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pv magazine special

Empowering a zero-carbon future

Leading power digitalization for a smart green society

Smart PV power

Chen Guoguang, the president of Huawei Smart PV, on the fourth industrial revolution

Energy storage at scale

Systems reimagined for reliable grid power, from the home to utility scale.

SPECIAL EDITION DEVELOPED IN PARTNERSHIP WITH HUAWEI

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Smarter Energy for a Better Life

With Huawei FusionSolar Residential Smart PV Solution

- Up to 30% more solar energy generated with optimizers
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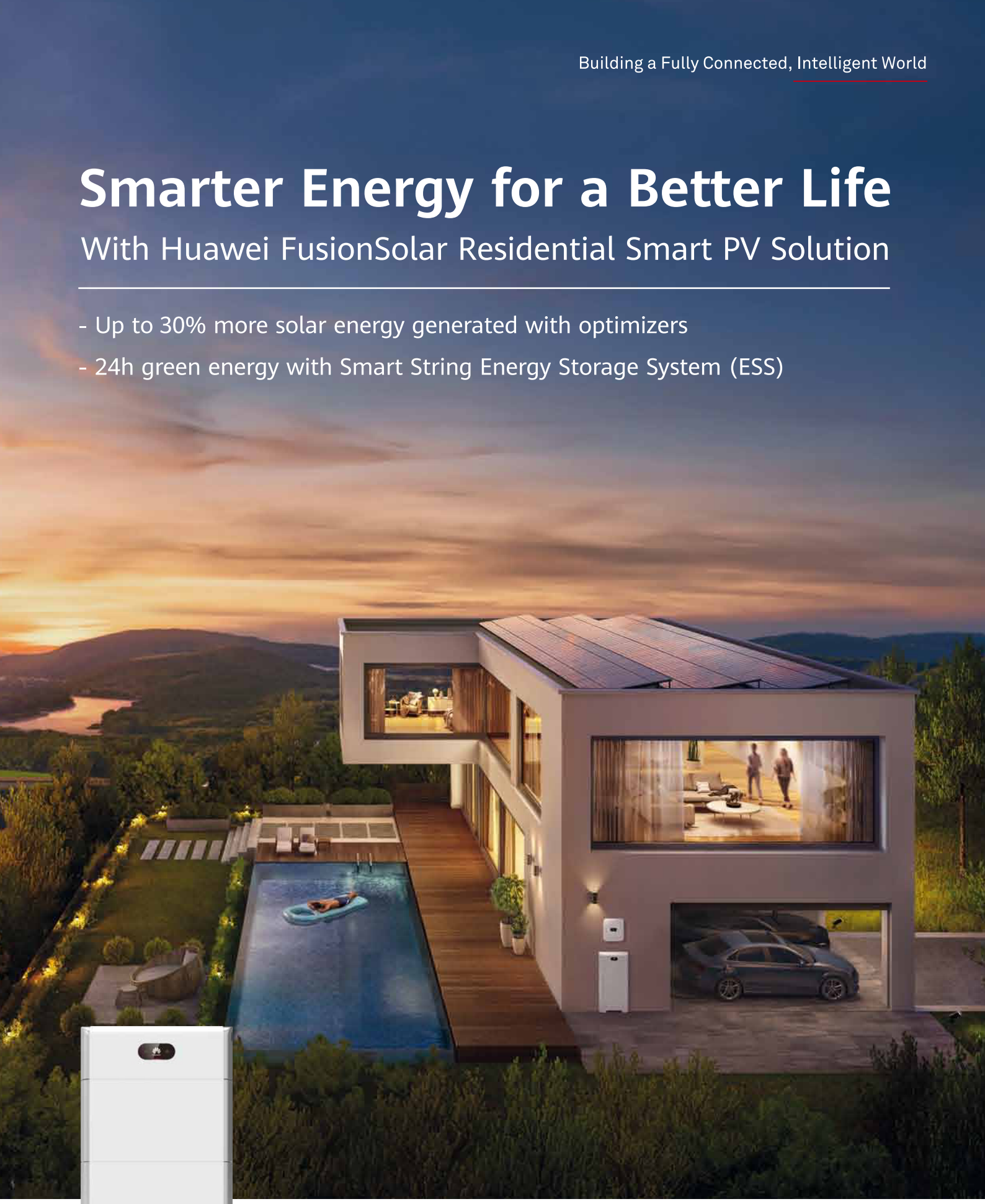

HUAWEI

Huawei: Making solar the bedrock of the global energy transition

Photo: pv magazine/Thomas Beetz

At **pv magazine** we are honored to partner with Huawei for the fifth consecutive year to produce this special edition showcasing the company's latest technology and key projects with customers around the world. What is very special about this edition is its focus on carbon neutrality and decarbonization, and Huawei's commitment to advance these goals not only in the electricity sector, but also in transportation and other industries. Huawei's leadership in this critical domain fits well with **pv magazine**'s UP initiative, which we launched in May 2019 to effect truly sustainable action in both the solar and energy storage industries. True sustainability in these two industries must include carbon neutrality in the not-too-distant future and the solar PV industry can (and should) lead the way when it comes to carbon reduction and net zero emissions.

When we launched the UP initiative energy, storage had already become commonplace in some residential PV markets like Germany, but in C&I and utility-scale markets, adoption had only just begun. With the continued drop in battery costs and further technological improvements, not least on the safety front, batteries have emerged as an attractive opportunity in these three markets. According to IHS Markit, 2021 will be a historic year for battery deployments, with installations set to surpass the 10 GW mark for the first time – more than double last year's figure. Huawei is set to provide an additional boost to this market with its brand new FusionSolar All-Scenario PV & Storage Solution. As it has done with previous FusionSolar solutions, Huawei is leveraging both its long-standing ICT expertise and its track record in solar PV to bring forth another solution, this time including the intelligent integration of battery storage. As Chen Guoguang, president of Huawei Smart PV, makes clear in this edition (pp.4-7), the outcome "turns the PV system from an uncontrollable current source that cannot be stored into a stable voltage source." This "Smart PV Generator" represents a paradigm shift for PV.

The opportunity is enormous. IHS Markit forecasts global battery installations to practically triple in this decade, from just over 10,000 this year to almost 30,000 in 2030. Competitive and intelligent battery storage applications will in turn provide a further boost to PV installations. As described in more detail in Chen's article, "Carbon neutrality with digital power" (pp.14-17), "installed PV capacity will increase from 750 GW in 2020 to 8,519 GW in 2050, replacing fossil fuels as the primary means of power generation." Already in 2030, the Huawei Institute of Strategic Research predicts the proportion of renewable energy will exceed 50%.

Huawei is no newcomer to such global disruption: The tech giant played a leading role in ushering in mobile telecommunications, and this know-how is proving critical in the drive to digitalize energy systems and networks, be it on the generation and interconnection side with Smart PV Generators, or on the demand side with smart homes, smart buildings and smart electric vehicles. The more data we can harness and process in an intelligent way, the more we can pave the way for higher levels of renewable energy.

The global energy transition and drive to net zero is a multifaceted one, as also evidenced by the name of Huawei's latest utility-scale solution. "All-Scenario" means that Huawei's latest FusionSolar solution can handle a wide range of applications, from standalone PV to PV+storage, microgrids and even standalone battery storage projects. It should also be mentioned that Huawei has built the world's largest agrivoltaics and solar-fishery plants in Ningxia and Shandong, China. But the same variety in applications is also evident in the C&I space, residential solutions and offgrid solutions. The solar minigrid in Shimankar, Nigeria, (pp. 32-33) is particularly uplifting, for example. In all of these cases, Huawei is poised to deliver solutions to make our drive to net zero a successful one, which is our common goal to preserve this planet and its possibilities for future generations.

Eckhart K. Gouras, Publisher, pv magazine

Photo: Huawei

Tools for the fourth industrial revolution

Creating a new green economy, with smart renewable energy as the central building block. In conversation with Chen Guoguang, the president of Huawei Smart PV.

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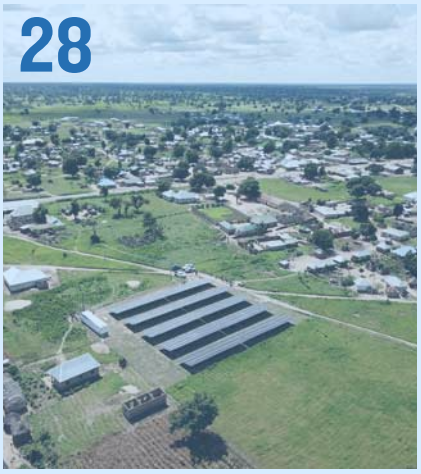
At the groundbreaking Mohammed bin Rashid Al Maktoum Solar Park in Dubai, Huawei inverters handle the desert heat and offer increased system flexibility.

Photo: Huawei



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A closer look at two unique solar projects at a city hospital in Jordan and a remote region of Nigeria, bringing reliable solar power to where it's vitally needed.

Photo: REA

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An exploration of where solar is headed, and some of the key trends, both in markets and technology, that will define the energy industry's future.

Photo: Orlando W/Pixabay

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The tools for the fourth

It takes deep commitment to innovate in PV's rapidly changing landscape. Huawei has continued the tradition for innovation in solar that it has built over more than a decade with the next frontier – dispatchable, smart PV power. Chen Guoguang, the president of Huawei Smart PV, elaborates on the importance of energy storage and Huawei's vision in this field.

Let us first take a step back to the original FusionSolar solution in 2013. Since then, solar PV has evolved rapidly, improving single- and dual-axis tracking technology, bifacial high-powered modules, and now competitive battery storage in the utility-scale sector. How does Huawei's latest FusionSolar All-Scenario PV & Storage Solution handle this complexity to deliver lower costs?

This year, we launched FusionSolar All-Scenario PV & Storage Solution, which offers the advantages of "smart string" design, such as intelligence, modularity, multi-MPPT, high protection and so on, and provides a completely new power electronics architecture, creating the world's first Gemini ±1500V design. This architecture design can help to support larger sub-arrays and higher voltages, further reducing LCOE by up to 7%. It can even enhance the power grid and can also adapt to large-scale wind + solar + storage projects. It will redefine PV plant standards in various market segments.

Our new solution integrates our smart string energy storage solution and is compatible with AC and DC coupling. It uses intelligent PV+storage collaborative control algorithms to realize synchronous characteristics to improve grid stability. The Smart PV Generator allows PV to no longer be a fluctuating resource, but instead to become a stable voltage source. It further integrates AI technology and couples with modules, trackers and the power grid, providing an end-to-end system covering multiple scenarios such as standalone PV, PV+storage, microgrid, and pure storage, to create a comprehensive and intelligent All-Scenario PV & Storage solution.

It has three major differences compared with traditional solutions. First, the world's first "bipolar" string: the use of "Smart PV controller" and "Smart PCS" dual controllers, through the "±1500V" design on the DC side, to achieve the "3000V" architecture. While achieving higher voltage, it can also meet all existing standard requirements related to electrical and safety regulations for PV power plants, achieving a larger sub-array (up to 8.8 MW), support for larger current components, and higher DC to AC ratios (up to 1.8).

Second is the coexistence of PV and storage. The PV+storage coordinated control algorithm turns the PV system from an uncontrollable current source that cannot be stored into a stable voltage source, creating the PV generator. The new Huawei smart string energy storage system, distributed energy storage architecture, fully modular design, pack-level optimization, rack-level optimization, and other innovative technologies will ultimately achieve a levellized cost of storage (LCOS) reduction of more than 20%.

Third is full intelligence: A variety of advanced ICT technologies such as AI and cloud are catalyzed and organically integrated with PV. Modules, trackers, cables, array controller, energy storage, grids and inverters are fully coordinated and fully coupled, including the latest intelligent IV 4.0 diagnostic technology, DC MUBS, intelligent PID protection, SDS algorithm, intelligent grid-connecting algorithm, etc. The combination of these fully releases the potential of each string, creating a "zero inspection" O&M experience, and stronger grid support capabilities, so that power plants have three-dimensional awareness creating an open, efficient and intelligent PV+storage system.

More than

5 GWh

Huawei's track record in lithium ion storage

Energy storage has been a key topic in the PV industry and a lot of companies are entering into this arena. What does Huawei bring to the table when it comes to energy storage?

Energy storage is an important foundation and key technology for building a new energy system with renewables as the main resource, in order to transition to a green

industrial revolution

Photo: Huawei

and low-carbon energy system, achieving the goal of "carbon neutrality" and ensuring energy safety.

In the field of energy storage, Huawei has accumulated more than 10 years of R&D experience and the global deployment of 5 GWh+ in lithium battery projects. This time Huawei is bringing a full-scenario smart string energy storage solution.

In the traditional energy storage solution, modules are connected in series into a rack, and multiple racks are connected in parallel. Thousands or even tens of thousands of modules are coupled with each other. If one module fails, it will affect the others.

Our solution features battery pack-level and rack-level optimization. The solution can achieve more refined management, with an accuracy of no more than a dozen batteries, which is hundreds of times higher than the traditional solution. Besides, the refined management can achieve precise management of each pack with optimized depth of charge, which improves the available power of the system.

On the other hand, this innovative design can support the mixed use of new and old batteries and the phased charging mode, saving customers on their initial investment. Meanwhile, it is equipped with fully modular design, including power conditioning system (PCS), air conditioning and so on, much improved system availability, as well as simplified operations and maintenance. The modular air conditioner realizes a distributed temperature control layout, the temperature equalization effect is far superior to the traditional solution – the temperature difference is reduced by more than 10 °C, and the battery life is greatly improved.

Huawei attaches great importance to the safety of energy storage systems. Through the "pack-level and rack-level optimization and management" design, the system can

"Huawei's smart string energy storage solution increases the discharge capacity, reduces O&M costs, ensures safety and reliability, and achieves a 20% reduction in LCOS"

Chen Guoguang, President, Huawei Smart PV

achieve accurate management of battery packs, which can accurately isolate faulty modules and improve system safety. At the same time, as a leader in advanced technology in the ICT industry, through intelligent and digital technologies such as cloud, battery management systems and big data, faulty batteries can be accurately identified with red flags of fire hazards, and system-level and active safety can be ensured.

Huawei's smart string energy storage solution increases the discharge capacity, reduces O&M costs, ensures safety and reliability, and achieves a 20% reduction in LCOS, helping to build a new energy system with renewables as the main source.

More than

20 %

LCOS reduction delivered by Huawei's smart string energy storage

What do you think about future energy trends? Based on its very impressive ICT track record, Huawei has become a leader in advancing digitalization in the power sector. We have also heard the big news that Huawei's digital power business is now independent. Could you please elaborate what this means for your PV customers? And what can we expect from the Huawei Digital Power business in the future?

