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pv magazine special

The future of smart PV
Trends evolving from AI, cloud, big data, and 5G technologies

Grid intelligence
Solar moves from grid adapter to grid supporter

From the lab to next gen PV
The new president of Huawei Smart PV talks R&D investment

PV is entering the AI era

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Huawei: Leadership on various fronts

Photo: pv magazine/Thomas Beetz

For the fifth consecutive year, the analysts at IHS Markit ranked Huawei the No. 1 supplier of photovoltaic inverters globally. The Chinese manufacturer and IT and telecommunications giant has held this top position since 2015. A number of factors account for Huawei's success in the global PV industry. First, the company's technology is highly advanced and is bolstered by increasingly leveraging its IT and telecoms expertise to deliver smart PV solutions. Second, the company's brand is recognized globally for quality while offering an excellent price-performance ratio. And third, the company delivers solutions to scale across the various market segments, from residential solar to C&I and utility-scale PV – and for each one, the company offers a competitive levelized cost of energy (LCOE) to its customers.

At **pv magazine**, we are honored to work with Huawei for the fourth special edition highlighting the manufacturer's latest technology, products, solutions, and projects in various markets. Huawei's success in the global solar PV industry is based on the company's continuous technological innovation. Most significantly, it has managed to integrate its powerful information and communications technology (ICT) with its PV products – to create smart PV solutions for lower LCOE and O&M costs. This integration has been instrumental for Huawei to become the leader in string inverter deployments. The company now has more than 100 GW of capacity installed, and is the only inverter manufacturer to have crossed this historic milestone. Huawei has ushered in a new era for large-scale PV development, with string inverters now selected as a mainstream option in utility-scale projects, which were previously dominated by central inverters.

Large-scale PV has also evolved in another way: Bifacial modules coupled with tracking systems are increasingly part of the system design. To address the added complexity and boost energy harvest, Huawei is leveraging its artificial intelligence (AI) technology to best integrate its inverters with both bifacial panels and trackers. Huawei's full-stack all-scenario AI solutions are already being used in the electric power sector, among other various industries, to provide for greater intelligence and higher performance results. In 2020, Huawei will expand the integration of these AI solutions with its smart PV applications to further improve system performance and yield. The company is also building a core architecture for device-edge-cloud synergy to maximize the value of each PV plant and technologically accelerate the industry.

Another frontier for the solar PV industry is the integration of battery storage technology. Here too Huawei is trailblazing ahead with its new LUNA2000 energy storage system, scheduled to be available in the third quarter of this year. Better yet, the manufacturer is adding AI capabilities to this solution to optimize self-consumption in smart homes and offer a safe, lower levelized cost of storage (LCOS).

Be it residential, C&I, or utility-scale, Huawei is pushing the boundaries when it comes to intelligent PV and storage. So, where does this all lead? A continuous drive toward lower LCOE, LCOS and O&M costs, for an accelerated journey to grid parity in markets around the world.

Eckhart K. Gouras, Publisher, pv magazine

Photo: Huawei

Huawei's latest intelligence

Guoguang Chen is the new president of Huawei's Smart PV Business Unit.

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Kurfürstendamm 64, 10707 Berlin, Germany
Managing Director: Eckhart K. Gouras

Editors/Contributors

Erica Johnson – Managing Editor –
erica.johnson@pv-magazine.com

Jonathan Gifford
gifford@pv-magazine.com

Mark Hutchins
mark.hutchins@pv-magazine.com

Emiliano Bellini
emiliano.bellini@pv-magazine.com

Marian Willuhn
marian.willuhn@pv-magazine.com

Authors: Vincent Shaw, Uma Gupta, Ilias Tsagas, Charles Thurston, Marija Djordjevic, Monishka Narayan

Proofreader: Brian Publicover

Translators: Tim Hanes, Veritas Europa

Photo editor: Tom Baerwald

Graphics: Harald Schütt

Cover: Adobe | metamorworks

Layout & typesetting

Alexx Schulz, mADVICE | Berlin

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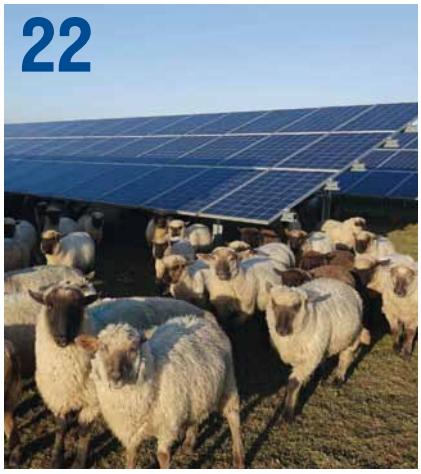

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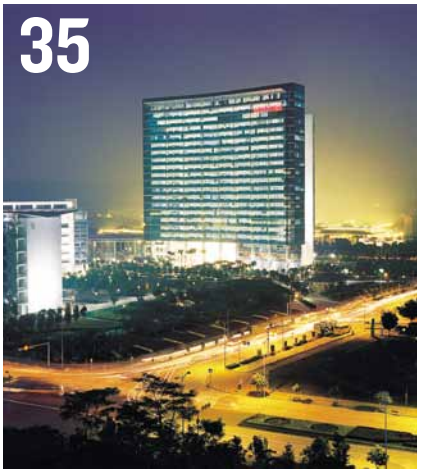

Photo: Huawei

Photo: Huawei

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Intelligently upgrading

With lower costs, increasing renewable energy portfolio demands and carbon emission reductions, the solar industry has grown at a robust pace – providing many prospects to support a clean energy future. But the continuous development of solar PV also faces a number of challenges. How do we cut the levelized cost of energy (LCOE) when subsidies are decreasing? What should we do to tackle high O&M costs? How do we turn new clean energy into a primary energy source that is both safe and reliable? How do we ensure safe access to PV plants on a large scale? Technological innovation and intelligent transformation are key – and Huawei is leveraging its expertise in telecoms to step up the industry's game.

There is a concerted effort being made across all industries toward all things 'smart' through continuous innovation – moving from price competition to value creation – and the solar energy industry is no exception. In 2013, Huawei pioneered the concept of 'smart PV' with an aim to develop multi-MPPT string inverters. It was the first time solar inverters were equipped with sensors and supported digital features controlling the operation of PV plants, generating more power with lower O&M costs. Although solar inverters account for only 5% of the total cost of a PV plant, they are considered the heart and brain that determine a project's energy yield. According to Huawei, a smart solar inverter can generate 3% more power, adding even more value to the $0.30 to $0. 40 cents per watt provided from cost reductions.

"We hope that all industries can work together to drive innovation across the entire industry chain and ecosystem, optimizing the size and efficiency of PV modules, and using monocrystalline and polycrystalline silicon, to fully utilize solar energy," says Jeff Yan, global brand director of Huawei's smart PV business unit.

Photos: Huawei

This innovation will lead to value creation. In the future, the telecommunications giant believes that innovation will span across the entire PV ecosystem, from a single device to a system, and finally to the whole ecological chain. "In this way, we can reduce LCOE, and create more value for our customers across the 25-year life cycle," says Yan.

Intelligent solar power systems also support the reduction of O&M costs. Huawei estimates that through the use of intelligent automated solutions, the number of maintenance personnel required are reduced from more than 10 per 100 MW, to two or three employees per 100 MW. In the future, the company predicts that PV plants will be unattended. Technological innovation will be key to transforming the PV industry from an auxiliary energy sector to a major energy source across the globe. However, there is still a long way to go before solar PV can replace traditional energy.

"The competition focus of the PV industry needs to shift from price to value," says Yan. The purpose of innovation is to reduce costs and improve efficiency. Yan says that the key to cost reductions is not in reducing component costs, but instead by reducing the LCOE. Efficiency improvement involves leveraging technical achievements such as 5G, AI, the cloud, and big data to incorporate the internet and AI into PV systems, improving efficiency across the entire industry.

Thanks to the joint efforts of Huawei and other enterprises, the intelligentization of the PV industry is world-leading. "The core motivation of Huawei smart PV innovation is to improve the efficiency of everything from individual components to the overall system, and to shift the focus from the cost of components to LCOE across the entire lifecycle, creating more value for customers," says Yan.

In the future, technologies such as 5G, AI, and the cloud will have a profound impact on, and even reshape, a diverse range of industries. This is particularly true of the PV industry.

Huawei is integrating information and communications technology (ICT) and new energy technologies to drive inno-

the PV industry

vation. "For example, our inverters have evolved from being mere power converters to becoming the brain of a PV system's operation, integrating a smart sensor, a smart controller, even an edge compute node," says Yan.

This year, Huawei launched the AI+PV solution to reduce the LCOE and enhance system efficiency. AI technologies repeatedly train the model and deduce the optimal version using high quality, massive data based on real-life situations. This significantly improves power generation efficiency and O&M efficiency in PV plants.

The inverter manufacturer is working with upstream and downstream industry partners to explore collaboration in intelligent manufacturing and detection through the use of technologies such as big data, cloud computing, AI, and 5G. Huawei has cooperated with Chinese component vendors in AI, cloud computing, and other fields.

However, the cost of interconnecting factories and carrying out manual detection are high, production management is non-transparent, and intelligent application is not developed. To address these problems, Huawei and PV module vendors use Huawei Cloud to implement intelligent EL detection, instead of using manual methods, for PV module manufacturing. "This increases fault prediction accuracy within the PV module production line from 33% to more than 80%, and we expect this percentage to be close to 100% in the future," according to Yan, who adds that it can also improve the production line and yield rate, minimize labor costs, and boost the production efficiency of enterprises.

Another application is intelligent inspection. In early 2019, Huawei replaced visual detection with AI detection, using image recognition to identify all defects caused by intrusions on power transmission lines. According to tests conducted by Huawei, State Grid Corp. of China (SGCC) and China Southern Power Grid (CSG), the inspection efficiency of high-voltage lines was found to be 80 times higher than that of manual inspection, successfully resolving industry pain points in an innovative manner. In addition, the use of 5G drones backhauled panoramic 4K HD videos of sites in real time, accelerating the realization of unattended inspection. These innovations not only greatly reduce the safety risks and labor costs of inspection, but also ensure its comprehensiveness.

Now 5G is being gradually deployed and applied in various countries. It has the following advantages over previous generations of wireless communication technologies: low latency (1 ms, a fraction of the 4G latency), high bandwidth (10 GB/s, 10 times higher than 4G bandwidth, with speeds comparable to those of optical fibers), and wide connection (millions of terminals connected in a single cell, 10 times more than 4G). "A fully connected world is becoming a reality, connecting people to people, and people to everything," says Yan.

This will lead to digital and intelligent upgrades and restructuring across various industries. The future outlook of industries will include telemedicine, autonomous driving, VR, smart energy, smart manufacturing, and smart healthcare. And 5G+AI will certainly usher in a new era of smart PV.

This 49 MW smart solar PV plant – located in Ipoh, Malaysia – is equipped with Huawei's Smart I-V technology and inverters.

Innovation in digital PV technology solutions are supporting daily O&M to reduce costs. This intelligently optimized 100 MW solar PV system was installed at a fishery in China's Jiangsu province.

Huawei's latest intelligence: Smart PV For Future

The new president of Huawei's Smart PV Business Unit, Chen Guoguang, talks to pv magazine about his new role in the company and the future of his division. Increased investment in smart PV R&D and technological innovation are at the top of the agenda. The intelligentization of energy products is also a priority, with much to be gained from the integration of information and communications technologies (ICT) and energy.

You recently took over as the new president of Huawei's Smart PV Business Unit. How does your experience lend well to the new function?

I have accumulated nearly 12 years' experience in global research and development and seven years' experience in international sales and management roles in Huawei's Smart PV Business, which has provided me with a profound knowledge and understanding of both industry challenges and customer needs. Now, my team and I are working tirelessly to develop the industry-leading products and solutions which will provide the best possible value for customers all over the world.

is there a new path that you plan to take the Smart PV Business Unit down?

The development of the smart PV business involves three aspects. First, we will continue to increase investment in smart PV research and development. Second, we will expand Huawei smart PV's global market presence, which involves establishing sales and service teams in more countries and regions to offer customers with better services. Finally, we will comprehensively integrate our leading ICT technologies – such as 5G, AI, and the cloud – which have developed rapidly over the last two years, with solar and storage. Our vision, which echoes the purpose of Smart PV For Future, is to expand the application of PV energy with innovative technologies and make smart PV accessible to all, while contributing to building a world that is both green and safe.

Leveraging the telecommunications business to solar is a clear advantage of Huawei's capabilities in the market.

It is the integration of ICT technologies and energy that differentiates Huawei from its competitors. We utilize digital technologies to connect energy products, enable preventative maintenance, and realize the intelligentization of energy products. The application of digital technologies to the energy industry enriches traditional dumb devices with intelligent capabilities, enhancing industry efficiency and delivering an optimized user experience. Huawei's PV business has evolved from digital PV to internet-powered PV, and now to AI-powered PV. The Huawei smart PV business unit has advanced communications technologies and huge investment in R&D.

> *"Huawei's PV business has evolved from digital PV to internet-powered PV, and now to AI-powered PV"*

Huawei recently predicted 10 trends for smart PV development in the next five years, which has sparked heated discussion in the industry. How do you interpret these trends and their impact on the industry?

We mapped out these trends after holding an in-depth discussion with global industry experts, consulting firms, as well as upstream and downstream partners of the industry chain from four dimensions: digitalization and intelligentization, grid friendliness, lower LCOE, and security and trustworthiness. The 10 trends specifically involve digitalization, AI-driven smart upgrades, unmanned PV plants, proactive support for power grids, solar+storage, virtual power plants (VPPs), upgraded safety, higher power density, modular design, and security and trustworthiness.

