

pv magazine publisher Eckhart K. Gouras meets with Huawei Chief Energy Scientist Dr. Yunfeng Liu in Shanghai, March 2018.



Photo: pv magazine

Huawei's Technological Leadership

Rick Fransen is building the largest PV power plant in the Netherlands. Fransen works for the international solar developer Solarcentury and this 45 MW project in Holland involves a staggering 160,000 photovoltaic modules. It is a challenging project, not only because of its size but because the plant is being built on top of contaminated land, specifically the discharge of an old zinc mine. This hazardous discharge has been sealed off by a protective membrane, which in turn has been covered by a sizable layer of soil. But Rick has the background to master such challenges: He has worked in the PV industry for 29 years and has been involved in PV project development, engineering, procurement, and construction in a wide range of projects.

I met Fransen this May at the launch ceremony of another landmark project in the Benelux region, an 18.2 MW battery storage facility powered by 140 Tesla Powerwall batteries in Belgium's Flanders region. This facility is tasked with stabilizing the European electricity grid, and eventually it will form part of a DC micro-grid involving both ground-mounted and floating PV power plants.

During our conversation next to these rows of Tesla batteries we also talked about the inverters being used in his 45 MW PV power plant. Here the choice was clear: Huawei would be the vendor of the inverters and Huawei's string inverters would be deployed at this plant. Rick is very keen to avoid any downtime at this facility and by selecting Huawei's string inverters to do the power conversion, he can quickly switch out inverters in case of malfunction. He also likes the reliability of the Huawei string inverter: the fan-less natural cooling of the inverters gets rid of a common failure point with inverters. He even points to the fact that Huawei has removed the display screen on the inverter to make the housing even more resistant to the environment. And in aggressive environments like an old zinc

mining field, such precautions can lead to fewer outages and as a result, better returns for the investors in such a power plant.

Rick also points to the smart I-V curve analysis Huawei offers for its FusionSolar Smart PV Solution. This analysis is automated and looks at the I-V curve of each string in the PV power plant. Utilizing an advanced diagnosis algorithm, Huawei's smart I-V curve analysis takes individual string-level data from the field and compares it to normal and abnormal patterns of the I-V curve. If abnormal patterns are detected, the smart I-V curve analysis can even render a fault analysis. For example, it can tell the O&M service provider that the fault is related to module shading or module defects, such as cracked glass.

The O&M provider can do all of this remotely and such a solution expedites problem-solving and minimizes the cost of sending specialists out into the field. So for Rick Fransen the clear favorite among inverter manufacturers is Huawei. As we show in this latest special edition on Huawei's inverter technology and solutions, much of this expertise Huawei brings to the global PV industry stems from its more than 30 years of information and communications technology (ICT) innovation and projects in 170 countries across the globe. It is one of the leaders in mobile 5G technology and we can be sure that this technological prowess will continue to provide smart and cost-saving solutions to our industry.

We hope you enjoy this special edition and if you would like to share any thoughts or comments, please email us at editors@pv-magazine.com.

Eckhart K. Gouras
Publisher



Photo: Nasa Earth Observatory

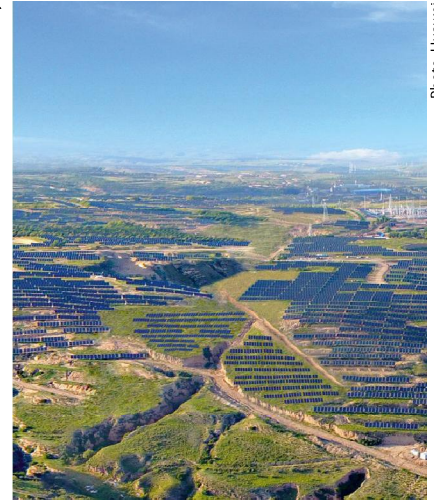


Photo: Huawei

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Photo: Adani

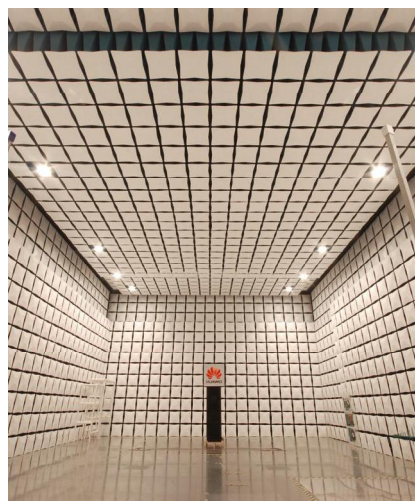


Photo: Huawei

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Huawei products are built to last in all conditions. This is ensured by the extensive testing conducted at the Global Compliance and Testing Center.

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Just four years after initially entering the smartphone market in 2012, Huawei had become the third-largest manufacturer in the world, behind only Apple and Samsung. The company's move into the PV business has seen similarly astronomical growth in just a few years.

From pocket to socket

A brief history: Huawei's long and impressive track record in the global information and communication technology (ICT) market provides an important foundation for the company's rapid growth and success in the global solar PV market. At the same time, Huawei's push to expand its footprint from B2B to B2C in the ICT sector dovetails nicely with its push to deliver cutting-edge PV solutions to residential customers.

When Huawei started as a small company in Shenzhen, China, in 1987, its focus was squarely on the information and communication technology (ICT) sector and B2B telecommunications in particular. It aspired to challenge the dominance of foreign telecommunications vendors in China, as China was rapidly expanding its fixed and mobile telecommunications networks. After meeting with success at home, it began to expand overseas and emerged as a leading telecommunications vendor to phone companies seeking to build powerful fixed-line and mobile voice and data networks.

Today Huawei does business in 170 countries with annual revenues of over \$92.5 billion. One third of the world's population is served by the manufacturer's ICT technology and Huawei employs

180,000 employees around the world, with half of this staff being involved in research and development. R&D centers are located not only in China, but also in the U.S., France, Germany, Sweden, the U.K., India, Japan, and Russia. In 2017 the company invested \$12.1 billion (€10.4 billion) in R&D, representing almost 20% of its annual revenues. According to the "2017 Industrial Investment Scoreboard" published in December 2017 by the European Commission, Huawei ranked number six among companies investing the most money in innovation. And it ranked first among companies filing patents at the European Patent Office in 2017. Huawei's 74,307 worldwide patent applications granted to date represent more than any other company in the field of digital communications.