We believe that there will be three major trends in the future. First, we are progressing toward the fourth industrial revolution and accelerating our entry into the intelligent world. Second, carbon neutrality accelerates the energy transition. In the future, the world will build a clean, low-carbon, safe and efficient energy system. And third, renewable energy will become the main energy source. The integration of energy and information technology has become inevitable. In the future, new energy systems will move toward high transparency, two-way interaction, intelligent and efficient, plus comprehensive digital and intelligent technology.

Huawei has more than 30 years of deep understanding in the fields of digital technology and energy technology. The development direction of Huawei's digital energy is to reduce emissions, accelerate the energy transformation, and realize a zero-carbon and smart society through technological innovation. For Huawei digital power, it would be one cloud plus four application scenarios and five root technologies, and all of that means an open ecosystem.

It integrates technology innovations such as electronic, thermal, energy storage, cloud and AI technology, and ICT technologies. We use "bits manage watts" by leading the digitalization of energy to build a zero-carbon intelligent society.

The FusionSolar 8.0 Gemini ±1500V design was displayed at SNEC 2021.

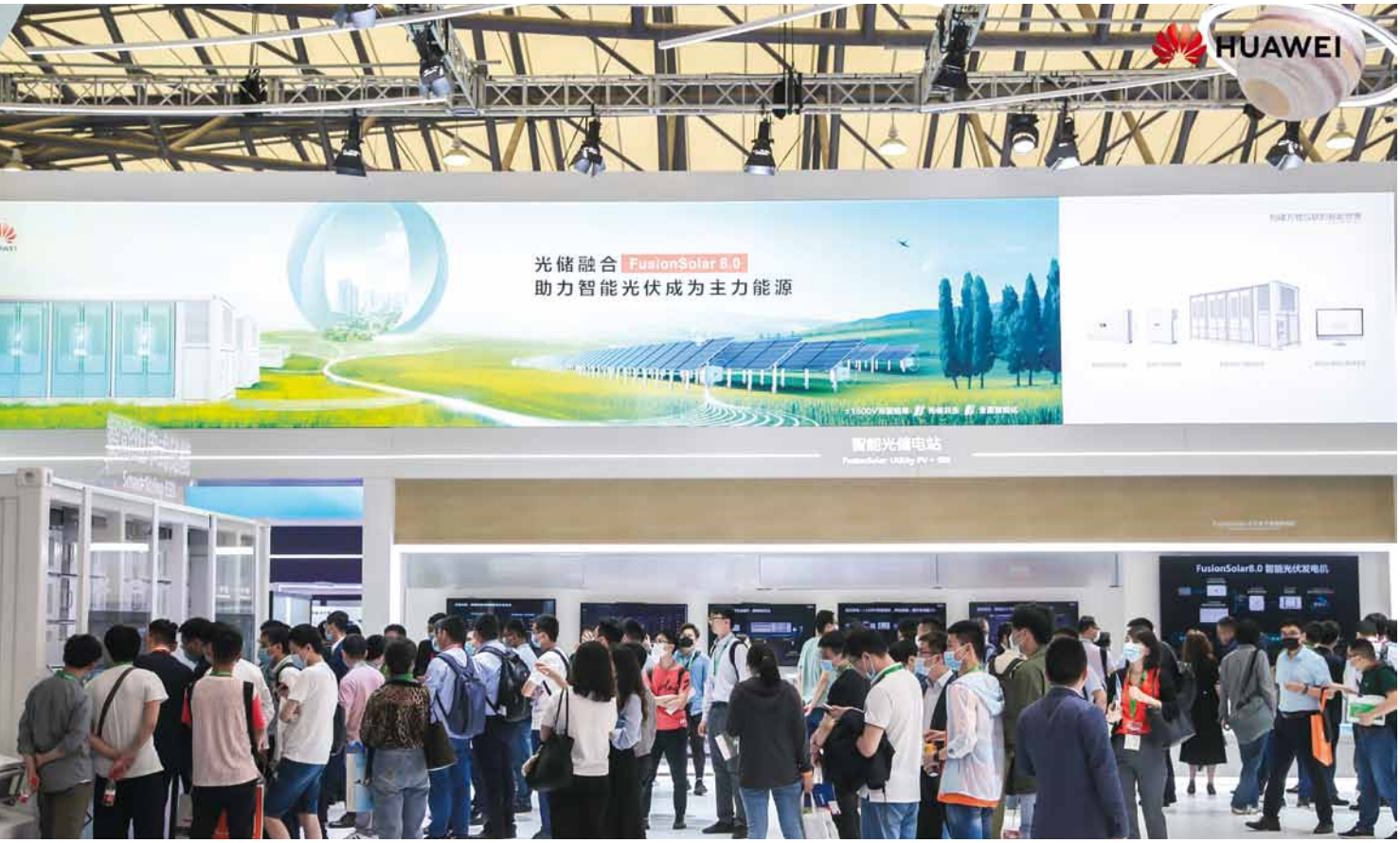


Photo: Huawei

Photo: pv magazine/Dave Tacon

For our solar customers, we are aiming to build a full ecosystem, end-to-end energy solution. Not only in energy generation, but also in energy storage and consumption, further lowering the LCOE to enable increasing PV grid parity and PV+storage grid parity. Through the integration of energy and information flow, an open energy cloud system, and an open technology ecosystem, we will enable renewable energy to become the main energy source.

Success is secured when people put their heads together. We hope to continue to innovate and create greater values for our customers to make technology benefit all.

Ever since Huawei shipped its first solar inverters in 2013, the company has moved fast to become a leader in the global solar industry, climbing to the top spot in inverter shipments by 2015. Huawei has also gained a reputation for rapid innovation. Can you tell us what new solutions and products we can expect from Huawei this year?

This year we will bring a disruptive solution to the industry. We refer to this solution as the "Smart PV Generator," to capture the wide range of smart photovoltaic generation applications covered by the solution. This includes large ground-mounted, C&I, and residential installations. It provides four major values: lower cost of electricity plus enhanced power grid plus comprehensive intelligence plus system-level safety.

Its main objective is to help the transition from PV to PV+storage, from traditional power generators to smart PV generators, turning the uncontrollable and non-stable current sources of PV to stable voltage sources. Instead of passively following the condition of the power grid, the Smart PV Generator actively enhances and supports the power grid, achieving a balance of energy supply and demand between randomly fluctuating load and power sources, and thereby building a new power system with renewables as the main source.

In terms of safety, Huawei has also created more innovations. Let me run through them. First is safe and reliable: in the scenario of large-scale, ground mount power plants, we pioneered intelligent string disconnection on the DC side to achieve active safety. The AC output adopts Huawei's patented technology with zero arcing and high safety standards; the medium voltage side adopts a vacuum circuit breaker to ensure the end-to-end safety of the entire power plant. In the C&I and residential scenarios, we use key innovative technologies such as AFCI (arc fault circuit interrupter), fast voltage 0V shutdown, and AI internal short-circuit detection to achieve passive safety to active safety.

In addition, we are also introducing a full-scenario smart string energy storage solution. In traditional energy storage solutions, chemical differences in battery modules result in mismatches, causing problems such as reduced capacity, degradation, O&M cost, and safety issues, and it is difficult to support large-scale applications of energy storage.

Huawei deeply integrates its power electronics with energy storage technology and uses the controllability of power electronics to solve the inconsistency of lithium batteries. Pack-level optimization allows for independent charging and discharging of battery packs, while rack-level management avoids parallel mismatch between battery racks. Finally, the modular design of air conditioner and PCS ensures the system is efficient and reliable, creating smarter and safer string energy storage solutions with lower LCOS. pv

> *"Instead of passively following the condition of the power grid, the Smart PV Generator actively enhances and supports the power grid"*
>
> **Chen Guoguang**

Corporate decarbonization

Low solar and wind costs, coupled with digitization and offtake arrangements such as power purchase agreements, offer a new frontier in which corporates can radically decarbonize. And with smart power electronics and energy storage, the transition will only accelerate.

In its March 2021 Roadmap to 2050, the International Renewable Energy Agency (IRENA) forecast that renewables would dominate electricity generation by 2050, with solar generating the largest capacity. The International Energy Agency (IEA) soon followed suit, projecting growth of 750 GW in 2020 to more than 8,500 GW in 2050. The big question is how the much-needed tripling of investment is going to be provided.

In investment terms, as Jonas Corne, chief executive of renewable energy software provider Greenbyte says, with the falling LCOE "it is simply better from a financial perspective to source from renewable energy." The increasing number of countries, 67 to date, and companies, over 20% of the top 2000 largest public companies, have commited to Net Zero by 2050 – a major driver of demand.

The fourth industrial revolution, and the shift to digital, continues to drive down solar operating costs through the optimization of software, and increasingly this is making strategies of corporate solar integration easier. Fang Liangzhou, the CMO of Huawei Digital Power Technologies, elaborates: "In the digital era of a fully connected intelligent world energy, digital infrastructure is also undergoing a transformation to adapt to the developmental changes of the digital world. We believe the combination of information and energy flow will bring us an efficient and intelligent new energy system."

With the rise of massive corporate PV looming, creative solutions like floating PV and new smart enabling technologies will be required in locations such as Singapore.

Corporate green awakening

The corporate market has woken up to the potential of solar. "Energy use, environmental impact and resource efficiency are hugely significant and ongoing considerations to the industrial sector," says Ian Thomas, managing director at merchant bank Turquoise.

Eduardo Insunza, global director of corporate customers at Iberdrola, adds that solar and wind PPAs provide corporates with decarbonization options. "Renewable corporate PPAs of all kinds open the door for companies to transform their energy consumption mix, become greener and meet their sustainability goals," says Insunza.

Richard Wall, CEO and founder of Emex, adds that "the potential of solar as a route to decarbonization is well documented. As the industry's expansion accelerates, more and more businesses are taking an interest in solar." Today large-scale purchases of renewable energy have been driven by technology companies with large data center driven energy demand, not simply to cut emissions to provide tangible evidence of the desire to be seen as a net zero company. Recently, Facebook signed multiple PPA contracts with Sunseap Group, including a 5 MW

offshore floating PV plant which Huawei is supplying with its Smart PV solution.

The interest in PPAs is spreading across industries and across the scale. Jack Eastwood, operations director at Protium Green Energy, says there are a number of factors driving the growing PPA market.

"For consumer-facing companies, like food and beverage or consumer electronics, use of renewables is a means of connecting with customers who are increasingly looking for brands that share their values," he says. Though noting that it's not just about brand value, "Cost of energy is an increasingly important factor, both the likely variability of future energy costs and the growing cost of carbon. This is turning solar into a great match for companies attempting to address their energy use and associated emissions."

Investor interest

The financial issues also relate to investor concern. As investors and central banks focus on future economic stability, investors want to know their investments are future-proofed, which means stricter reporting requirements are emerging in the corporate world and financial systems.

Whatever the sector and commitment to a lower-carbon future, many companies struggle to develop a cross silo interconnected strategy. Integrating solar is an easy step to take. As Thomas says, "the appeal of solar PV is simplicity, transparency and availability."

Tiago Mederios, director of sugar giant Czarnikow Group, says the company does not own or operate any of its own production or transportation assets. "Therefore our ability to facilitate change through our own operations is limited. In Brazil specifically, we are actively working with our clients to identify and support solar projects, whether through project finance, sustainability verification or commercialization support," says Mederios. "We believe that the solar energy market has a very positive future, and we are committed to supporting its growth as much as possible."

Photos: Sunseap

Facebook has signed multiple PPAs with Singapore-based developer Sunseap, including a deal for a 5 MW floating PV installation.

There are changes that still need to take place, however – particularly in terms of greater innovation and deployment of energy storage and grid management, which is the digital future of PV.

"The future solar system must shift from 'solar' to 'solar+storage,' and we need to make the 'solar+energy storage' system more intelligent, presenting the characteristics and capabilities of traditional power generation methods while delivering a lower LCOE to make green energy accessible and affordable to everyone," says Huawei Digital Power Technologies Fang Liangzhou.

Amazon recently become the world's largest buyer of renewable electricity. Jeff Bezos, Amazon founder and CEO issued a statement: "Our investments in wind and solar energy in the U.S. and around the world send a signal that investing in green technologies is the right thing to do for the planet and citizens – as well as for the long-term success of businesses of all sizes across all industries everywhere."

With Amazon's history of innovation and deployment of pioneering technologies, the direction of travel is clear, and the speed of delivery is accelerating.

67 nations

and more than

20%

of the world's largest 2,000 companies have committed to Net Zero by 2050

Carbon neutrality with digital power

Carbon-neutrality goals have gone beyond the energy and transportation sectors and will have an extensive influence on human society as significant as the emergence of the steam engine, electric power, or computers. Achieving carbon neutrality requires the collective effort of all countries, cities, enterprises, and individuals, writes Chen Guoguang, president of Huawei Smart PV Business Unit. Huawei is committed to helping multiple industries reduce their energy demand and facilitating the global shift to a low carbon economy.

Scientists warn us that human-induced climate change, brought on by the burning of fossil fuels, is pushing life on Earth toward a sixth mass extinction event. According to a World Meteorological Organization (WMO) report, we are at least 1 C above preindustrial levels – a rise of 1.5 C represents a tipping point capable of triggering catastrophic runaway feedback loops. The world, as we know it, would be lost forever.

The natural environment and the resources we depend on are inherited from past generations and borrowed from future ones. If we fail to limit carbon emissions, this natural wealth will be exhausted on our watch.

Consequently, carbon neutrality has become a global mission for today's international community. According to statistics from the Energy and Climate Intelligence Unit, more than 120 countries and regions have proposed carbon neutrality goals, marking a rare convergence of public policies and priorities right around the world. ''The Age of Resilience is now

This 2.2 GW power plant in Qinghai province, northwestern China, was the word's largest solar installation when it was connected to the grid in September. It supplies power over long distances via an ultra-high-voltage power line.

before us,' wrote Jeremy Rifkin. 'How we adapt to the new planetary reality that faces humanity will determine our future destiny as a species."

Huawei will actively support and participate in the fight against climate change and make every effort to help all industries continuously reduce energy consumption and accelerate the structural transformation of the energy sector through technological innovation. Huawei is committed to making a unique contribution to a new low-carbon and sustainable society.

Electrification and intelligence

As a company, Huawei is embracing three trends by way of pursuing this goal. First, the fourth industrial revolution propels the shift to an intelligent world. Second, carbon neutrality accelerates energy transformation and helps build a clean, low-carbon, safe, and efficient energy system. Third, energy and information flows must converge in a new power system where renewable energy serves as the primary energy source.