I believe that the 10 trends can guide the entire new energy industry by providing a reference for innovation and growth. However, the intelligent world is arriving faster than we anticipated. I think these trends will become realities well before 2025. Some trends are already occurring, such as solar+storage, AI-powered PV, and VPPs.

The trends are mainly related to intelligentization, digitalization, and cloudification – which are inevitable concepts in the industry. Today, an increasing number of innovations are driven by digital technologies – 5G, the cloud, AI, and other technologies are key to innovation and are accelerating the digital transformation of various industries. More importantly, these technologies are integrating with each other and bringing unprecedented revolutionary changes. Everything will be connected online, every-

thing will be connected to the cloud, and AI applications will be ubiquitous – thereby reshaping everything we know today.

How do you think industry players will remain competitive as we advance into the next era of digitalization at such a fast rate?

In this innovation-driven ecosystem, success will only be achieved by game-changers who propose new ideas, create new business models, and launch new products and services. Seven years ago, we promoted the smart PV solution with string inverters as the core. Facing significant challenges, we achieved an unprecedented performance, which entailed both courage and modesty, by firmly believing that innovations bring success. Today, we stand at the entrance to the intelligent world, where we expect another turning point. We will closely collaborate with partners to achieve further success.

You mentioned solar+storage. This is definitely stepping up as the new solution in the energy transition. How is Huawei adapting its business model accordingly?

In residential scenarios, the general LCOE of the solar+storage solution is more competitive than that of traditional power solutions due to the development and decreasing costs of PV and energy storage technologies. In areas with high feed-in tariffs, such as Germany, Japan, and Australia, the LCOE of solar+storage is even lower than the residential feed-in tariffs, allowing a new business model to be established. In the second half of 2020, Huawei will launch the distributed household solar+storage solution to help people in these areas improve the use of green and low-cost energy.

For large-scale plants, Huawei believes that the solar+storage solution will be mainly applied for the improvement of power grids. New energy is not completely stable in terms of power generation, and the stability issue will become more serious with the increasing application of new energy to power grids. For example, the power grid's requirements for frequency modulation and peak adjustment will become more intense. The solar+storage solution can address these problems, and it will be an inevitable trend of PV development in the future. Currently, markets are first being established in places where a stable power system is in more urgent need, such as Australia and the United States. In the future, this requirement will become universal.

Is Huawei leveraging its other business units to support the advancement of storage for the PV business?

Huawei has extensive experience in lead-acid and lithium battery system applications in the fields of telecom site energy, data center facilities, and terminal power supply. It also has abundant technical experience in efficient energy storage system architecture, high-performance bare metal server (BMS), electrochemical cell system safety, and intelligent diagnosis and analysis. Based on these platform technologies and experience in the PV field, Huawei is committed to building leading solar+storage solutions with optimal LCOE and levelized cost of storage (LCOS), optimal security, and simplified O&M.

Climate change is a growing global concern, and while the PV industry plays an active role in the energy transition, there are challenges surrounding manufacturing and waste processes. How is Huawei developing its products with environmental concerns in mind?

Energy conservation and emission reductions have long been an integrated part of Huawei's product life cycle. For example, we quantitatively evaluate the environmental impact of products in different phases, such as raw material extraction, production, transportation, use, and recycling, to identify product deficiency against environmental protection. In terms of innovation in environmental protection, the focus is on improving the energy and material efficiency of products.

We also innovate in manufacturing processes, packaging, transportation, and recycling, in order to promote environmental protection across ICT product lifecycles. For packaging, we adopt lightweight, green packaging. We also designed recyclable metal pallets to replace wooden ones, and we use strong paper boxes instead of wooden ones. This reduces wood usage and carbon emissions. Huawei is committed to minimizing its environmental impact during production, operation, and the product and service life cycles.

Photo: Huawei

Chen Guoguang is the new president of Huawei's Smart PV Business Unit.

> *"Today, we stand at the entrance to the intelligent world, where we expect another turning point"*

Predicting the future for smart PV

Over the next five to 10 years, renewables will assume a larger role as a main power source for electric grids, and PV has a particularly bright future. Considering the latest trends in power electronics technology, PV is quickly evolving down the path to intelligence. Given the rapid development of emerging information and communication technologies (ICT) – such as AI, cloud computing, big data, and 5G – Huawei has an idea of what's in store for the future of solar PV.

"Projections indicate that by 2025, the proportion of PV systems with energy storage will exceed 30%"

As renewable energy penetration increases to account for a greater proportion of total energy production, efforts to ensure safety, reliability, and cost-effectiveness across power generation assets will become a bigger priority for the solar PV industry. And with the quickly evolving world of digitalization and intelligence, Huawei is leveraging its telecom expertise to predict the future of the industry. The world's top-ranked inverter manufacturer has engaged with experts in the field and expects 10 technical trends to emerge for a smarter PV industry by 2025.

Huawei says that future industry trends span four dimensions: a lower levelized cost of electricity (LCOE), grid friendliness, intelligent convergence, and security and trustworthiness. These trends will start to drive the industry toward intelligent, green solutions, and they provide insight into innovation and soaring growth in the new energy industry.

Digital shift

"More than 90% of global PV plants will be digitalized," says Samuel Zhang, vice president of Huawei Smart PV. Despite a booming global PV market and promising outlook, there are still many PV plants that have not been optimized for intelligence – ranging from power generation to communications. "These devices cannot be effectively monitored, nor can they provide fault alarms," says Zhang. But this is expected to change. With the rapid development of digital technologies such as 5G and cloud services, Huawei projects that more than 90% of PV plants will be fully digitalized by 2025, making it possible for PV plants to become simplified and intelligent, with efficient management.

AI upgrades

The in-depth integration of AI and PV will facilitate mutual sensing and interconnection between devices, and will improve power generation and O&M efficiency through collaborative optimization. AI

Photo: Huawei

techniques can offer promising new avenues for PV systems, including: proactive identification and protection of PV module and device faults with AI diagnosis algorithms; tracker algorithm optimization with massive plant data and self-learning for higher yields; and AI-aided solar-storage synergy to automatically optimize PV-storage plant revenue. As LCOE continues to decrease and O&M complexity increases, AI techniques are likely to be widely adopted in PV plants. "More than 70% of PV plants will apply AI techniques," predicts Zhang.

Unmanned plants

Huawei predicts that by 2025, more than 80% of the work conducted on solar PV plants will be unmanned.

"With the continued emergence of AI and the Internet of Things (IoT), intelligent products and services will bring convenience to the whole PV solution," says Zhang. By integrating expert experience and continuous self-learning, the company suggests that aggressive AI deployment will replace O&M experts in many diagnostic and decision-making functions. Drone inspection and robot-based automatic O&M will handle dangerous and repetitive O&M work, which requires a continual high degree of accuracy, for enhanced productivity and safety in PV plants. In the future, Huawei says it expects that PV plants will be fully unmanned.

Grid support

The increasing penetration level of power-electronic-interfaced energy will undermine the strength of the power grid, which will also hindering the broader application of PV systems. Over the next five years, PV plants must gradually evolve from adapting to the power grid to supporting the power grid. To this end, "inverters should possess capabilities such as wide short circuit ratio (SCR) adaptability, capability to control harmonic current within 1%, consecutive high/low voltage ride-through, and fast frequency regulation, which are necessary for grid connection," says Zhang.

Solar+storage

The marriage of solar PV and battery energy storage technology has already begun to show its promise for the clean energy future. And this trend has no sign of slowing down in its trajectory. "Projections indicate that by 2025, the proportion of PV systems with energy storage will exceed 30%," says Zhang. With greater penetration of renewables, power grids will have increasingly stringent requirements for frequency regulation and peak shaving. Simultaneously, battery costs are decreasing with the technology's advancement. "Energy storage will work in tandem with PV systems, and become a critical component," argues Zhang.

VPP outlook

Over the next five years, ICT technologies – such as 5G, blockchain, and cloud services – will be widely applied in distributed power plants, forming virtual power plants (VPPs) for collaborative management. Such tech will also facilitate scheduling, transactions, and auxiliary services for power systems. "The development of VPP technology will inspire new business models and attract new market players in distributed PV scenarios, serving as an engine of growth for distributed PV," says Zhang. The tech giant predicts that more than 80% of residential systems will connect to VPP networks by 2025.

Active safety

"Arc-fault circuit interrupter (AFCI) will become a must-have feature in distributed-generation PV systems, and will be incorporated into international industry standards," predicts Zhang. With the broader application of distributed PV, building and personal safety has become a major concern. PV arcing risks caused by the poor contact of nodes in PV modules, poor connections from PV connectors, or aged or broken cables, have become a pressing matter in the industry. To mitigate such risks, Huawei says that AFCI will become a standard function for rooftop PV systems.

Higher power density

With decreasing subsidies and incentives, the forecast for solar is trending toward lower LCOE. "This calls for high power requirements for single modules and easy inverter maintenance," says Zhang. To achieve this, higher power density is required. With research breakthroughs in wide-bandgap semiconductors, such as SiC and GaN, as well as advanced control algorithms, Huawei projects that inverter power density will increase by more than 50% in the next five years.

Modular design

Inverters, power condition systems (PCS), and energy storage devices are key components of future smart PV plants. As the capacity and complexity of PV plants increase, Huawei argues that the traditional, expert-driven approach for onsite maintenance will be too costly. "Modular design will become mainstream to enable flexible deployment, smooth expansion, and expert-free maintenance – which will greatly reduce O&M costs and improve system availability," says Zhang.

Security and trust

The increase in the cumulative capacity of global PV plants – and the greater complexity of network architecture, according to Huawei – increases security risks for PV plants. Additionally, increased stringency requirements for user privacy are adding to the complexity of security for distributed PV plants. Huawei says that solar PV plants will increasingly need to possess security and trustworthiness capabilities in terms of reliability, availability, security, safety, resilience, and privacy.

"Our common desire to explore as human beings knows no limits. We are always looking to soar to new heights, plunge to deeper depths, and seek out new truths," says Zhang. The cloud, 5G, and AI technologies are converging to create a world in which everything is becoming sensed, connected, and intelligent at a speed that is faster than we may think – and the PV industry as we know it will quickly evolve. "Huawei hopes to play its part in inspiring the creation of a green, intelligent world," Zhang says. "The boundless potential of new energy solutions can be broadly shared across society."

The critical choice for Australian PV: inverter selection

Australia's slow-to-adapt transmission network has been a major roadblock for renewables in the country, as it drives up costs and causes delays for large-scale projects. As developers, contractors, and investors try to wrap their heads around grid-stability issues, the risks associated with transmission losses and connection problems continue to weaken confidence in grid-scale renewable energy investment. FRV Australia Managing Director Carlo Frigerio discusses the market and the importance of choosing the right inverters for the country's rigid power network.

FRV is one of the most established developers in Australia, having secured and developed six projects with power purchase agreements (PPAs) for a total of more than US$700 million in investment. Which states and regions are the most attractive for you as a developer, and why?

We have invested in all the eastern states except Tasmania. Our operating projects and projects under construction are located in the Australian Capital Territory, Queensland, New South Wales (NSW), and Victoria, and we have a project at an advanced stage of development in South Australia. We plan to keep investing across all these states, but, of course, each state has its peculiarities. For example, electricity prices and load differ from one state to another. However, it is more about the specific location of the project itself.

So, wherever a project makes sense in terms of grid and demand, we develop. We have a long-term view of the market, notwithstanding short- or mid-term issues that may affect some parts of the grid or states.

Announcements, surveys, and reports continue to pile up, showing a massive drop in investor confidence in Australia due to network woes and policy uncertainty. Has this caused you to review your plans in the country?

The short answer is no. Our projects have been little or not at all impacted by grid constraints and curtailment, so we will not be changing too much in the way we've been doing business from the very beginning. We do a lot of preparatory grid and connection analysis during the development process, and we know this market very well, so we know where to go and where not to go. We develop our own projects but during the past couple of years, we have decided to acquire projects from other developers to expedite the growth of our portfolio, always targeting strong parts of the grid.

Nonetheless, policy uncertainty and grid issues remain serious problems. We have been working with the Clean Energy Council and other investors for these issues to be addressed by the government, however we remain positive and we continue investing, hoping for a more clear energy policy at federal level.

> *"Policy uncertainty and grid issues remain serious problems"*

Despite the massive drop in investor confidence, Australia is poised for a record roll-out of big PV this year [prior to the Covid-19 outbreak]. All things considered, where do you see the market heading?

I believe the market is heading toward consolidation. We are already seeing some big investors leaving the market, and many small companies that are struggling to survive. Sometimes we are approached by smaller developers, including some based overseas with a small office and presence in Australia, requesting support. They started developing projects here but, in some cases, they did not have enough experience or funds to keep going and overcome the increasing market complexities. Another key trend is new technologies, including large-scale storage. This would improve the generation profile of non-dispatchable generators, adding ancillary revenues while improving the overall stability of the grid, rather than just selling electricity.

FRV pledged last December to develop storage projects globally and announced its first one in the United Kingdom. Are there any such plans in place for Australia?

Most of our PV projects are designed to add battery storage at a later stage and we are working on a couple of concrete opportunities that will be implemented soon. In Australia, we have a dedicated team looking only at storage opportunities and new tech-

nologies. We are also considering adding batteries to our existing projects, however only when this is feasible or it makes sense – feasibility has to be analyzed case by case.

Photo: FRV

Carlo Frigerio is the managing director of Australia for FRV.

The Australian Energy Market Operator (AEMO) has been talking about too much inverter-based generation in some parts of the Victorian and New South Wales grid affecting system strength, with five projects curtailed by 50% since September last year. How does your company go about choosing inverters?