Up until fairly recently, Huawei's ICT portfolio was largely directed at mobile operators or other enterprises around the world. However, in 2012 the company moved aggressively into the end-user market by launching an Android-based smartphone internationally, the first time a Chinese ICT manufacturer had done so. Just four years later, the company was already ranked number three among smartphone producers, selling 139 million smartphones in 2016, more than any other manufacturer except for Samsung and Apple. It has recently incorporated artificial intelligence (AI) into its mobile devices with one AI application involving facial recognition technology to improve photos. Another innovation involves ultra-fast charging utilizing Huawei's Magic technology.

Huawei invested

\$12.2 billion

in R&D in 2017

Household name

This push into consumer electronics is quickly making Huawei a household brand across the world. On the solar PV side, this global brand recognition can be leveraged to introduce cutting-edge PV applications to the residential sector. Since consumers are now familiar with Huawei's innovation in delivering a state-of-the-art ICT experience, they are open to new applications on the energy front, be it green energy or convenient ways to control a smart home. Since these energy and smart home applications are also taking advantage of a sophisticated end-user device, namely the smartphone, the entire consumer experience is brought together in one place and on one screen.

"From pocket to socket" is therefore a unifying experience, which taps into various areas of Huawei's ICT, green energy, and battery storage expertise. It also demonstrates what Huawei calls "New ICT," meaning the central importance of ICT technology in driving business in a wide range of markets. Previously, ICT was mainly tasked with supporting enterprises, be they actors in the energy field or in other markets. But with the rise of cloud computing, AI, and other technologies, ICT is now becoming a central asset in driving innovation in almost every sector.

A case in point is Huawei's smart I-V curve analysis in the PV sector. This is essentially AI applied to PV. Using cloud computing, Huawei continuously harvests string level performance data of a PV power plant and compares the I-V curve of each string to normal and abnormal patterns. This is done automatically by sophisticated algorithms, and if the actual I-V curve matches an abnormal pattern, the smart I-V curve analysis can even deliver a diagnosis of the likely fault involved. This could be anything from a simple shading issue to a more serious fault like hot spots or cracked glass in the solar panels.

The application of new ICT technology like Huawei's smart I-V curve analysis is making the PV operations & maintenance (O&M) business not only much more sophisticated, but more cost efficient over the life of the power plant. This intelligence is also being applied to the manufacturer's residential solution, where even individual modules can be monitored to ensure optimal output of the rooftop PV system. A combination of optimizers at the module level and ICT technology embedded in gateways and other devices in the home provide the needed granularity and control to achieve a truly cutting-edge solution.

Reliable solutions

But optimized output and ease of use for the consumer is only part of the story. Where Huawei's ICT track record also provides a strategic advantage in the PV industry is on the long-term reliability front. What good is a fancy smartphone or a PV inverter if it cannot be counted on all the time and in a wide range of environments? The better comparison is actually not with a smartphone, which usually has a lifetime of just a few years, but with Huawei's original product, the telecommunications network. Such networks will involve outdoor components, which need to perform according to the 99.999% availability standard common to the telecommunications industry, and often in harsh environments involving extreme temperatures and other challenging conditions. This has been the operating environment for Huawei's ICT equipment for over 30 years and the manufacturer has already applied many of the lessons learned to PV.

This includes natural cooling of Huawei's inverters, so fan-less cooling to remove this common failure point. It includes removing the display screen on the inverter, since this screen could over time prove to be a weak link in the housing of the inverter. In combination

these advantages create an exceptionally low failure rate of under 0.5% for Huawei's installed base of PV inverters on an annual basis. As Matthias Wagner, Director Business Development of Huawei Technologies Deutschland GmbH, pointed out at the MCE exhibition in Milan, Italy, this March, one lesson learned from the company's telecoms track record is that "the better the product is, the fewer problems we have afterwards with the service." Just like the smart I-V curve analysis, an exceptionally low failure rate translates into reduced O&M costs, and thus better return on investment over the life of the PV plant.

Wagner also mentions Huawei's telecoms background in explaining the very high service level offered by Huawei to its customers. A rock solid service-level agreement (SLA) is standard in the telecoms business, since any network outage is a critical event for telecoms operators serving a multitude of end-users around the clock. This approach has been applied to the company's PV customers, so that now, according to Wagner, "where our customers are, we have a service center."

Finally, the speed of this rollout, be it on the "socket side" (Huawei's PV solutions) or the "pocket side" (Huawei's smartphones), has been phenomenal. Just three years after it entered the PV inverter market in 2013, Huawei earned the top spot among global inverter suppliers with over 20 GW shipped in 2016. In 2017, Huawei passed the 30 GW milestone, and there will probably be 40 GW in 2018, which would account for about 30% of the global inverter market. Over on the pocket side, it reached the top three category in just four years and is now considered one of the frontrunners in deploying next-generation 5G technology in mobile networks. We can expect 5G innovation to also benefit PV innovation at Huawei, be it in massive gigawatt solar farms or in households keen to enjoy homegrown clean energy. ♦



Photo: Huawei

Remote monitoring and digital communication between devices are key capabilities pushing higher energy yields from PV plants.

The inevitable path to solar grid parity

Digitization: With the next round of China's Top Runner Program pushing efficiency and energy yield requirements ever higher, digitization – enabling cooperation between intelligent systems – is emerging as a vital development in the industry. Huawei's smart PV solutions have an important role to play here as well.

“In 2017, solar PV achieved grid parity in a number of countries and regions, including India, Latin America, the Middle East, and Africa. The progress is largely attributed to the favorable natural conditions of these regions. To catch up, China still faces huge challenges. Our goal is quite clear: to achieve solar grid parity by developing technologies,” said Tony Xu, President of Huawei Smart PV Business, as he shared his thoughts on the key to solar grid parity in China at a seminar on the country's Top Runner Program.

With the first demonstration base established in Datong in 2015, the Top Runner Program has since been rolled out to achieve its original goals: Accelerate the application of new technologies to markets, develop PV technologies and PV industry upgrades; reduce the cost,

electricity price, and subsidy for PV generation; and reach grid parity.

The program is now paying off in the preliminary stage by promoting manufacturing technologies and reducing the electricity price. Going forward, digitized and intelligent products and technologies are expected to lead a new round of development in the PV industry.

Simple and efficient

“Many Top Runner Projects need to deal with great challenges posed by natural conditions, including undulating terrain, scattered landmass, and ongoing mine subsidence,” says Jian Zhaohui, Deputy General Manager of Power China Guizhou Engineering Corporation. Overcoming such challenges requires high standards from solutions and products. “We prefer inverters that offer a long

life cycle, high conversion efficiency, and easy, quick maintenance. The monitoring system should provide proactive reporting, smart analysis, remote monitoring, central management, open interface, and continuous capacity expansion.”

