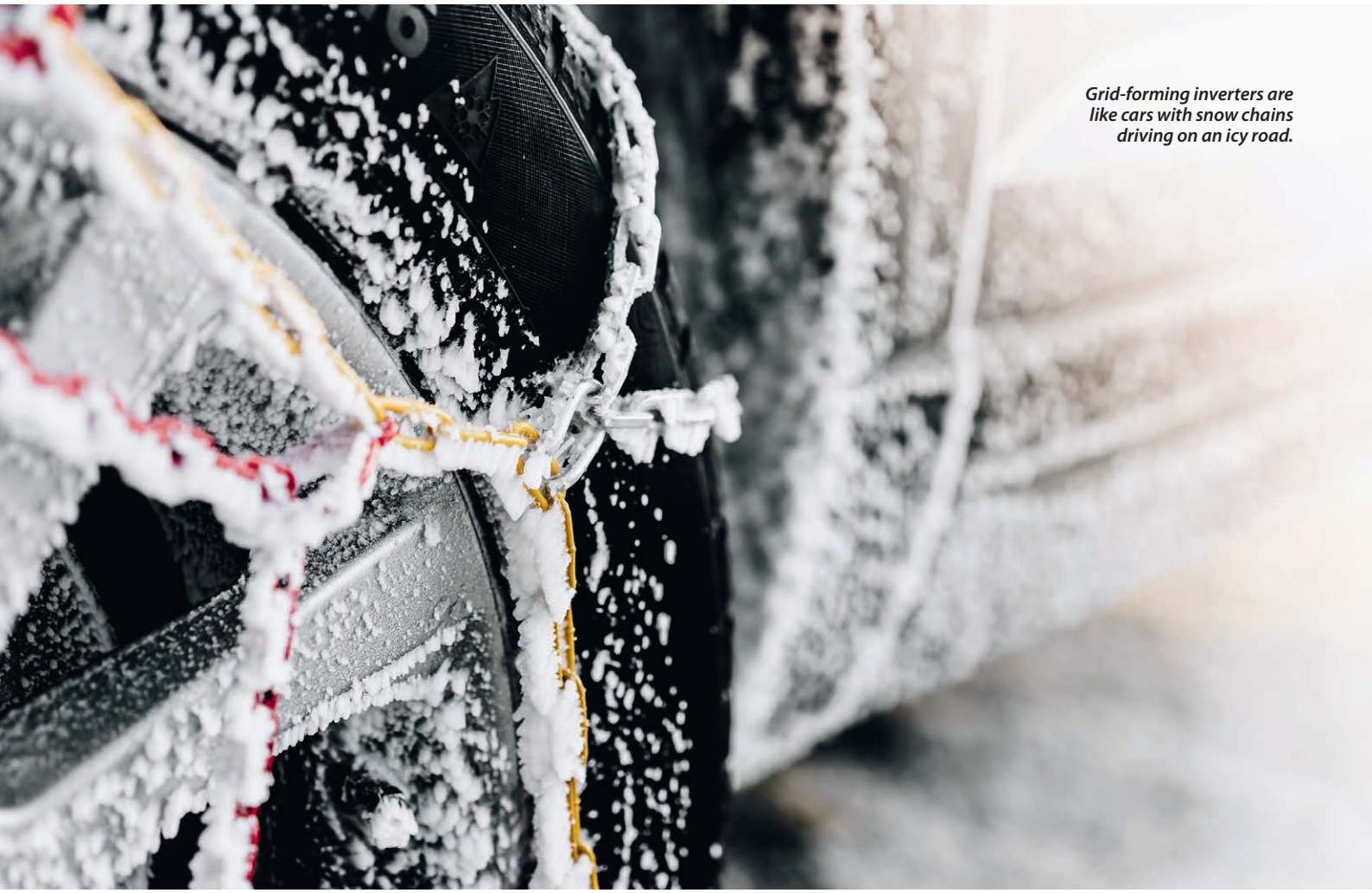
Four challenges

Phasing out conventional power plants based on synchronous generators is not just a political or financial challenge, but also a technical one. Grid operators will impose significantly stricter requirements on PV power plants than they have in the past, and it will be largely up to the inverters to fulfill these. pv magazine looks at four key challenges for grid operators and inverter manufacturers.

Hariram Subramanian is a man who likes giving examples. "A weak power grid is like a snowy road in winter," says the CTO of FusionSolar Solutions at Huawei's European research center near Nuremberg, Germany. Cars slide easily. If you drive with snow chains, the situation is a little better.

Today's advanced inverters are like cars with snow chains. But in the future world of electricity, it is the road that needs plowing. Translated to the inverter sphere, this is a grid-forming inverter. The higher the share of renewables in the grid, the lower the percentage of synchronous generators of conventional power plants, and the more slippery the road.

What snow and ice cause on roads, a too high impedance, the physics term for AC resistance, does to the grid. For example, the impedance increases if a power plant and a load are connected via a long power line with a relatively small cross-section. If a load is connected to a network point with high impedance, instability may happen, ultimately leading to a collapse of the power system. To use another comparison, this is like using old batteries. With-



Grid-forming inverters are like cars with snow chains driving on an icy road.

Photo: Luka Nguyen

out load, their voltage may still be close to the nominal voltage. If you add a load, it quickly drops to its knees.

"Grid-forming inverters control the voltage and frequency and thus are suitable for weak grids, whereas grid following inverters don't control grid voltage and frequency," says Subramanian. "Especially in a weak grid situations grid following inverters will have to follow the voltage angle at the point-of-common-coupling with the help of a phase locked loop, which creates unstable system effects." Besides this, there are more challenges in building a renewable energy system with a high share of power electronics interfaced generators.

"To dampen the harmonics in the inverter, you need adaptive intelligence"

Fault current

There may be sparks or even a smoldering fire if a short circuit occurs. To control the consequences, power lines are equipped with protection devices. These must be set to react when the short-circuit current is reached. On the other extreme, a power line can be as thick as it wants; it cannot supply a higher load through the fuse than is defined by the short circuit current rating.

Synchronous generators have steady state short-circuit currents well above the rated current. Typically, the short-circuit current exceeds the transformer's current rating by three to four times on the high voltage side of transformers. An inverter-based technology's maximum steady-state fault current contribution is around the current rating in per-unit terms. A behavior that protects their internal electronic components. The more renewable supply in the grid and the more synchronous generators are turned off, the lower the grid's short circuit ratio.

"You either have to design the inverter in a costly way, or you have to design the grid protection differently," Subramanian says. Regulators are aware of the problem. In China, for example, the Qinghai Electric Power Company requires since August 2020 that the renewable energy field operates stably at a short circuit ratio of 1.5.

Low harmonics

The scene of the Tacoma-Narrows Bridge dancing in the wind and ultimately collapsing due to aeroelastic flutter and resonance is legendary. This event is also part of Hariram Subramanian's treasure chest of vivid examples because such resonance effects and harmonics can also occur in the power grid, and inverters are intrinsic sources of harmonics.

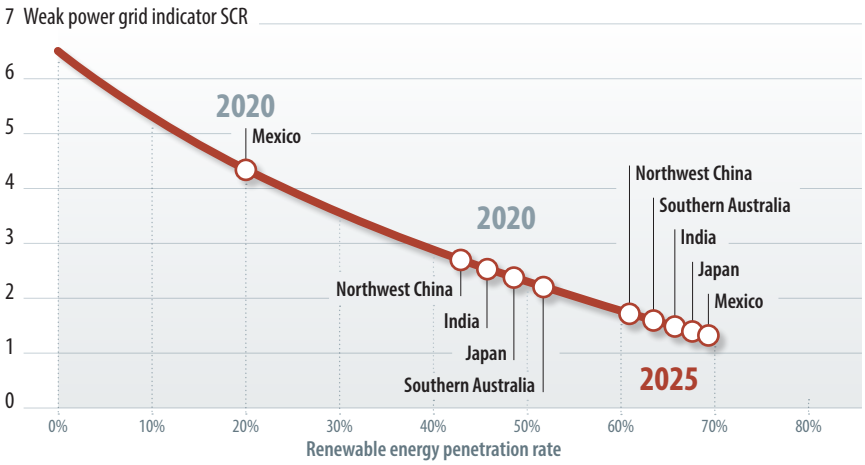
Put simply, when inverters chop direct current into alternating current, this procedure creates rectangular waveforms. Choke coils smooth these out to an almost sinusoidal shape that contains harmonic distortions as a reminiscence of their genesis from rectangular waveforms.

Poorly built bridges start oscillating because there is resonance between frequencies of the environment, such as pedestrians walking on the bridge or wind blowing onto it, and the resonant frequency of the bridge itself. Just like tuning forks start to vibrate when the sound in the environment exactly hits their specific resonant frequency. Such resonances and couplings are also possible in the power system, which contains many elements capable of oscillating, such as coils, transformers, and capacitors. Couplings of the harmonics in the inverter output and these structures can quickly destroy components in the grid.

"To dampen the harmonics in the inverter, you need adaptive intelligence," Subramanian says. Sophisticated control algorithms cut off the unwanted frequencies by impedance shaping. One

The grid-strength renewable energy nexus

Source: Huawei



of the challenges is that it must operate faster than the frequencies to be attenuated. This means sampling rates of several tens of kilohertz are needed. Huawei has succeeded in reducing the proportion of the energy of the harmonics to the total energy, known as total harmonic distortion (THD), to less than 1% (see p. 35). Also, the technology brings in high passivity through control algorithms which can dampen any resonance points within its control bandwidth that might occur in a power plant.

Incidentally, a grid's short circuit ratio also plays a role in the sensitivity to harmonics. The stronger the grid, the lesser individual inverters can create disturbances in the grid. Therefore, in the future, when the share of solar and wind power plants increases, the total harmonic distortion must be kept as low as possible. "A good control should make the system behave as a sink to harmonics rather than a source of harmonics," says Subramanian.

Inertia desired

Power systems need to maintain a precise balance of supply and demand at every instant of time. More power must be provided immediately when adding a large load to the power grid. Synchronous machines, such as coal or gas plants, would need a few seconds to a minute to fire more fuel and provide the extra power. The seconds it takes until this happens can be bridged using the inertia of the rotating masses. These may decelerate somewhat in the process, resulting in a slight reduction in frequency. Still, the consequences are controlled as the power stored in the rotation of the turbines is made available. The frequency returns to 50 or 60 Hz when additional power sources are switched on.

To replicate such behavior with inverters, they need energy storage. In the existing energy system, generation and inertia are physically linked. In the renewable energy system, you can also create inertia elsewhere. "In principle, it's better to install storage closer to the loads," says Hariram Subramanian. Therefore, you have to rethink the whole concept of grid formation in the future. In some cases, storage can be placed even at the generation and near the load side to create virtual transmission lines to help reduce any potential curtailment.

Incidentally, that was also the conclusion drawn by the regulator in the UK after a power outage on August 9, 2019. It is now providing tenders for the so-called stability pathfinder programs. It has already procured 2.5 gigavolt-Ampere-seconds of inertia at the cost of €377 million ($408 million) until 2026.

Differences between thermal power and renewable power

	Synchronous generators	Today's inverter
Type of source	Voltage source	Current source which does not establish voltage
Inertia	Large inertia through shaft kinetic and boiler thermal inertia for frequency control	No inertia
Waveform	Sinusoid waveform generated by rotating magnetic field	Square wave which is filtered inside the inverter
Controls	- Excitation controller for stable voltage - Power system stabilizer controller for stable voltage - Governor controller for torque and power	- Active power - Reactive power - Active current control - Reactive current control

Conventional plants

The Meinergy Ghana storage project, where Huawei is helping its customer build a significant array of PV and storage generators, demonstrates that the technical solutions to replace conventional power plants are available. The project will supply power to millions of citizens and be the world's first large-scale application of PV and storage as primary energy sources.

But still, that is only half the battle. Island microgrids, which can work based on self-defined specifications, have to be interconnected and form national grids. When grid forming is applied collectively under parallel operation in an interconnected system, it also needs to be grid sustainable. There are multiple combinations of grid-tied and grid forming systems. Henceforth, overall grid stability is imperative. To use the grid-forming technologies, common standards have to be defined for how the inverters of the future should behave in detail, and once the standards are in place, programs must be developed to test the components.