It is always a combination of price and quality. At FRV, we are technology-agnostic, so every time we have a new project developed, we work very closely with our EPC contractor to make sure we choose the right technology for each project. In Australia, it is probably even more important than in other parts of the world to make the right decision in this regard because of very strict grid modeling and compliance requirements. The preparation of the connection information and modeling usually takes several months – it can vary depending on the project – and the quality of the inverter and the inverter's manufacturer modeling input is key. Therefore, the inverter supplier plays a critical role, as they need to provide extensive information and help us in preparing the Generation Performance Standards application for AEMO and the transmission companies. If you make a wrong decision with inverters and discover that six months later, you'll need to start the entire process from scratch. In the end, you can lose up to one year or so. Therefore you really need to choose a technology partner that understands the market and the grid and can offer a top-notch product that is fit for purpose, so you can be sure your plant will not create any imbalance to the system and is easily approved.

For the Winton Solar Farm, FRV is using Huawei string inverters. What advantages do you expect to find in using Huawei's technology?

We are very excited about our partnership with Huawei on the Winton project because this will be the first large-scale solar farm in Australia to use string inverters. It is a significant achievement for both companies, and it has been an exciting journey, given the novelty of this technology. We have had an excellent collaboration with Huawei. Their products provide a credible option for solar farm developers in Australia, and we believe that string inverters are a very good solution for the peculiarity of the Australian grid. One of the greatest strengths of Huawei was their experience in handling the complex GPS modeling, and together we managed to prepare a comprehensive application to submit to AEMO and Victorian network service provider AusNet.

To support Australia's energy transition, the Winton Solar Farm will fund a research program at the University of Melbourne. What can we expect from this project?

The research is aligned with FRV's goals and the goals of the Victorian government. It aims to better understand the technical and regulatory constraints and opportunities for distributed renewable energy, as well as the social impact and equity implications of community energy projects.

The research aims to empower rural Victorian communities by supporting local investment in and ownership of energy infrastructure, as well as support the state of Victoria's energy transition. It also seeks to contribute to the economic growth and new job creation through innovations in technology and governance that will position Victoria's businesses at the leading edge of international renewable energy markets.

> *"We believe that string inverters are a very good solution for the peculiarity of the Australian grid"*

Navigating Europe's policies, markets, and trends

Europe is widely considered a renewable energy powerhouse, at least with regards to technology establishment and kick-starting the green economy. Installation trends and markets are expanding – and Covid-19 could provide new opportunities for the continent.

Photos: Huawei

Policy powerhouse

A primary tool for the growth of the European energy transition was the Renewable Energy Directive 2009/28/EC, which set individual binding targets for all European Union member states, the sum of which should lead to a 20% share of renewable energy in gross final consumption of energy by 2020. How each member state achieves its target – such as the choice of funding mechanisms or technology – is a matter to be entirely decided by each member-state separately.

> *"Low technology costs and new business models have allowed a new wave of PV installations, which are subsidy-free"*

The EU's Clean Energy Package, published in December 2018, goes even further. The Renewable Energy Directive 2018/2001, which is part of the Clean Energy Package, has set a target at the EU level, by allowing member states to meet their greenhouse gas targets and implement an energy mix at their own discretion. Member states are only required to bring forward national contributions to the union's overall target, which mandates that at least 32% of the bloc's final energy consumption is to be met via green energy, with a clause for a possible increase revision by 2023.

Regarding the remuneration policy for renewable energy more specifically, the Energy and Environmental State Aid Guidelines (EEAG) adopted by the European Commission in 2014 asks that all member states shift toward market-based remuneration mechanisms. This resulted in most countries ending their feed-in tariffs (FIT) schemes for new solar installations, which are now remunerated through premium tariffs for large-scale systems. For systems smaller than 500 kW, the EEAG allows any form of aid, including FITs, but most states have instead opted for net-metering and self-consumption policy schemes. Of great interest now though is that low technology costs and new business models have allowed a new wave of PV installations, which are subsidy-free.

Installation trends

We currently see three major remuneration policy trends in Europe. Firstly, solar PV capacity is allocated via tenders and is remunerated via premium tariffs. Secondly, there will be corporate PPAs unsupported by subsidies. And lastly, self-consumption remuneration systems will be aimed primarily at domestic and commercial electricity users.

Hariram Subramanian, CTO of Huawei's FusionSolar Smart PV division in Europe, told **pv magazine** that the company is offering solutions to target all different scenarios, from utility-scale plants to residential arrays and commercial and industrial systems.

"The sunnier regions of Europe will definitely experience more PV installations in the immediate future, however we also expect to see a significant shift to solar PV in northern states where wind was active before," says Subramanian. And what is the driving force behind this shift? He says it is "the impressive drop in the cost of electricity generation through PV, so that photovoltaics can now be deployed on market terms. Utility-scale PV, in terms of the levelized cost of electricity, is lower than compared to offshore wind."

The intensive energy-consuming data centers that are coming online are another driving force changing the energy dynamics in Northern Europe specifically. Subramanian says that such data centers call for more renewable energy projects, and it's important to maintain a good energy mix to satisfy demand around the clock. Solar PV and wind technologies can complement each other well in this regard, allowing for uninterrupted power during seasonal changes. Finally, Subramanian says that sector coupling will call for the convergence of renewable energy sources with heating and transportation.

A lot of these new installations, especially those commissioned by corporations and other businesses, will be developed subsidy-free. This is because "subsidy-free business models are being proven more and more as profitable," said Subramanian.

Huawei is located in every region of Europe where customers can harvest energy from the sun's rays. The company says its goal is to innovate and optimize PV throughout its entire life cycle of energy generation. To do this, Huawei integrates cutting-edge digitalized inverter technology offering smart solutions for customers to achieve faster solar payback periods with higher yields and lower maintenance costs, according to Subramanian.

Challenge or opportunity?

In light of the Covid-19 crisis, there are fears that Europe's subsidy-free PV market might come to a halt. This links to uncertainty over demand and financing availability. The rate of new solar installations might slow down due to precautionary measures to tackle the spread of the new coronavirus problem.

"The sunnier regions of Europe will definitely experience more PV installations in the immediate future"

SolarPower Europe, the continent's leading solar PV association, has called on EU leaders to build out a European Green Deal in order to develop an economic stimulus package to alleviate European economies of the burden of the novel coronavirus. SolarPower Europe's proposals indicate that investments should be channeled into cost-competitive technologies that have significant job-creation potential. In the aftermath of the Covid-19 outbreak, European solar PV markets could perhaps experience new leverage for growth. Solar PV technology – with its many forms of applications – can always offer solutions. pv

A 21 MW solar plant in Hungary – a growing European market.

Adding solar for a fully fueled story in the Middle East

Jad Jubaili's business idea to build a solar division under his company, Jubaili Bros. – traditionally a trader of diesel generators – came to fruition in 2017. This year, Jubaili Bros. opened its first business branch that is 100% dedicated to solar in Pakistan. pv magazine met with Jubaili to discuss the fully fueled future of the Middle East and Africa (MEA) Region – megasolar and smaller PV projects alike, oil price slumps, Covid-19, and technological developments.

"It is rather difficult to predict whether the region will migrate completely away from fossil fuels – considering that it has nearly free access to fossil-fueled electricity"

Jubaili Bros. has been focused on providing diesel generation sets, engines, and alternators for decades. How has your business model adapted for clean energy?

The Shams Dubai Initiative in 2015 was the catalyst for our end to get started in the solar industry. When joining the company in 2006, I requested that we start operations in solar but when we did the research, we found out that there was not much of a PV market back then. We ended up starting the solar division in 2017 – and it was as my personal initiative run separately from the rest of the company. The Jubaili Bros. Solar Division has its own team identity. Having become a distributor for solar equipment in the region gives us a much broader reach than we would if we did installations.

What role do you think that battery energy storage generation will play in the future for your company and the Middle East region?

Battery storage will play an important role in every region in the world offering grid stabilization, peak shaving and various other services. It will all depend on a region's migration to renewable energy. For the Middle East specifically, it is rather difficult to predict whether the region will migrate completely away from fossil fuels – considering that it has nearly free access to fossil-fueled electricity.

We have seen a new wave of 'mega' solar farms in the Middle East. Do you think that this is a trend that will continue in the region?

This trend will continue because of two main reasons. Firstly, because there are some large companies in the Middle East that are trying to become world leaders in the utility-scale space; and secondly, because the region has excellent solar irradiation which leads to world record-breaking prices for solar. A potential threat is that such 'mega' utility-scale projects are driven by local governments – and governments can change their minds. But the private sector will continue developing C&I projects regardless.

Is there place for smaller PV farm development, say 10 to 40 MW, in MEA?

We have seen a lot of appetite for C&I projects of that size via wheeling, meaning the PV plants are being installed away from the power consumption site and potentially generating electricity for a number of private customers. Wheeling projects are installed in Jordan, for example. However, regulation needs to allow it. In the United Arab Emirates (UAE), the Dubai Electricity and Water Authority has recently stopped allowing all ground-mounted C&I solar PV projects from the Shams Dubai Initiative, and have capped all rooftop projects at 2 MW. This regulation will hit the local market hard, putting many large C&I solar projects up to 50 MW in jeopardy of being canceled.

Several Middle East economies are strongly linked to the oil and gas industries. Given the current slump in oil prices due to Covid-19, do you think that there are new opportunities and/or challenges for solar PV in these countries?

We see from our experience working in Pakistan, Asia, and Africa that minigrid systems combining diesel, solar, and batteries provide effective solutions to rural areas. However, because we are in a market where oil is basically the economy, this can drive such projects down in the region. Regarding utility projects, I am not sure if governments will cancel them because, at the end of the day, an investment in solar is always a good investment. Solar PV is a proven technology, and there is also a lot of funding for renewable energies internationally. So in the end, these governments may not even need to use their own money to fund utility projects.


Photo: Jubaili Bros.

Jad Jubaili is the manager of the solar division at Jubaili Bros.

Do you see growing activity of solar-powered water desalination throughout the region?

Yes, we absolutely see this and we are currently working on a 35 MW solar PV water desalination project in the northern part of the United Arab Emirates. Since our client also operates other desalination projects, we will probably see this initial business venture extending to other sites too. Solar PV is cost-effective and can help reduce the cost of desalinating water all over the Middle East.

There is a widespread perception that solar PV systems in the Middle East have to undergo harsh weather conditions. What is your experience on this front?

You need to have very strong regulations for the construction of solar PV systems due to harsh weather conditions, such as humidity and dust, in the region. In fact, UAE regulators have been very strict on this, setting restrictions that have often brought on project construction delays. At the same time, due to these regulations we are certain that solar projects installed in the UAE are able to withstand local weather conditions.

Having said that, investors need to select their projects' equipment very carefully. I believe, for example, that Huawei's inverters, which are IP66-rated, are the best inverters in the world for this region. There are more and more projects designed with Huawei inverters, which reflects my view.

String versus central inverters? What is your take for projects in the Middle East?

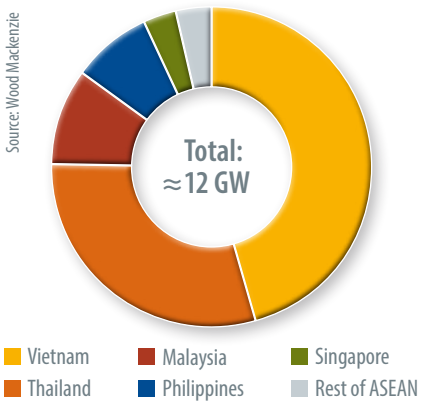
I am fully in favor of string inverters. Central inverters are typically larger in size and have more power capacity per unit, yet they require continuous maintenance during their lifespan; any failure will be significant due to their large electrical capacities. Furthermore, central inverters tend to need a lot of ventilation, and replacing a central inverter takes a lot of time. With bifacial panels too, there will be voltage fluctuations even from panel to panel and investors won't be able to maximize bifacial panels using central inverters. One reason that I favor Huawei's inverters in particular is that they come with multiple MPP trackers, allowing for multiple orientations.

An eye on growing Asian

Over the past decade, the entire Asian continent has soared in its power generation capabilities, bolstered by rapid economic growth. As costs have continued to decline for solar photovoltaics – coupled with the technology's ability to provide clean, emissions-free power – solar has become one of the most important energy sectors for many Southeast Asian nations. The rising deployment of solar PV has been significant – in some markets more than others.

"We see that ASEAN countries have the greatest market prospects for PV development"

ASEAN cumulative solar capacity 2019



Attractive feed-in tariffs have driven most solar installations throughout Southeast Asia. Vietnam, followed by Thailand, is the largest market and accounts for about 75% of the regional solar PV installation base. Research firm Wood Mackenzie predicts that more of the markets will transition to auctions over the next five years.

In 2019, Vietnam was a shining star among growing Asian solar markets. Driven by its generous feed-in-tariff (FIT) and other encouraging policies from the central government, the country is now Southeast Asia's hottest solar market. Between February and April alone, 4.46 GW of solar PV capacity was connected to the grid, spurred by a rush to have systems installed under a looming incentive drop and corresponding connection deadline. But the country's FIT, which supported the large-scale adoption of PV power plants, was suddenly suspended in November by Prime Minister Nguyen Xuan Phuc. According to Vietnam Electricity (EVN), the nation's largest power company, 135 projects had been approved to be installed under the incentive scheme – a cumulative total capacity of 8.93 GW. The country has since shifted its PV development focus to distributed generation – C&I, residential rooftop, and floating systems – but the upsurge of solar development will continue. Due to the latest policy changes and the time duration needed to upgrade the power grid to support additional development, market research firm Wood Mackenzie predict that the next PV installation peak will occur in late 2021.