Traditional power systems with limited digital automation and interaction will eventually be replaced by more efficient, digitalized, and intelligent alternatives capable of sensing and interacting.

Photos: Huawei

Completed in 2019, Huawei's SUN2000-60/70KTL is directing 4.1 MW of solar traffic at Beijing Daxing International Airport.

Achieving carbon neutrality goals requires a reduction of energy consumption and carbon emissions, as well as the gradual decoupling of economic growth and carbon emissions, driven by advances in science and technology. And there are a number of trends informing this development.

The levelized cost of electricity (LCOE) of renewable energy has decreased rapidly and is now significantly lower than that of fossil fuels. It has been forecast that renewable energy will account for more than 86% of total energy demand by 2050. The installed PV capacity will increase from 750 GW in 2020 to 8519 GW in 2050, replacing fossil fuels as the primary means of power generation.

Additionally, in terms of energy consumption, electric energy will gradually replace fossil fuels. It is predicted that electric energy will surpass oil by 2050, growing from 20% to total energy supply in 2017 to 49%. Green manufacturing, green building, and green travel are important growth engines of electrification, and heavy industry sectors will use renewables and improve energy efficiency to build green buildings and low-carbon campuses.

Finally, the forecast renewable energy expansion is set to introduce significant instability to traditional power grids,

"Achieving carbon neutrality requires the collective effort of all countries, cities, enterprises, and individuals"

Huawei expects renewables to account for more than 50% of all energy by 2030.

> *"In the future, we will focus on bridging the energy divide through stable, clean, and affordable energy"*

which will evolve from centralized to distributed systems. An increased number of electric vehicles also poses a challenge to the architectural stability of energy systems. To maintain the stability and reliability of power grids, improve energy efficiency, and reduce energy costs, intelligent technologies are required to coordinate power sources, grids, loads, and storage, and to implement peak shaving.

Huawei is already committed to bridging the digital divide and enriching life through communication with ICT technologies. Now, our foremost contribution is to help all industries continuously reduce energy consumption and accelerate the structural transformation of energy through technological innovation. In the future, we will focus on bridging the energy divide through stable, clean, and affordable energy.

Primary power

According to a recent report from the Huawei Institute of Strategic Research, the proportion of renewable energy will exceed 50% by 2030. Electric vehicles are expected to account for more than 50% of all vehicles sold. ICT technologies have the potential to help other industries reduce global carbon emissions by 20% over the next decade.

The new energy system will require the control of the flow of data and an optimized flow of energy and services. Data is a core production element for streamlining power sources, power grids, loads, and energy storage. Power generation then becomes visible, measurable, and controllable. Power grids can be controlled by the coordinated cloud and edge, and power consumption is supported dynamically by a massive number of resources.

Specifically, Huawei focuses on continuous innovation and open cooperation in the following six directions:

1. We will continue to integrate leading power electronics technologies with digital technologies and converge energy flows with information flows to manage watts with bits, promoting the digital transformation of the energy industry.
2. We will develop a clean power system that uses renewable energy sources like wind and solar, alongside energy storage, as the primary sources. This synergy of power sources, grids, loads, and energy storage will transform renewable energy from supplementary to the primary energy sources capable of replacing fossil fuels.
3. The key to fully electrifying the transportation industry is to ease consumer concerns relating to charging times, range anxiety, and safety. In this regard, Huawei will focus on the user experience to build a converged, simplified, safe, reliable, and intelligent electric power solution, as well as developing charging and swapping network solutions featuring the PV-storage-charging integration.
4. As the digital world rapidly grows, so too does power consumption, resulting in a significant challenge to ICT infrastructure. It is predicted that the power consumption of global data centers and sites will reach 950 and 660 billion kWh respectively by 2025, accounting for about 3% and 2% of the total global power consumption. We will focus on building zero-carbon, efficient, and intelligent green ICT infrastructure solutions for data centers and sites.
5. Energy storage will be integrated with power sources, grids, and loads, and will function as grid frequency regulators and stabilizers. We believe that the key to building a safe, cost-effective, and intelligent energy storage system is full-lifecycle intelligent battery management through the Cloud Battery Management System (BMS).
6. We will build an integrated intelligent energy service platform to streamline power generation, storage, distribution, and consumption for different scenarios

– such as wind and solar power, energy storage, energy conservation in industries, buildings, sites, data centers, and power distribution networks.

Huawei has more than 30 years of experience with digital and energy technologies. Through management, control, energy storage, and power electronics technologies, Huawei converges energy and information flows to accelerate energy conservation and the reduction of carbon emissions for all industries. To date, Huawei digital power solutions have been deployed in over 170 countries and regions, serving more than a third of the world's population.

Green generation

Having begun life in the power generation field with a focus on inverters, Huawei became the first in the industry to launch a smart PV solution using string inverters, which function as intelligent sensors for PV arrays and collect information from each string. This innovative solution was capable of fully digitalizing PV plants. Over six consecutive years, from 2015 to 2020, Huawei has ranked No. 1 in global inverter shipments.

In 2021, Huawei further integrates smart PV and new ICT technologies to build a comprehensive, intelligent, and all-scenario PV+storage solution, which not only significantly reduces LCOE, but transforms PV from requiring the adaptation of the grid to being grid forming as a primary energy source.

Huawei has always been an advocate and practitioner of technological innovation. By Dec. 31, 2020, Huawei digital power solutions generated 325 billion kWh of green electricity, saved 10 billion kWh of electricity, and reduced carbon dioxide emissions by 160 million tons – equivalent to planting 220 million trees.

In addition, the Huawei smart PV solution has been used in more than 60 countries. Meanwhile, Huawei has built the world's largest agrivoltaics and solar-fishery plants in Ningxia and Shandong, China, and these have become showcases for local environmental protection. On Sept. 30, 2020, Huawei leveraged its expertise to ensure the successful connection of the world's largest PV plant to the power grid – with a massive 2.2 GW of total capacity.

Green power generation enables wind-solar-hydro-thermal-storage and generation-grid-load-storage integration, and helps build clean energy demonstration bases to accelerate the low-carbon transformation of energy. It also enables agricultural production to achieve energy independence and sell excess power to the grid, thereby maximizing the associated benefits while also contributing to poverty alleviation.

Commercial rooftop PV installation in Dubai. By the end of 2020, Huawei solutions had generated 325 billion kWh, and saved 10 billion kWh of electricity.

Huawei is committed to building zero-carbon cities and a zero-carbon Earth, which is conducive to the realization of carbon neutrality goals. These efforts are demonstrated in the following solutions: zero-carbon power, zero-carbon home, zero-carbon travel, zero-carbon sites, zero-carbon data centers, and zero-carbon campuses.

Energy ecosystem

As the old Chinese saying goes, victory is assured when people pool their strength; success is secured when people put their heads together. Achieving peak carbon emissions and carbon neutral goals requires the collective effort of every player in every industry. Huawei will continue its open cooperation with partners throughout the industry chain, facilitating the upgrade of various industries and ensuring that everyone is a winner.

I feel hopeful when I see our shared devotion to tackling climate change. Only by realizing our ambitious zero carbon goals, can we leave a better planet for future generations. pv

Chen Guoguang

About the author

***Chen Guoguang** is president of Huawei Smart PV Business Unit. Chen joined Huawei in 2001, after graduating with a degree in Mechanical Engineering and Automation from Southeast University. He has served in various senior positions, including chief R&D engineer. In 2010, Chen was made responsible for the establishment of the Huawei Digital Power Europe R&D Center in Germany, where he worked on tech development, including Smart PV and data center provision. He became the head of the Huawei Smart PV Business, Europe, in 2013 and established the region's marketing and service team. In 2018, Chen was elevated to the role of President of Huawei Smart PV Business global sales and service department, where he was instrumental in integrated ICT to solar and promoting digitization. He currently serves as the president of the Huawei Smart PV Business, where he works with partners to accelerate the adoption of Smart PV.*

Sites, market conditions, O&M drive tech decisions

The move by hydropower leader Statkraft to acquire Solarcentury in late 2020 brought solar front and center to its renewables strategy. Christopher West, the head of central engineering for Statkraft's solar engineering division, says that flexibility and the ability to adapt to specific site and market conditions are dictating project development in Europe.

How would you describe Statkraft's engagement with solar project development in Europe in 2021?

Statkraft has been developing solar for a while now – it never really stopped. But obviously it's accelerated now because Statkraft acquired Solarcentury. The move brought quite a good pipeline of projects in with it, and a lot of project development capability. Developing and building the solar farms this year is very attractive for Statkraft.

In the past Statkraft was particularly active in developing some of the quite early floating PV projects in Europe. As an engineer, what is your expectation for that application? Will it remain a niche?

Though the vast majority of our projects are ground mounted, Statkraft has some good synergies regarding floating PV as well, because obviously, Statkraft constructs hydroelectric dams, and they provide a really interesting space to build a floating PV project. Of course, you're always going to be limited a little bit by how many hydroelectric dams exist.

"The things we value in all our key suppliers are a quick and effective response to our requests and good technical support in our target markets"

You say ground mounted on tracking; my understanding is that there's kind of a latitude at which tracking stops making sense in Europe. Is that right?

Every site is different. Every country has particular grid constraints, land constraints, and the situation with capex and price – namely, the differential between trackers and fixed structure costs at any point in time. You have to analyze the effect on cost of electricity: like bifacial versus monofacial, whether it's worth deploying it in a certain area. In some areas, even in Northern Europe, it can make sense [to deploy tracking] under certain conditions, and in other situations, it doesn't make sense. The answer is always that you have to look at the site and the conditions around it to determine whether fixed or tracking is going to be your best option.

You're saying PV development in Europe in 2021 is very contingent on site, market, tariff, and PPA conditions, or even all of these different factors combined?

Yes, and the technology has been changing a lot over the last few years. The fact that bifacial modules are now becoming more and more common is an example, and that impacts your decision on tracker or fixed. This is true also of the larger-format mod-

Photo: Statkraft

Christopher West, head of central engineering for Statkraft's solar engineering division

ules. And we can't forget storage, which is a whole new thing coming into the equation. It's complex, but it's an exciting time.

We've discussed FPV, bifacial technology, large format modules and energy storage, how would you describe working with Huawei to meet these technical challenges?

The things we value in all our key suppliers are a quick and effective response to our requests and good technical support in our target markets, as well as an openness to work with us in developing solutions to many of the challenges we've discussed today.

In terms of power conversion, string versus central inverters is an important choice. For developers, what factors are you considering when you make that choice?

Historically, a large number of Solarcentury projects, which is now a part of Statkraft, have been string inverter projects – something like 90% or so. We were one of the early adopters of string inverter technology, using it in the U.K. before it had been widely adopted. And the reason why Solarcentury went so strongly with string inverters at the time was really thinking ahead from an O&M point of view.

One of the advantages you can have with a string inverter is if it breaks, you can simply replace it. You don't have to actually repair it, and you can replace it quite quickly. That means that your availability is increased. That flexibility remains even if, for example, a manufacturer goes bust and you need another type of inverter to fill the void.

Solarcentury made the decision at a time when the price differential [between string and central] was quite big, and even then we still sort of came down on the string side.

What are the other considerations when you're selecting a vendor for power electronics?

It's really important that they [inverter suppliers] have products which are compatible with all the other components we want to use. What is quite a big issue these days is the new types of modules. Up until last year or so, we just had the sort of 72-cell modules, and everything was quite standardized with the voltages and the currents that you'd be expecting, and manufacturers were designing inverters to match those.

Now, there's a whole bunch of different PV modules of all shapes and sizes. And the inverter designs weren't necessarily optimized to this new generation of modules. Now they are available, and the modules continue to change – so it's a bit of a moving target. The fact that they [inverter manufacturers] can respond quickly to changes in the market and changes in technology is really important.

You mentioned energy storage. How would you describe the amount of activity there in terms of adding storage to PV projects in Europe at the moment?

We have a pipeline of projects that take into account energy storage which are actively under development. We have very high hopes and a high level of confidence in energy storage. We have to consider some sort of storage more and more as solar and wind begin to saturate the grid, because we need to be able to smooth out the peaks.

The batteries are getting cheaper and cheaper. Now it's starting to become very obvious that we can deploy batteries and actually gain an advantage.

Thai solar CEO goes Huawei at home

Cathleen Maleenont has led Thai Solar Energy PCL for more than a decade, steering the company to its position at the forefront of renewables development in the Asia-Pacific region. After selecting Huawei to be its technology partner for what will be Japan's largest solar plant, Maleenont has quite literally decided to take Huawei's solutions home with her, by installing them as part of her own personal solar system.

In the time Cathleen Maleenont has been at the helm of Thai Solar Energy (TSE), the company has been named among Asia's Best Performing Companies in the Asia Corporate Excellence and Sustainability Awards and has secured some of the most notable utility-scale solar PV projects in the region. In her decade at the company, including the last seven years as chief executive officer and chair, Maleenont has also managed to carve out a foothold for Thai Solar Energy in Japan, one of East Asia's most significant renewable energy markets.

TSE is currently constructing what will be the country's largest solar park, the Onikoube Solar Power Plant. The project is being built on a 156-hectare former golf course in the city of Osaki, in northeastern Japan's Miyagi prefecture. The CNY 35.5 billion ($320 million) project will have a generation capacity of 147 MW once it goes online in 2023. Owned by PurpleSol, an affiliate of Thai Solar Energy, the solar

Photo: Thai Solar Energy

Thai Solar Energy's 147 MW Onikoube Solar Power Plant utilizes Huawei's 1500 V Smart PV Solution.

Photo: Huawei

At home as at work: Maleenont selected Huawei's Smart PV Residential Solution, including the Luna2000 battery system, for her home.

park has been designed so the 362,960 solar panels it features can accommodate the sloping terrain and snowfall in the area.

TSE has selected Huawei as its technology partner for the ambitious project. In 2019, they entered into an agreement with each other under which Huawei will supply its 1500V Smart PV Solution with Smart I-V Curve Diagnosis. Combined with Huawei's AI algorithm, the solution will optimize the Onikoube Solar Power Plant's operation and maintenance efficiency and reduce its operating costs. Thai Solar Energy partnered with Huawei on this "mega" project after the two companies successfully collaborated on a pilot array in July 2014.

Maleenont said that TSE selects its technology partners based on three metrics. The first, naturally, is quality, with Maleenont saying that the company chooses only "state of the art technology." Reliability is also crucial, with a key component of that including "brand name and customer acceptance." Lastly, the technology must be reasonably priced. Evidently, Thai Solar Energy found that Huawei's Smart PV Solutions fulfilled all these benchmarks.