Smart inspection, for instance, has huge advantages over manual troubleshooting. According to Pei Yongfeng, Chief Electrical Engineer at Zhongtai Power Plant of Huaneng Shandong Power Generation Limited, the annual energy yield of the Xintai 100 MW solar-agricultural project could rise by 2.433 million kWh, thanks to the Smart I-V Curve Diagnosis function provided by Huawei FusionSolar Smart PV Solution.

Xu says, “With the technology advancement and rapid expansion of scale, the upgrade of PV power generation has transformed from component-

led to system-led.” He agrees with Wan Hong, Chief Engineer at the Design General Institute of Golden Concord Group Limited (GCL), when he says that smart PV plants should adopt system-level upgrades for future development. For example, a simple circuit system with digitized lights would not make much difference if the switch is not digital. Digitization requires full integration.

Xu explains, “Likewise, the previously interdependent PV module, inverter, and mount cannot sense [each other] or integrate with one another. In this way, the angle of the mount can hardly be adjusted to the geographical location and astronomical algorithm. When bifacial modules are put into use, a fixed algorithm does not work anymore because the reflection varies with the surface, and the intensity of sunlight also varies with the height of the module. The traditional inverter cannot collaborate with the tracker either. To increase energy yield, we should combine the inverter and bifacial module with the tracker by digital integration.” According to Xu, the combination of the three devices will be a major achievement of digitization in the next phase of the Top Runner Program.

“The first step is to replace the power supply and communication devices with the string inverter, which will improve reliability, optimize general investment, and most of all maximize energy yield.”

Intelligent integration of the tracker and inverter has taken effect in the Huaneng Xintai 100 MW solar-agricultural project. According to Pei, it reduces the workload of building communication and power supply circuits, as well as the communication failure rate.

The capacity of a single PV array is 1,750 kW. Using the Huawei smart string inverter can cut the construction cost by CNY 0.02/W (\$0.003) by sparing the dedicated power and communications cables for trackers. According to Wang Mengsong, Product Director at LONGi Solar, joint verification projects have been launched in Xinjiang, Heilongjiang, Guangdong, and Shaanxi to test the performance of bifacial module and string inverter integration at different latitudes, surfaces, and sunlight conditions.

On most occasions, the ground surface for a bifacial module cannot be chosen. “The ground reflection index varies with the season, since grass grows in summer and withers in winter. There is no way

to adjust the angle of the tracker by any algorithm. The digital string inverter, however, can detect the optimal power given a reflection index. The module can also send the real-time power back to the inverter. Then the angle of the tracker can be adjusted by an adapting algorithm.”

Digital integration enables interworking between systems. As for the seamless integration of the inverter, tracker, and bifacial module, Huawei has been a leader in the industry. Based on big data platform analysis, it has developed a leading smart design toolkit for the bifacial module. The toolkit combines an all-scenario, adapting and auto-learning “bifacial module + tracker” smart algorithm with the most efficient PV module maximum power point (MPP) intelligent tracking algorithm. Compared with the normal solution design, the toolkit helps reduce the electricity cost of a PV plant by CNY 0.08/W and raise the energy yield by more than 3.9%.

Raising the system energy yield

Xu uses a metaphor to illustrate the importance of reliability to digitization: “We use a kettle basically to boil water. To make it smart, we install a sensor and turn it into a digital kettle. If the sensor often breaks down and we can’t even boil water, no one would appreciate this type of digitization. The tracker is not widely used, mainly because the motor has a high fault rate. It is our ultimate goal that the machine serves the human, not the other way around.”

“A Top Runner project in Wuhai, Inner Mongolia, is located in a mining subsidence area with unstable terrain and large dust emission,” says Wan of GCL. “It adopted the Huawei string inverters with a high protection level and wireless transmission to adapt to the terrain. The project has maintained a device fault

rate lower than 0.5% and an energy yield rise of more than 2%, reducing the device maintenance workload.”

“To be a top runner, a PV plant should focus on efficiency. For long distance, however, it should put priority on reliability, which is determined by the device fault rate,” adds Ji Zhenshuang, Deputy Director of the China General Certification Center. The center collected the data of 150 PV plants for reliability analysis in the first half of 2017. “Taking the inverter for example, the energy yield loss rate incurred by faults is around 1.5% on average, and 0.5% for some quality products. The industry benchmark, represented by Huawei, is below 0.3%. So there is still plenty of room to improve reliability or reduce the loss rate incurred by faults.”

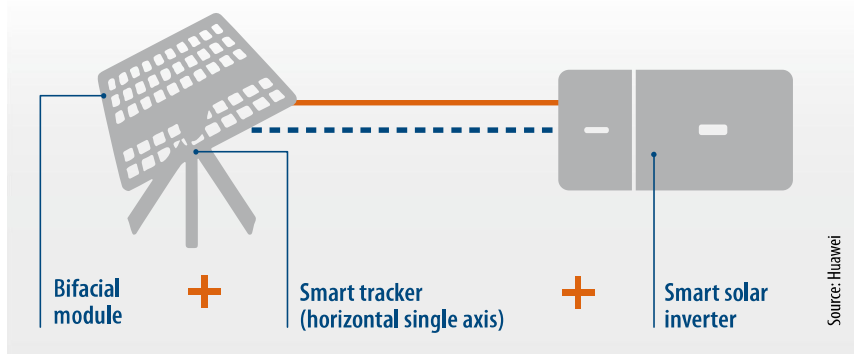
With regard to the reliability of the PV plant monitoring system, Ji says, “We usually evaluate the system function by the completeness rate of the monitored items and data collection. The figure is 85% for the industry’s average level, but more competitive companies like Huawei can reach above 95%.”

In December 2017, China’s National Energy Administration released the project list of the third-phase Top Runner program, including 10 application bases.

It is required that the bases started the bidding by March 31, 2018, start the construction by June 30, and complete the capacity building and connect to the power grid by December 31, 2018. The three deadlines for the technology bases are April 30, 2018; March 31, 2019; and June 30, 2019.