Thailand, meanwhile, promulgated its long-term power development plan (PDP) in mid-2019, supporting the country's already vibrant solar market. As of last year, it had 3.5 GW of solar capacity installed. The PDP institutionalized a 20-year development plan for solar PV. Renewable energy will supply 30% of the national energy mix by the end of 2037, increasing from its current 10% mark. Under the plan, there will be approximately 10 GW of rooftop PV capacity and roughly 2.3 GW of floating PV to be developed by the Electricity Generating Authority of Thailand (EGAT) on nine dams in the future. The country has provided a solar FIT for projects between 10 MW and 90 MW in size. But to further push solar adoption, Thailand has applied a net-metering (NEM) scheme for small PV projects in the residential sector. The shift from a FIT to a net-metering scheme is expected to drive the adoption of distributed PV for private and public facilities to sell power to the grid, to benefit multiple parties and the economy.

Singapore-based Sembcorp is one of the largest energy development companies in the PV market of the Association of Southeast Asian Nations (ASEAN). Jen Tan, senior VP and head of vertical solar at the company, says the region is full of promise: "We see that ASEAN countries may have the greatest market prospect for solar PV development, and we work closely with our local partners to enhance the power capacity of these countries." One such company is Huawei. Tan says that Huawei has been a good partner for Sembcorp, as the inverter manufacturer provides quality products and customer service with quick response times. And with the incentive drops seen in Vietnam and Thailand, it is more crucial than ever to quickly move installations forward to maintain project economics.

China, Taiwan, meanwhile, also has an ambitious plan for future solar PV development. It reached a solar PV installation capacity of roughly 1.6 GW in 2019, with a cumulative total of 4.3 GW deployed. The rapid growth of the market has been partially due to the "Solar PV Two Years Sprint Plan" implemented by the Taiwan local government in 2016. The government also decided to upgrade its local grid network to accommodate even more renewable energy to facilitate a jump in solar PV development from 2020 onwards, in support of its ambitious goal to reach 20 GW of solar PV installations by the end of 2025. Taiwan's premier, Su Tseng-chang, has said that the new plan will build on the one that was implemented in 2016, with the goal of achieving 6.5 GW of PV capacity by the end of 2020, and 3.7 GW in 2021.

After the Fukushima nuclear disaster in 2011, South Korea pumped the brakes in

markets

This 58 MW solar PV plant – located in Ninh Thuan province, Vietnam – was developed by EVN PECC2 and uses Huawei's FusionSolar Smart String inverters.

Photo: Huawei

its pursuit of nuclear energy and instead turned to other renewables, such as wind and solar. With the release of its Renewable Portfolio Standard Scheme (RPS) in 2012 as a replacement of its pre-existing FIT, it became required that power generators needed to have a certain proportion of new clean energy in their portfolios. The policy currently mandates 6% renewables in their energy mix, and requirements will gradually rise to 10% by 2030. In 2017, South Korea entered the GW club of PV markets – and the numbers are showing no sign of slowing down. In mid-2017, newly elected South Korean President Moon Jae-in called for an energy shift away from traditional fossil fuels and nuclear power, in favor of renewables and natural gas. He canceled six planned nuclear reactors, restricted license renewals of existing nuclear power plants, and stopped the construction of new coal power stations. And then in late 2017, the president proposed the now widely known "RE3020" plan, whereby the proportion of renewable energy in the power supply will increase to 20% by 2030 – which means 30.8 GW solar PV will be installed by then. pv

This 100 MW project – located in Kampong Speu province, Cambodia – is one of the largest PV plants in the region.

Photo: ScheiTec Co., Ltd.

Moving from grid- following to grid-supporting

Solar PV generation is one of the world's most promising technologies for a sustainable energy future. However, as solar and other intermittent renewable energy sources increasingly enter the grid, the establishment of grid connections has become a challenge that could threaten future expansion. Now, solar PV technology is rapidly moving from a passive role to an active one, as it takes on a starring role to support electric utility power grids.

Large-scale solar PV plants are often located in remote areas with particularly poor grid conditions, as they rely on sunshine and geographical space. With vulnerable grid infrastructure and limited short circuit capacity in desolate areas, solar farms tend to connect to weak grids. Coupled with long-distance transmission and high-voltage direct current, large PV plants face the additional challenge of needing to achieve favorable grid connections. When transmission is faulty, this can result in a voltage transient peak at the grid-connected spot near the fault point.

AI algorithms

Huawei has taken its software algorithms and experiences with weak grid operations in the telecommunications industry and has applied them to PV power generation. In addition to establishing mathematical models that are tailored for different grid-connection scenarios, PV plant designs, and power grid operating points, Huawei utilizes big data to train the optimal grid-connection control algorithm.

"In the event of poor power grid waveforms, this ensures a seamless and high-quality solar inverter power generation," says Yao Chang, an energy scientist at Huawei. Chang points to the company's latest AI Boost FusionSolar 6.0 solution, which is an AI self-learning algorithm for impedance reshaping.

The solution integrates multiple algorithms: an adaptive algorithm for dynamic damping, a self-adaptive algorithm for intelligent series compensation, and an active harmonic suppression algorithm. "The electrical characteristics of the PV plant are dynamically adjusted to the power grid via AI self-learning to ensure stable operation and a continuous connection," says Chang, adding that the capability shifts the status of PV from a passive grid adapter to an active grid supporter.

Huawei says its AI Boost solution has made a notable difference at the site of a 50 MW solar PV plant located in a remote, desert area in Rajasthan, India, with a fairly weak grid scenario. "The voltage of the PV plant is boosted multiple times before connecting to the grid," says Chang. "Huawei's AI Boost technology has helped to facilitate a smooth grid connection, whereby the quality of power generated is markedly superior compared to other PV plants in the same region."

Huawei's AI Boost has supported this 50MW solar PV project in Rajasthan, India, with a smoother grid connection. Photo: Huawei

Supporting stability

In the past, the stability and power quality of power grids relied on thermal and water electric generator sets. However, with the increasing penetration of renewable-energy generation and the decreasing use of traditional electric generator sets, the short-circuit ratio (SCR) of power grids will gradually decrease. As such, power grids are facing challenges in terms of stability.

The short circuit ratio (SCR) is a key indicator of the grid status at the grid-connected point. A smaller value indicates a weaker grid and inevitably, a more challenging grid connection. Huawei says its new solar inverter solution is capable of controlling and supporting weak grid connection with an SCR lower limit of 1.5, and fault ride through capabilitities.

"In order to ensure that solar can be connected to power grids on a large scale, solar inverters must have a stronger SCR adaptability," says Chang. "Renewable energy with a strong high voltage ride through (HVRT) capability is imperative to maintaining the safety and stability of power grids." AI self-learning can proactively identify the electrical features of a PV plant and automatically adjust the grid-tied algorithm to match the power grid.

Chang points to one solar PV plant that provides power to 89 hillside villages across 12 towns in Ningxia, China. "The 26 MW project was experiencing power difficulties due to grid resonance and voltage exceptions," he says, noting that Huawei resolved the issue by installing its FusionSolar solution. "All power grid faults were rectified – ensuring stable operations."

UTILITY-SCALE

Smart PV Inverter

SUN2000-185KTL-H1

Smart Array Controller

SmartACU2000D

Monitoring Portal

NetEco1000S

COMMERCIAL & INDUSTRIAL

Smart PV Inverter

SUN2000-12/15/17/20KTL-M0
SUN2000-12/15/17/20KTL-M2

Smart PV Inverter

SUN2000-29.9/36KTL
SUN2000-33KTL-A

Smart PV Inverter

SUN2000-50/60KTL-M0

Smart PV Inverter

SUN2000-100KTL-M1
SUN2000-100KTL-INM0

Smart Dongle

Smart Dongle-WLAN-FE
Smart Dongle-4G

Smart Power Sensor

DTSU666-H 250A/50mA
(Three Phase)

SmartLogger

SmartLogger3000A

Monitoring Portal

FusionSolar Management System
& FusionSolar APP

RESIDENTIAL

Smart Energy Center

SUN2000-2/3/3.68/4/4.6/5/6KTL-L1

Smart Energy Center

SUN2000-3/4/5/6/8/10KTL-M1
SUN2000-3/4/5/6/8/10KTL-M0

Smart PV Optimizer

SUN2000-450W-P

Smart Dongle

Smart Dongle-WLAN-FE
Smart Dongle-4G

Smart Power Sensor

DDSU666-H (Single Phase)
DTSU666-H 250A/50mA
(Three Phase)

Monitoring Portal

FusionSolar Management System
& FusionSolar APP

Europe's emerging PV markets

For large-scale installations, Hungary and Greece are two of Europe's emerging solar PV markets. The solar PV sector in the two countries kicked off years ago predominantly via feed-in tariff (FIT) remuneration policy schemes. In the case of Hungary, FITs created a PV market primarily for small systems up to 500 KW in size, while Greece's FIT supported both small-scale installations and larger systems with multi-MW capacity. But today's picture has changed significantly – creating both new opportunities and challenges.

Photos: MVM

"Greece's engagement with a tender regime in recent years has created a significant secondary market"

Hungary

Hungary's FIT law was passed in 2007, with tariffs differentiated by plant size, time of licensing, time zones (three per day), and energy technology. For PV specifically, FIT installations started to take off in the 2012-13 period, when solar costs started to drop significantly.

Hungary's PV sector had its biggest surprise in 2018, when the country added about 410 MW of PV capacity. Of this, around 320 MW was added through the FIT scheme (KAT) and another 90 MW came from net energy metered systems. Of the total installed capacity, 267 MW of the FIT installations in 2018 comprised systems up to 500 KW each and only 53 MW were larger parks.

This year is also expected to be strong for the market, although the coronavirus pandemic in Europe might slow down the rate of installations. Nevertheless, local PV associations expect the country to add approximately 400 MW to 600 MW of annual PV capacity.

The country's FIT will continue to be the primary driving force for new installations. Despite the phase-out of the FIT policy in December 2016, the scheme had attracted 2 GW of applications by then and construction deadlines have been extended to 2021. But eventually new systems larger than 500 KW will have to be allocated through competitive tenders, in accordance with the European Union policy mandate, to increase market competitiveness and lower tariff prices. Such a tender was held for the first time in Hungary in October and the country's energy regulator said that all the winning projects, totaling 131.4 MW, included photovoltaic systems, with the exception of a 500 KW landfill gas plant based on biomass. The winning projects will receive a 15-year long feed-in premium on top of what they will earn in the electricity market.

In more detail, Hungary's renewable energy tender procured 42.8 MW of PV systems ranging between 300 kW to 1 MW and another 88.6 MW of PV capacity for systems between 1 MW to 20 MW. Thus, the country will gradually start seeing a wave of larger PV parks than it has already experienced. But while Hungary is set to add installations remunerated by both FITs and premium tariffs in 2020 and 2021, new PV will only be able to claim premium tariffs via competitive auctions from 2022 onwards.

Huawei has been providing inverters for all sizes of plants. For example, its inverters have supported PV systems in schools and hospitals, but also larger installations.

Some of Hungary's biggest solar PV parks belong to state-owned electric utility MVM. In 2017, MVM launched the first phase of its renewable energy program, which included two 20 MW solar farms in Felsozsolca and Paks, respectively, and an additional 108 small PV plants scattered around Hungary, each with 0.5 MW of capacity. All of these systems have been supported by Hungary's FIT scheme. The two large farms have been operational since 2018, while 91 of the 108 smaller parks were connected to

the grid in late 2019. The other 17 projects will go online in the middle of this year.

And the forward-looking trajectory for the utility's adoption of solar remains bright. Gyorgy Edelman, project manager at the renewable energy arm of MVM, told **pv magazine** that in the near future, the company aims to double its current solar PV capacity, which currently stands at about 120 MW.

"We are a state-owned enterprise, so our task is to support the Hungarian state's energy policy, which aims to achieve a share of renewables in electricity generation of 13% until the end of 2020," said Edelman. "Considering the country's conditions, solar power is the most expedient of renewable energy production options. Currently, this technology can be deployed and operated cost-effectively."

Private-sector investors have also rushed to invest in solar PV. MET, a major gas market player in Hungary and Europe, is such an example. The company owns the 21 MW Szazhalombatta solar project, which includes two systems – the Zagyter and Tehag PV Power Plants – installed near each other on the same high-voltage grid connection. The Szazhalombatta project, commissioned in August 2018, is also supported by the country's FIT policy.

Like MVM, MET also plans to expand its development of PV systems. Daniel Pintacsi, project manager at MET, said new solar is helping the firm "to create a diversified energy portfolio, in which renewables play a key role." MET has several PV plants under different stages of development, with a 42.7 MW project comprising a cluster of four PV plants currently under construction in Kaba.

Tech-giant Huawei has its eyes on the market, and is working in partnership with both public and private developers in the deployment of large-scale Hungarian PV projects. It supplied the inverters for 100 MW worth of capacity for MVM's Zold Generacio project – the largest state-owned installation. It has also deployed its inverters in collaboration with MET for their 21 MW project. The inverter manufacturer is optimistic about Hungary's PV future, with an additional 170 MW of capacity currently scheduled to be built with their products through 2025.

Pintacsi noted that Hungary was one of the last countries in Europe to end its FIT remuneration policy. Therefore, the country has experienced a rather belated rush of solar PV investment and "most of the PV power plants which are currently under construction are still qualified for getting this FIT-type of subsidy." Moving to a premium tariff scheme based on competitive tenders means lower levels of expected returns, but "the market is also now much more developed, which means lower risk for the investors," concluded Pintacsi.

MVM's 20 MW Felsozsolca solar plant in Hungary, a growing European PV market.

Greece

"We have been there and our journey from FITs to premium tariffs has been successful," Greece could tell Hungary.

In fact, Greece legislated its first FITs in 1994, although the PV market only took off after 2006 and began deploying high-penetration volumes of PV starting in 2010. Following miscalculations of the FITs and a huge economic crisis, the Greek PV market dwindled off, only to restart again in 2016 via a new policy scheme. It now requires competitive auctions and awards successful projects with premium tariffs. The winning projects need to participate in the electricity market and their earnings are topped up by premium tariffs for a period of 25 years.