Often mentioned, for example, is the black start capability that inverters need to have. Inverters in the future will have to maintain the grid and build it up from scratch. "It's not yet well defined how that will be done," Subramanian says. Inverters can already build island grids today, but there needs to be a precise definition of how an island grid will be connected and synchronized to a grid that is being formed. Then it is just a matter of installing enough renewables so that energy suppliers can take fossil-fuel power plants off the grid.

"You either have to design the inverter in a costly way, or you have to design the grid protection differently"

‘We are only working with Tier 1 suppliers’

Photo: Alter Enersun

Jose Luis Morlanes looks back at over 13 years of experience at Alter Enersun. Previously, he has been active in the chemical production sector. Morlanes holds degrees from the University of Barcelona and the EADA Business School in Barcelona.

Alter Enersun CEO Jose Luis Morlanes spoke about his company’s high standards when it comes to project development. In Spain, Alter Enersun is working a sizeable pipeline of solar projects, some of which will also include large scale storage solutions.

What are your quality requirements when choosing your partners? What do you consider when you are selecting a vendor for power electronics?

The company policy consists in requesting the highest quality from the equipment suppliers. In fact, we are only working with Tier 1 suppliers for panels, inverters, trackers, and transformers. We believe that the quality, efficiency, and durability of our installation is directly related to the quality, durability, and innovation capacity of our suppliers. Additionally, the price of the equipment is important once all the above is guaranteed.

Have you chosen to work with Huawei as an inverter supplier? Why?

We started our relationship with Huawei two years ago when we introduced its string inverters in our 50 MW Project in Huelva. This was a new experience which aimed at verifying if this type of equipment offered a greater security in the event of problems and if it contributed to a greater plant efficiency (LCOE reduction).

The experience has been positive. The existence of a small equipment stock allows the plants not to stop when there is a failure, and the start-up has been very simple.

Today Huawei is one of the most important and committed partners that Alter Enersun has.

String inverter market share has been growing exponentially. What do you usually choose? What’s your take on the everlasting central versus string-inverter debate?

We are verifying that the string inverters are functioning properly, in fact we have been using Huawei in the last six installations which we have put into operation. Honestly speaking, the string inverters are efficient, safe, and competitive.

Since mid-2020, a series of cost rises in the industry has caused trouble for many solar project developers. How has Alter Enersun been impacted?

The existing problem in the global supply chain has had an impact, first in delays in work execution and then in the huge freight cost increase, especially for products originating from China.

To complete this difficult scenario, we have seen how the cost of practically all equipment and supplies that make up photovoltaic installations has increased. The result has been a delay in projects and a substantial cost increase.

How do you see the role of energy storage in solar projects? Are you interested in combining PV with batteries?

To complete the energy transition and leave fossil fuels behind we need to guarantee the manageability of renewable energy. In our opinion, we will achieve this with storage of all kinds: reversible jumps, batteries… and with the development of hydrogen as fuel and storage medium.

Alter Enersun is building one of the largest storage projects in Spain. Specifically, 62 MWh in the Extremadura projects that should be in operation in Q4 2022 and Q1 2023. That is the best proof of our confidence in battery storage.

Photo: Huawei

Back in 2020, this 50 MW project in the Spanish region of Huelva marked the beginning of the cooperation between Alter Enersun and Huawei.

What are the technical challenges with large installations in Spain? How important is selecting the right inverters for the job?

We must develop efficient installations that minimize the use of land and water per megawatt; that coexist with livestock and agriculture and above all, we must be a "good neighbor", respecting and creating value on a local level.

The inverter, panels, trackers and transformers are the critical equipment of the plant. Choosing the inverter well results in reliability, improved production, and an easy start-up.

Do you have any projects in development that you would like to share with our readers?

We are building four projects in Extremadura totaling 120 MW and the first part of a storage project with 9 MWh batteries of an eventual 62 MWh. Before the end of the year, we will start five additional projects in Andalusia that will total 250 MW, in addition to building 40 MW of self-consumption for large industries.

What needs to be taken into account when building a solar plant with a battery storage? Is the project size crucial for the choice of these devices?

We expect an improvement in storage costs in the coming years due to increased production in Europe and increased competition.

To the extent that storage costs are reduced, its use will be extended and not necessarily related to large projects.

Several companies are searching for new partners, to grow. Do you also have such plans in mind? What do you think needs to be in place for solar investment to accelerate?

Alter Enersun is a group of companies capable of developing, investing in, building, and operating photovoltaic installations of all sizes. Our intention is to continue with organized growth and to deepen our relationship with our partner Bruc Energy.

"We must be a "good neighbor", respecting and creating value on a local level"

Green steel – powered by

SolarApex has built what it calls the world's largest rooftop PV array. A 140 MW project on a steelmill will help Turkish steelmaker Tosyali to shift its production to carbon-free 'green steel.' Chief Marketing Officer Besime Özderici says the project could be an example for other energy-intensive industries.

SolarApex is Tosyali Holding's solution partner for what it calls 'the world's largest rooftop solar power plant project' – a 140 MW installation across multiple sites. What are the challenges of such a large project?

Besime Özderici: The biggest challenge we face during construction is quite simply the organization of such a large and multifaceted project. You can imagine, 140 MW of rooftop solar across multiple facilities, it took a lot of ambition but perhaps even more planning and execution. Coordinating the resources, keeping our teams safe and healthy, especially during a global pandemic, was quite challenging to say the least. But we tackled each and every aspect of this project through the joint efforts of every person on the team, each of whom proved determined in achieving our goals.

How does Huawei's FusionSolar Smart PV Solution enable such a large project?

Huawei's FusionSolar Smart PV Solution means high quality products and it means no fuses. To be sure, Huawei's products provide higher yields, so from an economic point of view its solution enables investors to obtain maximum efficiency. And from an O&M perspective, the intelligence of the systems means the PV plant, even a diffuse rooftop system like this project, is easy to maintain.

How many individual installations make up the 140 MW project? How many panels will be used? Approximately how much roof space will be utilized across how many facilities?

The Tosyali Solar Project in Osmaniye/Adana is the world's largest rooftop solar project. It took 300 people to complete the installation which took place in two phases. The amount of materials used was simply staggering – 260,000 solar panels, 1,400 inverters, 2,000 km of solar cables and 3,500 tons of steel profiles are going into the project. With a total capacity of 140 MW, you can imagine that is spread across many rooftops, indeed covering approximately 632,000 square meters of Tosyali's production facilities.

***It took* 300 people**

to build the Tosyali PV project

Why did SolarApex use the 'purlin connection' technique for this project?

With the purlin connection technique, the steel profiles are mounted right on the column instead of the roof itself, so that the system is not affected by the strong winds nor the strong vibrations. This technique is rather rarely applied, probably because it requires a considerable amount of engineering expertise. But we at SolarApex employed it for this project because the region where the various rooftop installations were to be installed can see pretty harsh weather conditions, particularly heavy winds. On top of that, the heavy machinery within the buildings causes quite a strong vibration during production. If we had employed conventional installation techniques in these circumstances the rooftop system would not be as solid and durable as we'd like it to be. And we are not in the business of putting the system at risk.

a rooftop

Photo: Solarpex

Besime Özderici, who holds a degree in economics from Turkey's Koc University, started working in the national energy sector six years ago as a marketing manager. Over the last three years, she has served as the chief marketing officer of SolarApex, the solar energy spin-off of Turkish energy giant Yenelsis Enerji.

Huawei Turkey is now in its 20th year – did your previous experience with Huawei give you confidence that such a large and coordinated project was possible?

Huawei is a partner we trust with the quality of its product and technology. We share a common vision, and that is why we have been collaborating with Huawei for almost all of our previous projects, in which Huawei's smart PV inverters are always present. Both SolarApex and the investors are more than satisfied by the performance and service of Huawei's projects, and as a result of that mutual trust and contentment our bond is only strengthening. At SolarApex, we are honored and proud to have collaborated with our long-time solution partner Huawei on this world-wide legendary project. And it is a sweet coincidence that Huawei's 20th year in Turkey has come in the same year as we collaborate on realizing this significant project.

Is this project a sign that energy-dense commercial rooftop PV can deliver enough energy for companies to cut their emissions?

We estimate that 140 MW will generate approximately 250 million kWh of green energy annually. For Tosyali Holding, a portion of this energy will be used to produce hydrogen for the production of green iron and steel – two very hard-to-decarbonize sectors. This project will definitely be seen as a magnificent example of what large-scale rooftop solar can do, an example which will lead major industrial companies to consider their own energy transition. After all, in terms of size and scale, as well as quality and technology, this project is one of a kind, pioneering, but hopefully one day in the near future there will be many others like it.

How important are partially independent energy supplies for big industrial players like steel producers, in order to maintain a competitive edge?

Stability of power supply is absolutely crucial for producers with large energy consumption, and of course the heavy industry is highly energy intensive. With electricity prices surging almost constantly, generating energy through renewables means independence from those fluctuations, and that stability is extremely important, not only because it saves money in the long run, but because it protects against grid outages and other issues that arise from dependency. Moreover, generating energy where you use it reduces transmission losses. Big industry players like steel producers must eliminate their carbon footprint in order to maintain their position in the global market. In response to the Paris Climate Accord, and more and more countries pledging carbon neutrality targets, global players must reduce their emissions while continuing to export and remain competitive, especially with mechanisms like carbon taxes in the mix.

Photos: Huawei

2.2 GW Qinghai, China

The world's largest PV plant, with an installed capacity of 2.2 GW, is located 3,000 meters above sea level. The project slows wind speeds by 41.2%, lowers ambient temperatures by 0.5 C, and has helped to restore grasslands and the ecosystem.

220 MW Sonora, Mexico

The Navojoa PV project is backed by a long-term power purchase agreement awarded via an auction. By 2050, Mexico wants clean power to account for 50% of its electricity.

152 MW Montmédy-Marville, France

The second-largest PV plant in France, with a power rating of 152 MWp, is built during the various challenges that came with the Covid-19 pandemic. It can supply electricity to more than 23,000 people. The project location went from being a wasteland to a vast source of green energy for the region.

65.4 kWp Knysna Elephant Park, South Africa

The Knysna Elephant Park has adopted more than 40 orphaned elephants. Elephants are a fundamental part of the African ecosystem. The solar plant at the park generates enough electricity for daily consumption and saves the facility up to 10% in operating costs.

A notion of partnership

Ludovic Baviere, is the General Director of RMT Industrie und Elektrotechnik GmbH – Groupe Eiffage. For some years now, the EPC contractor has been active in Africa's renewable energy landscape. In this interview he speaks about the company's future plans. Baviere says he keeps an eye on hydrogen developments as demand for the fuel will rise in future.

Can you tell us more about the positioning of Eiffage in the renewable energy sector as a construction and infrastructure group?

The market move towards renewable energies was made more than ten years ago via the Eiffage Energie division, which has today become one of the group's four pillars of activity and whose focus is on the energy transition.

Can you provide some of Eiffage's main achievements in renewables and solar energy?

The giant French solar projects of Toul-Rosières (155 MW in 2010) and Cestas (300 MW in 2013, still the largest PV plant in France today) marked Eiffage's shift to photovoltaic. At the time, the group was chosen for its ability to carry out large scale electrification projects and to mobilize its operational expertise in a very short timeframe. The plant of Cestas was Eiffage's first full EPC (engineering, procurement and construction) solar project and the group has since had positioned itself in this segment within PV development. Our Spanish-speaking subsidiary, Eiffage Energia, has also developed some major solar projects including the Quilapilún and the Huatacondo PV power plants that together have over 200 MW in Chile.

What is your vision regarding renewable and solar energy development?

Our deployment in renewable energy is carried out by geographical area, with three key markets identified: Latin America; Europe, where Eiffage is also developing renewable energy through other businesses such as mechanical construction in low-lying structures for offshore wind power; and Africa, where we operate with the subsidiary RMT that has been present in the continent for over 45 years. Africa has been a major focus for our renewable energy development in recent years.

You are currently developing two large scale solar power plants in sub-Saharan Africa: one in Benin (25.9 MW) and the other in Ivory Coast (37.5 MW). Can you tell us more about these projects and the issues they address?

The project will be coupled with 12 MWh of storage and that will be one of the largest in the sub-region

The two projects will be developing the most important solar installations in both countries. They are a first step towards mass solar production. Solar energy, when combined with a storage solution, can help address the current low quality of the grid's electricity supply as well as the heavy dependence of the continent on thermal energy, which is currently penalizing the economies given the surge in fuel prices. The power plant in Ivory Coast is actually being coupled with a 12 MWh storage system that will be one of the largest lithium batteries in the sub-region. All in all, it is essential to integrate a larger share of photovoltaics into African grids, given the affordability and the local potential of this energy.