After a decade developing utility-scale solar farms in Thailand and more than seven years in Japan, Maleenont said the main differences in the two markets involve rules and regulations, rather than product preferences. "The economic terms versus the efficiency of products used are currently competitive, therefore operators like TSE have choices in selecting the best products at the best economic return," Maleenont said.

Thai Solar Energy's portfolio today comprises 41 renewable energy projects with a total combined capacity of 300 MW. This includes 15 utility-scale solar farm projects in Thailand and eight in Japan. In May, The Bangkok Post reported that Thai Solar Energy is also in the process of acquiring two new renewable assets. These installations will add a further 50 MW to its portfolio, as the company targets increasing its capacity by up to 200 MW in the next three to five years.

While Thai Solar Energy specializes in utility-scale solar, it has also installed more than 10 MW of rooftop solar. "[Rooftop solar] is getting more popular due to the lower cost of investment and higher efficiency of the equipment installed," Maleenont said. Thai Solar Energy currently has 14 commercial rooftop solar projects installed in Thailand.

Taking work home

This year, Maleenont herself installed rooftop solar on her own home. For that project she again selected Huawei technology, installing its 10 kW three-phase string inverter and Luna2000 battery at its maximum 30 kWh capacity. Those Huawei systems will control and store the solar energy harvested by the 24 PERC monofacial 530 Wp solar panels now installed on Maleenont's roof.

Maleenont noted that Huawei's Smart PV Residential Solution also gives her the opportunity to see her solar generation, battery charge and discharge status via its mobile monitoring system. Through the system, she is also able to view load consumption and calculate her percentage of self-consumption.

Like many households with solar, Maleenont said she chose to install her system to both save energy and reduce her carbon emissions. "It's the business I'm in for over a decade ... I do have a passion for it," she added.

The CEO said she had selected Huawei for her home as it is "one of the forefront providers" in the residential solar segment and because of the credibility it established through its work with Thai Solar Energy.

While Thai Solar Energy doesn't currently have any future projects planned with Huawei, the CEO said she would gladly partner with the company again.

"It's the business I'm in for over a decade ... I do have a passion for it"

Cathleen Maleenont, CEO, Thai Solar Energy

Photo: Thai Solar Energy

Scaling up string in Chile

French multinational energy company ENGIE plans to cease all of its coal-fired power generation activities in Latin America by 2025. In Chile, which enjoys some of the highest solar irradiation levels in the world, much of this capacity will be replaced by PV projects – many of which are already in development. pv magazine spoke with ENGIE's energy efficiency product manager, Francisco Retamal, as well as Senior Project Chief Julio Saintard and Senior Business Developer Cristopher Llanos about their experience working on solar projects in Chile, and the growing role for string inverters like Huawei's in all market segments.

Francisco Retamal, energy efficiency product manager at ENGIE. The company plans to develop 2 GW of renewable energy capacity in Chile by 2025, including a large chunk of solar.

ENGIE has invested heavily in Chile in recent years and some of its rooftop solar projects have featured Huawei string inverters. How would you describe the reasoning behind this choice? What is the rationale for using string instead of central inverters in Chile?

Francisco Retamal: ENGIE has plans to develop 2 GW of renewable energy capacity in Chile, and to cease its coal-fired power generation activities in the whole of Latin America by 2025. This presents an additional 1 GW since the last announcement in 2019. A big portion of this renewable energy capacity will be solar.

Alongside our transformation plan, we have developed a couple of rooftop photovoltaic systems at client sites, accompanying these clients through their own energy transition. For these projects, we have already used Huawei string inverters, learning the advantages of this technology.

String inverter technology is always the best option for rooftop projects because it has easy installation, and if one string fails, the whole array's energy is not lost, just the power from that string. Maintenance is also simple, and you can reduce the amount of DC cabling needed. We also used Huawei string inverters in a project at Santiago's Arturo Merino Benítez International Airport: 720 kW string inverter capacity from 14 inverters, which generate around 1.2 GWh per year of renewable energy. This project adds on to recent similar agreements with different companies for a total inverter capacity of around 1,100 kW.

ENGIE is working with central inverters for its latest utility-scale project in Chile, but the aforementioned advantages of string technology can also play out in larger projects. And given our experience in rooftop projects, we're considering string inverter technology for utility-scale project designs.

What advantages are offered by string inverters in the Chilean PV market in terms of logistics? Are these devices the best option for all kinds of projects?

Julio Saintard: String inverters offer a high level of redundancy and plant availability; in case one of the inverters goes down, the rest of the plant continues to operate at a high-capacity level. From the installation point of view, considering that the packaging size of a string inverter is much smaller than a central one, the transport from the factory, unloading and its disposition of the work is made easier, requiring less specialized equipment and fewer hours of labor. This optimizes execution times and reduces risk for the project.

What needs to be taken into account when building a solar plant with string inverters in Chile's climatic conditions? Is the project size crucial for the choice of these devices?

JS: Most of the large photovoltaic plants are located in the desert regions of northern Chile, where the "chusca" is abundant. This is a kind of dust with very small granulometry, that requires components rated with at least IP65 protection, as well as a comprehensive maintenance plan to be carried out according to the specific site conditions. Site selection is also relevant in terms of corrosivity – many areas of northern Chile reach the 'C5 – very high' classification, based on the ISO standards. Finally, the size and flexibility that a site has for mounting systems also has implications in terms of required earthworks and the need for seismic certifications.

Photos: ENGIE

Construction is underway at ENGIE's 97 MW Capricornio project, close to the city of Antofagasta.

Chile is known for having the highest levels of solar radiation in the world. Would ENGIE only use string inverters in a similar environment?

Christopher Llanos: It is one of the options that we are considering. Project feasibility for any technology will depend mainly on the LCOE of the overall project, taking into account the advantages on opex, capex and yield of the complete project can have.

How are O&M and monitoring activities being implemented after project completion? And how would you describe the ongoing after-sales service from Huawei?

FR: We have received solid customer service from Huawei, based on strong knowledge of string inverters and clear communication for solving problems and supporting ENGIE with different post-sales requirements. In addition, we have had very positive experience with Huawei's monitoring platform, which gives us the opportunity to watch our PV systems operating in real time.

Looking forward, is the share of string inverters expected to Increase in ENGIE's projects in Chile?

FR: It is possible, but it will depend on the market and on how the economic variables of the project between one solution to another move, and their impacts on the overall cost of the project.

Smart solution for dispatchable solar

World-record prices have become the default setting for large-scale solar development in the Gulf Cooperation Council region. At the forefront of this development is the United Arab Emirates, which has led the way with its Mohammed bin Rashid Al Maktoum Solar Park in Dubai. And, as the latest stage of the vast project reveals, intelligence, optimization and ongoing high performance is making all the difference.

Phase IV will feature

12 -15

hours of energy storage

The multi-stage and multifaceted Mohammed bin Rashid (MbR) Solar Park in Dubai has been a trailblazer in many ways. Not only has the vast PV and concentrating solar power (CSP) project set the agenda for large-scale solar deployment in the Gulf Cooperation Council (GCC) region, but it has also set records for low levelized cost of electricity (LCOE) in the process, while fostering the development of large-scale solar throughout the Middle East.

The eventual 5 GW MbR project has also been at the forefront of solar technological demonstration at scale. Once completed it will be the largest solar project in the world. Over its various stages, the MbR project proponents have deployed thin-film module technologies, dual-glass crystalline silicon modules on single-axis trackers, and bifacial technology.

The 950 MW Phase IV of the MbR Solar Park, being executed by ACWA Power, DEWA, and SRF under the Noor Energy 1 PSC project vehicle, is implementing the only two CSP technologies in the MbR solar park, alongside 250 MW of PV. The project is the world's largest CSP plant, hosting the world's tallest central tower. Remarkably, it achieves an LCOE of $0.073/kWh for nonstop dispatchable power, making it "a competitor against unsubsidized fossil fuel generated electricity, generating reliable and dispatchable nonstop clean energy through the day and night," explains Abdulhameed Al Muhaidib executive director, portfolio management at ACWA Power. The 950 MW project will additionally have 12 to 15 hours of energy storage capacity.

These innovations, along with the most bankable of offtakers and access to flat, easily accessible land, has resulted in MbR project stages regularly setting records for world-beating PPA prices for solar. The 200 MW Phase II of the project set a record with a PPA tariff of $0.0561/kWh. Going further still, the 800 MW Phase III of MbR achieved a strike price of $0.0299/kWh – another world record at the time of financial close in June 2017.

PV power long after sunset – the 950 MW fourth phase of the Mohammed Bin Rashid project is redefining large-scale solar power provision.

Photo: Ghadir Shaar

Inside MbR innovation

Beyond the module, the MbR Solar Park has utilized innovative power electronics, O&M technologies, such as robotic cleaning, and ownership structures to achieve low prices. The 200 MW Phase II was the first in Dubai to be developed via a public-private partnership. Phase III used 1,500 V architecture and inverters – an early application of higher voltages at the time.

The 250 MW PV component of Phase IV also pushed the boundaries of technology innovation. The plant utilizes bifacial modules, delivering impressive power output with the relatively high albedo from the desert sands.

Photo: ACWA Power

Phase IV is also pushing the envelope in terms of power electronics and digitization.

"When it comes to the inverter and power stations, Noor Energy 1 is adopting the latest technologies from Huawei's line of products, consisting mainly of the string inverters and Smart Transformer Stations that allow for a more modular system to be built on a fast-track basis," says ACWA Power's Abdulhameed Al Muhaidib.

"As we strive for the best-in-class operations, we are optimizing our land use and leveraging digital tools and robotic solutions to ensure sustainable and reliable energy production throughout the lifetime of the plant."

The decision by Noor Energy 1 to use Huawei's string inverters for MbR Phase IV, was based on "lessons" and "past experiences" of the previous stages, says Al Muhaidib. In particular, the environmental conditions – which include extremely high operating temperatures and pervasive, fine dust.

"The main advantage that we see with the use of string inverters is the modularity of the system, which in turn allows for higher availability and less downtime for the plants as a whole," says Al Muhaidib. "Not only that, but the string inverter brings in the advantage of operating at higher temperature thresholds and utilize cooling systems that require minimum attention and maintenance from the operator side – an advantage that truly shows its value throughout the operation of the plant."

In terms of digitization, the Huawei power electronics platform, including its transformer station, provides advanced data analytics, delivering insights into the solar field's operation and maximizing power output, reports the ACWA executive. And with Phase IV of the vast MbR Solar Plant poised to provide power for many hours after the desert sun has set, high performance and digitization will be key.

> *"We are optimizing our land use by leveraging digital tools and robotic solutions to ensure sustainable and reliable energy production throughout the lifetime of the plant"*
>
> **Abdulhameed Al Muhaidib**

Residential value after

Solar energy is smarter and more affordable than ever before. And with its LUNA2000 distributed battery storage product, Huawei is further unlocking the value of PV, enabling the use of solar energy long after sunset. By taking a closer look into some key residential storage markets, how this value stacks up truly becomes clear.

"Residential batteries are likely to play an increasingly important role in the creation of a clean energy future"

Few people with knowledge of what will be required for an economy-wide transition to renewable energy doubt that battery energy storage will play a key role in the energy system of the future. But what is needed and what is wanted from end consumers can often be very different things. As such, the adoption of residential energy storage systems in homes and small businesses has been patchy, even among leading rooftop solar marketplaces.

There are an increasing number of drivers for residential battery storage systems each year. But they do differ from market to market. The picture is a complex one, based on public policy, subsidies, grid characteristics, electricity pricing and market structures – to name but a few. Add to this the way in which consumer preferences vary from market to market, and the complexity in battery adoption drivers is notable.

Inside the market

Despite this complexity, the key drivers for residential battery storage adoption can be summarized as follows:

1. **Use of "own electrons":** This is both a financial and an "emotional" driver, and is often described by the somewhat unsettling moniker of maximizing "self-consumption." In markets where there is a sizable gap between the feed-in tariff received for rooftop PV sent back into the grid and the retail rate for electricity consumed in the home, this delta provides a financial incentive for energy storage. There is also an emotional aspect to this, in that consumers want to use "their" solar electrons, generated on their own rooftops. Relatively good levels of self-consumption can be achieved using load shifting and other smart devices. However, there is a threshold to the efficacy of such measures, which can only be overcome through the installation of a battery storage product.
2. **Provision of backup power:** When the lights go out, many households are severely impacted. Outages can cause particular disruption when fridges and freezers go out of function with the loss of grid power, and losses to household communications and entertainment can be inconvenient at best and dangerous at worst. When this is coupled with an increase in extreme weather events, the smooth provision of electricity to a household or small business by virtue of a residential battery system can be a very attractive prospect. Of course, local environmental and grid factors play a major role here, and in places where the grid is particularly robust, such as Germany, backup power is less of a driver for consumers. However, in some key battery storage marketplaces, such as the United States and Australia – two geographically large and developed economies where power outages still feature – the provision of backup power can be a compelling value proposition for homeowners and businesses.
3. **Contributing to the energy transition:** As an increasing number of households see and even experience the impacts of climate change, they feel compelled to make a contribution. Taking control of your energy supply and consumption is one way of doing so, and a battery energy storage system provides an unprecedented opportunity to do so. Distributed battery systems also become more important in terms of grid stability and the ability of electricity distribution networks to absorb very high levels of rooftop PV – itself a necessary feature of a 100% green energy system. As such, residential batteries are likely to play an increasingly important role in the creation of a clean energy future at the distribution network level, and are an important way in which households can play an active role in averting catastrophic climate change.

sunset

Consumer drivers

These and other drivers for residential battery storage system adoption play out on the macro level – across various distributed battery marketplaces around the world – but in each market there are discrete versions, each with more tangible value propositions. A household in Vietnam desires backup power, but for different reasons to a consumer in the United States. For an Australian household, the need for a battery may be closely linked to solar feed-in-tariff structures, while in Belgium, existing subsidies provide a significant driver.

Consumers place varying levels of importance not only on the value proposition, but on attributes offered by an ESS supplier. These include brand recognition and trusted service, and extend to size and ease of installation, battery chemistry, and issues linked to the sustainability of the materials. And safety cannot be ignored, as is evident in Germany, where households want to be sure the battery in their basement is "as safe as houses."

The following three case studies provide insights into the wider drivers and in particular, customer choices in key residential battery storage marketplaces.

Thanks to Huawei's optimizers, and the Smart String Energy Storage System Solution, this rooftop installation in Ho Chi Minh City, Vietnam, can incorporate modules of different power ratings and provide 24-hour electricity to its owner.

Photo: Red Sun Company

As many rooftop PV projects in Germany are reaching the end of their feed-in-tariff agreements, owners have increasingly turned to storage to boost their self-consumption rates and the value of their installations.