To date, Greece has run seven tenders, starting with a pilot auction in 2016 that awarded 40 MW of PV capacity. Following the pilot tender, it started a regular program of renewable energy auctions that include separate pots for solar PV and wind power technologies, as well as joint solar and wind auctions, where both technologies compete with each other in the same pot. Overall, Greece's tenders have awarded a total of 1.137 GW of solar PV capacity. The country is also running a net metering scheme for small-scale residential and commercial PV projects, adding a much slimmer volume of capacity, of about 10 MW of PV each year.

More vitally, Greece's new national energy plan, published in December 2019, mandates 7.7 GW of cumulative solar PV capacity by 2030, up from approximately 2.8 GW of installed capacity at present. Greece's state-owned utility (PPC) also also has plans to build 3 GW of new solar PV in the country's mining regions. In April's auction, PPC won a contract to develop the first slice of this investment – a 200 MW solar farm in Ptolemaida – at a €0.04911/kWh premium tariff, which is the lowest tariff ever awarded for a renewable energy project in Greece. The 3 GW project aims to support the country's pledge to phase coal out of its electricity system by 2028.

Greece's engagement with a tender regime in recent years has created a significant secondary market, with many projects changing hands either before or after installation. Greece's Metka-EGN, for example, sold a group of PV parks totaling 47 MW to Motor Oil SA earlier this year. The parks are supported by the premium tariff regime and also use Huawei's inverters.

"For our first Greek projects we have chosen Huawei technology, as its inverters are robust, performing properly under the high temperatures that are usual in Greece, while their advanced product features, including but not limited to the multiple MPPTs, the powerline communication and the string level monitoring accuracy," said Nikos Papaoikonomou, Metka-EGN's EPC director. "And their easy serviceability do maximize the energy yield and reduce operating costs."

A dependable PPArtner

The falling cost of PV has increasingly driven the adoption of solar technology in recent years. But for a long time, the solar industry was fully dependent on subsidies. German PV project developer BayWa r.e. made headlines in 2018 with its 175 MW Don Rodrigo plant just outside of Seville, in southern Spain. The company backed the array with a 15-year power purchase agreement (PPA), marking the first time a project of that size had been refinanced in Europe without the help of subsidies. It later charted new territory again with the completion of Germany's first subsidy-free PV project in 2019.

BayWa r.e.'s subsidy-free Don Rodrigo solar plant was a remarkable achievement. The project site, located on the southern tip of Spain, is also blessed with some of the best irradiation conditions for solar power generation in Europe. So when the company announced that it would do it again – this time in northern Germany with an 8.8 MW solar array on the coast of the Baltic Sea – it became evident that it isn't just about irradiation intensity, or economies of scale, but adding more strings to the bow.

Albert Schlaak, project manager at BayWa r.e. Solar Projects GmbH, led the development for the fifth phase of the solar array in Barth, Germany, on the premises of the Stralsund-Barth regional airport. "We already had excellent relationships with the municipality and the airport operator, which made the development process much easier for us," Schlaak says, adding that the breeze from the Baltic Sea has a positive cooling effect – potentially offsetting the slightly lower irradiation at the site, compared to locations in southern Germany. But the right ingredients for a successfully delivered subsidy-free project and PPA differ.

The project at the Barth airport now includes six individual arrays. Schlaak explains that by working at the site with the same stakeholders since 2012, BayWa r.e. was able to streamline its processes in project development to drive down costs. Above all else, the grid access point – which tends to account for a sizable share of project costs – was simplified.

Photos: BayWa r.e.

"Of course, the grid access point was a little further away, but when we built Barth III, we already had Barth IV, V, VI in the pipeline, and built the grid access accordingly," Schlaak explains. "We didn't have to open everything up from scratch, but figuratively speaking just had to flip a switch, and we had a grid connection."

Long-term planning and streamlined processes on which to rely on are what is giving BayWa r.e. the support it needs to further drive down costs. The company's business model is based on developing and building solar arrays and selling them to new owners shortly after completion. In many cases, BayWa r.e. will continue its involvement in the project as an O&M contractor.

"The ingredients for a successfully delivered subsidy-free project and PPA differ"

This is where BayWa r.e. needs to trust its carefully selected suppliers of equipment. Schlaak notes that for the company to be successful in its model, it is imperative to build long-lasting, highly dependable, robust solar PV plants. If the company retains the O&M contract, each failure and downtime event ends in a company loss. "That means that we are only selecting top products with supreme longevity and very low failure rates," says Schlaak. "And this also, of course, includes Huawei's inverters." For Barth, the company installed 43 units of Huawei's SUN2000 60-100KTL inverters.

BayWa r.e. has been working with the world's largest inverter manufacturer for many years. It also equipped its Don Rodrigo power plant in Seville with Hua-

for subsidy-free PV

wei inverters for the same reason. It is not just that Huawei's inverters offer high dependability; BayWa r.e. also chooses the company's solutions because they make its PV plants more reliable.

"Power line communication is one good example of these features. It makes additional cabling obsolete, which reduces the probability of cable failure, which in turn means we don't have to dig up cables if there is a problem," Schlaak explains. Without that feature, an additional communication cable between the inverter substation and switchgear would need to be laid. This adds to capex, because they have to dig in, but it can also be a source failure, as the communication lines are typically more fragile than the power lines from the inverter to the substation.

BayWa r.e. has optimized its solar PV plant designs for many years, supported by a custom-created master layout design that has been certified by German technology certification organization VDE. The plants are designed to exceed 20 to 30 years of operation without major issues, as problems would hurt the sensitive economics of the solar PPA.

The German PPA market is still in its nascent stages, Schlaak reports, with banks, investors, and potential corporate off-takers still in the learning and trust-building phases of purely renewable deals. The agreement for the Bath V project was closed with the company's in-house electricity trader, Clean Energy Sourcing GmbH (CLENS), and lasts only five years. "That is the time frame over which we could fix the prices. At the time, the market for renewable PPAs in Germany was not very mature," Schlaak explains. The Umweltbank, a German bank with green credentials, was the lender. Schlaak says that the bank is currently pioneering Germany's PPA market.

For the Don Rodrigo site in Spain, BayWa r.e. locked in a PPA for 15 years with Statkraft. Since then, Spain's subsidy-free solar PPA market has experienced an enormous uptick, with several gigawatts currently being developed, and not just by BayWa r.e.

In Germany as well, the PPA market could grow and be a welcome alternative to the FIT tariff system. Had it not been for the Barth PPA, BayWa r.e. would have had to wait for two years to sign up for another auction for the project cluster. As the company wanted to move ahead without this requirement, it found a solution with investors and stakeholders. The accomplishment was a trailblazing one, with new announcements of additional German PPA projects now making headlines. And at BayWa r.e. headquarters, the minds behind Barth V are now working on new projects, which the company says we will hear of soon. pv

BayWa's Barth V project is Germany's first subsidy-free solar plant.

The 8.8 MW solar array in Barth, Germany, features 43 Huawei SUN2000 60-100KTL inverters.

Going off-grid

The global market for off-grid applications is enormous. Wood Mackenzie recorded roughly $2.1 billion in investment in offgrid energy markets from 2010 to 2019, and that was just based on what investors revealed. The analysts believe that with 420 million people now using standalone off-grid PV and an additional 47 million people depending on minigrids to obtain electricity, the decade ahead offers a huge opportunity. And Huawei is stepping in to support the microgrid market.

"The economics of distributed solar+storage now pose a threat to the use of diesel in commercial and industrial demand applications"

More than 850 million people throughout the world still lack electricity, according to the International Energy Agency (IEA). But microgrids can play a critical role in expanding access. And while diesel-based microgrids are still the most common setup globally, solar-backed systems have become increasingly common in recent years.

"Off-grid deployments will take an increasingly larger bite out of present and future power demand on the grid, particularly where systems and incomes are large enough to support modular system upgrades," WoodMac senior research analyst Benjamin Attia said in March.

These sentiments are echoed by other analysts. Navigant Research, for example, said in November that it expects "tremendous growth" in the global market for distributed storage over the next decade or so. It expects the segment to expand from 1.07 GW of new annual capacity additions now to yearly growth of 19.9 GW by 2028.

Photos: Huawei

Huawei, with its Smart Li-672V-100AH Cycle Lithium Battery platform, is well-positioned to serve demand for microgrid solar energy storage. The lithium iron phosphate battery (LFP) system – which measures in at a compact 2,000 x 600 x 850 mm – provides storage for continuous power supplies. LFP cells offer a longer lifecycle than other lithium batteries, which makes them ideal for remote applications.

Electricity access

Renewables-based, decentralized energy systems are poised to significantly affect business models for utilities as they displace diesel generation throughout the developing world. The sector is still in its early days, but the International Renewable Energy Agency (IRENA) revealed in April that global off-grid solar installations hit 3.4 GW at the end of 2019.

The economics of distributed solar+storage now pose a threat to the use of diesel in commercial and industrial demand applications. In emerging economies, solar home systems and equipment like solar lanterns have played an important role in expanding electricity access in rural communities, but new approaches are needed.

That is where larger-scale, modular solutions come into play – and Huawei can fill that void. WoodMac says innovative solutions that utilize machine learning and artificial intelligence will also be critical. Huawei – given its track record with sensor technologies and artificial intelligence – sits at the PV industry forefront of such trends.

Challenges and opportunities

The challenges and opportunities for microgrid deployment in sub-Saharan Africa are particularly immense. In April, consultancy Infinergia said that it expects between 5,500 and 17,000 new solar PV minigrids to be installed across the continent by 2026. Much of this deployment will be likely driven by necessity – the IEA estimates that nearly 600 million people throughout the entire region still live without electricity.

For remote applications in Africa, Huawei's storage solutions are ideal because "the UPS features a monitoring bus redundancy design with no single points of failure." O&M is particularly difficult for remote microgrid installations, but Huawei's three-layer bare metal server system ensures battery reliability.

Infinergia has tracked more than 1,000 installed PV minigrids across the region, with most of them installed in Nigeria and Senegal, as well as Cameroon, where Huawei has already deployed its Smart Li-672V-100AH systems in a number of microgrid projects.

Huawei's presence in Cameroon's microgrid market dates back to 2013, when it started working with the government to deploy its PowerCube5000 microgrid solution. By 2017, the company had installed a number of solar-backed microgrid systems in the country, with systems ranging from 30 kW to 300 kW in size, featuring advanced maximum power point tracker (MPPT) technology, high-efficiency inverters, and advanced charging-discharging management.

Technological reliability is critical in the hot environments of sub-Saharan Africa, as such weather conditions can quickly degrade the life expectancies of batteries. Infinergia notes that only a fraction of minigrids installed in Senegal between the mid-1990s and the early part of the past decade are still operational, for example. But Huawei's technology is an ideal match for such projects, as its systems feature a natural cooling design suited to the region's climate, as well as cabinet-level extinguishing to prevent fires.

Future deployment across the region is promising, partly due to policy support. In recent years, a number of sub-Saharan African countries have started to launch public tenders for minigrid projects. This has been backed by supporting policies, as well as new national targets for rural electrification. This has in turn accelerated deployment, with 997 MW of off-grid PV capacity in place across the continent by the end of 2019, according to IRENA.

Asia accelerates

However, Asia is still the global hot spot for off-grid PV, with roughly 1.91 GW deployed by the end of 2019, according to IRENA. India, China, and Bangladesh host the lion's share of operational capacity.

Huawei has been at the forefront of regional deployment, as its Smart Li-672V-100AH Cycle Lithium Battery is especially well-suited for emerging off-grid markets in countries such as Myanmar. The Huawei Smart Li-672V-100AH Cycle Lithium Battery's modular design keeps Capex low, and has a 10-year lifespan, with 4,500 cycles – roughly 2.5 times that of a lead-acid battery.

A 92 kW solar PV array was completed in April 2020 to serve 297 households in the isolated mountainous village of Paluzawa, Myanmar. The microgrid project, developed by Mega Global Green Automation, is supported by 226 kWh of lithium-ion battery storage capacity and features Huawei inverters.

In Myanmar, which has one of the lowest electrification rates in Asia, solar-backed minigrids are the quickest way to offer energy access. As one village leader told Huawei, its systems have allowed his rural community to finally obtain information from the outside world in real time, as they now finally have continuous power supply.

But challenges remain and the Covid-19 pandemic is the most obvious new concern. In March, Julian Jansen, head of energy storage research at business analyst firm IHS Markit, said in a research note that the impact of the global health crisis on supply chains poses a threat to the energy storage and solar industries.

Beyond such immediate concerns, microgrid developers need to consider a range of other issues. Many investors remain skeptical about microgrids due to concerns about scalability, for example. But as WoodMac notes, electricity markets beyond the edge of the grid will become a key part of the energy transition in the years to come – particularly in emerging markets.

> *"Electricity markets beyond the edge of the grid will be a key part of the energy transition in the years to come"*

Three years of intelligent

In 2016, Huaneng Hainan Power and Huawei jointly digitalized the Dongfang solar power plant in Hainan, China. As the first solar PV project to be digitalized, it is worth taking a look back to see how the new technology has actually bolstered performance.

"Discrete rate analysis serves as a powerful tool for improving O&M efficiency"

The 12 MW Dongfang solar project, owned by Huaneng Hainan Power, was initiated on June 30, 2016, for grid-tied power generation. It adopted 280 W monocrystalline PV modules and Huawei's Smart PV Solution. The project jump-started the phenomenon of PV plant digitalization. Since Huaneng Hainan Clean Energy's power plant was enriched with intelligent capabilities in 2017, the energy yield and O&M indicators have skyrocketed to historic levels.