The third-phase Top Runner program is about to begin. With a total capacity of 6.5 GW and more projects involved, the scenarios will be more complicated. Digitization and intelligent components are driving the optimization and development of the PV ecosystem. ♦

Intelligently integrated PV system diagram



Graphic: pv magazine/Harald Schütt

Source: Huawei



Photo: NASA Earth Observatory

Satellite image of the 850 MW Longyangxia PV plant in China's Qinghai Province. In 2016 PV plant capacities exploded, requiring a more elaborate grid integration than the much smaller systems just a few years earlier.

Pioneering silicon-based green power systems

Energy transition: **pv magazine** had the chance to speak with Huawei Chief Energy Scientist Dr. Yunfeng Liu about the energy transition and the technologies that will drive it further, as Huawei takes a leading role in connecting more solar to China's grid.

When we meet Dr. Yunfeng Liu, Chief Energy Scientist at Huawei Technologies Co., Ltd. in Shanghai in March, Dr. Liu starts the discussion by mentioning Jeremy Rifkin and Rifkin's book "The Third Industrial Revolution." Rifkin coined the concept of the "energy Internet", which is premised on a high penetration of distributed energy resources that call for a different kind of grid than the top-down model based on conventional energy generation with its fleet of large scale plants.

As Dr. Liu points out, this transition to an "energy Internet" does not mean that conventional electricity networks are not sophisticated. They might not be premised on multiple nodes of distributed energy resources, but their operation is in fact anything but primitive, as described in more detail later in this article.

Germany's Pioneering Role

Dr. Liu also mentions the role of German science and technology, going back to the

19th century in the development of DC to AC power systems. He values Germany's pioneering role in making the shift to clean energy, including the deployment of distributed energy resources and a power system incorporating a large amount of renewables. Thanks to Germany's Renewable Energy Sources Act ("Erneuerbare Energien Gesetz" or EEG), promulgated in the year 2000, Germany provided the model to drive the investment in renewables.

The EEG provided the foundation for the country's energy transition (Energiewende) and the ongoing overhaul of Germany's established energy system.

China is undergoing its own massive Energiewende, as the Chinese government tries to replace polluting thermal power, still the backbone of the country's power system, with renewable energy resources. In 2017 China added a very impressive 53.06 GW of solar PV capacity, representing a year-over-year (YoY) increase of 53.6%. This amounted to more than half of what was added worldwide in 2017 (98.9 GW according to Solar Power Europe, the European PV industry association). On the wind side, China added 19.7 GW last year, about 38% of the global wind power capacity added (52 GW according to a report from the Global Wind Energy Council), making it the number one market for both solar PV and wind in 2017.

Strong central government support allows for a massive infrastructure build-out to transition away from thermal power generation to clean energies like solar PV. China's Three Gorges hydro-power project is the best example, but China's power sector also offers other prominent examples: The massive build-out of ultra-high-voltage (UHV) transmission lines from western to eastern China is a case-in-point. Most of these UHV lines use direct current, and a recent project completed in Anhui province involved the world's first 1,100 Kv UHVDC transmission line with a transmission capacity of 12 million kilowatts. As Dr. Liu explains, these UHV transmission lines collect energy from wind and solar farms in China's western regions and transmit them to China's major load centers on the eastern seaboard.

Making the connection

Huawei's focus is on the power generation side, and connecting these increasingly large renewable energy plants to the country's electricity grid. Despite the fairly recent rollout of these UHV DC lines, the paradigm is still the transmission and distribution system developed by mainly European and American inventors in the late 19th and early 20th centuries. Dr. Liu is full of admiration for the work of pioneers like Albert Einstein, Werner von Siemens, Charles Steinmetz, Nikola Tesla, and George Westinghouse, who perfected such a power system to

provide for a remarkably stable electricity grid capable of transmitting electricity at almost the speed of light over very long distances.

Their technology still governs how electricity grids are run today and instead of being "dumb grids" that need to be replaced by "smart grids," these grids are remarkably sophisticated: Subtle frequency shifts provide the control layer to run these grids to make sure that power generation and demand remain balanced and to maintain a frequency of 50 or 60 hertz. Conventional power plants, such as coal-fired thermal power plants that still provide the bulk of China's electricity, can also utilize shaft inertia to provide very short-term flywheel-like power to the grid. This is essentially short-term energy storage, and Dr. Liu points to a study of China's southern power grid, the second largest grid in China with a total power generation capacity of 270 GW in 2016. The effective moment of inertia provided by power plant turbine shaft inertia in this network, is 120 kilotons, comparable to a massive flywheel.

This ability of conventional power networks to supply short-term bursts of energy to stabilize the grid is lacking in renewable energy power plants. As China continues to push the envelope when it comes to ramping up renewables and decarbonizing its energy landscape, this deficiency is becoming a bigger issue for both the renewables camp and the established gridcos. Low cost energy storage is the holy grail, but Dr. Liu does not see a sufficient decrease in battery prices, at least in the short to medium term, to remedy this deficiency using battery tech-

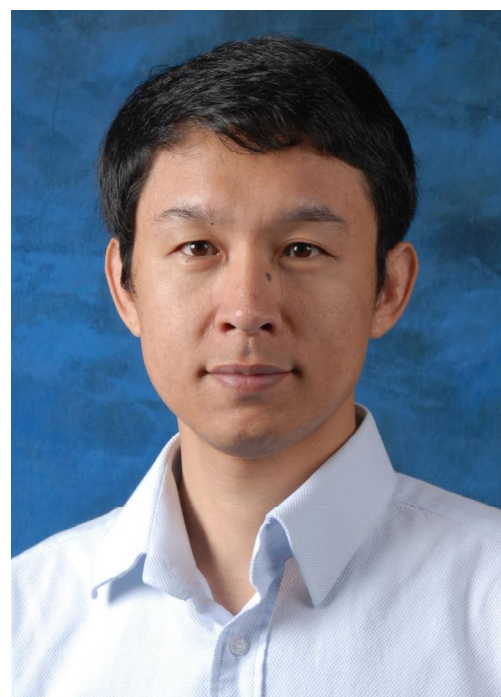


Photo: Huawei

Dr. Yunfeng Liu is Chief Scientist at Network Energy Product Line Huawei Technologies Co., Ltd.

nology. Nevertheless, Dr. Liu and his colleagues at Huawei's Watt Lab, which he manages, are devoting considerable resources to improving battery performance, be it on the energy density side or the power density side. While the former describes how much energy in kilowatt hours can be stored in a battery, the latter describes the speed at which a battery can be charged and discharged. Ramping-up charging times is especially difficult, but Huawei's Watt Lab has been especially productive in this area with its "magic" fast charge technology, which delivers up to 8 A of current, quadruple the 2 A used to charge conventional smartphones.