Are there specific challenges you experienced in the region? What advice could you provide to PV players willing to enter the African market?

Implementation of projects takes longer in Africa and many IPPs have been affected by the increase in raw material prices. For PV development, whereas in Europe it is coherent from a technical and economic point of view to allocate the construction of a power plant, in Africa it is necessary to retain expertise in logistics and interface with local utilities through a full EPC model. But even if it is more difficult to access, the market exists. Over the years, Eiffage has secure a large number of competencies through its RMT local subsidiaries that operate in 20 countries. This allows us to be competitive and to limit operational challenges.

Huawei supplied the inverters installed on both projects. Apart from the technical aspects, what are the advantages of building strong partnerships in the region?

Solar projects can be replicated and the notion of partnership is important to limit costs and development time. Huawei's strength lies in its customer and solution-oriented culture that is welcomed in export projects where quick feedback is needed.

for Africa

Photo: Yannick Folly/Pixabay

Benin's capital city Porto-Novo.

What is Eiffage's specific roadmap in Africa?

We are looking towards photovoltaic development, with a major R&D focus on storage systems for solar plants so as to overcome the limits of intermittence in PV deployment. A lot of developments are expected, particularly in the green hydrogen economy. The group wants to be a driving force in providing recommendations and guidance to the various utilities and major industrial companies. This line of business implies the pursuit of RMT's core activities in Africa, namely the electrification, development and rehabilitation of medium and low voltage networks.

What role could solar energy play in Eiffage's future development plan?

Solar energy will be an important axis of development in the coming years. If hydrogen becomes a significant storage solution and is incorporated into car manufacturers' models, the production of green hydrogen will become a major growth vector. Positions are already being taken in Africa, particularly in the Sahara, where solar megaprojects could quickly emerge to support the European supply of green hydrogen. We are following these projects very closely.

What synergies do you intend to leverage to contribute to the expected growth in renewable energy worldwide?

Eiffage's energy divisions, which are RMT, Eiffage Energia, and Eiffage Aquitaine's energy branch, operate with a cooperative approach on technological and commercial aspects. The group also has access to extensive financial engineering through its concession segment, which holds long-term leases for highway and airport development. These resources enable Eiffage to take up positions on investments or markets that would otherwise have been difficult to develop.

Do you have any projects in the pipeline that you would like to share with our readers?

Eiffage has about ten solar projects on the starting blocks in Africa. These projects will be launched in the coming months after the rebalancing of their business models, which have been heavily penalized by price volatility.

> *"Solar projects can be replicated and the notion of partnership is important to limit costs and development time"*

Big batteries in Africa

Huawei Digital Power Technologies, a unit of Chinese multinational tech giant Huawei, recently signed a deal with Ghana-based solar developer Meinergy Technology to build a 1 GW solar plant coupled with 500 MWh of storage in Ghana over the next years. Under the terms of the deal, Huawei will supply solar-plus-storage systems for the project. Meinergy will be responsible for the development and construction of the facility. pv magazine recently spoke about the project with Kevin Wu, CEO of Meinergy, and Peter Acheampong, Deputy Director of Renewables for the Bui Power Authority, which owns the installation.

The project will spread across

12 sites

pv magazine: *Huawei and Meinergy recently launched one of Africa's largest solar-plus-storage projects. Is it challenging to plan, develop and build such a project?*

Kevin Wu: Meinergy has vigorously expanded its renewable energy business in Ghana and other countries in Africa to provide stable green power for local communities and bridge the electric power divide. We have been in Ghana for many years, and our business covers the mining, electric power, and PV sectors. We already built ground-mounted and floating PV plants in Ghana and also middle-sized hydroelectric plants. We have gained enough experience and found the trusted long-term partners such as Huawei to deal with big projects.

When did development of the project begin?

We started to develop the project in 2018 and initially we intended at building it in several 50 MW phases for a total capacity of 400 MW, mostly in the northern part of the country, where there are high solar radiation levels. Then we decided to increase the project size and reach other territories in central Ghana.

When is construction scheduled to start?

The project will spread across 12 sites and will see the deployment of PV plants ranging in size from 80 MW to 100 MW and each of this plant should be linked to around 50 MWh of storage. We already started construction on two 100 MW facilities. By the end of this year, were looking to connect to the grid the first 200 MW. And another 200 MW should be deployed each year.

What PV components will be used in the project?

We are adding storage in compliance with grid requirements, as our grid code is very strict. We are using Huawei Smart Energy Storage System with a minimum capacity of 2 MWh. We are using bifacial modules with nominal power ranging from 450 W to 650 W and inverters from Huawei with power of 200 kW. We consider ourselves lucky to have Huawei's setup here. Huawei's string inverter solution, in fact, is an ideal solution for sites with logistics issues. For example, if you have issues with a string inverter, you just isolate that string and the plant keep operating without any problem. However, I would like to stress that there were no particular issues of this kind for our projects in Ghana, in particular at the two sites where we already began work. The real issue we have in Ghana right now is long delays in importing PV components and with Huawei we had the chance to import all the equipment for the two projects under construction in just two months. Once you get the equipment, no more real and technical issues prevent a smooth construction of a project.

Photo: Meinergy

Meinergy CEO Kevin Wu has worked on one of the largest PV and storage projects in Africa.

How is the project being financed?

The funds are currently provided by local lenders. The projects under construction are currently being built at cost of $700,000 per megawatt installed. Its levelized cost of energy should be between $0.06 and $0.07 per kilowatt-hour. The energy produced by the facilities will be sold via power purchase agreements to private clients and the national utility.

What kind of innovations might be introduced during the development of the next phases of the project?

We are planning to bring in new innovations during the development of the whole project. For example, in the first of our two plants under construction we used modules with power of 450 W and for the second we decided to utilize bigger and more powerful modules of 650 W. And as for the inverters, in the first project we used 185 kW devices and in the second we are using 200 kW products supplied by Huawei. We look at trends in the market and we adapt.

Strong partner, big growth

Jen Tan is the Head of Integrated Solutions (Singapore & Southeast Asia) and Renewables (Indonesia) of Sembcorp Industries. The project developer is following through with big growth plans in the region of Southeast Asia.

Sembcorp aims to quadruple its gross installed renewable energy capacity to 10 GW by 2025, up from 2.6 GW at the end of 2020. How do you plan to achieve this target?

At Sembcorp, we are driven by our purpose to play our part in building a sustainable future and have long been in the business of providing sustainable solutions. With the rapidly evolving energy landscape and the move towards a low-carbon economy, repositioning our energy business to strategically benefit from the global energy transition and navigate disruption is an important thrust of the company's strategy. Today, we are one of Singapore's largest renewable energy players and a growing regional leader. We have the track record and capabilities across various segments of the renewables sector and operate a solid portfolio of wind, solar and energy storage assets. In wind, we have the highest wind capacity under self-operation and maintenance of any independent power producer in India. In solar, our expertise cuts across utility scale, floating and rooftop solar. With a strong starting position to build upon and an established footprint in the growth markets – coupled with our in-house capabilities – we believe we are walking the right path to achieve this target. In 2021, we gained momentum in the execution of our strategy with 2.9 GW of renewable energy projects secured.

With a scarcity of land, Singapore's PV sector is focused on rooftop installations.

What are some of the key growth markets for Sembcorp's renewables business and what are your expansion plans?

We are one of the largest home-grown renewable energy players, with a renewable energy portfolio comprising solar, wind and energy storage in key markets such as Singapore, China, India and the UK. While we continue to target growth in these markets, we have extended our reach across Southeast Asia with a growing portfolio.

Vietnam is one of Southeast Asia's fastest growing economies. Sembcorp has been a long-time power generation partner of Vietnam through the development of the country's first independent power project – a 746 MW combined-cycle gas turbine facility. As part of company's strategy to transform its portfolio from brown to green, Sembcorp is also scaling up its investment in renewables in Vietnam. Most recently, it collaborated with state-owned Vietnam Electricity (also known as EVN) to power Vietnam's economic growth and green sustainable development. A memorandum of understanding was signed for the exchange of best practices in enhancing the efficiency and reliability of the power system with technologies such as smart grids and energy storage systems, as well as developing renewable energy projects.

Indonesia is also another core market in Sembcorp's transformation strategy and we see ourselves being able to support its clean energy goals and transition. A signatory to the 2015 Paris climate agreement, Indonesia aims to have 23% of its energy from renewable sources by 2025. We have signed an exclusive joint development agreement with Indonesian renewable energy developer PT Trisurya Mitra Bersama (Suryagen) to develop a large scale integrated solar and energy storage project in Indonesia's Batam, Bintan and Karimun (BBK) region. This project consists of approximately 1 GWp of solar power generation capability and a large scale energy storage system in BBK to support managing the intermittency, for clean energy deployment and export. To support the clean energy needs of the two markets, the renewable power generated onsite will supply the clean energy needs of the local communities and is proposed to be transmitted via subsea cables into Singapore.

Amid the current scenario of rising component costs, how does technology help lower capex and ensure better LCOE for solar projects and those coupled with storage?

It's important to be at the forefront of innovation. Using advanced technology products and solutions like Huawei's can definitely help lower capital expenditure and ensure better levelized cost of energy for solar projects. Intermittency is still one of the major criticisms of solar power but one possible way to counter this and enhance the overall stability and resilience of the grid lies in energy storage solutions. Energy storage is a critically important technology that is gaining momentum globally and I believe will be a game changer, especially in the clean energy space for Singapore. We have invested in such systems overseas, in the UK, and are now looking to apply the technology at home in Singapore. Energy storage solutions can also work synergistically with Sembcorp's other power generation assets, including conventional gas-fired generation, to create more value too.

What role does your network of partners play in ensuring the bankability of a project?

Having a strong network of partners, including quality suppliers and contractors, can definitely help to ensure a smooth and successful project completion. This includes getting the most cost efficient products and services without compromising on the safety and quality of our projects. Having the best value does not necessarily mean lower prices but analyzing the total cost of ownership as well. With a ready network of reliable partners, we can also jointly mitigate potential disruption or service failure due to any unforeseen circumstances and, continuously look to ways to improve productivity with the implementation of the latest innovative technologies.

Tell us more about your partnership with Huawei.

Huawei has been one of Sembcorp Industries's key partners since 2018. Both companies have jointly collaborated on many fronts, from inverter performance managing systems to data logger hardware and energy storage solutions. We are constantly working closely with Huawei to improve the efficiency and reliability of our products and the solutions that we offer to customers.

Photos: Sembcorp Industries

As Head of Integrated Solutions (Singapore & Southeast Asia) & Renewables (Indonesia), Sembcorp industries. Jen Tan is responsible for growing the portfolio in Singapore and Southeast Asia. Jen has over 11 years of experience in the solar industry and holds a BA degree in economics and statistics from the National University of Singapore.

> *"It's important to be at the forefront of innovation"*

‘Solar plants should work for 35 years’

Engineering, procurement and construction companies must take special steps to ensure that PV plants operate reliably and efficiently. Japan’s ORIX Renewable Energy Management (OREM) is one such company. pv magazine recently caught up with Executive Vice President Kazuhisa Yurita to discuss the current challenges of O&M.

You are currently operating C&I rooftop systems and ground-mount solar stations in Japan. In terms of O&M, what are the differences you experience between the two asset classes?

In the C&I sector, it’s approximately 400 assets, but in total is only 150 MW capacity. In the ground-mount sector, we have approximately 100 sites, but at 850 MW. Regardless of sizes and installation form, the access cost pertaining to maintenance is uniform. Therefore, we should take into account the proportion of maintenance costs relative to the total revenue. That also means that in ground-mount installations we proactively exchange spare parts as preventative maintenance, whereas on rooftops, we only practice corrective maintenance, exchanging broken equipment. This is simply because the financial impact of downtime is much bigger than the additional Opex to exercise preventive maintenance for ground-mount installations.

What are the common challenges in terms of O&M?