In 2017, when the plant was designed to reach 1,319 utilization hours, actual comprehensive utilization hours reached 1,483, exceeding the planned value by 12.43%. In that same year, on-grid energy was 19.14 million kWh, or 19.77% higher than the planned energy yield (15.98 million kWh), with an annual average performance ratio (PR) of 84.58%.

In 2018, on-grid energy reached 19.05 million kWh, with 1,476 utilization hours, and a performance ratio of 84.43%.

In 2019, on-grid energy increased to approximately 20.56 million kWh, with utilization hours reaching 1,594, and an industry-leading performance ratio of 85.3%.

Huawei says that the Dongfang Power Plant was recognized as a 5A-level PV plant, according to national evaluations and key statistical indicators, for two consecutive years in 2017 and 2018. The plant's average annual performance ratio exceeded 84.43% over the course of three years, and Huawei says the failure rate was close to zero. Additionally, the annual energy yields exceeded the planned value by approximately 20%.

And 2019 witnessed key breakthroughs. The annual solar irradiance of Huaneng Dongfang Power Plant ranges from 502 x 104 kJ/m2 to 586 x 104 kJ/m2, but it still managed to generate 20.56 million kWh of power in a single year, with 1,594 of utilization hours – a record level of performance.

So why does the energy yield of Huaneng Dongfang Power Plant keep climbing over time? The company says that the answer lies within seven key technologies.

Multiple MPPTs

PV module mismatch is usually caused by PV module attenuation, direction, and shading in the morning and at sunset. On the project site, PV module performance may be mismatched due to the shading caused by cloud cover, bird droppings, and water stains following heavy rain in Hainan. All of these factors can contribute to undermining energy yields.

To tackle the problem, Huawei's smart string inverter solution involves connecting two strings to a single MPPT circuit, and configuring each megawatt with 80 MPPTs. When compared with the central inverter, Huawei's technology minimizes PV string mismatch, to improve system efficiency.

Wide operating voltage range, extended power duration

As the PV string MPPT features a wide operating voltage range, this in turn enables a longer operating time for the solar inverters, extending the power generation time and further improving the overall yield of the power plant.

Huawei's smart string inverters use a bipolar topology, which enables the output voltage of each PV module to pass through the DC voltage boost circuit. When DC input voltage is low, the voltage can be boosted to meet the requirements of the bus capacitor. The MPPT operating voltage can range from 200 V to 1000 V. In contrast, a central inverter uses a unipolar topology, and the MPPT operating voltage ranges from 520 V to 1000 V. Therefore, Huawei smart string inverters can

operations data

work for a longer period of time to generate more power.

No fuse + no vulnerable components = No O&M

Simplicity is an important principle for smart PV design. Simple networking design provides for fewer fault points and lower fault probability throughout the system. "Huaneng Dongfang Power Plant has been running for three and a half years, and has maintained a failure rate of close to zero even in high-temperature environments, characterized by high salt mist as well," says Yan Zhang, senior product manager at Huawei. The availability of Huawei string inverters has been verified to be 99.996%, according to onsite tests conducted by TÜV.

Prior to their launch, Huawei solar inverters were reportedly required to pass more than 1,400 tests conducted by the Global Compliance and Testing Center (GCTC) to account for scenarios ranging from salt mist and corrosive wet dirt to lightning strikes and high-altitude environments, with temperatures from –60°C to +100°C. This ensured their stable operation across a diverse range of unfavorable environments. "The simple design ensures that the PV plant remains reliable over the long-term," says Zhang.

Anti-PID technologies prevent losses and ensure safety

The Huaneng Dongfang Power Plant is located just 220 meters off the coast. Therefore, the PV modules have continually operated in a high-temperature, high-humidity environment, in which potential induced degradation (PID) is more frequent.

To resolve this challenge, anti-PID modules are placed in communication boxes. They automatically adjust the output voltage based on the solar inverter voltage, and inject voltage between the phase wire and the ground cable from the AC virtual neutral point to balance the voltage between PV– and the ground, thereby preventing PID from effecting them.

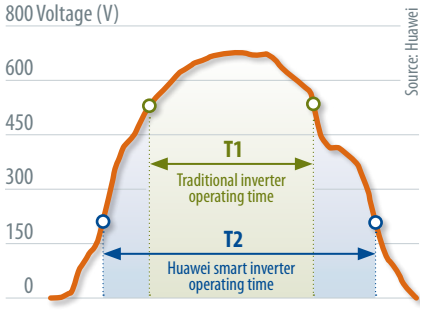
Photos: Huaneng Hainan Power

"More importantly, Huawei's latest PID suppression technology utilizes proprietary technology to build a virtual neutral point through solar inverter circuits," says Zhang. Compared with traditional solutions that use resistors or inductors to build the neutral point, Huawei's PID suppression technology represents a major upgrade, reducing compensation loss and making the compensation process safer. "The result is an increased energy yield by more than 2%, and the support for a larger array of more than 5 MW," says Zhang.

Reduced costs via the replacement of RS485 With PLC

To transmit communication, the Huaneng Dongfang Power Plant uses power line communication (PLC) in place of RS485, which Huawei says reduces the invest-

Extended operating time of a string inverter



Anti-PID modules have been placed in the communication boxes of the Huaneng Dongfang Power Plant to address its susceptibility to system degradation, given its location 220 meters off the Chinese coast.

ment required for communications cable deployment and construction.

By applying PLC technology, Huawei says that deployment and commissioning can be completed within two weeks, without the need to dig trenches or bury cables. A single solar PV plant can cover a maximum of 10 km2 on the ground, enabling fast deployment and mobile O&M. Maintenance personnel are also able to use wireless terminals to make video calls with the central control room.

Discrete rate analysis for pinpointing faults

Discrete rate analysis serves as a powerful tool for improving O&M efficiency. For this project, discrete rate analysis detects faulty PV strings, facilitating onsite inspection by O&M personnel. With the analysis, personnel are able to repair low-efficiency solar PV strings in a timely manner, in order to ensure that each PV string in the power plant remains free of defects for an extended period of time.

Smart I-V curve diagnosis

"Smart I-V Curve Diagnosis has proved to be extremely effective when implemented at the Huaneng Dongfang Power Plant," says Zhang. The scanning for PV string faults of a 12.9 MW PV plant with 1,920 PV strings can be completed within four minutes – covering issues such as hot spots, cracks, and diode short circuits –to enable precise onsite troubleshooting. The detection can be performed online, and a detection report is automatically generated when faults are detected. "The O&M that once required months to complete, can now be fulfilled within mere minutes," says Zhang.

In 2019, the Smart I-V Curve Diagnosis was upgraded to version 3.0, and all PV strings for a 100 MW PV plant can now be detected within 15 minutes. Additionally, AI and machine learning technologies were integrated to incorporate the experience of Smart I-V Curve Diagnosis and optimize the fault models.

After the conclusion of the project, Huaneng has continued working with Huawei on additional smart PV projects, with a total scale in excess of 1 GW. More than 80% of the projects in the FusionSolar Management System. In August 2019, Huaneng Group and Huawei signed a strategic cooperation agreement, for the establishment of a long-term partnership to promote the further integration of digital information and AI technologies in PV plants, and facilitate further technological progress for benchmark PV plant construction in the grid parity era. pv

‘PV is entering the AI era’

We are becoming a fully connected, more intelligent world – this is the mantra of Huawei. The telecoms giant is playing a leading role in integrating the cloud, AI, and 5G technologies to expand its portfolio with a comprehensive strategy that spans a wide range of its business units – and solar PV is no exception.

In 2019, Huawei launched its Ascend AI processors, the all-scenario AI computing framework MindSpore, the Atlas full-series products, and Ascend-based cloud services. “Huawei completed the construction of full-stack, all-scenario AI solutions, which have been widely used across various industries,” says Tony Xu, president of Huawei’s Ascend Computing business unit.

Digital transformation

With the development of digital information technologies, Huawei’s Smart PV business unit started with a digital + PV era, moved to the internet + PV era, and now the conglomerate says it is entering the AI + PV era.

In 2014, Huawei launched its Smart PV solution with string solar inverters functioning as the core. “This solution has

Huawei’s Digital Energy Innovation and Experience Center showcases the integration of information communication technologies (ICT) and power electronics technologies.

Photos: Huawei

Artificial intelligence will support O&M functions historically managed by field personnel.

> *"Modules will collect device data and infer AI models for optimal power generation in real-time and enable grid-tied control of the PV arrays"*

enabled inverters to serve as PV array sensors that support precise information collection for each PV string, essentially achieving perception intelligence," says Chen Guoguang, president of Huawei's Smart PV business unit. From 2015 to 2018, Huawei further integrated digital technologies, with typical applications including wireless private network technologies, MBUS technologies, Smart I-V Curve Diagnosis, and an intelligent O&M cloud center.

In 2019, Huawei released its first Smart PV solution, which integrates AI technologies with its Smart I-V Curve diagnosis solution. In 2020, the company says it is continuing to deepen the integration between smart PV and full-stack, all-scenario AI solutions. "We are currently building a core architecture for device-edge-cloud synergy," says Chen. "This will maximize the value of each PV plant and accelerate the industry's intelligentization upgrade."

Full-stack AI

At the device-level, Huawei says its solar inverters will be further upgraded at some point to serve as smart PV controllers. "This will enable the implementation of high-precision real-time data collection, real-time control of string-level energy yield optimization, real-time DC arc detection, and real-time response to grid-tied control, with real-time inference, execution, and self-closed-loop control capabilities," says Chen.

When referencing edge, Chen says that AI inference modules are embedded in the PV array controllers for an intelligent upgrade. The modules will collect device data and infer AI models for optimal power generation in real-time and enable grid-tied control of PV arrays.

The cloud refers to Huawei's the deployment of the AI inference AI inference platform on a management system that provides continuous training and optimization of the AI algorithm models, without the need for altering existing devices. "As a result, the system energy yield and potential fault diagnosis accuracy are continuously increasing," says Chen. "The inference models of devices on the device and edge sides can be promptly updated in batches, achieving efficient collaboration."

Huawei says that its full-stack, all-scenario AI solutions have already been widely adopted by the electric power, manufacturing, and healthcare industries. "In the power sector, for instance, China Southern Power Grid utilizes the Atlas 200-based intelligent O&M and inspection system," says Chen. And with full-stack, all-scenario AI now being applied for the Smart PV business unit – the company says its next era will offer a variety of new solutions.

Stringing MPPT

To build a closed-loop, collaborative, and convergent system, Huawei has developed a Smart DC System (SDS). The system is designed to integrate the previously independent PV modules, trackers, and solar inverters into a closed-loop synergy among bifacial PV modules, trackers, and smart PV controllers with multiple MPPTs.

A smart PV controller will work as an artificial brain that self-learns and optimizes tracker optimization algorithms. "AI training and modeling will adjust the trackers to the optimal tilt angle to realize the full potential of each PV string in a solar plant," says Chen. For example, an optimal front-to-rear tracker linkage is provided based on the shadows, scatter-

ing ratios, and cloud movement, implementing optimization of the tracker angle in real time.

"Over the last year, Huawei has tested a large number of PV plants, with tests in Huixi and Anhui, indicating a real energy yield increase by 1.31% over a period of 183 days," says Chen. "Both China General Nuclear Power Group and Huanghe Hydropower have increased their energy yields by 0.5% to 1%."

AI Boost AFCI

Solar PV fire incidents are typically caused by DC arcs through poor contact, insecure connection of solar PV connectors, and cable aging and damage. And while historically manual inspection and maintenance would be required to locate problems, AI is stepping up to the challenge. "Nearly 100% of arcs can be identified using AI algorithms that ensure system safety by enabling quick-break protection," says Chen.

Huawei says it has made the industry's first attempt to integrate AI algorithms into arc-fault circuit interrupters (AFCIs), which it believes will become the global industry standard. By providing more accurate arc detection and faster fault rectification, the company's AI Boost AFCI feature is set to enhance safety for PV systems.

Unmanned O&M

Remote scanning of all PV strings is now happening in a one-click mode for the solar industry. Huawei says that's its Smart I-V Curve Diagnosis can now scan a 100 MW PV plant can be scanned within just 15 minutes – but that remote scanning is just the beginning.

Driving down the cost of operations and maintenance from manual labor will be further supported by AI technologies. "Drone inspections and robot-based automatic O&M will replace massive repetitive work," says Chen.

Drones equipped with a high-definition (HD) or infrared camera can negate the need for manual inspection and complete real-time analysis and judgment.

Grid-tied support

With a higher penetration of intermittent renewables being tied into power transmission infrastructure, the grid faces stability challenges. "Renewable energy with a strong high-voltage ridethrough (HVRT) capability is imperative to maintaining the safety and stability of power grids," says Chen.

Huawei believes that its self-learning algorithms will be able to build considerably stronger control capabilities from PV plants to support the grid. By proactively identifying the electrical features of a given PV plant, AI will automatically adjust the grid-tied algorithm to match the power grid.

In the future, the grid-tied control capability of solar PV inverters will support connections to weaker power grids, so that the solar power system can still run stably without disconnecting from the power grid.

Building synergies

Using digitalization, Huawei says that independent devices of solar PV plants will start to work in a much more collaborative fashion as systems moving into the future. With "three-level collaborations" – the solar inverter, solar array, and solar PV plant – all elements will be optimized to build gains and maximize efficiencies more cohesively.

"At the device level, improvements have been made not only in the efficiencies and power densities of solar inverters, but also in maintenance-free designs," explains Chen, adding that grid-edge support and new AI perception and inference capabilities will continue to rapidly expand in the years ahead.

At the array level, many devices are becoming much more interconnected and optimized in a collaborative manner. An intelligent DC closed-loop system has been formed, consisting of bifacial solar PV modules, solar trackers, and solar inverters. "The AI self-learning and big data feature mining technologies are used to dynamically adjust the tracker angle online to the optimal state, fully achieving the potential of each PV string," says Chen.