Photo: Huawei

Huawei inverters at a 590 MW PV project in Qinghai Province, northwestern China.

But if low cost battery units are still not available for large-scale ground-mounted PV power plants in a harshly competitive market like China's utility-scale PV market (where price pressures are far higher than consumers wishing to buy the latest smartphone gadget), Huawei can still provide technology to stabilize the integration of renewable power plants into China's grid. To replicate what pioneers like Steinmetz and Tesla achieved with conventional power systems, Huawei, under Dr. Liu's leadership, has developed silicon information chip technology to control the silicon power chip, to in turn control the power flow between generation assets and the grid. The aim is to simulate the turbine shaft inertia of conventional power plants to provide a certain reserve to help stabilize the grid.

Such DSP technology is already being deployed by Huawei in its Power Elec-

tronics Router, and this silicon-based grid stabilization mechanism became available just in time to alleviate serious PV curtailment issues in China and make an even higher rate of solar and wind power adoption possible. As Dr. Liu recounts, PV's ramp-up has come very quickly in China, with 10 MW PV power plants being the norm just five years ago in 2013. In 2014 the norm leaped to 30 MW, only to be replaced by 100 MW solar farms in 2015. And in 2016 plant capacities went to 1 GW, requiring more elaborate grid integration than the much smaller systems just a few years earlier.

Monitoring

Improved plant monitoring provides another mechanism to better understand and predict plant behavior, which in turn provides another lever to improve grid integration and stability. But we should

not expect Huawei's innovative string-level monitoring of PV plants to go to the module level anytime soon, cautions Dr. Liu. It is like the battery technology that could provide the final anchor of stability for renewable power plants, but are still too expensive to make it into the bids in fiercely competitive energy auctions in China or other big markets. Dr. Liu reckons that module-level monitoring would add 20 to 30% to the cost of the inverter, and this is simply too much for PV developers and EPCs in China. He does, however, point to the residential sector, which is still underdeveloped in China, but very far along in markets like Australia, Europe, and the U.S. Price pressures are not as extreme in this sector, and in its latest residential solution Huawei is already offering module-level monitoring to optimize output.

Eventually, Dr. Liu believes, module-



Photo: BMZ

Lithium battery cells are assembled at BMZ in Karlstein, Germany. Due its reliance on rare, relatively expensive materials, lithium-ion battery technology cannot rely on the model of falling prices seen in silicon PV.

Photo: Huawei



Huawei inverters installed at a project in Parsberg, Germany. Germany's Renewable Energy Sources Act, promulgated in the year 2000, provided the foundations for the energy transition. China is also undergoing its own massive energy transition with huge amounts of new PV being connected each year.

level monitoring will also reach utility-scale PV, but for now string-level monitoring is already providing significant benefits to large-scale PV power plants, especially when combined with Huawei's smart I-V curve analysis, which uses a range of algorithms to diagnose faults at the string level. As Dr. Liu recalls, when Huawei first rolled out string inverters for the PV market in China, the assumption was that the grid the PV plant was connecting to was a strong one. As plant sizes quickly grew to hundreds of megawatts and even gigawatt scale, the manufacturer realized that this assumption was no longer valid. For China's large gridcos, connecting hundreds of solar megawatts to their grid was a wholly different matter than a few here and there. The challenge for Dr. Liu's team (and Huawei's PV business as a whole) was to develop smarter inverters, which would work better with the grid and simulate some of the behavior of traditional power plants, with their turbine shaft inertia and other stabilization mechanisms. But unlike their thermal counterparts, this was going to happen with chip and IT technology, the core expertise of Huawei.

The right materials

Silicon-based technology plays a fun-

damental role in this story and also featured prominently in **pv magazine's** interview with Dr. Liu. Not only are the chips in Huawei's PV equipment silicon-based, but the main component in the PV power plant, the solar panel, is a silicon-based component. As Dr. Liu points out, silicon is essentially free, allowing micro-mechanical manufacturing improvements to drive down cost as scale increases. This has allowed PV electricity costs to decrease by 73% since 2010 and is also helping inverter manufacturers like Huawei reduce their cost as the supply increases. But as Dr. Liu makes clear, lithium-ion battery technology cannot rely on this model. Battery technology is not silicon-based and the materials used in making battery cells are not as bountiful as silicon. Instead relatively expensive materials like lithium and cobalt make up most of the cost of lithium-ion batteries – the batteries which exhibit the best performance characteristics (cycle time, energy density, and power density).

Accordingly, Dr. Liu does not see the learning curve "success story" of PV applying to lithium-ion batteries. Large new battery gigafactories being built in China will require extended government support until we reach the tipping point where batteries can be sold to electric

vehicle manufacturers or energy companies subsidy-free to make them competitive. This could well take 10 years, and as we have learned from other precious materials like copper, it is very difficult to predict the future price curve of these materials. That is the beauty of the basic material silicon, which is abundant and not subject to market speculation.

Once we get to this tipping point we might return to the direct current power system first deployed by Thomas Edison in New York City in 1882. The deployment of cheap battery storage systems within microgrids and other electricity networks might obviate the need to deploy power systems premised on DC to AC conversion. Already today we can see such power systems at work in small off-grid solutions, where DC appliances utilize clean DC electricity from PV arrays. This renaissance of DC power systems is clearly within Dr. Liu's vision of a future power grid supplying clean energy from distributed solar and wind resources to a universe of electricity consumers (a universe which will grow much larger as electrification conquers sectors currently relying on fossil fuels). We can expect Huawei to play an even more important role in such a power grid, both on the PV side and on the battery side. ♦



Photo: Huawei

Higher power ratings are a definite trend in the string inverter space, enabling suppliers to target portions of the utility-scale market that were previously off limits.

China's transition, India's growth, inverters' insight

Global inverter market: A strong 2017 for the solar inverter market may have mirrored growth elsewhere in the PV component chain, but the vital role that the inverter plays in a typical solar system may offer some clues as to where the solar industry is headed, both in 2018 and beyond.

It is often said in solar that the inverter is the 'brains' of the PV system. And as these systems themselves become more intelligent and sophisticated, the role of the inverter is evolving beyond simply inverting direct current (DC) into alternating current (AC), to incorporate a broadening range of functionalities.

"Twas ever thus, of course. Even the very early solar inverters boasted rudimentary intelligence features to ensure safety and consistency of energy supply. In 2018, the inverter remains at the vanguard of innovation in the solar industry: 'dumb boxes' no longer cut it, yet, by the same token, there exists a wide spectrum of inverter capabilities, from containerized central inverter units to module level power electronics (MLPE).