A big challenge of our 400 rooftop assets is, that during the time of construction we did not have a single policy on how to choose components and how to design the assets. The result is a multitude of unique plants. The challenge today is setting the Opex budget. In practice, we calculate the financial impact of materialized and potential defects,

Photo: ORIX Renewable Energy Management Company

Kazuhisa Yurita has worked in the upstream and downstream sectors of the PV industry, showing more than 14 years of experience. In 2013, he joined ORIX from where he established OREM five years later and has been serving as the new company’s Chief Strategy Officer. At ORIX he continues to keep oversight over the companies solar fleet in his role as Head of Asset Management.

then we calculate the cost to fix the problem to see if the feed-in-tariff rate still justifies the cost of the repair. For our C&I fleet, this must be done manually for each site. By contrast, for our ground-mount systems we have automated most of these processes. Not just the monitoring but also the cost-efficiency calculation of maintenance work.

What role does procurement strategy play in this?

For the rooftop segment there was no procurement strategy a couple of years ago and that was a mistake for ORIX. But today, we only procure power conditioners, inverters and dataloggers from selected manufacturers. For us, suppliers must be highly bankable, with a good track record and reputation on reliability and demonstrate a high throughput. Huawei is among the list of suppliers that fulfil these requirements. With solar modules it is bit easier as no such strict procurement regime is necessary.

Why do you think it's important to optimize the O&M strategy of solar arrays?

That is pretty much the key. Making successive improvements in plant design to bring down Capex have been successful in the past. But under a high feed-in tariff regime for 20 years nobody cares about operational and technical asset management. It doesn't matter if you consider the rooftop or ground mount sector. In order to achieve a lower LCOE, we have to extend the lifespan of solar plants. The operational life should be 30 or 35 years, so that solar maintains a competitive edge against other energy sources.

"Under a high feed-in tariff regime for 20 years, nobody cares about operational and technical asset management"

What proportion of your portfolio features power electronics equipment to enable digital O&M?

Within our company I was leading the ground-mount sector nine years ago. So, from this time all the assets are equipped with digitally enabled equipment because I was the one insisting on them. Regarding the rooftop sector: I would say 20% of the assets have advanced digital communication features. If we invest additionally, 60% of the fleet could have these features. For the remainder there would be no economic rationality to retrofit such digital capabilities.

Is it possible to compare and quantify the improvements?

In 2014, we calculated to take JPY 3,300 ($26) per installed kilowatt-peak and year to run proper O&M on a 450 MW ground-mount project in Japan. Today, it will cost JPY 1,000, or a little less than one-third, to do the same job. But instead of letting O&M determine the cost reduction, we decided to take on more add-on services catered to improve profitability and improved the quality of maintenance with drone inspections and the use of AI since 2018. This shift has added to the cost of O&M. Based on the above, yearly O&M cost is JPY 2,100 per kilowatt-peak. Even with the increased O&M cost, the amount of revenue improvement exceeds the invested costs.

Some of Japan's early PV projects will reach the end of their FIT periods soon. Just how important are well refined O&M practices to be able to continue to run these 20-year-old plants?

The easy answer is that for every plant we need to take into consideration the cost and effect of an O&M measure. Without a high FIT the revenue per produced watthour becomes smaller. In that case there are fewer measures that are worthwhile applying. But the basic principle of calculating the loss resulting from a damage and matching that loss against the cost of repair to see if a repair is economically justified remains the same.

Drawing from your experience and practical perspective, what do you think can be done in future to improve digital O&M even further?

What I would suggest adding is artificial intelligence to calculate how much loss is accruing and then match that with cost to fix the problem. We can then make decisions based on the cost-effectiveness. We have currently installed that function to our software. What I would like to add as the next step is to include the CMMS. In this case, the system will learn conditions of each site, automatically changes the maintenance schedule and engineers will make certain actions based on it. Furthermore, I would also like to connect the weather forecast, eventually enabling the system to predict tomorrow's production. In two or three years, the operation will shift toward this direction for sure. pv

For your convenience

In Thailand, the 7-Eleven convenience store chain uses PV systems at its shops to lower its electricity consumption. Cristobal Chin, the CEO of Chow Energy, shared his thoughts on these projects.

Photos: Chow Energy

Chow Energy CEO Cristobal Chin says reliable real-time monitoring systems can help the company to manage more than 1,000 decentralized PV arrays, at competitive costs.

You plan to mount PV systems on top of all 7-Eleven stores in Thailand. Just how many rooftops are we talking about?

Since we obtained the information regarding the policy to start utilizing green energy in 7-Eleven stores, we, at the time of design, had been sending our teams to investigate electricity usage and available installation area of each branch to come up with the optimum design and capacity. With such information, we have been awarded with and will be installing more than 1,200 solar rooftops systems and this collectively would result in more than 22 MW capacity nationwide.

What portion of the stores' energy consumption will be covered by rooftop PV?

According to the data derived from our load-optimization investigation the rooftop systems should be able to support approximately 20% to 25% of the stores' energy consumption.

What are the technical requirements to operating such a vast decentralized fleet?

First of all, it must be noted that each part of Thailand has different conditions of weather and pollution that would definitely impact electricity generation. Our requirement for the system is actually simple; the performance of each system must be at its optimum at all times where possible. Managing these many systems located in various locations would normally require excessive resources, including cost and manpower, if we did not have a reliable and real-time monitoring system. With Huawei's Fusion Solar monitoring system, we instantaneously know the condition of each system which allows us to promptly analyze its performance and dispatch our team to the site in a timely manner. Moreover, Huawei has made available a broad variety of functions. Apart from being able to pinpoint performance on the inverter itself, we can even obtain information on PV modules' health and condition. Therefore, Huawei's inverters can match our high operating standards and objectives to provide only the highest performance and reliable systems to our customers.

How has your tech helped to overcome challenges?

There are many challenges that we have encountered during development and construction of the project. Selecting Huawei gives us strong stability of electricity generation as the inverter's technology provides high efficiency, high stability and durability for the lifetime of the project. These are the main reasons why we generally choose Huawei as our partner in many projects in Thailand as well as our overseas projects. This is also in line with our principle as solar rooftop system providers which is to always provide our customers with the highest reliability.

Chow Energy placed 1,200 solar systems like this one on the shops of the 7-Eleven convenience store chain.

Huawei's inverters offer remote monitoring functions and smart I-V curve diagnosis. How important are these features for such a decentralized project?

One of the biggest advantages that we see in Huawei's inverter is the in-built function for monitoring and I-V curve diagnosis. These functions will be able to efficiently support our operation and maintenance program. More specifically, the data will be used to verify and control installation work while we can also check I-V curve for all rooftop systems at our headquarters under the supervision of our dedicated team for each rooftop.

What is Chow Energy's future direction and target regarding solar and renewable energy in general?

Chow Energy has enjoyed great success in developing solar projects both domestically and overseas bringing a cumulative total of more than 100 MW capacity to commercial operation across various types of projects including large-scale ground mount projects and both commercial and residential rooftop projects. With a pipeline in excess of one Gigawatt across Asia-Pacific region, we aim to continue our growth, both in our home market of Thailand and internationally, in the renewable energy sector across various renewable sources, though it will be underpinned by our expertise in solar. With projects involving solar storage, agricultural-sharing, or even floating solar projects with fisheries, we are very excited for what the future holds for Chow Energy and the customers that we serve.

Chow Energy supports

25%

of the energy consumption at 7-Eleven stores

A new bet for Brazil's C&I market

Brazil's C&I market is about to experience serious growth on the back of two new laws, the country's legislature recently passed. Huawei has partnered with a range of new distributors in the country to bring its solutions to customers.

Brazil's C&I market grew

60 %

last year

This year, Huawei adopted a new strategy to expand its sales and distribution channels in Brazil through several new partnerships. In doing so, the company demonstrated interest in having its share of the growing Brazilian PV market, especially through systems owned by commercial and industrial (C&I) consumers. The timing is right, as Brazil's C&I market segment is slated for sizable growth.

Two laws recently passed by the National Congress in Brazil should encourage a rush of projects to guarantee tariff discounts, especially this year. Published in January 2022, Law 14,300 creates a framework for distributed generation of renewable energy, with up to 5 MW of capacity for dispatchable sources like hydro and 3 MW for non-dispatchable sources.

Under this law, consumers can invest in their own energy system. Energy production that exceeds consumption is converted into credits, which are deducted from the energy tariff. The law guarantees that current rules will be valid until 2045 for already-installed systems and for new connection requests made until January 2023.

As of January 6th, 2023, new distributed generation systems will have to pay part of the tariff component that remunerates the grid infrastructure (TUSD), without being able to use the net metering credits to deduct from it. The charge will reach 90% of the TUSD in 2028. The law determines that from 2029 the tariff rules established by Aneel will apply. It is implied that 100% of the tariff component must be paid, from 2029.

Since March 2021, Law 14,120 amended several regulatory parameters in the electricity sector. The changes include the gradual withdrawal of current discounts on distribution and transmission tariffs, for generation and consumption of electricity from renewable sources. The law determines that such discounts will only remain valid, during the entire period signed in the PPA, for projects that have already requested a grant by March 2022 and that start operating by March 2023. Currently, there are 35 GW of solar projects that already have a grant and that can be built in this period to guarantee discounts if they come into operation by March 2023.

To meet the expected demand, Huawei partnered with eight of the main Brazilian distributors of photovoltaic equipment: WDC, Ecori, GEL, Mazer Solar, Mirasol, L8, Megacomm and Connectway, to reach all regions of the country.

"An important criterion for choosing the new partners was regionality and their sales force in each of the regions," says HDT Energy CEO Leonardo Cyrino. "They also have their own stock, which facilitates prompt delivery; they have good sales policies, conditions, and after-sales support."

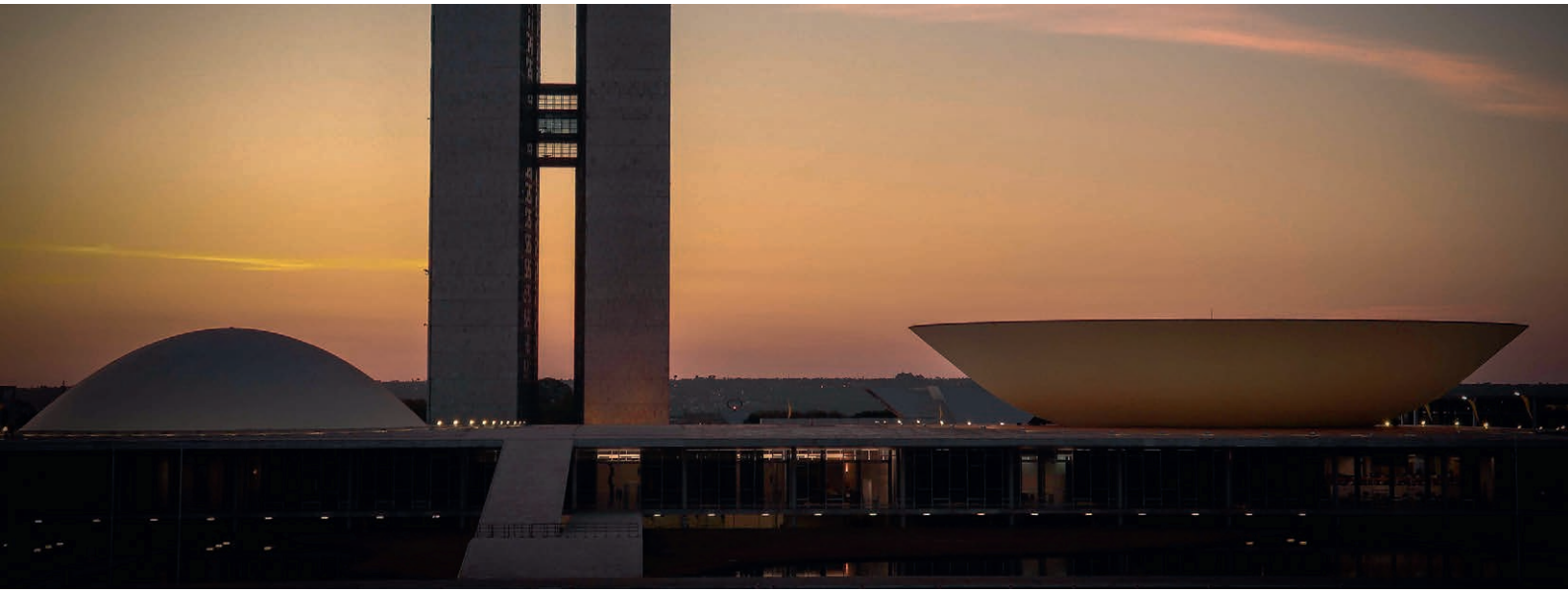
Until the end of 2021, the company focused its commercial efforts on large scale projects, mainly those contracted at federal auctions, says the executive. HDT Energy is Huawei's official representative for commercialization of the company's inverters in the Brazilian market, acting as a bridge to equipment distributors and big clients such as utilities.