Photo: Hülsdünker Elektroanlagen GmbH

Germany: Optimizing energy costs

Germany has long had a strong market for residential energy storage systems, and with thousands of rooftop PV installations in the country reaching the end of their feed-in-tariff agreements in the next few years, strong growth is expected to continue. Installers are forecasting 20-30% year-on-year growth for the market in 2021.

Local distributor Wagner Solar has been working with Huawei's latest battery offering, the LUNA2000 solution, for several months already and sees this product as a strong value prospect for the German market.

"We believe that the Huawei LUNA2000 solution is closing a gap. We now have one system by one manufacturer which makes service and support easier for the installer and end customer," says Stefan Rösch, product manager at Wagner Solar. "Huawei's brand awareness in the consumer business and their reputation for constant innovation in the solar space, makes it easy to place in the German market."

Rösch points to a recent report published by EUPD Research that found 79% of end customers in Germany want to increase consumption of their self-generated electricity. Taking a system installed in the western German town of Schermbeck, as an example – where a 10 kWh LUNA2000 battery system accompanies Huawei SUN2000-8KTL-M1 inverters and 20 x 400 W PV modules, along with 12 x 450 Wp optimizers – he explains: "The typical customer in Germany has recently built or renovated their own house, and constantly optimizing their energy costs is a very important factor. So the main motivator to install a battery storage system is still electricity self-sufficiency. The LUNA2000 energy storage by Huawei makes this possible as it also includes optional backup power."

Belgium: Storage subsidy leader

Belgium is among the first countries to offer a subsidy for the installation of residential energy storage systems. At up to €300/kWh, the scheme promises to reduce the payback period from seven to four years. "Without the LUNA battery the energy self-consumption for residential rooftop PV averages about 15%, and unused power is sold to the grid for 0.04 cents," explains Robin Maes, founder of local installer MR Solar. "After installing the battery, the owner can raise self-consumption to 65-75% and use stored energy at night instead of buying at 0.25 cents."

Maes expects similar subsidy models to be adopted across Europe in the near future, as more regions and system owners realize the added value of self-consumption. "Homeowners with solar systems need to store energy for use later into the evening," he explains. "There is no time to waste energy by feeding it into the grid."

Photo: MR Solar

Belgium has emerged as a leader in residential storage, as it is the first country in Western Europe to offer a subsidy to customers for residential batteries. Installers estimate this subsidy could reduce the payback period for energy storage systems from four to seven years.

MR Solar has chosen Huawei for several residential projects in Belgium, including one in the town of Beerse. Here a 10 kWh LUNA battery system was added to a solar installation already operating with Huawei three-phase inverters. And as demand for residential energy storage picks up, MR Solar expects Huawei to remain a key player in the industry and in successful installations. "Huawei FusionSolar provides an all-in-one solution – one service center for all your questions and warranty concerns, one energy storage solution, one inverter fits grid & backup operations, one optimizer, and one software to monitor your solar system," Maes explains. "Together with easy plug and play installation, this brings great benefit to installer and home owner."

Vietnam: Rooftop PV powerhouse

Vietnam has seen an unprecedented boom in rooftop solar recently, with installations in 2020 amounting to more than 9 GWp. In Ho Chi Minh City alone, local installer Red Sun Company estimates there are more than 200,000 houses with suitable rooftop conditions for solar, as well as a wealth of office buildings, apartment blocks, supermarkets, traditional markets, hospitals, schools and more.

Benny Diep, director of Red Sun Company, cites multiple reasons for Vietnam's rooftop solar boom, in particular rising electricity prices, falling solar installation costs, and strong public awareness of both the benefits of residential solar and the need for environmental protection and emissions reduction.

Meanwhile, rising energy demand, falling feed-in-tariff rates and concern over grid constraints mean that adding energy storage is an increasingly attractive proposition in the country's rooftop PV sector. "Vietnam's energy consumption continues to grow as the economy recovers from the pandemic. Meanwhile, we have seen the PV market explode since 2020 to support this growth," says Diep. "It is a great opportunity to start focusing on self-consumption and the application of energy storage solutions."

To demonstrate the advantages afforded by incorporating energy storage into residential solar, Diep points to a 7.37 kW PV system Red Sun installed in Ho Chi Minh City, featuring Huawei's Smart Energy controller, Smart String Energy Storage System and optimizers. The system was shown to generate 995 kWh per month on average, and the installer estimates the customer will recover their costs in less than five years.

Using Huawei optimizers to control shading impact increases the system's energy yield by 15%-30% and allows modules with different capacities to be integrated in one string. the Smart String ESS is capable of 100% discharge, can charge from the grid, and means the system can provide power 24 hours a day: increasingly valuable for consumers in Vietnam concerned about rising prices. "The price of electricity after 400 kWh is very high," explains Diep. "Therefore, solar power users want to be able to store electricity generated during the day to use at night, minimizing the amount of electricity used from the grid." pv

In pictures: Global power

VivoCity, Singapore
Capacity: 830 kW
Model: SUN2000-60KTL-M0
Connected: November 2018

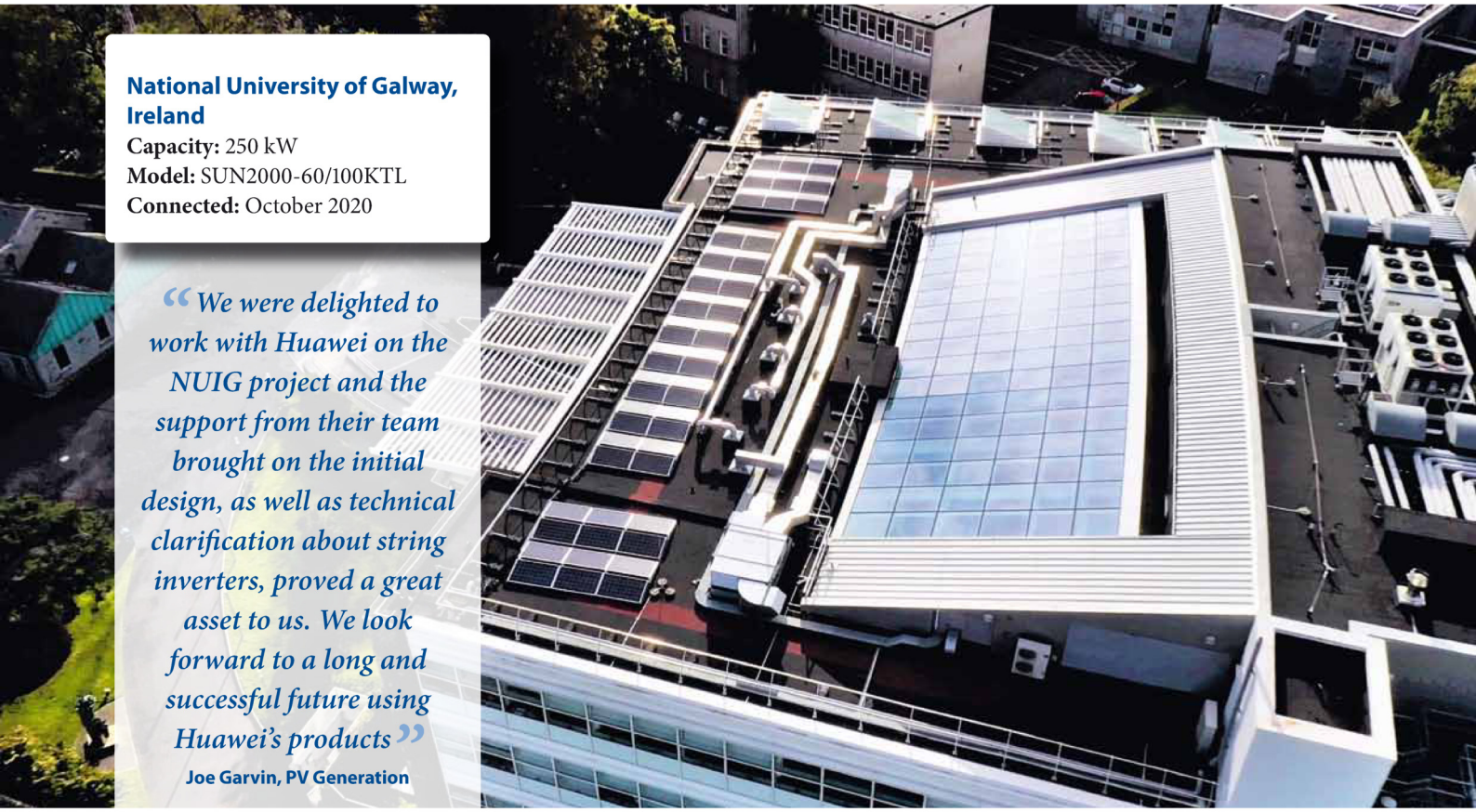
"The largest shopping mall in Singapore. Its PV system utilizes Huawei smart inverters, offering high availability and zero-touch maintenance"

Haneda Airport, Tokyo, Japan
Capacity: 843 kW
Model: SUN2000-63KTL-JPM0
Connected: 2020

"Huawei's technical advantages in ICT enable high-speed communication and processing of the system to ensure high-precision control and reduce RPR (Reverse Power Relay) actions"

player

International transport hubs, commercial centers and research institutes: Huawei technology is helping businesses all over the world to secure a reliable energy supply and integrate solar power into their day-to-day operations.



National University of Galway, Ireland
Capacity: 250 kW
Model: SUN2000-60/100KTL
Connected: October 2020

"We were delighted to work with Huawei on the NUIG project and the support from their team brought on the initial design, as well as technical clarification about string inverters, proved a great asset to us. We look forward to a long and successful future using Huawei's products"
Joe Garvin, PV Generation

Jabi Lake Mall, Abuja, Nigeria
Capacity: 610 kW
Model: SUN2000-60KTL
Connected: May 2020

Winner of African Solar Industry Association Commercial and Industrial Project of the Year 2020

A beacon of light

Solar energy is not only key to the energy transition and the reduction of greenhouse gas emissions; it is also a way to empower remote and rural communities that are isolated from easy access to electricity. Across the globe, distributed solar solutions are being implemented to improve the well-being of individuals, communities, and businesses by providing access to clean, affordable energy. Huawei technology is at the heart of many of these solutions, as the following case studies from Africa and the Middle East demonstrate.

Nigeria

Near the center of Nigeria lies the Jos Plateau, which gives its name to Plateau State. The region's mountainous geography means it has proved difficult to electrify using conventional means. Huawei's Microgrid Solar Solution, however, has proved indispensable in delivering reliable power to settlements and industry across the state.

According to World Bank statistics, as of 2019, only 55.4% of Nigerians had access to electricity, meaning approximately 85 million Nigerians do not. A statistic made more startling when one realizes Nigeria is set to surpass the United States in population by 2050, becoming the third most-populous country on the planet.

Hence why the Federal Government of Nigeria's Rural Electrification Agency (REA) and the Nigeria Electrification Project (NEP), which receives funding from the World Bank and the African Development Bank, commissioned a 234 kW solar hybrid microgrid in the Shimankar Community of Plateau State.

Shimankar is a farming village on the banks of the River Shimankar. Traditional rulership of the village resides with His Royal Highness Miskoom Maurice Manu Danjuma III. His Royal Highness attended the ribbon cutting event for the completion of the solar minigrid in October 2020, thanking all those involved for this great aid to local businesses. "Our businesses are now fully operational – especially at night," he said. "Our businesses are growing; we can buy and enjoy cold beverages in the provision shops. Today is indeed the beginning of better things to come for Shimankar."

Approximately 85 million Nigerians do not have access to electricity. Solar + storage microgrid solutions like this one in Plateau State are changing that.

Photo: Nigeria Electrification Project

The project, which consists of 234 kW of solar, 236 kWh Huawei lithium-phosphate batteries, 200 kVA Huawei Powercube microgrid inverter and diesel backup generator, was installed by Green Village Electricity (GVE), a specialist in solar minigrid solutions throughout Nigeria. GVE projects limited CEO, Ifeanyi Orajaka, said the project's aim was to provide reliable electricity to 1,972 households, 273 commercial users, five productive users, and 19 public users. "It's a thing of pride that GVE, an indigenous Nigerian firm, can be a part of developing Nigeria's rural areas," said Orajaka. "Thanks to this project, Nigerian solar developers, like myself, can access these investment opportunities in growing Nigeria's evolving offgrid sector."

REA CEO Ahmad Salihijo Ahmad reiterated the sense of pride and fulfilment felt by GVE's Orajaka, saying that "as an agency, we are responsible for powering unserved and underserved communities, therefore, it is fulfilling every time homes, businesses, schools and medical centres are connected to sustainable solar power. Almost immediately, we are able to witness rural communities being transformed with clean energy through the jobs that are created during construction, to their micro and small businesses scaling to larger capacity thanks to reliable electricity."

Agriculture is a key beneficiary; prior to the microgrid's installation, the region's 3,500 weekly tons of rice were processed with diesel engines, but is now enhanced by the project's 28 km of low-voltage electricity distribution network infrastructure, delivering power to a total of 2,314 off-takers. pv

Jordan

The 200-bed multi-speciality Abdali Medical Center in Jordan's capital, Amman, is one of the newest and most advanced hospitals in the MENA region, a record at least in part provided by its 8.2 MW solar plant.

Local manufacturer Philadelphia Solar's turnkey solution generates enough clean solar energy to cover the hospital's consumption, enable extensive medical research and testing, and all with the security of reliable solar self-generation. Philadelphia installed over 25,090 325 Wp panels in an 86,000 square-meter field, and yet still the array meets Huawei's design concept of "less is more". The brains behind the operation, the Huawei FusionSolar Smart PV Solution, including a smart PV string inverter SUN2000-42KTL and SmartLogger, help reduce reliance on components like DC combiner boxes and power distribution cabinets. The brains, therefore, make things easier for the brawn.

Abdulrahman Shehadeh, CEO of Philadelphia Solar, whose installation period was shortened and made simpler thanks to Huawei's contribution, told **pv magazine** that the 8.2 MW system, which began commercial operations in August 2019, is "considered to be the largest PV system installed for a single medical center in the world."

So, it is no wonder Mohammed Abu Ghazaleh, chairman of the Abdali Medical Center is pleased to be the owner of this unique solar plant. "We felt the difference in many aspects," said Ghazaleh. "For example, economically we avoided rising energy costs and that enables us to earn a great return on our investment."

"Choosing the clean energy option means the sun is the direct source that will enlighten our buildings," continued Ghazaleh. "That encouraged us to go solar for a better world." pv

The Abdali Medical Center's 8.2 MW solar system is thought to be the largest PV system in the world supplying a single medical facility.