The result is that inverters can represent the sentries on duty atop PV's towers: alert to trends appearing on the distant horizon, attuned to the shifting winds of change, and with a bird's eye view of movements and developments within the industry itself.

In 2017, for example, three-phase string inverter sales outstripped central inverter sales for the first time ever. There are numerous reasons for this shift, not least the continued growth of the Chinese market – and especially its distributed PV sector – allied to Huawei's domestic dominance. Huawei only deals in string inverters, of course.

Growth in string-controlled solutions could also hint at the exhaustion of available large-scale sites in mature markets

(Japan), surging residential sectors (Australia and the U.S.), and maturing and re-emerging utility markets eager for greater data monitoring capabilities (Europe and MENA, for example).

Such trends can be extrapolated by pulling at just one thread in the inverter cloak – with many more awaiting to be examined.

2017 – a look back

According to IHS Markit's Senior Solar Analyst Cormac Gilligan, global inverter shipments in 2017 were around 30% higher year-on-year (YOY) against 2016, reaching above 100 GW for the first time ever.

"First and foremost, it is the Chinese market that has been performing

extremely strongly in 2017,” says Gilligan. “In that market I would suggest that inverter shipments are higher than actual installations. This is attributed to an expectation that 2018 will perform strongly.”

The intense competition to survive and thrive in China is not solely confined to the module players. In the inverter space exist not only market leaders Huawei and Sungrow, but also TBEA, Sineng and Kstar, each performing strongly in the utility-scale space.

However, while China’s utility-scale solar market remains bullish, growth dynamism has shifted notably eastwards away from the vast plains of the western regions and towards the more urbanized parts of the country in the east.

“This shift means that the sales channels for many domestic suppliers have evolved as more rooftop opportunities emerge,” Gilligan suggests. Companies such as Growatt, GoodWe and Ginlong have all benefited from this new trend. “From an international perspective this means that we may begin to see the likes of Growatt, GoodWe, and Ginlong build their presence in markets in Europe and elsewhere, with domestic stability giving them a launchpad to expand globally,” Gilligan says.

Analysis of inverter trends in India yields similar insight into how the solar market there is shaping up. The record year witnessed in 2017 was a major factor in the ~30% global growth in inverter shipments, with a number of installers active in India feverishly stockpiling inventory of inverters in an attempt to beat the Goods and Services Tax (GST) that applies an additional 5% import tax on the already-painful 18% rate for inverters.

“Many firms pre-ordered their inverters in bulk in 2017 in case they were going to be taxed, so we will see the majority of these inventories used up and installed over the course of 2018,” elucidates Gilligan.

The GST may compel more international firms to build local production facilities in India, particularly if the wider Indian solar market can stay the current growth course. China’s Sungrow recently finalized the details of a 3 GW inverter plant in Bangalore, and ABB has large capacities in the country. “Other companies growing their presence in India include General Electric, Fimer,

2017 World PV inverter supplier rankings Shipments (MW)

Rank	Company Name
1	Huawei
2	Sungrow
3	SMA
4	TBEA Sunoasis
5	Wuxi Sineng
6	ABB
7	Kstar
8	Goodwe
9	Growatt
10	Power Electronics

Source: IHS Markit © IHS Markit 2018

Gamesa, Siemens, and Ingeteam, joining the more established players such as TMEIC, SMA, Schneider Electric, ABB, and Hitachi,” says Gilligan.

Central reservations?

The threat of string inverters to the central inverter market space has been kicking up dust on the horizon for many years, and last year the tangible shift arrived. But does this mean the gap will continue to widen as string inverter solutions eat deeper into markets traditionally ringfenced for central inverters?

Yes and no, says Gilligan. Some of the most rapidly growing markets are to be found in Latin America and MENA, and in these regions there remains a firm preference for central solutions. “Mexico is growing strongly, and that market has a lot of Spanish and Italian players active, including the likes of Fimer, Nidec, and Ingeteam – all of which have centralized solutions.” However, Mexico’s potential will see a number of Chinese firms attempt to build on the foothold they already have in the country, and this could mean a growing acceptance of using string inverters to build utility-scale solar plants.

“It is not as simple as saying one technology will triumph over the other,” Gilligan opines. Inverter-driven market insight allows us to know, for example, that India’s cost-conscious approach to large-scale solar development sees central inverters – which are still significantly cheaper on a dollar-per-watt basis than string inverters – remain the dominant choice.

“Logistically too, companies like ABB, Schneider Electric, and General Electric have been present in India in other capacities for some time, so they can simply upscale their technical engineers to be

able to service a central inverter and away they go – in India they have that advantage,” says Gilligan.

The MENA region is becoming a hotbed for vast, gigawatt-scale solar plants and that is where central inverters will still have a role to play. “The continuation of development of very large solar farms in India, MENA, and Latin America – and to some extent in the re-emergence of Spain and Portugal – will deliver a steady stream of revenue for suppliers of central solutions,” predicts Gilligan.

Higher power, higher cost

Despite the growth in three-phase string inverter solutions, central inverters remain more attractive on a dollar-per-watt basis. This begs the question: Are solar developers now more versed in looking at longer-term opex costs as opposed to fixating on the initial capex?

By digging a little more deeply into the types of string inverters gaining traction, the answer to that question becomes a little clearer. Most leading inverter providers are now offering – or will soon offer – string inverters with far higher power ratings than previously. This trend, driven by incremental technological developments that allow for more power in less space, means that a typical string inverter could be 60 kW to 80 kW, or even above 100 kW (Sungrow and SMA are just two inverter firms offering this string solution).

“The impact of this trend shows that the solar industry is almost coming full circle,” reveals Gilligan. “Inverters sized at 100 kW were quite common around seven to eight years ago, but they were designed as central inverters and very heavy. They died off, but now that the technology has caught up, many firms are in a position to miniaturize the string inverter.”

High-powered string inverters are proving good solutions for ground-mounted plants in the 20-50 MW range, and thus have begun to be embraced in markets such as Japan and the U.S. where solar plants of this size are increasingly in vogue. “Lots of string suppliers have gone down this route because it is an effective way to compete with central inverters on cost, although suppliers of central inverters have also been showcasing their higher power solutions recently and so stayed ahead of the game.”