Now, with smaller projects leading the recent growth of solar energy in Brazil, the company is looking to expand its participation in distributed generation as well. And the new partners offer the necessary logistical structure to serve this more dispersed market.

C&I Market

Brazil's C&I market grew significantly last year – approximately 60%. It represented one third of DG installations in 2021. By the end of March 2022, the systems installed in the C&I sector had a cumulative capacity of 3,960 MW, according to data from the National Electric Energy Agency (Aneel). More specifically, commercial consumers had installed 3,223 MW of photovoltaics, while the industrial

Photo: Lummiz/ pixabay



Dawn for Brazil's C&I market. Two new laws passed by Brazil's National Congress are believed to significantly increase annual installation capacity in this segment.

sector accumulated 740 MW. It is important to note that in Brazil net metering is available only to so called regulated consumers – those with a contracted demand of less than 500 kW – that are served by electric utilities. In fact, most of the country's industrial consumers have already migrated to the unregulated market, where they can purchase energy through private PPAs. In other words, commercial consumers are generally more likely to add a distributed generation system to their rooftops than industrial ones.

Approximately one third of the installed capacity in the C&I segment was connected to the grid in 2021, when commercial units added 1,139 MW and industrial units added 272 MW. In the first quarter of 2022, 281 MW were added in commercial consumer units, and 62 MW in industrial units. Historically, the last two quarters tend to be stronger in new connections.

By March 2022, net-metered systems accounted for a cumulative capacity of 10,297 MW, of which 98% were PV systems. That figure also includes 6 GW of non-commercial consumer's systems in the residential sector. This is nearly double the capacity of large-scale projects.

The equipment distributor Ecori, one of Huawei's new partners, estimates that the market for solar systems between 20 kW and 1 MW should reach 3,500 MW this year, against 1,726 MW installed in 2021. This power range has become a new focus for the distributor, which hopes to gain competitiveness in the segment with Huawei's inverters.

In the unregulated market, PV's share has also increased, driven by the gain in the technology's competitiveness and by ESG targets set by large energy consumers. According to data from Aneel, a PPA-backed generation capacity of 2,491 MW should come online this year. Last year, Aneel gave the green light to the operation of 775 MW from large scale PV projects with private PPAs.

Huawei anticipates market needs

In 2021, the distributed solar generation market in Brazil added 3.9 GW – and this volume is expected to double in 2022, following the growth trajectory observed in recent years. To compete for this growing demand, Huawei is betting on technology, intelligence, and security, anticipating the needs of a maturing market.

"The systems in operation in Brazil are still recent," says Cyrino. "We have not yet experienced major problems that can be caused by poorly made installations and low-quality products. More mature markets have responded with quality norms and standards. Brazil does not yet have this type of standard but we will reach this moment when the market demands this. In anticipation of this development, Huawei only offers products that are already compliant with common quality standards."

Through new commercial partners, Huawei is offering optimizers and batteries that can be crucial to the project's competitiveness, even after the end of the tariff discounts planned for the coming years.

> *"Brazil's distributed solar generation market is expected to double in 2022"*

Innovation spreading through Argentina's largest PV plant

Argentinian state-owned power company Jemse built the country's largest PV facility between 2017 and 2020 under the RenovAr program for large-scale renewables. Thus far, the 300 MW project has produced more than one million MWh of clean electricity and is now on the verge of being expanded to 500 MW, with the addition of 30 MW/100 MWh of storage. pv magazine recently spoke with Willy Hoerth, the president of Jemse's Cauchari Solari unit, and its project director, Guillermo Giralt. The 300 MW asset was financed with funds from Export-Import Bank of China, and a $210 million bond issued by the Argentinian province of Jujuy. Jemse has full ownership of the project. Huawei was the supplier of the string inverters in the first phase and likely for the second phase.

Photos: Cauchari Solari

Willy Hoerth is the president of Cauchari Solari, a project-specific unit of Argentinian power company Jemse.

pv magazine: ***The Cauchari solar plant is Argentina's largest PV facility. The project is currently being expanded from 300 MW to 500 MW. How is work moving forward?***

Hoerth: The provincial government is currently reviewing the power purchase agreement (PPA) for the sale of power to the Electricity Wholesale Market Administrator, the Compañía Administradora del Mercado Mayorista Eléctrico (CAMMESA). The final resolution should be issued over the next weeks and the PPA should then be signed. We will have a time frame for the construction of the plan of between 500 and 600 days starting from the financial closing. Compared to the Cauchari I, II and III projects, which totaled 300 MW, the Cauchari IV and V plants will have several technological innovations, including storage.

Giralt: The Cauchari IV and V facility will have a capacity of 100 MW each and will include storage systems totaling 30 MW/100 MWh. This is going to help CAMMESA stabilize its grid. Furthermore, the solar plant will use bifacial modules with a higher power output, compared to the Cauchari I, II and III. It will occupy less surface for the same capacity of the first project.

Huawei has provided its inverters for the first phase of the project. Will it also be the supplier for the second phase?

Giralt: String inverters from Huawei have been used for the project. There were many technical and logistical reasons why we have chosen inverters of this type. Fundamentally, the plant is located at 4,200 meters above sea level and is three and a half hours from San Salvador de Jujuy, which is the closest city. The only route to reach the plant is badly accessible and the maintenance of central inverters for 300 MW of solar would require between six and eight people, who would have to be there every day. Central inverters are very sophisticated artifacts that can only be handled by very specialized people and professionals of this type are not going to live in towns

> *"The levelized cost of energy for the new project is between 20% and 25% lower than that of the Cauchari I, II and III projects"*

Cauchari Solari Project Director Guilermo Giralt oversees the $200 million Cauchari project.

like the one where the Cauchari project is being carried out. So, the idea was to have inverters that can allow maintenance operations with people with low training and, in eight minutes two people can change a string inverter. In the first phase, we used inverters with a power of 50 kW and in the second phase we will use 215 kW devices. On the other hand, the power of the inverters in the market has followed the trend we have seen for modules. In Cauchari I, II, and III we used modules with a power of 330 W and now we are planning to use panels with power ranging from 540 W to 570 W.

What advantages will be brought by this level of innovation?

Giralt: Well, as I said, we will need less surface, structure and cables for the second part of the projects, which means the facility will have less electric losses and a higher power yield. As a result, the levelized cost of the energy of Cauchari IV and V is between 20% and 25% lower than that of the Cauchari I, II and III projects. The PPA, however, also include the contribution made by the batteries, for which we plan to invest around $20 million.

The first phase of the project represented an important milestone in Argentina's energy landscape. Could you provide some details about this 300 MW facility?

Giralt: The 300 MW of the installation are generated by PERC polycrystalline panels provided by China's Talesun. The project location has an irradiation of between 1,000 W/m^2 and 1,200 W/m^2 with temperatures close to zero degrees. Such conditions increase the performance and efficiency of solar modules. The project was selected by the Argentinean government in the first round of the RenovAr program for large-scale renewables. This section of the plant is selling electricity to the CAMMESA at a price of $60 per MWh under a 20-year PPA, for the second plant we will have different conditions, as we will also integrate batteries. The plant was built at an altitude of more than 4,000 meters, where there is less oxygen. That could lead to de-rating problems and all the electronic parts of Huawei inverters are sealed and the power module has convection cooling. These are inverters that are very well prepared to maintain low temperatures in the power section, without the need for fans. Thus, even though the solar park is at 4,000 meters of altitude, the inverters do not have a de-rating problem and spend less energy cooling, which means an improved performance by 3% and that means a lot more financial gains.

Residential smart PV optimized to the fullest

Higher yields and more safety are the promise that power optimizers are well geared to deliver on. As the global rooftop PV fleet continues to grow at an unprecedented pace, higher standards are being set, shaping expectations for installers and tech-savvy owners alike. And DC optimizers are coming up trumps in terms of yield, efficiency, and peace of mind.

A chain is only as strong as the weakest link, and so are all solar modules connected in a string with one another. While all PV systems perform best when the sun shines on them without obstruction, chimneys, trees, or dormers can make it impossible to always avoid shading. Even if the shadow would fall only on a single module, this would tend to reduce the entire energy flow though the string. And this is where power optimizers come in.

Beyond shading, optimizers can address PV module performance discrepancies caused by other reasons as well, such as soiling, uneven module degradation, manufacturing mismatch, and thermal mismatch. What is more, they can also maximize the roof usage, allowing the modules in the same string to face different directions, thus making complex, multi-pitched roof structures equally suitable for high-performing PV installations.

On the back of their unique capabilities, power optimizers are all set for expansion in the coming years. According to a forecast from London-based business intel-

Roofs with multiple pitches, facing different directions and casting uneven shadows, can limit the usable space for solar. However, power optimizers can handle such rooftops, allowing homeowners to future-proof their houses for the clean energy transition.

Photo: Huawei

ligence company IHS Markit, the shipments of module-level power electronics (MLPE), which include both power optimizers and microinverters, will surpass 70 GW globally in the next five years. While the US is expected to remain the key market for MLPE suppliers, due to the local requirement set for rooftop PV and aimed at keeping fire fighters safe, other markets such as the Netherlands, Germany and Australia will be increasingly important target markets throughout the forecast period, the analysts say. And Huawei stands ready to cater to the demand.

Maximizing yields

With Huawei optimizers installed behind each module, the energy yield can be increased by up to 30%. Its Smart PV Optimizer ensures module-level maximum power point tracking (MPPT) so that each module can work at its best without being impacted by the underperforming modules in the string before sending the optimized voltage to the inverter to convert from DC to AC. It is a one-size-fits-all type of solution that matches most poly and mono PV modules available on the market. With solar optimizers, project owners are looking at lower balance-of-system costs and a higher oversizing potential in one-string designs.

In real applications, the achievements of Huawei's optimizers speak volumes about their potential. In Dongguan, China, a client with a very high electricity consumption of around 35,000 kWh annually has reported that after installing Huawei optimizers, the energy yield of his 28.81 kW PV system increased by 27% whereas his electricity purchase from the grid was reduced by around 85%. His systems' annual energy yield stood at 32,280 kWh compared to 22,470 kWh produced by a similarly sized system on his neighbor's rooftop without optimizers.

Ideally, all solar panels should face the same direction to avoid mismatch but often enough there are multiple sides of the roof that can be utilized for PV, though this exacerbates costs of energy yield. To put this in perspective, modules oriented in two directions and connected into one string will result in around 11% power loss, compared to the same set up with a unidirectional orientation for all modules. For three directions, the loss stands at a whopping 22.5%, according to PV*SOL simulation results. With this in mind, PV modules are often installed on rooftops facing a maximum two directions coupled with an inverter that has only two MPPT channels. Beyond that, the inverter can also condition the rooftop installation with its minimum input voltage requirement, making it impossible to install enough modules on a small rooftop area with unique orientation. All these concerns are put to bed with Huawei optimizers, allowing from as little as four to as many as 35 of them to be connected in a string.

Take for instance a multi-pitched rooftop on a house in Guangdong, China. To overcome the problems of a complex roof structure with five different orientations and chimney shading, the homeowner turned to Huawei Smart PV Optimizers and managed to install a PV system 70% bigger than originally planned. Namely, instead of installing only 14 kW without optimizers, the homeowner had 24 kW of PV on his roof, comprising 96 modules running at 250 watts each, which added up to a difference of 12,000 kWh in annual energy yield.

Safety focus

In addition to maximizing energy yield, power optimizers are taking safety to the next level. The primary risk associated with solar panels is electrocution, which deters some homeowners from installing PV systems. When a blaze takes hold of the solar roof, the energized PV system usually poses a threat to firefighters attempting to extinguish the flames. To address this, Huawei's optimizers allow module level voltage shutdown ensuring maximum safety for installers, maintenance personnel, firefighters, and homeowners alike. The PV rapid shutdown function is designed to automatically reduce module's voltage to a safe level and de-energize PV wires in case of emergency. On the back of their module level monitoring, Huawei optimizers support pinpoint arc fault positioning for easier troubleshooting. Namely, they reduce the onsite troubleshooting time by as much as 80%, thereby saving costs and ensuring less power loss due to the shorter downtime after nuisance tripping.