"And finally, at the plant level, driven by the smart PV array and edge computing, PV plants can proactively receive power grid requirements, automatically adjust the operating status, and implement real-time online collaboration," he adds. "And this is where real evolution of the PV ecosystem arrives with AI."

An optimal adjustment of active and reactive power in a PV array can be implemented to optimize the energy yield of an entire PV plant under the power factor requirements of the power grid.

"AI training and modeling will adjust the trackers to the optimal tilt angle to realize the full potential of each PV string in a solar plant"

Sights on storage

The residential storage market doubled last year, driven by catastrophic outages that have included wild fires, hurricanes, and other problems in countries around the world. The booming global market for residential battery storage is being supported by new solutions that are linking rooftop PV assets to battery banks controlled by powerful new software platforms. Huawei is stepping into position to support the growing demand with a new suite of smart solar+storage solutions.

"Self-generation capability is rising, with homes being wired with solar+storage to shield themselves"

The global $6 billion-plus residential energy storage market is expected to grow significantly over the next decade. In mature solar PV markets, changing regulations and policies – such as the expiration of solar feed-in tariffs (FITs) and net-energy metering schemes – are creating the desire for customers to increase their self-consumption rather than feeding power into the grid. Research firm IHS Markit projects that the residential energy storage market will grow from annual installations of 792 MW in 2019 to 2.7 GW in 2025. The largest distributed-generation (DG) storage markets will be Japan and Germany, with Australia and the United States rapidly emerging as key growth countries.

"The major market driver for residential energy storage are a mix of high retail electricity rates, high penetration of residential solar PV and a desire by customers to increase their energy independence," says Julian Jansen, head of energy storage research at IHS Markit.

Last year's wildfires in California – with subsequent widespread preventative power shutoffs – and severe bushfires in Australia led to billions of dollars in estimated losses from power outages, pushing utility customers across the globe to seek backup power. Events such as these are driving homeowners and businesses to look to solar and storage, not just as a cost-effective source of power, but more importantly to ensure reliability during outages.

Under the pressures of unforseen power outage events, residential solar PV owners' rooftop systems were unable to power their homes, as safety shut-off protocols were put in place to protect utility line workers. The addition of battery storage has therefore become a more and more attractive option for solar generators. A battery storage system plus software can create a grid for the home – islanding it off from the local utility – for homeowners to have energy when the grid fails.

"As climate change is increasing the frequency and strength of natural disasters, this has elevated the crucial role that energy storage plays not only in providing resilience for end-customers, but also supporting the rebuild of power infrastructure in the aftermath of natural disasters," notes Jansen.

Storage solutions

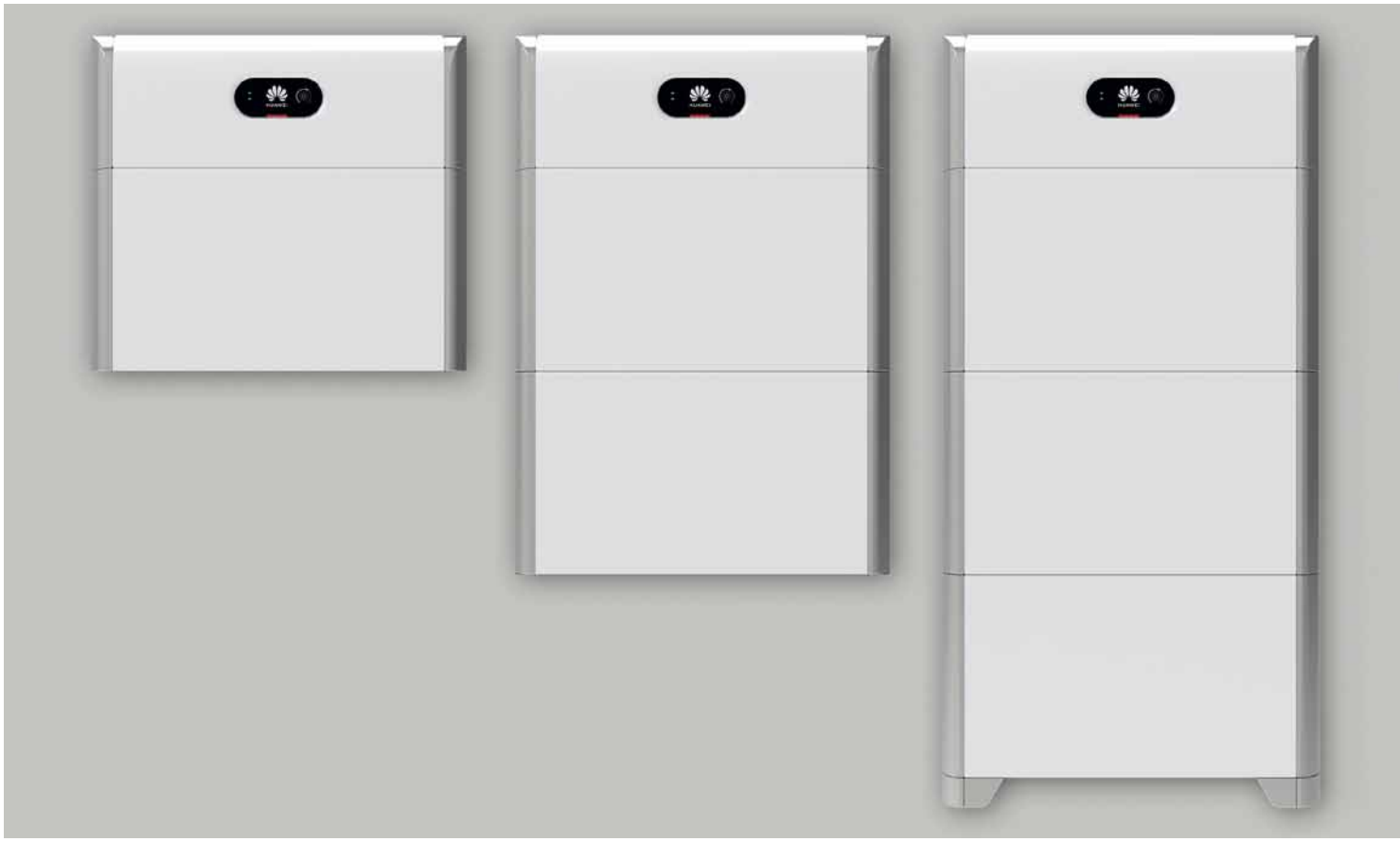
One example of storage stepping in as a solution to catastrophe is the response to 2017's Hurricane Maria in Puerto Rico, which devastated infrastructure and caused long-term supply challenges. This drove uptake of solar+storage not only for residential customers, but also for microgrids restoring power supply. Overall, microgrid formation is flying.

As of the first quarter of 2020, Navigant Research identified 6,610 projects representing more than 31 MW of planned power capacity to be installed. The Asia-Pacific region has recently emerged as the global leader in microgrid capacity, followed by North America and the Middle East and Africa region, Navigant researchers say.

The development of self-generation capability is rising, with homes being wired with solar+storage to shield themselves from the grid. Microgrids (or nanogrids, as some call residential microgrids) are seeing significant uptake. And while DG market projects used to be seen as competition to electric utilities' business models, today, they are seen as an opportunity to further support the needs of utilities.

For instance, South Africa's weak transmission and distribution (T&D) foundation is resulting in regular planned outages, impacting commercial and residential customers alike. This is driving up the demand for DG battery energy storage systems and helping to alleviate the grid.

Photo: Huawei



Huawei's new Smart Energy Storage System offers a plug-and-play solution including an inverter, battery bank, monitoring, and mobile software controls.

In an ever more digitalized world, cloud-based smart technology is being adopted with rigor in conjunction with today's increased number of distributed energy resources (DERs) – such as solar, battery storage, and electric vehicles. By pairing together smart energy technologies and software, the emergence of virtual power plants (VPPs) is quickly supporting utility challenges of the past – while providing greater independence for homeowners and communities alike.

"The emergence of virtual power plant (VPP) business models and utilities looking to procure balancing services from aggregated distributed storage assets, is creating additional revenue streams for customers and improving financial returns," says Jansen.

Brand names

The swell in sales of residential battery storage systems has encouraged many manufacturers to jump into the fray. "Pioneers of turnkey residential battery storage products – Outback, SMA, SolarEdge, Enphase – have been joined by just about every company that manufacturers inverters or batteries, including Fronius, Delta, LG Electronics, Q-Cells, Panasonic, Sonnen, Generac and others," according to solar PV analyst Barry Cinnamon.

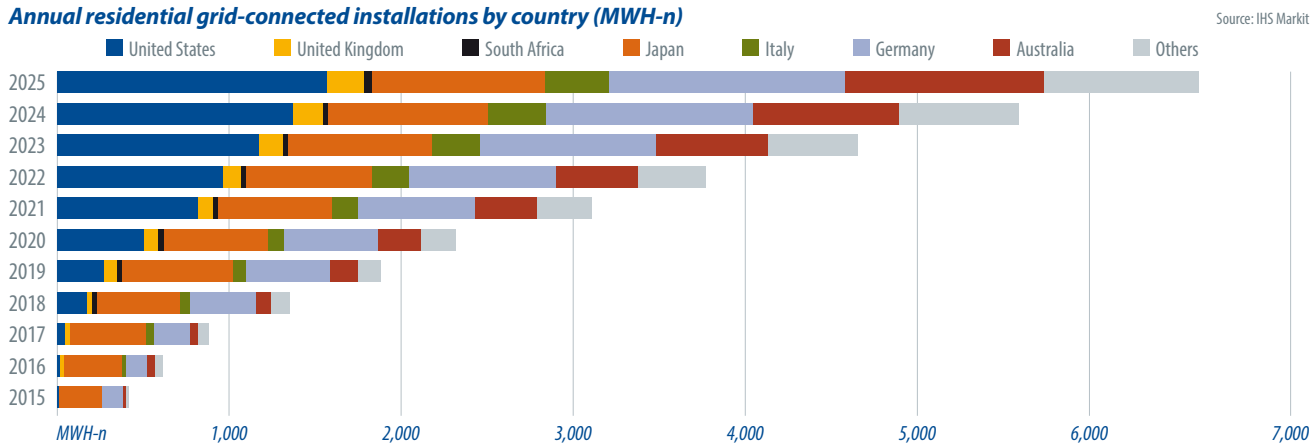
While some of these vendors are vertically integrated – producing everything from solar panels to batteries to inverters to software – few do it all. Tesla is one of the most integrated among the suppliers, but even it has had supply chain issues. Key to the provision of integrated residential battery storage systems is the software platform that operates the system in conjunction with energy generation assets.

Among the many well-known brands that have entered the market over the past year is Huawei, which is globally known as an innovator in the smart PV market segment for its inverters, artificial intelligence, and software platforms. Its Smart Energy Storage System, available in the fourth quarter of 2020, offers a plug-and-play solution with an inverter, battery bank, monitoring, and mobile software controls.

Integrated approach

As the deployment of solar+storage grows rapidly, one of the key challenges for developers and system owners alike has been dealing with warranty claims and liability issues that can arise between differ-

> *"The swell in sales of residential battery storage systems has encouraged many manufacturers to jump into the fray"*



Residential storage is booming throughout the world, and key markets will continue to grow over the next five years.

ent inverter companies and battery energy storage suppliers.

"By expanding FusionSolar and adding Smart ESS into Huawei's residential offerings, we will provide an upgraded experience for both installers and end users," says George Qiwei Zhang, the company's storage solutions expert. "While other competing solution providers need to source components from different vendors, that leads to higher procurement and stocking costs, and no clear line of warranty responsibility in the case of inverter or battery failure," he adds.

By bringing together the two systems, Huawei believes it will provide end-customers with an optimal solution. "The addition of a residential battery into the Smart PV Solution will allow Huawei to offer a one-stop, end-to-end solution with a simple interface for sales, fulfillment and after service," says Zhang.

"Our AI self-learning battery is helping customers to achieve an optimal electricity cost"

Next level

Huawei's FusionSolar Smart PV and Storage System creates an integrated approach to residential storage, by combining its Smart ESS, Smart PV Optimizer, Smart Energy Center, Smart Energy Power Sensor, FusionSolar Smart PV Management System, and Smart Dongle.

The system includes the capability of mobile remote inverter and battery diagnosis, along with troubleshooting guidance. The cloud-based data link also enables automatic firmware upgrades to the system, according to Zhang. The homeowner interface with the system is centralized and already on the market.

For safety, Huawei says its system uses lithium-iron phosphate (LFP) batteries, which provide more heat tolerance than basic lithium-ion batteries and pose less of a fire risk. "We are offering BoostLi, an enhanced battery technology with pack-level charge/discharge optimization, which not only allows homeowners to fully utilize battery energy during its lifecycle but also facilitates future system expansion with perfect compatibility," Zhang says.

The battery banks are available in modular 5 kWh units, and are scalable up to 30 kWh. The system is available in a single-phase design for the broad residential market and a three-phase design for large homes and small business applications. The battery packs permit a 100% depth of discharge, unlike many competitor systems, in which much lower discharge levels are permitted to uphold the product warranty.

Part of the consumer decision to select an integrated software platform for energy storage is the faith that the vendor will be around 10 years down the road. Huawei, with more than $100 billion in annual sales, is able to guarantee its 10-year warranty for many years to come, unlike a half a dozen other inverter companies that have exited the U.S. market over the past decade. Huawei says that it is putting customers first in its design smart design processes.