Photo: Philadelphia Solar

In pictures: powering China

Shanghai Longyan Road Metro Station

Capacity: 3.66 MW

Model: SUN2000-110KTL

Connected: June 2020

"Green power for green transportation"

Xiong'an railway station

Capacity: 5.97 MW

Model: SUN2000-196KTL

Connected: December 2020

"The largest high-speed railway station in Asia"

Beijing Daxing International Airport

Capacity: 5.61 MW

Model: SUN2000-60/70KTL

Connected: September 2019

"The world's largest airport"

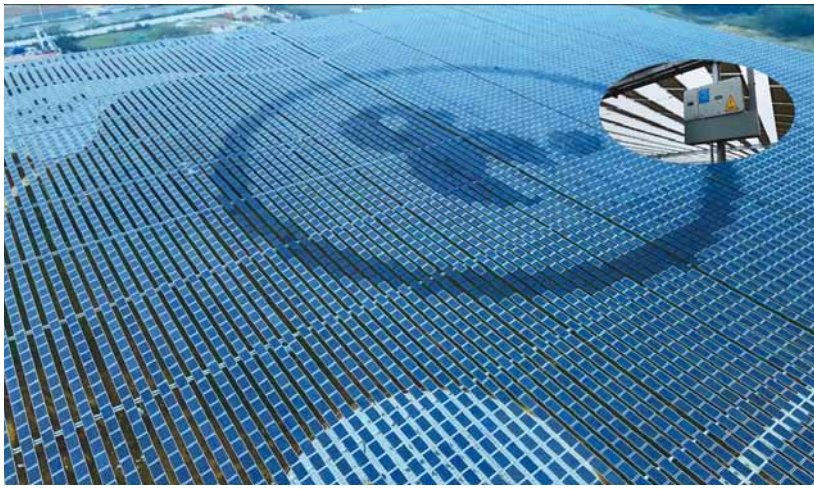
Changsha Leifeng Water Purification Plant

Capacity: 3.65 MW

Model: SUN2000-60KTL

Connected: 2020

"Offering high availability and zero-touch maintenance to this vital rooftop project"



Changsha Hospital for Maternal and Child Health Care

Capacity: 120 kW

Model: SUN2000-60/100KTL

Connected: 2019

"Bringing new life into the world with safe, green power"

Beijing Wukesong Stadium

Capacity: 620 kW

Model: SUN2000-60/100KTL

Connected: 2020

"The world's largest ultra-low energy sports building"

Smart energy storage in

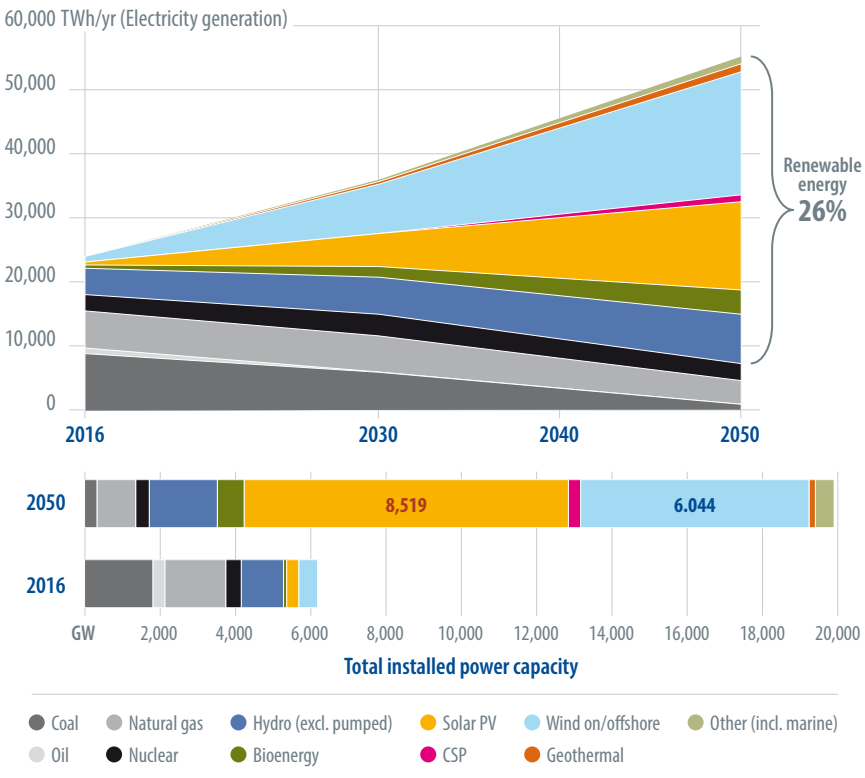
As intermittent renewables like solar and wind continue to grow, it is estimated that half of the world's regions could face problems with weak power grids over the next five years. Energy storage can turn this challenge into an opportunity, and Huawei is working to ensure that energy storage systems are ready to offer valuable services to electrical grids the world over, facilitating the transition to renewable energy.

According to the International Renewable Energy Agency, by 2050 global annual electricity yield will reach 55,000 TWh, of which renewable energy will account for 86%. Total installed capacity will reach 20,000 GW, of which PV (8,510 GW) and wind (6,044 GW) will account for 72.8%.

Feeding renewable energy into power grids in large volumes creates challenges to their safe and stable operation. To address this, energy storage systems can deliver multiple services to the grid: frequency regulation, voltage support, and peak load regulation during power transmission and distribution. Energy storage systems can also be used to reserve power for outages, address transmission congestion, minimize the capacity expansion needs of power transmission and distribution networks, and serve as DC power sources for substations.

Proportion and installed capacity of renewable energy

Source: IRENA



Frequency regulation

When wind and solar account for a larger proportion of generation, system inertia decreases and system frequency is more likely to fluctuate. With more renewables and the retirement of coal-fired plants, frequency regulation resources will be inadequate. This risk is much higher at peak solar and wind generation hours. Energy storage, due to its quick response and accuracy, has become the first choice for frequency regulation in many regions.

Energy storage systems (ESS) offer fast response and precise tracking, with better efficiency than traditional frequency regulation methods. The ESS can output specified power within the range in one second with a precision of 99% or higher. Its comprehensive response capability fully meets the power conversion requirements within the time scale of automatic gain control (AGC) frequency regulation, greatly outstripping the regulation capacity of conventional thermal power plants.

High short-time power throughput, charge/discharge capability, bidirectional adjustment, and independent frequency regulation or working with common frequency regulation reduces the needed capacity of traditional frequency regulation power supplies. Take South Australia as an example: As the penetration rate of renewable energy increased from 2016, the number of power grid overfrequency occurrences increased rapidly. The number in March 2017 alone exceeded 350. However, after an energy storage system was put into operation, the number of overfrequency occurrences of the power grid decreased significantly.

Peak shaving

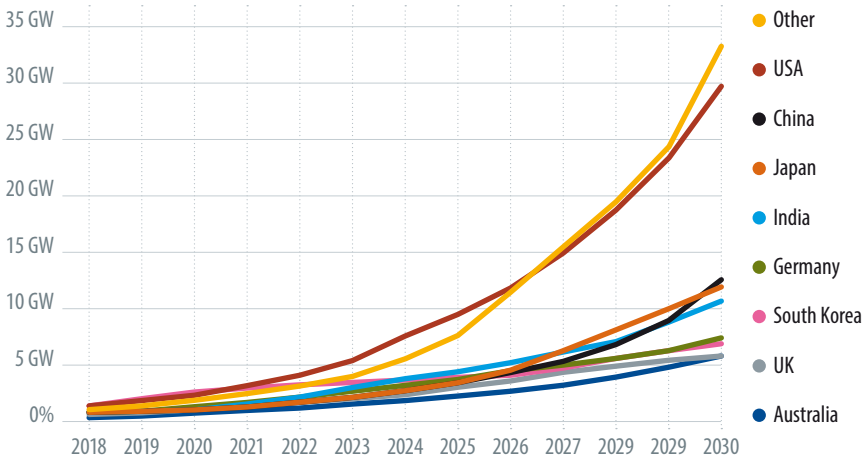
Energy storage technology can store excess renewable energy generated dur-

a clean power future

ing off-peak hours and release the stored energy during peak hours. In addition, ESS has advantages such as fast response, high power and energy density, dynamic performance, long service life, high temperature performance, mobility, and ease of installation and maintenance. Therefore, the ESS can adjust the peak and valley states of a power grid. This not only reduces the installation and maintenance investment in power transmission and distribution equipment, but also minimizes the line loss and improves the economics. It is estimated that by 2050, the global ESS market for peak shaving will reach 74.6 GWh.

Global ESS deployments 2018 to 2030

Source: Bloomberg New Energy Finance



PV + ESS

According to China Energy Storage Alliance (CNESA), by the end of 2019 total installed energy storage capacity (including molten salt energy storage) in operation in China reached 800.1 MW. The proportion of lithium battery systems in China increased from 51% to 99% of all energy storage systems from 2017 to 2020. According to the forecasts of multiple industry organizations, installed capacity of battery energy storage systems in the country will likely exceed 24 GW by the end of 2025.

Although growing fast in recent years, these lithium-ion energy storage systems are not competitive in levelized cost of storage (LCOS), which is a major challenge. Other challenges include safety issues, low efficiency, short service life, and difficult O&M.

The available capacity of battery packs in series is limited by the capacity of the weakest battery pack. In parallel circuits it is the weakest battery rack. At one battery project in China, Huawei observed SOC deviation between battery packs hit 12% after only one month of operation. In parallel circuits, the available capacity is the capacity of a weakest battery rack. As a result, other battery racks or packs with higher capacity cannot be fully utilized.

Differences between the internal resistances of old and new batteries cause cross current, which increases battery temperature and accelerates aging. In addition, more power will be needed for heat dissipation. This further reduces charging and discharging efficiency.

The battery lifespan is closely related to temperature. If the temperature is not within the allowed range, undesired chemical reactions will occur, generating unwanted compounds and accelerating aging. Currently, the average lifespan of batteries in the market is about seven to 10 years.

Air conditioners are usually used for battery cooling. When a cabinet is far away from the air conditioner, the temperature difference between batteries in the container might be greater than 10 C. As a result, the battery lifespan is shortened by more than 15%. In addition, if the temperature difference between the cabinets connected in parallel is large, the difference in aging increases.

Even if no fault occurs, maintenance needs to be performed every six to 12 months. The maintenance items include the battery (such as main circuit connection, SOC calibration, and battery capacity calibration), converter maintenance, HVAC maintenance, and fire extinguishing system maintenance. When a battery pack is faulty, manual repair is required to balance the battery, because the system does not have a pack balancing function.

Innovation in energy storage technologies is key to addressing these challenges. Huawei has developed the concept of

"Energy storage, due to its quick response and accuracy, has become the first choice for frequency regulation in many regions"

Huawei estimates that its prefabricated battery solution reduces installation costs by

$0.01 to $0.03/Wh

string energy storage systems, inspired by the PV string inverters pioneered by the company a few years ago. These manage multiple MPPT circuits precisely to minimize the impact of mismatch between strings and improve the system energy yield. String inverters have advantages in terms of fault rate, system safety, and O&M efficiency and have become a mainstream solution in the industry. Therefore, we propose the smart string energy storage system solution.

Smart String Energy Storage System

Huawei's smart string energy storage system solution differs from the traditional centralized energy storage system solution in three aspects: string architecture, intelligent management, and modular design.

An optimizer is used for each battery pack to minimize the impact of mismatch between packs connected in series. The battery rack controller balances capacity during charge and discharge to minimize the mismatch between battery racks connected in parallel and implement rack-level energy management. Each rack is equipped with an independent string-level air conditioner to minimize the temperature rise difference between racks and improve the temperature balance of the entire system.

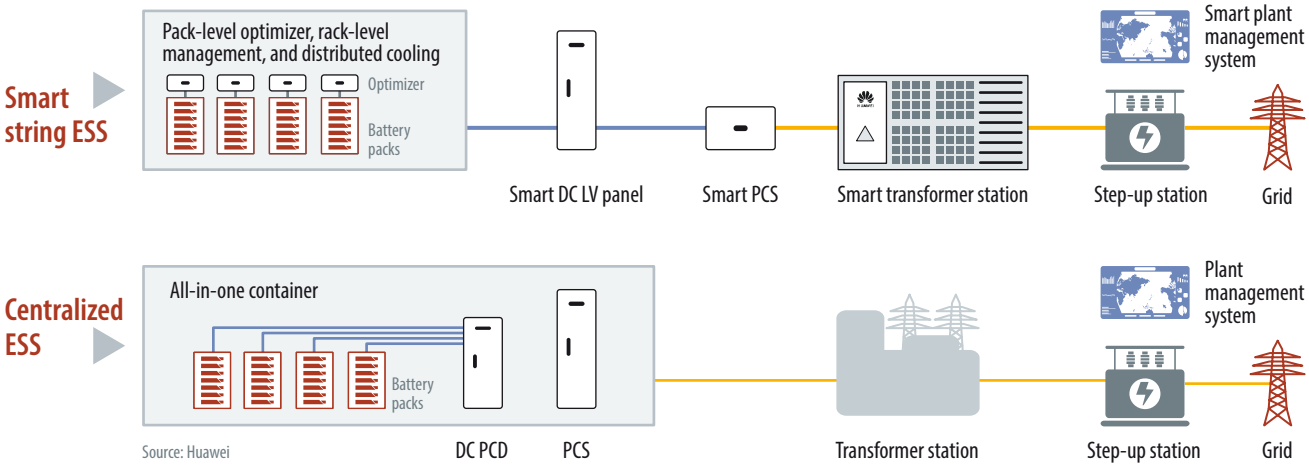
AI and cloud-based battery management can accurately locate derivative internal short circuits, calculate internal short circuit resistance, identify unexpected internal short circuits in real time, and promptly warn of battery fire risks. Moreover, the AI technology can be used to build a model to predict battery SOC parameters and battery health conditions, reducing excess initial battery configuration. Finally, the intelligent cooling based on multiple models, such as battery lifespan, battery behaviour, and environment prediction, is used to find the optimal balance between battery aging and energy consumption for cooling, achieving optimal LCOS in real time.

Modular design is used for the entire system. A faulty battery pack can be isolated to avoid impact on others in the rack, and manual SOC adjustment is not needed after pack replacement.

Technical features

The pack-level energy optimizer avoids capacity loss caused by mismatch. The optimizers improve available capacity, eliminating the battery pack mismatch caused by internal resistance differences within the rack. The intelligent battery rack controller prevents capacity loss caused by cross current. A battery rack with a lower internal resistance has a larger current and a higher charg-

Smart string energy storage system



Source: Huawei

ing speed. After the battery rack is fully charged, all other battery racks connected in parallel will stop charging, causing capacity loss. Intelligent rack-level management allows the racks to run independently, eliminating the mismatch between parallel racks, maximizing the potential of each battery rack, increasing the discharge capacity throughout the lifecycle by 15%.