Finally, while installing DC power optimizers comes at a price, they also enable shorter payback period of rooftop PV investment through greater energy yield. And the peace of mind they can give to solar homeowners in terms of safety is priceless.

Energy yield can be increased by up to

30%

"The homeowner turned to Huawei Smart PV Optimizers and managed to install a PV system 70% bigger than originally planned"

50 MW Binh Dinh, Vietnam

Located around the eastern cost of the country it is one of the biggest floating solar plants in Vietnam, located on a large water surface to bring 78 million kWh clean energy annually.

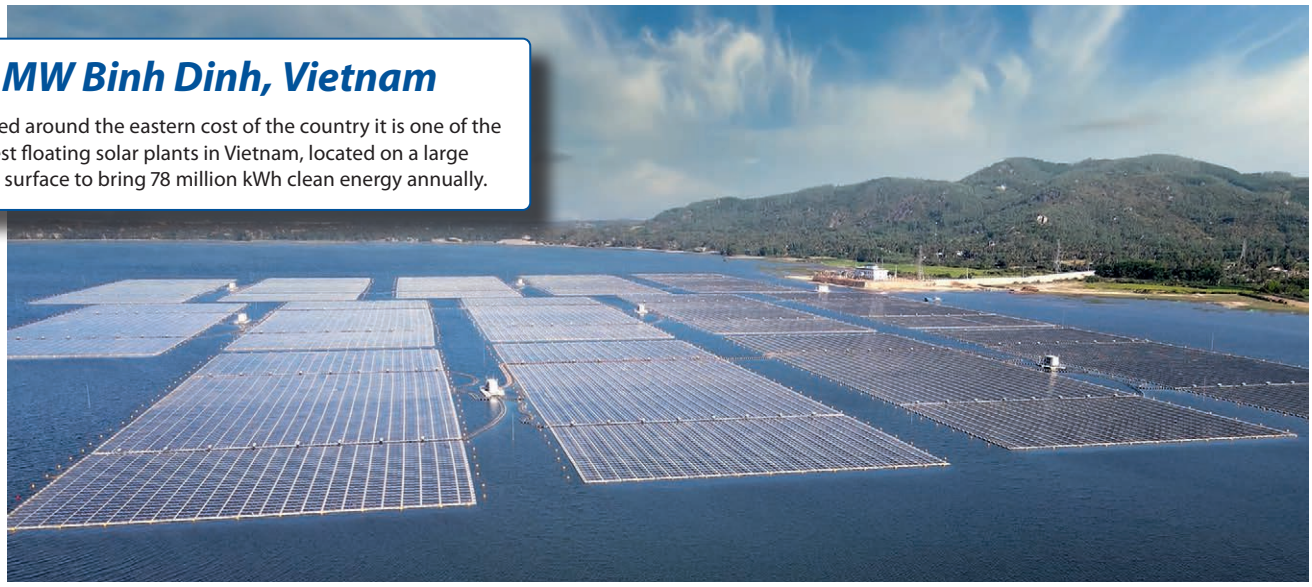


Photo: Huawei

175 MW Seville, Spain

The Don Rodrigo project marked the advent of a new era for solar PV in Europe. Enabled by a low LCOE its developers could financially back it solely on a long-term PPA making it the first of its kind in Europe to be free of any subsidies.

Photo: BayWa r.e.

825 kWp Arturo Merino Benitez International Airport, Chile

The solar power plant generates approximately 1.2 GWh each year, used on-site for clean airport operations.

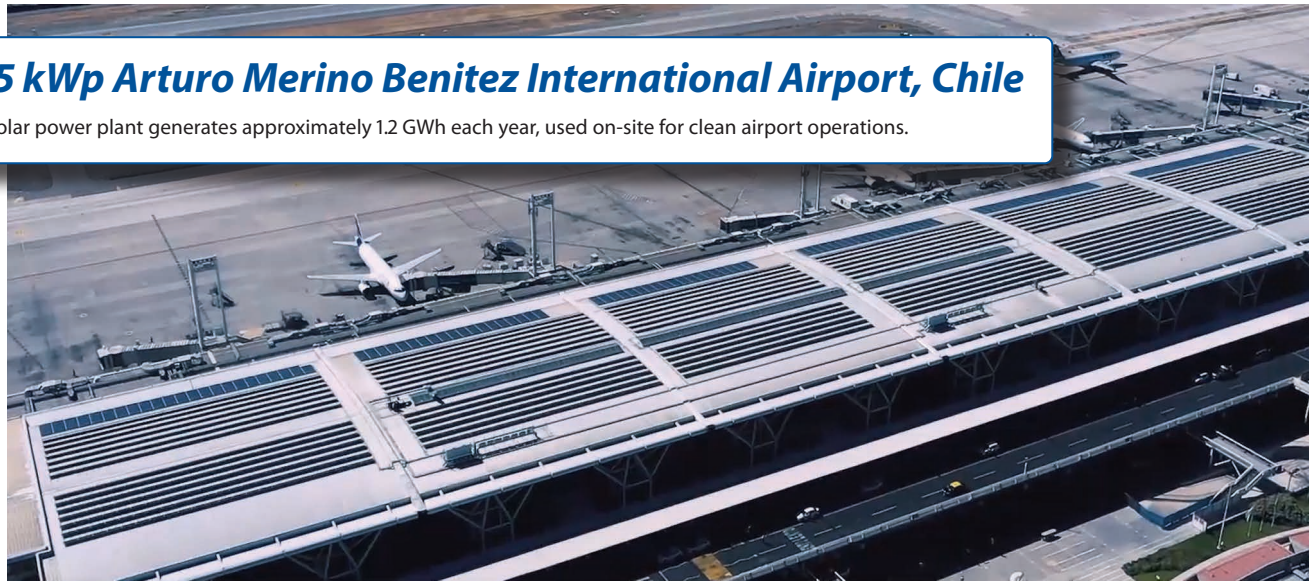


Photo: Huawei

Photo: Huawei

1.1 MW Shenzhen, China

With more than 1 MW of solar and 2 MWh of storage, China's first nearly zero-energy facility, is slated to become a best practice among global carbon peak and carbon neutrality projects.

Photo: Huawei

300 MW Shandong, China

The world's largest fishery-solar project, covers 6.4 million square meters of abandoned saline-alkali land with 860,000 PV modules to generate clean power alongside green aquaculture.

Photo: Huawei

50 MW Grange Solar Farm, UK

The site is among the UK's largest bifacial PV power plants, which supplies 44,261 MWh per year, equivalent to the energy needs of 13,441 households. It saves 16,920 tons of carbon emissions, per year.

A smart way to disconnect

PV plants can be a fire hazard. Loose, worn connectors can cause arcing on the DC side of the generator. To prevent this from happening, Huawei's engineers have designed a string-level disconnector to de-energize affected strings before they trigger catastrophic blazes.

An arc creates a

3,000°C

hot plasma of ionized air

In October 2020, a fire occurred at a PV plant in Ullum, in San Juan province, Argentina. The blaze started in the central inverters. Thankfully, firefighters managed to regain control of the situation, and nobody was hurt. While solar energy is an environmentally safe form of energy generation, it still poses fire risks. Photovoltaic cells, inverters, cables, connectors, and combiner boxes are at risk of arcing, similar to a lightning strike, resulting in fires. Although fires caused by PV systems are rare, any fire involving a PV array can have devastating consequences for people, property, and the environment.

But incidents like the one in Argentina highlight the importance of ensuring that PV systems are correctly designed, with properly tested components, which are then competently installed and regularly maintained.

It is also an issue that is becoming more relevant for a growing number of people. Renewable energy is poised to be the primary source of power supply as countries look to end their contribution to the climate crisis by building carbon-neutral economies. The European Union, for example, aims at carbon neutrality by 2050. This will involve the doubling of the share of renewable energy in final energy consumption to 32% by 2030. Solar power is one of the fastest-growing new energy sources worldwide, with PV tech dominating. The global share of PV projects in new power plant installations has risen from 16% to 32% over the past 10 years. China, the United States, Germany, Japan, Italy, and India have installed the world's biggest solar PV fleets.

With solar PV power plants proliferating for utility-scale and distributed-generation applications, with no signs of slowing down, these solar plants must be designed and operated efficiently, reliably, and safely.

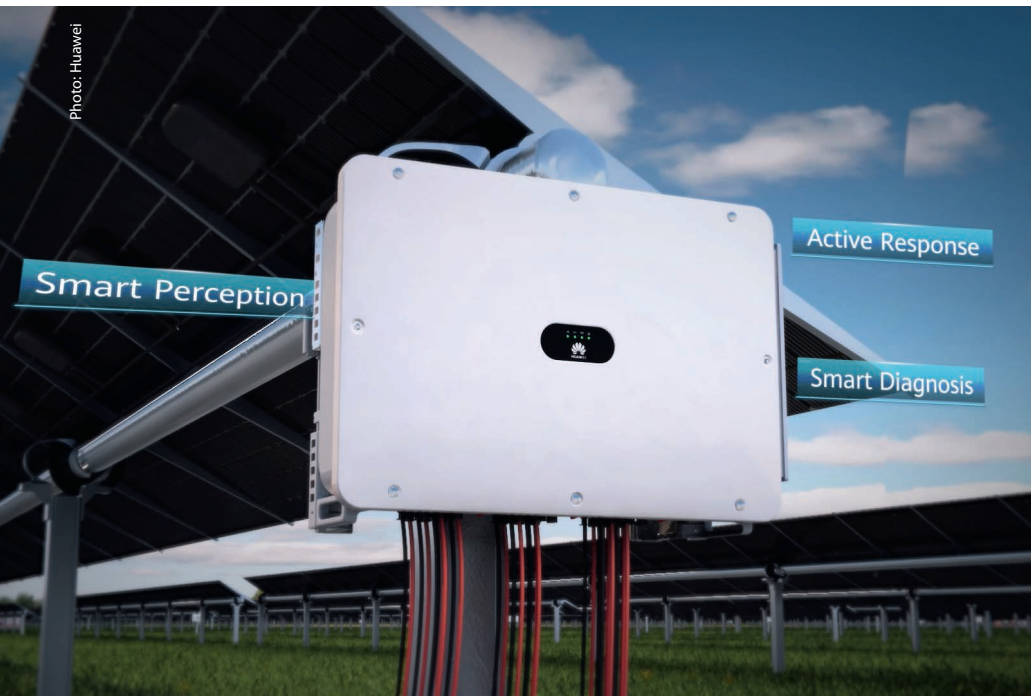


Photo: Huawei

Electric arcs are much easier to suppress in AC circuits, which makes the task of protecting PV power stations from this phenomenon technically challenging. But Huawei's Smart String Disconnector filters out the arcing signal from the noise and de-energizes systems before any damage is done.

Origin of arcs

The electrical safety of PV systems is vital, and asset managers should take preventive measures to reduce failure rates. Most defects occur in DC plugs, with junction boxes and inverters also topping the list of components with the most flaws. This isn't surprising, given that these are all complex PV system components. In many cases, defects are caused by installation errors and poor connections.

Other factors increasing the risk of fire at PV power stations include the high-current technology of new modules, the rising capacity of inverters or combiner

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Arcing on the DC side of a solar system is very similar to a lightning strike during a storm.

Photo: Brandon Morgan

boxes, and the more complex and diversified application scenarios of solar PV. But above all, the most significant fire hazards within PV systems are electric arcs, which occurs due to loose contacts, broken wiring, aging insulation materials, carbonization, dampness, and corrosion.

When an electric device such as a PV module or inverter experiences a fault in its circuit to cause an electrical arc, the arc could be sustained, creating a 3,000°C hot plasma of ionized air and posing a severe fire hazard.

Safety gap

International standards for PV plant safety are considered to be a basic requirement for PV manufacturers and equipment suppliers. But the rapid pace of the PV industry's development means safety standards may not keep pace with the new risk profile. Huawei has released a white paper focusing on inverter safety for PV arrays. It identifies gaps in current standards that component manufacturers should address to avoid safety issues.