Gilligan is confident that most leading inverter firms in the string space are now

Photo: Ian Clover/pv magazine



Huawei has famously shaken up the inverter space with its string-only portfolio, and in seeking wider market share and broader revenues is set to go after the lucrative residential spaces of the U.S. and EU.

working on products that have a power rating above 100 kW – a trend that has been driven by the coming-of-age of very nascent solar markets in Sub-Saharan Africa and Southeast Asia.

To compete here, Gilligan says, most suppliers will have to be able to offer string inverters of between 100 and 125 kW in order to compete on price. “Given the low tenders that went into some of these markets, that is the only way to be competitive from the off.”

From string to module level

The growth of string inverters should also be examined, of course. In markets such as Turkey and Brazil, both of which are expected to be gigawatt-scale markets, companies such as Sungrow, SMA, and Huawei are having joy with their string solutions, with the former two firms happy to let their customers decide which type of product to select from an increasingly broad portfolio.

“We should not overlook the role that strong C&I markets globally are playing

in boosting string inverter adoption,” adds Gilligan. “In this segment there have been some nice wins in India for Huawei, for example, and also in Japan where domestic brands are strong.”

In the module-level power electronics (MLPE) space, 2017 represented another exceptional year of growth and development for the sector’s leading players, not least Israeli firm SolarEdge, which rose to third place in the U.S. in terms of inverter shipments – a rise underpinned by its premium rooftop offering of DC power optimizer+inverter+energy management system.

Microinverter specialist Enphase also returned to growth in the U.S. last year, and both firms – alongside optimizer specialist Tigo – can expect success in the markets of Australia, Europe, and the U.S. this year, Gilligan believes. He goes on; “2018 will be another exciting year for MLPE because we will really see Huawei push into this space. We are yet to have confirmation that Sungrow will do likewise, but we do anticipate some type of MLPE solution to emerge from them sometime soon.”

China, on the other hand, is not ready for the type of premium offering that most MLPE solutions provide. Instead, companies such as SMA and Huawei may find some joy with their selective deployment solutions, where some but not all modules in an array are fitted with an MLPE component.

A sea of modules, controlled by string inverters: Such a sight is increasingly common across the globe. Trends within the inverter space that shape PV in more ways than are immediately obvious.



2018 and beyond

Inverters may be solar's canary in the coal mine with their fingers on the pulse (and all manner of other lazy clichés and idioms), but they are not crystal balls. By analyzing this industry, one can certainly get a hint of the forces shaping other links in the solar chain, but nothing is set in stone. "The overarching theme we see from looking at inverter data is the undoubted growth of grid requirements as PV becomes a larger proportion of the energy system," says Gilligan. "Grids will need more controls in place, and this will most likely be done with the power electronics that exist, which means MLPE in residential and the C&I context becomes vital, and more string inverters at scale play their part in data analytics and cloud-based control."

Beyond that, inverter installation perspectives can give a flavor of what to expect from the world of solar in 2018. "Installations in India will continue to be strong and we expect further manufacturing announcements from particularly Chinese companies over the next five years there," Gilligan predicts. "In China there is certainly good supply at the moment, but we do expect Q1 data to show a post-rush relaxation."

Utility-scale growth can tend to be lumpy as developers and EPC companies take breathers after finishing massive projects, but inverter demand will be a little smoother and is likely to enjoy



Photo: Huawei

Huawei inverters installed at a ground mounted PV project in Japan.

global year-on-year growth in the single digit range for 2018, the IHS Markit analyst forecasts.

"If inverter suppliers feel that markets are cooling, they are quick to enter other markets and other segments," concludes Gilligan. "SolarEdge, for example, has developed a 100 kW solution for the C&I space, while Huawei has gone in the opposite direction with its residential offerings."

Most firms in the inverter space are also looking to expand into other tech-

nology areas including energy storage, O&M, or using the data that they harvest, as seen with SMA's new subsidiary, Coneva.

"This is the great trend we will continue to see. Whether it's inverter firms developing electric vehicle charging stations, or battery inverters, or cloud-based O&M and monitoring control, the industry will witness a continuation of inverter suppliers not solely trying to compete on costs, but targeting greater integration and broader portfolios." ♦



Photo: Huawei

David Naismith is the Founder and Executive General Manager of Solgen Energy Group.

Commercial appeal

Partner interview: The Australian market for both residential and commercial solar has seen major growth in recent years, and new installations continue to appear at breakneck pace. **pV magazine** speaks with David Naismith, Founder of Solgen, an Australian company providing EPC services for commercial solar projects, on the advantages of partnering with Huawei, and further prospects for this market.



Photos: Solgen

pV magazine: *Can you tell us briefly which markets Solgen is currently most active in, and why?*

David Naismith: Our project business is focused on the commercial and industrial sector. Our internal definition of this market is systems in the range of 30 kW – 3 MW, usually rooftop, usually behind-the-meter.

As an extension to this we are also active in the small-scale utility market up to 30 MW and have a new ventures team looking at adjacent opportunities across storage, energy networks, financing and several other areas to support our market.

Domestically, Australia's rooftop solar sector has been soaring in the past few years. From your perspective, are you expecting further growth across both the residential and commercial & industrial (C&I) rooftop space?

The C&I market has not only grown in average system size, but also in volume; and the residential market has seen average system sizes grow, while total installed capacity has remained relatively flat. We expect that this trend will continue as market penetration in both commercial and residential markets matures.

The runway for growth in the C&I market is enormous, and the residential market will continue to unlock opportunities in new areas such as storage, peer-to-peer energy trading and new technologies.

As the market has grown, what new challenges has Solgen had to face? Are cost pressures much more difficult these days?

Becoming the largest player in the commercial market has focused our attention on having the right people in place to deliver the promise we make to our customers. We are a cus-

tomers-centric business and maintain industry leading standards across our people and processes. Attracting and retaining people that meet this standard takes time, as we invest heavily in training and development in what is a relatively new industry. While this has been a challenging process, we are confident that this investment will underpin our industry position well into the future.

As a result, we have not experienced significant price pressure in the C&I space. Our market and the type of investment our customers are making in solar means that lowest-cost operators from yester-year do not really have a place.

From a customer perspective, are their needs and wants altering? If so, in what way?

Most recently we have seen customers seeking opportunities for new technologies across several areas including storage and monitoring, along with financing opportunities. Customers are now looking to maximise their budget for solar as returns against traditional energy have increased. This has introduced opportunities to leverage customer spend through financial structures such as leases and power purchase agreements.

Post-installation performance and monitoring of a rooftop solar system is becoming even more imperative as more and more people adopt solar. What role does Solgen play in ensuring this market segment in Australia maintains high standards?