Old and new batteries can be mixed, allowing for phased deployment and reducing the initial capacity configuration by 30%. Traditional system architectures do not support the mixing of old and new batteries. Therefore, considering factors such as battery capacity loss over time, excessive configuration is performed during initial deployment to meet the capacity threshold, peak shaving, and frequency regulation requirements. Traditional solutions require not only batteries but also power conditioning systems and even transformer stations. This increases the cost and makes future reconstruction more difficult.

With the smart string energy storage system, new batteries can be deployed with existing batteries when needed. This reduces the initial battery capacity by 30%, minimizes the initial cost, and eliminates the need for PCS to reduce required investment.

The energy storage container is designed with high power density. This reduces the weight of a 20-foot container to less than 30 tons. Batteries can be transported within the container, and onsite battery installation is not required. The pre-fabrication model also simplifies deployment. Only simple operations, such as cabling, are required. Compared with the traditional solution, the pre-fabrication solution reduces installation costs by $0.01 to $0.03/Wh.

Manual adjustment is not needed after battery pack replacement. In traditional solutions, experts need to adjust batteries on site, resulting in high O&M costs. The smart string energy storage system does not require SOC adjustment. New battery packs are plug-and-play, and the charge and discharge are automatically optimized.

Due to the modular design and the elimination of wear parts, the availability of the ESS reaches 99.9%. Traditional energy storage solutions have a large fault impact scope and low system availability. In contrast, the modular design of the smart string energy storage system allows independent replacement of faulty battery packs without affecting other packs in the rack. These technologies improve the system availability to 99.9%, offering greater flexibility and scalability, minimizing the impact of faults and O&M cost.

The innovative intelligent cooling solution ensures that the temperature rise inside the container is less than 3 C to 0.5 C, ensuring a 15-year service life. The fresh air and return air mixture is used for the cooling of battery packs to minimize the temperature difference between cells in each battery pack.

More than 100 sensors are deployed to collect data for analytics using an intelligent algorithm to determine a cooling strategy that can deliver optimal LCOS. Distributed air conditioners are deployed in the container.

Each battery rack has an independent air conditioner, reducing the temperature rise difference between battery racks and slowing down battery capacity attenuation, ensuring a 15-year service life.

The internal short circuit detection can identify two types of short circuits: The first is the instantaneous burst internal short circuit, caused by events such as puncture by a foreign body. In most cases, the voltage drops rapidly, causing thermal runaway of the electrochemical cell. The second is derivative internal short-circuits such as those caused by diaphragm attenuation. Such short circuits are difficult to identify and can quickly lead to severe internal short circuiting and damage if left unnoticed. The AI algorithm is used to accurately calculate the internal short-circuit resistance, capture the slight deviation of the charging curve, accurately locate potential risks, and warn of fire risks in advance.

As energy storage grows into a trillion-dollar market, systems need to provide sophisticated functions such as power grid frequency regulation, voltage support, peak shaving, and reactive power support, placing higher requirements on intelligent technologies. Innovation will overcome the challenges of the energy storage market, such as system safety, system efficiency, battery lifespan, and O&M difficulty. More importantly, the smart string energy storage system solution adopts the string, intelligent, and modular design to implement refined energy management, increase discharge capacity, achieve optimal LCOS, and eventually, achieve the transition from PV parity to PV+energy storage system parity.

“As energy storage grows into a trillion-dollar market, systems need to provide sophisticated functions … placing higher requirements on intelligent technologies”

Top trends for the future of PV

This year marks the fifth anniversary of the Paris Agreement. To meet the ambitious goals it set out, our energy system must transform from analog to digital. To assess the trends informing the power system of the future, Huawei assembled a team of global technical experts, consulting firms, and energy think tanks to form the Huawei Digital Power Industry Working Group. Some of the key findings are presented here.

Digitalization is rapidly changing many aspects of our lives. In the energy sector, the switch away from an analog system is profoundly reshaping provision and consumption. The good news: Digitalization of energy will be a key facilitator of the fundamental changes that are required to create a zero-carbon future.

Power digitalization

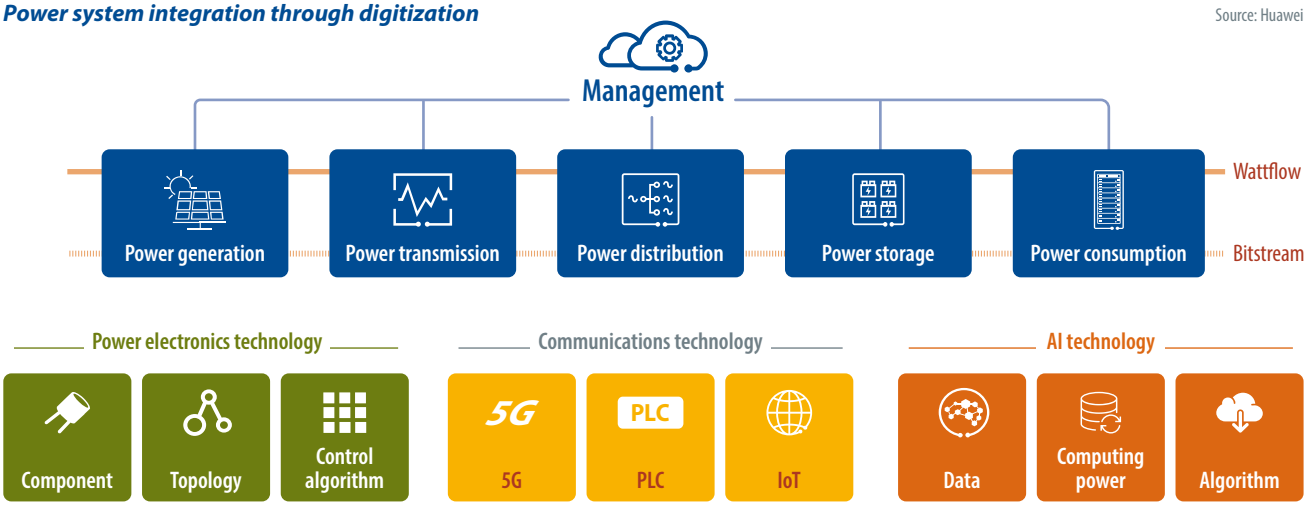
Bitstreams are added to the watt streams, which will profoundly affect the whole power system. This integrates power electronics and digital technologies by introducing 5G, artificial intelligence, big data, and internet of things. Traditionally, the flow of power watt per watt was what concerned power utilities. Generation, transmission, distribution, storage, and end use were isolated and could not be coordinated. The large number of devices that cannot be managed autonomously results in low power generation efficiency and low energy efficiency.

On top of that, non-digital devices require manual maintenance protocols for fault detection, which can incur O&M costs. Now, power system operators can tap into the bitstreams to coordinate the watts and spot any potential problems early on. This will maximize power generation efficiency and drive down maintenance costs.

Virtual power plants (VPP), which can orchestrate the dispatch and trade of electricity, represent another milestone in the development of a digital energy system. In the coming five years, VPPs will create new business models, bring new market players, and boost the growth of distributed PV plants. It is estimated that 80% of residential PV systems will connect to VPP networks by 2025. With the rapid evolution of digital technologies such as 5G and cloud services, it is estimated that more than 90% of power plants will be digital by 2025, turning solar power generators into smart dispatchable energy assets in the grid of the future.

Power system integration through digitization

Source: Huawei



PV+storage

The renewable energy revolution is led by solar and wind, and these will be the fastest-growing energy sources over the next 30 years. According to market predictions, the proportion of PV will grow from only 3% in 2020 to a massive 24% in 2050. At that point, it will be the world's largest power generation source.

The cost of PV power generation has fallen sharply over the past decade. In most countries, PV electricity costs are lower than traditional energy grids, contributing to a further increase in global investment in PV.

As the penetration rate of new energy increases, power grid operators have begun to impose stringent requirements on grid connection.

To meet these requirements, storage coupled with solar will play an increasingly important role in providing flexible and stable power system operation. Following predictions, by 2025 the proportion of PV plants built in connection with storage will reach more than 60%, which will promote PV from a supporting technology only available at certain times of day to the primary source of power generation on the grid.

The combination of PV and storage transforms solar plants from a current source to a voltage source. The PV and storage integration control algorithm is used to implement synchronous machine features such as virtual inertia. The technical specifications of PV power generation are being aligned with those of thermal power generation. This ensures that PV power can be controlled and stored, further improving grid support.

Grid support

With the rapid development of renewable energy worldwide, adaptability standards for grid integration are also evolving to better support power grid stability. Countries with high renewable energy penetration, such as Germany and Australia, have proposed new modeling and strict power grid connection standards. China's GB/T37408 technical standard, which was released in 2019, emphasizes power grid adaptability requirements such as high-voltage ride-through (HVRT) stability and low-voltage ride-through (LVRT) capability, as well as frequency adaptability.

In the future, PV inverters need to have a more accurate grid-connection algorithm in a low short-circuit ratio (SCR) power grid environment. PV plants must gradually evolve from adapting to power grids to supporting power grids in the next five years.

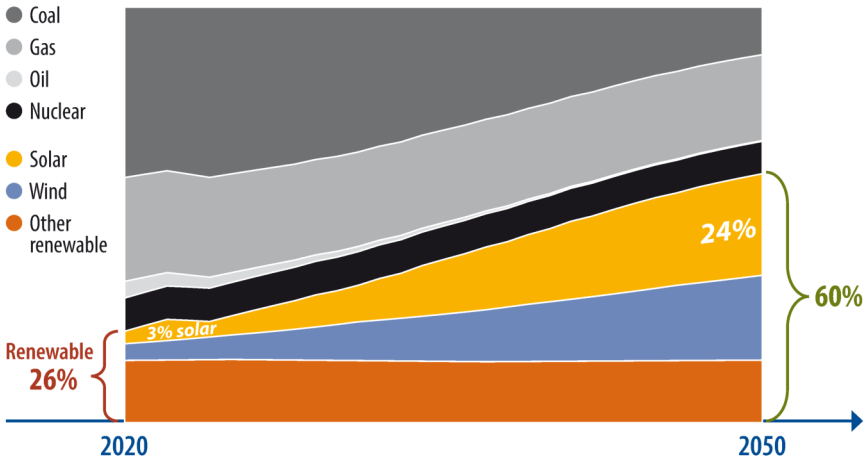
More grid stability and auxiliary services will also come on the back of VPP deployment. ICT technologies, such as 5G, blockchain, and cloud services, are widely used in distributed power plants. This makes it possible to collaboratively manage VPPs and allow them to participate in power dispatching, trading, and auxiliary services. In the coming five years, the development of VPP will create new business models, bring new market players, and boost the growth of distributed PV plants.

Distributed resources

Distributed PV is integrated into various industries due to its flexible deployment, use of idle roof space, and an attractive ROI. New application scenarios, such as zero-carbon homes and the increasing use of rooftop areas on factories, data cen-

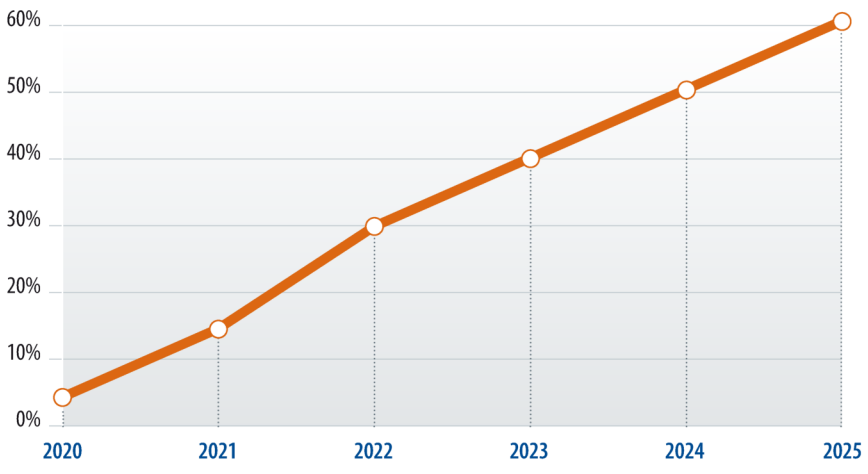
2020–2050 global power generation structure proportion change

Source: DPWG



Steady increase in solar power

Source: DPWG



ters, parking lots – to name but a few – are strong drivers of this market segment.

On top of that come ambitions for local and regional zero-carbon commitments, which can be fulfilled by utilizing rooftop space, especially in urban areas.

It is predicted that the distributed system will account for more than 40% of the world's newly installed capacity by 2025, which translates into 47 GW per year.

In traditional solutions, PV systems may be operational for an extended period, which can result in problems such as loose connectors and aging cables. Such conditions can result in arcs. If the situation is not handled promptly, fire risks may occur, posing risks to buildings and personal safety.

As a result, arc suppression systems become a crucial factor in distributed PV applications. Currently, the industry has developed related specifications and standards, such as the rapid shutdown solution. Huawei's approach uses artificial intelligence to accurately identify arcing based on millions of arc feature samples, and automatically disconnect circuits within 0.5 seconds to ensure safety (see page 46).

"A modular design approach will enable a longer plant lifecycle and higher system availability"

LCOE reduction

With the arrival of the era of global PV price-parity, technological innovation is urgently needed to further reduce the levelized cost of energy (LCOE) and improve customer ROI. Power electronics have become significantly more efficient than in the past. Engineers and researchers have updated components, as well as system topologies and control algorithms.

Currently, the inverter conversion efficiency in the industry has reached 99%, the uninterrupted power supply module efficiency has reached 97.5%, rectifier efficiency has reached 98%, and electric vehicle charging can reach an efficiency of up to 96.5%. Also, on the solar module level, there is little headroom for efficiency improvement left.

This necessitates shifting the focus toward the entire system, beginning with the inverter's shipment and including all aspects such as power transmission, storage, and use, to further improve the overall efficiency. For example, a modular design approach will enable a longer plant lifecycle and higher system availability. The potential LCOE reduction is somewhere to the tune of 25%. Therefore, fully modular design will become the mainstream in the industry.

On top of that, standard ports will be used between core components and devices, such as inverters and batteries. This offers greater flexibility, scalability, and deployment efficiency. Moreover, a modular design also increases system availability and reduces O&M costs by eliminating the need for O&M by trained experts, which is increasingly costly since PV plants are growing in size and complexity.