Currently, there are relevant standards for DC arc detection and shutdown, such as UL1699B-2011, UL1699B-2018, IEC 63027, CGC/GF 175-2020. They have specific requirements for cable lengths, protection thresholds, and fault clearing actions. IEC 62548:2016 sets out design requirements for PV arrays, including DC array wiring, electrical protection devices, switching, and earthing provisions. The standard can effectively protect modules and cables, but there are still gaps in DC junction boxes and inverter protection measures.

The issue at hand is how inverters detect arcs in the DC circuit. An electric arc causes a fingerprint signal, which can be detected in the 10 kHz to 100 kHz bandwidth with an oscilloscope. The problem is that arcs are by no means the only cause of frequency in the line. Inverter manufacturers use the term "noise" to describe the various frequencies that attenuate the arc signal. Chopping DC into AC creates significant amounts of noise, identifiable as sudden spikes that are "louder" than the signal of an arc. Additionally, the signal that comes out of the chopping from the transistors is smoothed out by a choke coil, which provides a large electromagnetic field. As the exact layout of transistor choke coils and other magnetic components is different for each inverter manufacturer and model, each product needs unique approaches to arc fault detection.

Therefore, in addition to complying with existing standards, future PV power stations should consider deploying active safety. Through smart equipment and monitoring, risks can be managed early without becoming major incidents. Active safety includes the active detection and identification of safety risks (such as the protection of grounding, insulation, and leakage current) and protection mechanism when faults happen.

Some PV systems are more vulnerable to safety risks, so let's take the centralized system as an example below. When a short circuit happens at the combiner box or DC Power distribution cabinet, the electrical system can only protect the AC side. A fuse is usually used to protect the DC side, but it is unreliable. When a fault occurs, neither the fuse nor the DC circuit breaker would be triggered as each string's current is small, resulting in a continuous injection of energy, which is a potential fire risk.

Smart disconnection

Huawei's Smart String-level Disconnector can strengthen short circuit protection of the DC bus in a string inverter system. The controllable DC disconnect switch has an automatic tripping device and digital string-level monitoring. It ensures detection accuracy, response consistency, and timely response. As the solution does not require any fuses for protection, it can reduce daily inspections and maintenance costs.

The unique DC disconnect switch solution is combined with the inverter's cascade-level smart detection and control system. It meets the IEC 60947-2 related certification standard, providing multi-dimensional protection of DC electrical safety at power stations.

With the increasing power and electric current of PV modules at power stations in the future, the risk of fire due to faults is also rising. Smart DC Disconnect solution can help power plant owners future-proof their PV systems. Smart technology makes solar power plants highly efficient, safe, and reliable.

These technological developments are crucial to realizing the promise of a sustainable future using clean and renewable energy sources.

"As the solution does not require any fuses for protection, it can reduce daily inspections and maintenance costs"

Overcoming harmonic issues

In the power system of the future, power electronics must be able to manage harmonics, or power generation equipment and consumer electronics could be damaged. There are measurements to see how well inverters suppress distortions to the sinusoidal waveforms in the AC grid, and it turns out that a combination of revised hardware and smart software achieves new records.

A solar farm in China's Shandong province has deployed Huawei's smart inverter to improve its grid management and comply with stringent standards for grid-connected PV systems. In a comparative experiment on April 27, 2020, there was a considerable difference between the claimed harmonic level and the actual harmonic level of traditional string inverters according to test-meter data. The harmonics level generated by traditional inverters was seven times higher than that of Huawei inverters.

This is an impressive achievement as the PV system's ability to perform at optimal levels is compromised when harmonic distortion enters the system. Therefore, it is crucial for PV plant owners to consider the right technology and measures to monitor and manage the issues to avoid inefficiencies, higher costs, or catastrophic consequences. With renewable energy slated to become the dominant energy worldwide, grid stability risks are rising, and the grid short circuit ratio (SCR) decreases. Especially in a weak grid where SCR equals 1.2, it would be imperative to ensure that the harmonic current injected into the grid does not exceed 1%.

Harmonics explained

The ideal power source for all power systems is smooth sinusoidal waves. However, when waveforms deviate from a sinewave shape, they become harmonics. A harmonic is a voltage or current at an integer multiple of the fundamental frequency in an electric power system. Inverters that convert DC power to AC also create harmonics. Current harmonics distort the voltage waveform and create distortion in the power system, causing a range of issues, including overheating of components such as power transformers, switchgear, and cables; nuisance tripping of circuit breakers caused by the distorted load current; resonance of the power system; and telecommunication interference with communications and signaling and inaccurate measurements on sensors.

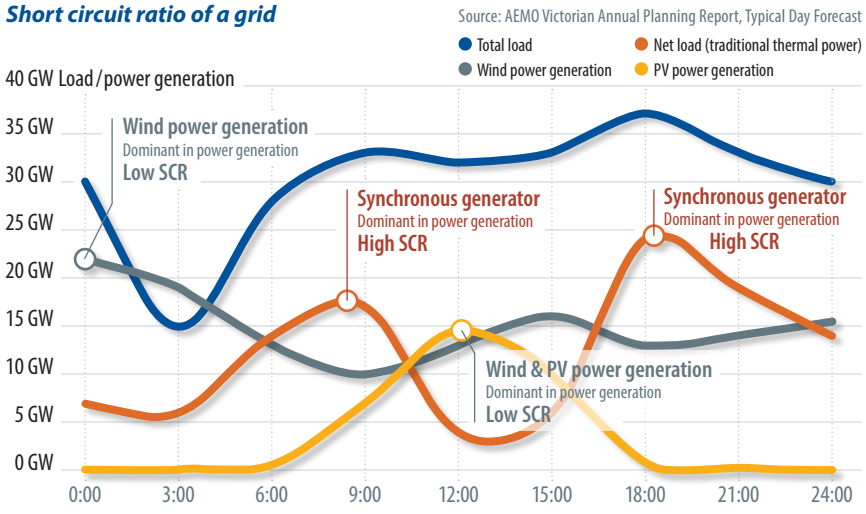
In the Shandong experiment, the harmonic current injected into the grid by the Huawei inverter was reduced to 1% when the inverter ran at rated power. At the same time, the harmonic current at other load rate operating points does not exceed the value during rated power operation. More importantly, the solar farm fulfills the grid code requirement most cost-effectively, with no need for additional filtering devices or active power filters (APF).

Quality issues

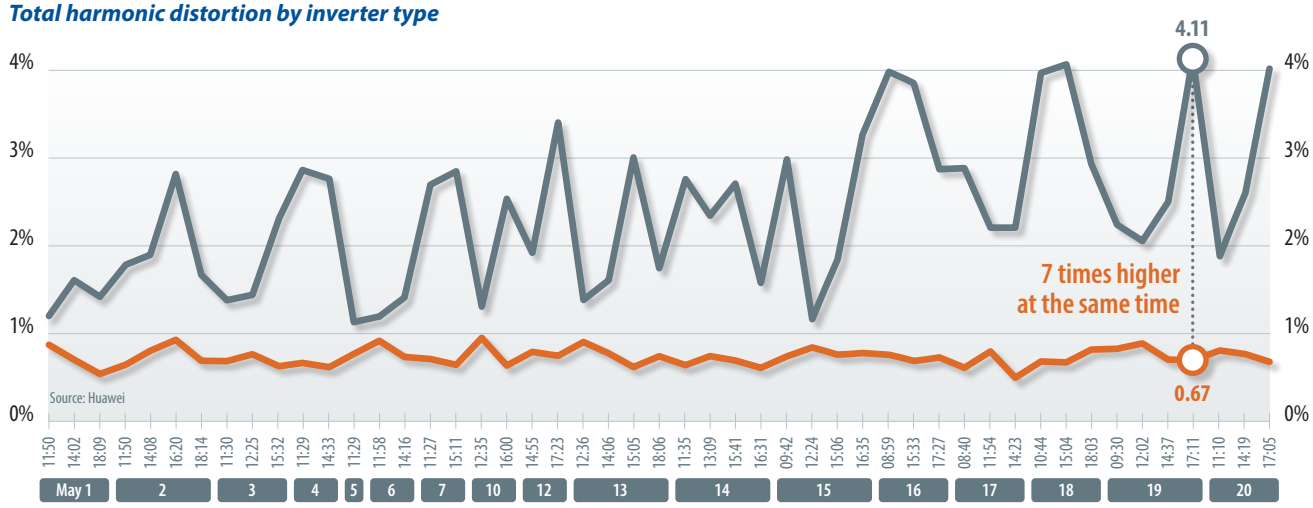
The total harmonic distortion (THD, THDu, or THDi) defines the ratio of the sum of the powers of all voltage or current harmonic components to the corresponding power of the fundamental frequency. For example, as mentioned in the VDE-AR-N 4120 technical requirements, limits on harmonics for power plants connected to a high-voltage network are thus set at less than 1% for any single order voltage harmonic for the

> *"The project cost due to installing filtering devices was increased by $2.5 million"*

Short circuit ratio of a grid



Total harmonic distortion by inverter type



VDN guide. As we have seen, keeping low THDi values on a system will ensure proper operation of equipment and a longer equipment life span.

In contrast to other inverters claiming a harmonic current of less than 3%, the Huawei FusionSolar team has reduced THDi to below 1%. The team has developed innovative technologies which analyze and mitigate harmonics to almost zero in closed-loop PV systems to ensure grid stability, optimize power quality, and increase equipment longevity. This has been achieved on the back of breakthroughs in two key areas:

- **Hardware circuits:** Harmonic performance presents higher requirements for the consistency of switching devices, hardware sampling accuracy, and LCL filter parameters. For example, the LCL filters in Huawei inverters are designed to attenuate the high order harmonics. The IGBT switches and the gate driver circuits are also designed to ensure the switching delays of IGBTs in different phases are symmetrical, which is the basis for suppressing harmonics.
- **Control algorithm:** Under the conditions of fragile power grids and power grids with background harmonics, active harmonic suppression algorithms are needed to improve power quality. Huawei inverters implement a grid sensing system and intelligent harmonic suppression algorithms to accurately sense, actively optimize power quality, and control the high order harmonics to almost zero in a closed loop. An AI model-based algorithm improves the harmonic performance in a weak grid with background voltage harmonics.

Huawei's inverter THDi is less than 1%

Weak grids

In the case of weak power grids, Huawei's algorithm is more effective than traditional algorithms. The advantage of Huawei's algorithm is evident as it keeps THDi under 1%, compared to more than 9% for conventional algorithms. Huawei's solution can achieve active suppression of harmonics by quickly and accurately calculating and recognizing each harmonic instead of using fundamental frequency measurement. The harmonic suppression algorithm can effectively reduce current harmonics even under different power grid test conditions.

Additional filtering devices can be very costly in grid-connected projects and must be considered in advance. In a project in the Middle East, grid connection was delayed for four months because the harmonic current THDi injected by traditional inverters into the grid-connected point exceeded the requirement rate. Due to the influence of cables and electrical equipment, the harmonics of the grid-connection point will be larger than that of inverters. As the harmonic level of inverters has commonly reached 2.8%, it would be impossible to achieve less than 3% at the grid node. Due to installing filtering devices, modification of models, and grid simulations, the project cost was increased by $2.5 million.

Better option

Inverters with low harmonics would be a better option, and using passive filters like capacitors and inductors or APFs like STATCOMs, should be considered. The location of claimed harmonics and whether a well-known certification firm provided the certification of the harmonics of the inverters need to be considered.

Good connection

It is not just how battery cells and packs are built, but how they are connected to one another, that determine their capacity and longevity. With smart power electronics wired into storage systems, they can boost usable capacity and lower their degradation rate, while being considerably cheaper to maintain.

Battery energy storage systems tied to solar production are one of the industries' hottest products, both at utility scale and for the home. Yet battery prices are currently increasing and there are constraints on supply. The industry is scrutinizing both the levelized cost of storage (LCOS) for battery systems and raising concerns over their longevity. The idea that battery energy storage systems (BESS) will get continuously cheaper and become more available as a fast, limited-life-span commodity is no longer valid. Batteries naturally degrade over time through use, but mitigation strategies and products can drastically improve power performance.

Simple series

Batteries in an ESS are normally connected via simple series or parallel connections. Although a reasonable expectation might be that battery cells would share a load equally, data suggests that centralized charging and discharging causes differences in operating conditions. Each cell performs differently, with even tiny differences growing over time.