"Our AI self-learning battery is helping customers to achieve an optimal electricity cost," says Zhang. "The FusionSolar Smart PV Management System estimates how much energy your PV system will generate in the near future, it considers a customer's previous energy usage data, and it automatically recommends adding additional or replacement batteries to increase self-consumption." pv

Talking investment: From the lab to next-gen PV

Huawei says it invests more than 10% of its revenue in research and development each year, with this figure reaching around 15% in the last two years. Over the past decade, the company's R&D investment totaled CNY 480 billion ($67 billion). Huawei has established 14 R&D centers and more than 60 basic technology laboratories worldwide, covering materials, heat dissipation, mathematics, and wireless technologies. Chen Guoguang, the new president of the Smart PV Business Unit, discusses what this means for the advancement of solar.

Huawei is known for making significant R&D investments. What kind of spending are we talking about for the energy business?

Our Digital Power Product Line, which is one of Huawei's eight product lines, has recorded some of the fastest growth, covering fields such as a data center facility, telecom energy, smart PV, and mPower. This product line currently includes nine R&D centers, over 1,200 patents, and more than 3,000 R&D personnel. And at least 15% of annual sales revenue from the product line is invested in R&D. Currently, Huawei Digital Power Product Line R&D centers have been established worldwide, including in Germany, Japan, Sweden, and the cities of Shenzhen, Shanghai, and Xi'an.

"Huawei will further integrate new ICT technologies such as AI and 5G with PV to embrace the era of grid parity"

Huawei is a huge entity with many different business units. How are you bridging the Smart PV business unit with the company's other technological arenas?

For example, 2012 Laboratories is a renowned Huawei laboratory that mainly focuses on the development of next-generation communications, chips, wireless, cloud computing, audio and video analysis, data mining, as well as machine-learning technologies for the next five to 10 years. It is Huawei's 'Noah's Ark' – leading the way to the future. It also includes an energy-related laboratory called the Watt Laboratory, which created the 40 W super-charging technology that is used in Huawei Mate series smartphones. The Watt Laboratory serves as the cradle of numeous technologies that are applied in our solar inverters, such as the AI-powered grid-tied technology and energy storage technology.

Is there any other R&D work taking place for Huawei's Smart PV business across different facilities?

The 2012 Laboratories includes various other sub-laboratories named after world-

Photo: Huawei

Huawei's R&D center in Shenzhen, China. The company says it invests more than 10% of its revenues in R&D each year.

renowned scientists or mathematicians, such as the Shannon Laboratory, which focuses on frontier research on key technologies and algorithms for the intelligentization of ICT technologies. Further examples include the Gauss Laboratory, which aims to build an industry-leading database management system; the Shield Lab, which focuses on cybersecurity, device security, cloud virtualization security, and cryptographic algorithms; and the Turing Laboratory, which concentrates on research regarding AI technologies and applications.

As Huawei's research base, 2012 Laboratories not only represents top-level research in China, but it also has considerable global influence. The powerful global R&D platform ensures the world-leading performance of Huawei solar inverters. Huawei applies new technologies and materials, developed by company experts and doctors, to new products to maintain our industrial competitiveness.

With grid parity, large utility-scale PV projects are taking off globally. How is Huawei innovating to serve this market segment?

For large-scale PV plants, Huawei will further integrate new ICT technologies such as AI and 5G with PV to embrace the era of grid parity. The AI Boost Smart DC System (SDS) integrates bifacial PV modules, trackers, and smart PV controllers configured with multiple MPPTs to ensure optimal DC system performance. Based on neural networks, AI training and modeling enable trackers to be adjusted at an appropriate angle to ensure the highest energy yield of each PV string. AI Boost Smart I-V Curve Diagnosis 4.0 is an upgraded version that supports more application scenarios and delivers higher diagnosis efficiency. For example, the detection for a 100 MW PV plant currently only takes 15 minutes. In addition, it is applicable to various scenarios such as shingled modules and mixed PV module installations.

In terms of grid-friendliness, the Huawei smart solar inverters can ensure seamless and high-quality solar inverter power generation. Huawei applies an AI self-learning algorithm for impedance reshaping. This algorithm integrates multiple advanced algorithms, such as the adaptive algorithm for dynamic damping, and supports a minimum short circuit ratio (SCR) of 1.5, an industrial-leading figure.

"This year, we have launched a new smart PV solution that will reconstruct a secure and reliable open digital platform"

Where are you currently focusing R&D efforts within the Smart PV Business Unit for the distributed-generation (DG) rooftop market?

For distributed deployment, we will continue to improve the rooftop smart PV solution to become the most comprehensive string solution provider in the industry. The arc-fault circuit interrupter (AFCI) and Digital Turbo are powered by AI technologies to provide a more safe, better user experience.

For residential scenarios, we will launch the One-Fits-All 450 W optimizer. The optimizer can adapt to all 60-cell and 72-cell crystalline silicon PV modules in the market, and it can be configured as required. The single-phase and three-phase solar inverters both support DC coupling and are battery-ready, enabling storage capacity to be expanded as required.

In industrial and commercial scenarios, the safety of the solar inverter and the whole PV system can both be guaranteed. With AI technologies, DC arcs within the system life cycle can be detected more accurately and quickly cut off.

Are there any exciting innovations that the industry can expect from Huawei over the course of the next year in terms of digital PV solutions?

Software and algorithm R&D still focuses on fully enabling the PV field through AI Boost, including improving power generation efficiency, O&M efficiency, and proactive safety, to support the increasing use of new energy in future power grids. Huawei will also build a smart PV ecosystem through software and cloud platforms. This year, we have launched a new smart PV solution that will reconstruct a secure and reliable open digital platform. The open data interface supports third-party ecosystem applications, enabling ecosystem partners and customers to conduct customized app development. As a result, digital dividends can be shared – creating more opportunities for our customers. pv

Preventing fires with AI

Fires present significant potential risks to solar installations. They can destroy PV system components – such as modules, cables, and inverters – and also damage entire buildings. Inverter manufacturer Huawei says that arcs are the primary cause of serious fires in solar PV systems, as they account for more than 60% of all incidents involving rooftop PV systems. Manufacturers, developers, and governments alike have been implementing precautionary measures for years to prevent arcing and system fires – and now artificial intelligence (AI) is starting to emerge as another important safety solution.

Huawei's Southern Factory Smart PV plant

Photo: Huawei

"Digital intelligence continuously self-learns to recognize millions of arc features and compiles them into a vast library"

Direct current (DC) arcs can occur due to loose terminals, poor contact, broken cables, old insulation materials, carbonization, damp wires, corrosion, and insulation layer cracks. "Distributed and residential PV systems are usually installed on rooftops, making it particularly difficult for workers to detect all potential risks during routine inspections," says Bin Xie, senior product manager of Huawei.

Detecting an arc – caused by faulty, poorly installed or worn connectors, cables and junctions among the heavy DC load of a PV array that comes into the inverter – requires some higher level of engineering trickery. An arc-fault circuit interrupter (AFCI) device serves as a safety shield for rooftop PV plants. AFCI technology breaks the circuit when it detects arc feature signals to prevent electrical fires and short circuits.

Countries across the world are publishing safety standards for rooftop PV plants, and in 2011, the U.S. National Electric Code introduced the NEC 690.11 regulations to prevent fires in PV arrays with arc fault detection. However, it takes time to update product designs and meet new regulations. When testing laboratory PV Evolution Labs (PVEL) examined inverters for its scorecard, one finding that stood out was that 30% of the tested inverters did not detect arcs the way they were supposed to. But self-learning technologies are ramping up – and may be a new solution.

In 2019, the Chinese inverter conglomerate introduced its first AI-based solar distributed smart inverter. It received a wide range of industry acclamations, including the InterSolar award, for its use of AI to enhance safety features. Of particular note are the AI algorithms that are being used to prevent fires, especially those caused by DC arcs through poor contact. The company says its AFCI solution is capable of modulating PV system operations when fire risks are detected.

Huawei's new approach – based on machine learning – has been set up to improve the detection capabilities of systems. The company says its inverters, which feature built-in AFCI powered by AI, can automatically detect DC arcs and disconnect circuits.

"Being powered by AI, it has several advantages," says Xie. "Digital intelligence continuously self-learns to recognize millions of arc features and compiles them into a vast library."

The manufacturer claims that it has developed more than 100 test cases, taking into consideration multiple factors such as ambient temperature, grid condition, number of strings, and reactive power regulation, to improve the algorithm. The machine-learning technology is said to be based on a database with more than 1 million arc features.

"The powerful computing power of the local chips enables them to actively identify and analyze more than 92 arc characteristics comparison points, with greater than 99% accuracy," says Xie. "The SUN2000 also shuts down and cuts off the power supply within 400 ms, which is much quicker than the industrial standard of 2.5s and prevents fires, ensuring rooftop PV plants are safe."

Xie references the success of Huawei's AI-based SUN2000-20KTL-M0 smart solar inverters at the site of its 150 kW distributed-generation solar PV plant in Xi'an, a city in China's Shaanxi province. The manufacturer says that on July 27, 2019, the project's solar inverters cut the circuit and shut down immediately after detecting DC arcs. "The Huawei management system automatically sent alarms to O&M personnel, who promptly arrived at the site and carefully checked the DC terminals." Xie says that staff discovered that the DC terminals had not been properly connected. "A thermal imager indicated that the ambient temperature of the DC terminals was too high. The fault was rectified in time, and a fire was averted."

Using the machine-learning element, Huawei says 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 wave forms that it needs to react to, and those that it should not.

In May 2020, Huawei announced its extension of AI integration for its string inverter products.

AI steps into maintenance

The Covid-19 pandemic quarantine has introduced a new set of challenges for solar PV operations and maintenance. The topic has gained industry attention now that PV sites lack onsite personnel. Huawei says its new Smart I-V Curve Diagnosis – integrating artificial intelligence, digital technologies, and PV – is a first-step solution toward unmanned O&M. With the levelized cost of energy (LCOE) ever decreasing, improvements in O&M efficiency and accompanying cost reductions may accelerate the arrival of the grid parity era.

Operations and maintenance personnel no longer need to conduct onsite inspections of entire PV plants. In 2019, Huawei launched its AI Boost Smart I-V Curve Diagnosis 3.0. By scanning PV strings using its smart PV inverters, the solution can find the relationship (I-V curve) between output voltage and output current. Huawei says the smart PV management system uses big data to analyze the I-V curve of PV modules, applies artificial intelligence (AI) diagnosis algorithms, identifies faulty strings, and creates a diagnosis report.

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

Photo: Xi'an Heavy Equipment Manufacturing Group Co., Ltd.

PV problems

"Faults in solar PV modules affect a plant's energy yield more than any other factor. These faults vary greatly depending on the stage at which they occur," says Zhang. He argues that manual inspection and traditional supervisory control and data acquisition (SCADA) often cannot pinpoint the root cause of faults with accuracy in a short period of time.

Traditionally, an I-V inspection has required personnel to visit project sites, bringing equipment with them. A 100 MW PV plant has tens of thousands of PV modules and covers an area equivalent to more than 300 football fields. "Physically scanning all PV modules is just not practical," says Zhang, adding that manually generated reports can result in errors and is also time-consuming. Increasing application scenarios, challenging terrain, and the advent of new types of solar PV modules. such as bifacial technology, can make for particularly complex and expensive manual inspections.

> *"Physical scanning of all PV modules is just not practical"*

Artificial intelligence

Huawei's Smart I-V Curve Diagnosis 3.0 offers an alternative to the manual sampling method of detection. The system

Photo: Entrutech SDH BHD

This 49 MW project in Mudajaya, Malaysia, had all strings scanned with Huawei's Smart I-V Curve Diagnosis.

is said to perform full detection on all PV modules and automatically generates detection reports covering 14 different types of faults, accompanied by automated reports. "The AI Boost Smart I-V Curve Diagnosis supports remote scanning of all PV strings in one-click mode," says Zhang, claiming that a 100 MW PV plant can be scanned within 15 minutes.

> *"AI technologies further collect expert experience to search, filter, check, and identify faults – proactively maintaining the health of PV plants"*

As the detection is completed online, it negates the need for site visits. "This greatly improves the O&M efficiency of PV plants by more than 50% and reduces O&M costs over the lifetime of the system," says Zhang.

The AI technologies further collect expert experience to search, filter, check, and identify faults – proactively maintaining the health of PV plants for long periods. In this context, maintenance does not refer to locating specific faults. Instead, it refers to comparing performance indicators and the data provided by sensors with algorithms to check whether solar PV plant devices are running properly. Once an exception is detected, a warning is generated.

Huawei says its solar PV solution works similarly to the fault preprocessing systems that have already been widely adopted in the field of aviation. For example, when an aircraft engine is about to fail, a warning will be first delivered to the airline control center. Subsequently, the control center will provide the pilot with instructions, and arrange maintenance personnel to arrive at the destination in advance to eliminate potential risks before an accident occurs.

Smartly applied

The Smart I-V Curve diagnosis solution from Huawei is said to have already been utilized for various PV plant setups, for residential rooftops, commercial & industrial, and utility-scale groundmount applications. "We are currently the only vendor that have successfully applied Smart I-V Curve Diagnosis on a large scale," says Zhang, referencing a 100 MW smart PV plant in Golmud, in China's Qinghai province, where he says Huawei's Smart I-V Curve Diagnosis detected all strings within 15 minutes. "It accurately detected and identified all faults, supporting our customer to increase their revenues by CNY 10 million ($1.39 million)."

For a 50 MW solar PV plant in the mountains of Datong, in China's Shanxi province, Huawei says its Smart I-V Curve Diagnosis was used to scan 14,626 PV strings. It detected 909 faulty strings, with a fault rate of 6.21%. Based on the Smart I-V Curve Diagnosis report, O&M personnel gained a detailed understanding of the condition of each PV array, which allowed them to take a more targeted approach to site maintenance. Zhang says, "The resulting impacts are estimated to save them CNY5.42 million in maintenance costs over 20 years."

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