In the future, PV plants will adopt a bipolar voltage architecture to reduce cable costs and power generation loss. With the bipolar technology it is possible to increase the DC-side voltage to an effective 3,000 V, by using the capacity of 1,500 V and minus 1,500 V. System voltage has been increased first from 600 V to 1,000 V, and then to 1,500 V. And it will go even higher in the future.

Data centers go green

According to forecasts, the power consumption of global data centers will rapidly increase from 660 billion kWh in 2020 to 950 billion kWh in 2025, accounting for about 3% of the world's power consumption. Building green, efficient, or even zero-carbon data centers and sites is based not only on their own business needs but also on primary social responsibility.

In the future, software giants will widely deploy zero-carbon networks and zero-carbon data centers. Global leading operators have proposed zero-carbon network strategies and will deploy PV in typical ICT scenarios, such as in equipment rooms and data centers. In Greece, the application of PV on sites reduces the mains usage by about 40% and saves 14,500 kWh of electricity annually, effectively protecting the island environment. In Pakistan, PV and AI technologies are applied at sites to reduce the D.G. operating time to less than 10% and reduce the OPEX by 81%. In Qinghai, China, PV is deployed in data centers to help achieve zero-carbon operations.

A traditional data center uses a chilled water system with seven components and requires heat exchange four times. As a result, the cooling system consumes large amounts of power, and the power usage efficiency (PUE) is high. To reduce its PUE, the industry-leading data center uses a modular indirect evaporative cooling system that maximizes the uses of natural cooling sources to provide cooling capabilities and reduce heat exchange. AI

optimization is used to further reduce the PUE and power consumption of the cooling system. For example, in a data center of Ulanqab in China, the annual power usage efficiency is as low as 1.15.

In scenarios such as charging and discharging, battery-pack heating or cooling, and inbuilt compartment heating or cooling, the management of electric energy, kinetic energy, and heat energy involved in electric vehicles is independently controlled and not effectively linked. As a result, the energy consumption of electric vehicles cannot be optimized in the vehicle dimension.

To further save energy or improve the vehicle's battery range, the hyper-converged and domain control architecture is used to implement the three-energy complementation through the linkage control of electric, kinetic, and thermal energy, achieving full-link vehicle-level efficiency from charging, storage, and consumption.

Artificial intelligence

AI will perform expert functions to enable autonomous collaboration and optimization of systems and open infinite possibilities. Through self-learning from massive expert experience data, AI and IoT technologies will fully leverage algorithms, computing power, and data.

AI can diagnose failures like experts can and control modules, trackers, and inverters using an intelligent tracking algorithm to find the best angle and maximize solar potential. AI can accurately locate failures in minutes instead of months. Drones can inspect PV plants, cleaning robots can clean PV modules, and intelligent security protection and identity authentication technology protects PV plants from unauthorized personnel. All these technologies improve power generation efficiency, O&M experience, productivity, and safety.

Security and trustworthiness

Cybersecurity and user privacy risks of PV plants are of increasing concern. By 2025, system security, resilience, reliability, availability, safety, and privacy will become mandatory requirements. Hardware security requires high-availability design and manufacturing as well as predictive maintenance. Software security requires multi-layer defense and control. Security and trustworthiness capability becomes a mandatory requirement for PV plants.

Guided by these trends, Huawei will continue its openness and cooperation with industry customers, partners, and third-party organizations in the smart PV industry to explore innovations and achieve win-win outcomes in the new digital energy era.

"Artificial intelligence can accurately locate failures in minutes instead of months"

Scratching the surface

Floating PV (FPV) is a niche market that is set to double in size in 2021. In a future of limited land and emissions, nations will increasingly turn to FPV's unique offering. Huawei is already immersed in some of the world's leading FPV projects, and thanks to its Smart PV solution, we can be sure that we are only just beginning to scratch the surface of FPV's potential.

On the surface, floating PV might look like a niche market, but so did both ground-mount and rooftop PV at one time. Riding on the wake of solar, FPV is a rapidly growing niche with capacity set to double in 2021, including the world's largest FPV plant to date, the 200 MW Dongzhuang Reservoir Phase I project, which was connected to the Chinese grid in May. Asian countries are particularly keen on FPV due to land constraints. Another example, Singapore, recently installed one of the world's largest offshore floating PV (OFPV) farms – a 5 MW project in the Straits of Johor. Huawei's Smart PV solution was utilized in both projects, keeping things afloat.

When the second phase of the $128 million Dongzhuang Reservoir FPV plant is finished by China Huaneng Group's Power China Hubei Engineering Co., it will have a total capacity of 320 MW. The 200 MW Phase I covers 147 hectares in Shandong province. Of course, that was 147 hectares going unutilized.

The vast 200 MW Dongzhuang Reservoir Phase 1 floating PV project was made possible thanks to Huawei's Smart PV solution.

Photo: Huawei

The key to making any PV plant work, especially on water, is stability and reliability. Anyone who works on the water will tell you that you need to expect the unexpected, in the same way an FPV project need its brain, which is to say its inverters, to be resilient and smart.

This is precisely why the Dongzhuang Reservoir FPV project utilizes Huawei's SUN2000-196KTL smart string inverters, which increase the energy yield more than 2% by minimizing string mismatch and equipping each 3.15 MW array with 162 MPPT circuits. String mismatch can be a particular challenge in FPV applications, as wind and chopping waves can lead mounting structures to become slightly misaligned, causing partial shading.

Safety in an aquatic environment is also key, and Huawei's Smart PV solution negates the need of a DC combiner box, significantly lowering the risk of leakage.

Boasting 99.99% availability, the fully enclosed design of the IP66-rated system is ideal for FPV not only because of its patented PID suppression module, but because it isolates the power compartment from the wiring compartment, reducing susceptibility to the impacts of high humidity and temperature which hassle FPV projects seeking to minimize exposure to moisture.

Inspecting large-scale projects for ongoing O&M is much more difficult on water than on land. The perpetual movement in FPV arrays can accelerate component degradation and bird droppings are a constant challenge. Huawei's Smart I-V Curve Diagnosis 4.0 function enables 100 MW of solar panels to be inspected remotely in 20 minutes. This means that time and money spent on inspecting the project can be used to direct maintenance work 50% more efficiently.

Offshore operations

Singapore is a world leader when it comes to FPV. Not only is it home to the world's

Photo: Sunseap Group

This 5 MW floating PV project in Singapore, developed by the Sunseap Group, powerfully demonstrates the effectiveness of such applications when executed with the right technology providers.

largest FPV test bed at the Solar Energy Research Institute of Singapore (SERIS), but Sunseap Group recently developed one of the world's largest OFPV plants, installing 13,312 solar modules, 40 string inverters, and more than 30,000 floats on an area of sea-space the size of five football fields.

Singapore's search for clean energy is no small task. After all, it is well known that the island-state is seeking to import approximately 25% of its energy from a 10 GW solar farm in Australia's Northern Territory via undersea cables. The 5 MW OFPV plant is expected to generate more than 5 million kWh of electricity annually – the equivalent of the power needed for 1,250 Singaporean apartments, offsetting 4,258 tons of CO_2. It just goes to show what FPV systems can do for countries with severely limited land availability.

For a country with a 97% dependency on natural gas for electricity, these figures are significant and contribute to Singapore's goal of 1.5 GW of solar by 2025 and 2 GW by 2030. It is fair to assume that more FPV and OFPV will be utilized in and around Singapore to meet these goals.

As opposed to inland FPV projects, OFPV projects are open to a far greater range of elements and challenges, including swells, waves and saltwater, to name but a few.

As a result, Huawei's SUN2000-90KTL-H2 smart string inverters were chosen for the project, particularly for their artificial intelligence and information communications capabilities. The inverters themselves have been successfully tested for their resilience in temperatures ranging from –55 C to 80 C, and with the increased efficiency of the smart PV solution the constant O&M upkeep of an OFPV system is streamlined.

"The portability of Huawei's string inverters was a key feature as it allowed us to install the inverters directly onto the floating platform, next to the PV panels" said Sunseap Vice President of Engineering Shawn Tan. "This eliminated the need for a DC cable hose and DC combiner boxes, reducing costs and deployment times. Owing to the unique design of the inverters, heat is dissipated more efficiently, increasing the overall reliability of the entire PV system."

"Huawei's technology is simply a game-changer," said Wilson Tsen, Sunseap's manager of business development and project management. "Not only can we diagnose plant issues remotely, but we can also troubleshoot without having to be physically on site." pv

20 minutes

is the time taken by Huawei's Smart I-V Curve Diagnosis 4.0 to inspect a 100 MW plant

A triumph against arcs

Arcing remains a hot topic in the PV industry. Numerous fires are still occurring, and some inverters are known to fall short of accurately detecting arcs to trip early enough to prevent fires.

When an electric device such as a dishwasher experiences a fault in its circuit to cause an electric arc, the respective fuse in the fuse box will overload and open the circuit – crisis over. But if the fuse doesn't do this, the arc could be sustained, creating a 3,000 C hot plasma of ionized air, and posing a severe fire hazard.

Similarly, the issue can occur in solar installations. It can happen much more quickly because DC circuits are more susceptible to the phenomenon. The alternation of AC circuits creates idle moments during which arcs cannot be sustained, which extinguishes arcs to some degree. Also, detecting arcs in AC circuits is considerably more manageable, as the extra resistance in the respective circuit overloads the fuse which opens the circuit.

Detecting an arc – caused by faulty, poorly installed, or worn connectors, cables, and junction boxes among the heavy DC load of a PV array that comes into the inverter – requires some higher level engineering trickery. The IEC has introduced a standard for arc fault detection, the IEC 63027 CDV, but the problem has still not been entirely resolved.

Detection challenges

The issue at hand is the way inverters detect arcs in the DC circuit. An electric arc causes a fingerprint signal, which can

Huawei's inverters can shine with a shutdown time that is far quicker than what is required to fulfill the IEC standard.

Photo: Huawei

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. DC cabling and modules also create significant inductance and capacitance – further complicating the job of isolating the arc signal. The longer the DC cabling, the more inductance between the modules, and laying the wiring in switchbacks will result in antenna effects, causing additional distortions.

Early attempts at compliance with the IEC standard resulted in "nuisance tripping." The inverter will identify wrong "fingerprints" as arcs and open the circuit to switch off the system. If that happens, the array must be switched back on by hand after a thorough check-up – a lengthy and costly exercise.

Collective learning

Manufacturers must consider the noise that is created on the DC side in their design. To this end, Huawei has, for example, laid DC cables of 80 meters for single-phase inverters and 200 meters in length for three-phase inverters in the arc fault development setup. The DC cable was placed in a way that switchbacks simulated antenna effects and crosstalk of the cabling. The modules themselves have high capacitance in relation to the ground, which further attenuates the signal.

Additionally, Huawei has introduced a new approach using machine learning to improve systems' detection skills. The manufacturer's devices can access an extensive database of millions of arc faults. Tapping into this database, the software can continuously update its fault detection mechanism, which takes into consideration multiple factors such as ambient temperature, grid condition, number of strings, and reactive power regulation, among a bigger list, to improve the algorithm.

> *"The standard demands inverter shutdown within 2.5 seconds of an arc developing, but with Huawei's machine-learning-supported AFCI system, this can be achieved in just under 0.5 seconds"*

Using the machine-learning element, Huawei said that its installed base of inverters around the globe can exchange records of parameters during arcs and false alarms to improve the algorithm. So installations that have a similar layout can find out from each other what a false alarm might look like. The system, over time, will learn different arc types and the different waveforms that it needs to react to and those that it should not.

As a result, Huawei's inverters can shine with a shutdown time that is far quicker than what is required to fulfill the IEC standard. The standard demands inverter shutdown within 2.5 seconds of an arc developing, but with Huawei's machine-learning-supported AFCI system, this can be achieved in just under 0.5 seconds.

Not only is the system faster to react, but it can also be more sensitive. An industry-wide trend was to set the AFCI systems up in a less sensitive way to avoid nuisance tripping. The IEC standard sets out that the inverter must detect arcs with an energy of 750 joules, but Huawei's system already reacts at 500 joules.

Final thought

Stacking energy storage value

Hariram Subramanian, CTO, Smart PV – Europe, Huawei

With the acceleration of the global electrification process, the demand for electricity will continue to rise. In the next decade, non-fossil energy will become a major source of incremental energy demand for the first time in history. However, the increase of renewable energy penetration can also weaken the grid.

As a result, energy storage technology has become necessary to enable renewable energy to transition from being a liability to a grid asset. Despite the rapid development of energy storage markets in recent years, the technical barriers remain a hindering factor to a wider range of applications. For example, lithium-ion batteries can face some safety challenges, short lifespans, and require refined energy management, as well as complex O&M routines.

To solve these problems, Huawei has launched the Smart String Energy Storage System solution this year, which resolves inconsistencies and uncertainties in lithium batteries through the controllability of power electronics. It reduces the LCOS by 20%. In addition, the smart string energy storage system solution improves grid stability and enables solar power to be regarded as a stable voltage source instead of the current source.

The inverter has evolved from centralized to string, with more than 80% of large-scale utility PV power plants using string inverters at present. The main reason for the switch is that multiple MPPT design minimizes the impact of PV string mismatch.

Huawei has gone further to extend the string architecture to the energy storage system field. Traditionally, thousands of battery cells are coupled with each other. If one cell is faulty, other cells are affected. In contrast, Huawei's solution uses a pack optimizer in each battery pack and the rack controller in each battery rack to implement refined energy management of the energy storage system.

The management granularity gets finer (at battery pack level), which is a hundredth of that in the traditional solution. Fine-grained management at pack level achieves full charge and discharge. This not only increases the available capacity of the system by 15%, but also allows new and old batteries to mix. As a result, customers can deploy batteries phase by phase, lowering the initial investment by 30%.

Safety is vital in energy storage systems. Huawei's smart string ESS solution enables active alarm and system quadruple safety protection. For pack-level protection, pack optimizer active bypass achieves fault isolation. For rack-level protection, multi-level intelligent linkage protection enables overcurrent protection and fault isolation. As for system-level, it has sensors for smoke, temperature, water and the insulation, not to mention exhaust and fire extinguishing devices, enabling environmental awareness and multi-level linkage. The Cloud BMS enables smart internal short circuit protection through high-precision SOX algorithm for early warning protection.

Moreover, the fully modular design, such as for PCS and air conditioner, greatly improves the system availability and simplifies O&M. The distributed cooling design greatly improves temperature equalization compared with the traditional solution, reducing the temperature difference to less than 3°C, and significantly prolonging the battery lifespan.

Photo: Huawei

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- Modular Design
- Rack-level Optimization
- Distributed Cooling

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