From data found during commissioning of a project in Anhui, China, the difference in the state of charge (SOC) of cells connected via serial averaged 8%, with the highest difference found to be 12%. From this uncomfortable starting point, a difference grows over time. With some cells failing to be fully charged and discharged in this mismatch, overall charging and discharging capacity is reduced, which degrades plant performance. Even without defects, the plant in question in Anhui exceeded an alarming 50% degradation after just three years of operation.

> *"The SOC difference between racks when completely discharged was 4.4%"*

Similar problems face racks of parallel connected batteries. The performance of the battery pack in a typical centralized solution is limited by the poorest cell. From rack-level testing data found during commissioning of a project in Qinghai, China, the SOC difference between

Battery rack mismatch explained

The phenomenon at play here is that Li-ion batteries, during operation, are affected by a variety of undesirable features, such as over-voltage, under-voltage, overcharge, discharge, thermal runaway, and voltage imbalance between batteries. The problem comes down to chemistry: No two cells are identical, despite the state-of-the-art battery manufacturing of today.

Cells have different SOC due to capacity differences, degradation, and internal impedance differences, all of which can lead to a variety of issues, notably imbalance. Voltage imbalance is the most critical feature. Without close control, the capacity of each battery cell in a battery cabinet is affected, and the weakest cell determines the performance of the overall battery pack, sometimes referred to as Liebig's Law of the Minimum, or Cannikin Law, where the capacity of a barrel is always determined by the shortest stave.

Example: Consider three 2,200 mAh cells charged to their maximum, with different SOC levels. Each is discharged by 100 mAh from a fully charged state, with the third discharged by 200 mAh. The first two cells show a SOC of 95.4%, with the third cell 91%, implying an imbalance of 4.4%. This results in a different open circuit voltage for cell three. A battery system unable to monitor and control these imbalances during charging and discharging sees faster degradation in overall capacity.

racks when completely discharged was 4.4%, affecting total discharge capacity by about 5%.

Smart String ESS

An alternative approach comes from a higher level of control: down to pack-level and rack-level optimization, thanks to an array of power electronics and software control. One example is from Huawei's new Smart String ESS Solution, which aims to resolve natural inconsistencies within the overall chemistries of lithium-ion batteries using pack-level integrated battery module optimizers, and smart battery controllers.

For pack-level optimization, the optimizers eliminate mismatch between packs to improve the available capacity of the battery system. Single faulty packs can be isolated, reducing external short circuit risks. And for operation and maintenance (O&M) considerations, manual adjustments by site personnel are no longer required.

At rack-level, smart battery rack controllers provide optimization without buses, independent operation between racks, and full charge and discharge of each battery. Huawei claims it can reduce the LCOS by 20% and increase discharging energy by 15%. O&M savings, based on a 100 MW/200 MWh project, and given the reduced need for site visits for manual balancing by professionals experienced in batteries, were estimated at €1.7 million ($1.9 million) per year.

In terms of a track record for Huawei's new installations, it is supplying a sizeable solar and storage operation in Ghana: a 1,000 MW PV plant combined with 500 MWh of battery storage, developed by Meinergy. Huawei previously said it had more than 8 GWh of energy storage system applications in operation. Huawei's Smart String ESS is also applicable to residential applications. In particular, the system provides continuous power to previously identified critical loads, such as lighting, refrigeration and security cameras. It supports offgrid operation, with PV providing power during daytime, charging the battery as well. pv

Huawei's system can reduce LCOS by

20%

Photo: Huawei

Big batteries next to PV plants help to smooth out production and provide solar power on demand. Just like the solar generator itself, the BESS needs maintenance and has a maximum operating life. With smart technologies, these can be optimized.

Maintain smarter, not harder

Photo: Huawei

Troubleshooting for large solar plants used to take days and incurred big production losses. But with the latest technologies, asset managers can easily ensure stable revenue streams from their assets.

O&M accounts for a non-negligible chunk of total solar investment costs. Field cost reductions are enabled by smart algorithms, and they are getting better every year.

While conventional power stations require a lot of personnel to operate, one of the advantages of PV lies in the fact that they function with little human oversight. That is until something goes wrong, or a maintenance cycle is due. In that case, maintenance crews ought to make a site visit to address the issue. With solar plants often located in very remote areas, driving a crew out for hundreds of kilometers can become a rather costly endeavor. As PV plants are becoming larger manual on-site inspection is taking longer to perform. This means that maintenance crews also must stay on site for several days or weeks, further exacerbating maintenance cost. Fortunately, digitalization has made its way into the realm of O&M. Sensors and internet connectivity allow asset managers to remotely check the vital functions of a solar plant in real time. Periodic monitoring and troubleshooting can be done from the O&M service providers' headquarters. Only actual physical repairs need to be performed by technicians at the plant.

Huawei has introduced to the market its latest version of digital O&M tools: Smart I-V Curve Diagnosis 4.0. As the name foretells, it is the fourth version of the technology company's digital take on O&M. While its first version already showed a fault diagnosis accuracy rate of at least 70%. This latest version provides above 90% accuracy when it comes to finding technical hiccups.

"Thanks to AI self-learning, the solution continuously accumulates I-V experience and optimizes fault models, marking the start of AI operations and maintenance for PV," says Yan Zhang, senior product manager of Huawei.

I-V curve testing on a 100 MW site takes

20 minutes

To check if the modules and strings work flawlessly, traditionally, maintenance crews must apply a voltage at each string and measure the voltage and current coming out of the inverter. This test must be performed at a series of different voltages. If the modules and the string work flawlessly the measured I-V curve matches the theoretical values of the string configured in the system. If there is a deviation, there is something wrong. The precise shape of a potential deviation can also indicate to the maintenance crew the root cause of the problem.

"On a small 16.1 MW plant, this translates into an annual gain of $160,000"

"Faults in solar PV modules affect a plant's energy yield more than any other factor. These faults vary greatly depending on the stage at which they occur," says Zhang. And while traditional manual O&M can come at a high cost, omitting maintenance cycles is likely to become even more expensive. Analyzing the monitoring data of multiple Gigawatts of solar plants around the world, show that digital asset management and improved O&M practices could recover more than 5% of the energy yield of PV plants. On a small 16.1 MW plant this translates into an annual gain of $160,000.

In the latest product update, the Smart I-V Curve Diagnosis 4.0, Huawei have enabled the export of raw data, O&M reports as well as return on investment estimates. This means that the system itself can give priority to solving faults with a higher power loss and thus a greater impact on revenue.

To ensure the performance ratio and availability of a solar asset are high, it has become industry standard to run the above mentions I-V curve tests twice per year. Taking ACWA Powers 300 MW Sakaka project in Saudi Arabia as an example; checking all string individually and manually. To do this, the maintenance company must bring in 12 professionals specialized in I-V curve testing for a duration of more than 30 days. This comes at a cost of $24,000. On top of that come the cost for bespoke instruments and software. This can easily go as high as $46,000. On top of the maintenance bill comes that while testing the respective inverter must be switched off hampering PV production and thus revenues during the time of I-V testing. For the 300 MW site in Saudi Arabia this would come in at a cost of nearly $5000. This results in operational costs of $500 per MW each year, or roughly one-fifth of the LCOE.

These high costs have not improved at the same pace, some of the other solar equipment has. Between 2009 and 2020 module costs had come down 85%, for example. This development has greatly contributed to reducing the LCOE of solar and with further technological improvements the technology will become cheaper still. O&M cost efficiency improvements have been rather miniscule. Through turning an eye on operational expenditures rather than only hardware costs open great potential to achieve serious LCOE reductions.

Huawei's fourth generation Smart I-V Curve Diagnosis can run such a test at high accuracy on a one 100 MW site in less than 20 minutes. Since the all the necessary sensors and software are integrated in the inverter, there is no need to acquire additional instruments to perform these tests. Additionally, the inverters don't have to be shut down while performing the test, which means yield is not hampered by the operation. Asset managers can also schedule the I-V curve scan and receive the result in their email, without making a physical site visit. In analyzing the test results and the shape of the I-V curves the staff can determine what exactly the root cause of the underperformance is. Knowing that means they can also bring the necessary tools and spare parts when eventually having to make a trip to the actual site. According to Zhang, this greatly improves the O&M efficiency of PV plants by more than 50% and reduces O&M costs over the lifetime of the system.

For a 50 MW PV plant in the mountains of Datong, in China's Shanxi province, Huawei says its Smart I-V Curve Diagnosis was used to scan 14,626 PV strings. It detected 909 faulty strings, with a fault rate of 6.21%. "The resulting impacts are estimated to save them CNY 5.42 million ($851,300) in maintenance costs over 20 years," says Zhang.

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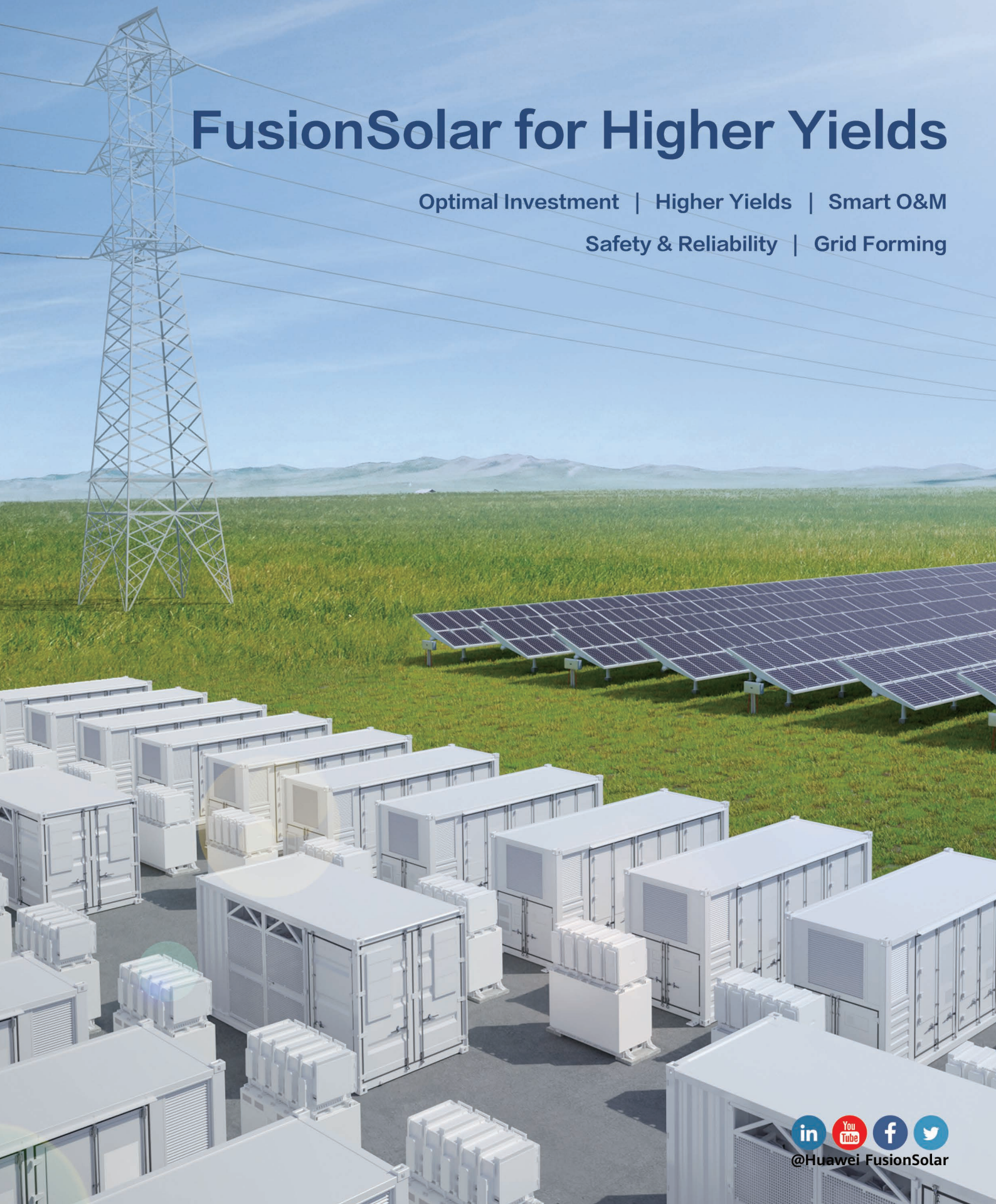
FusionSolar for Higher Yields

Optimal Investment | Higher Yields | Smart O&M

Safety & Reliability | Grid Forming



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