Consistent with our customer-centric approach, we are one of the few industry players with a dedicated operations and maintenance team. This team monitors our customer systems 24/7 and actions ad hoc and periodic maintenance regimes. This means we can confidently guarantee the performance of our



Solgen developed this 100 kW solar system on the rooftop of Hollick Wines winery and restaurant in Coonawarra, South Australia. The project is estimated to have reduced the winery's consumption of on-grid electricity by more than 50%.

customers' systems, thus underwriting their business case for solar.

Can you describe some of the benefits of working with Huawei? When did the partnership first begin, and what has been the feedback from customers using Huawei's technology?

Huawei had established the foundations for an industry leading product and service platform in other markets before entering the Australian market. This gave us the confidence to partner with Huawei within Australia. Huawei is an adaptable organisation that fits with our own standards across delivering industry leading technologies with outstanding support.

We have been working with Huawei for over a year now and in this time our customers have begun to recognise the product and service benefits of Huawei inverters over its peers while delivering at an attractive price-point.

The string inverter landscape is extremely competitive and offers a multitude of varieties for customers to choose from. Typically, what type of customer opts for – or is recommended – a Huawei inverter?

Customers generally realise that the inverter is effectively the heart of the system. As a result, there are many attributes that customers seek. Most visibly, these attributes focus on warranties, service and support, while other attributes such as inverter efficiency are less prioritised.

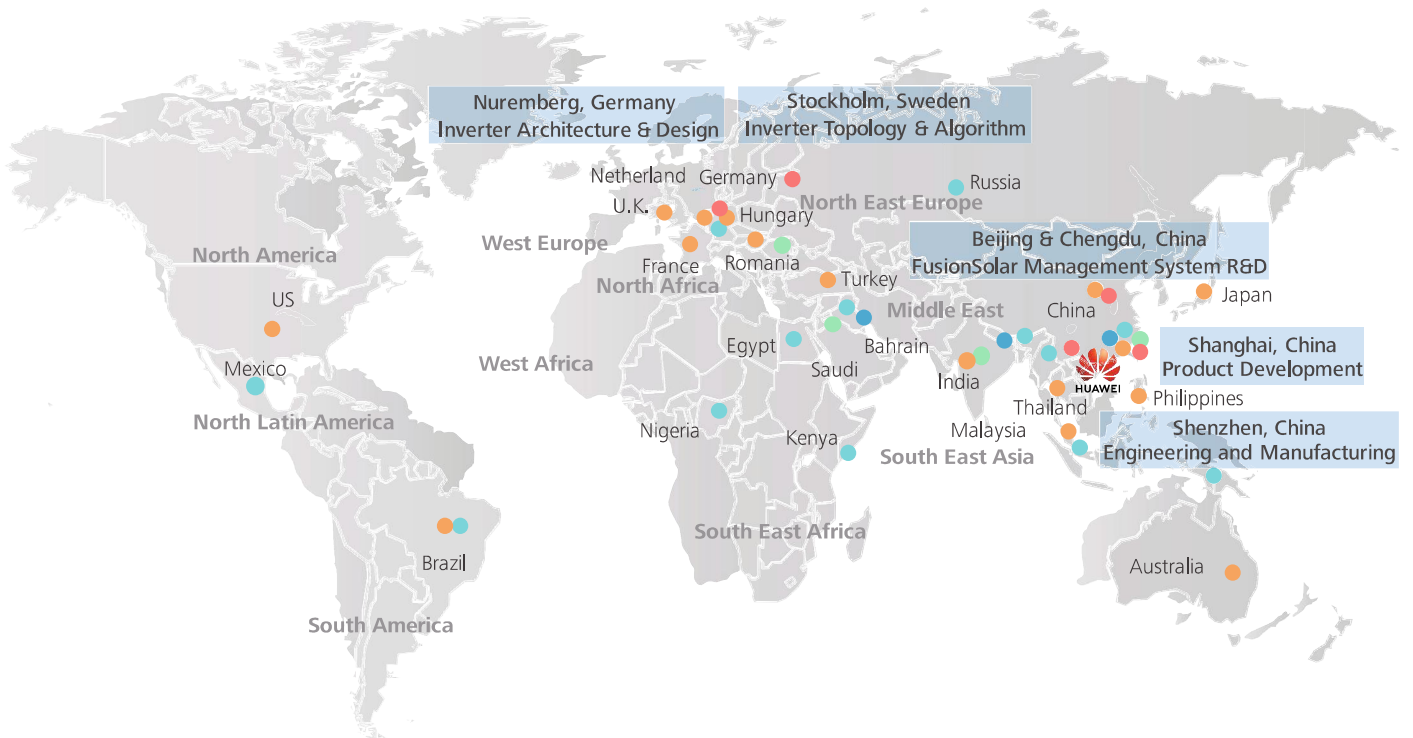
Our comprehensive design process highlights more salient attributes of the Huawei inverter such as flexibility across string configurations. Ultimately this can save the customer money while delivering an industry leading solution with the backing of a global inverter brand. ◆

“Huawei is an adaptable organisation that fits with our own standards across delivering industry leading technologies with outstanding support.”

Huawei Global







Where there is our product there is our service



- Global R&D Center of Network Energy
- GNOC: Global Network Operation Center
- Service Regional Center
- Global Customization Center
- Spare Parts Center



Huawei in Australia

<p>2004 Established with 20 staffs</p>		<p>50% + Australians use Huawei product for telecommunications needs</p>
	<p>vodafone 100% LTE & Networking OPTUS 50% LTE & Networking TRG No.1 Access Networking</p>	
<p>800 + Employees</p>		<p>10 Authorised Service Centers</p>

Huawei FusionSolar

As a global leader of ICT solutions, with **over 27 years** of experience, HUAWEI has developed the **FusionSolar Smart PV Solution** that combines **PV technology** with **digital information** and **Internet technology**.

FusionSolar Smart PV Solution: A Simple, Fully Digital Solution with Automatic O&M

According to the reports released by global consultancies **IHS** and **GTM**, the shipment of Huawei inverters is ranked **No.1** worldwide.



Excellent Inverter Performance and Operation Verified by TÜV, **Availability - 99.996%**





Andy Tang is Chairman of New Green Power. To date, the company has developed around 150 MW of PV projects in Taiwan and Japan.

Unique challenges bring O&M into focus

Partner interview: From two employees just five years ago to more than 100 today – Taiwan’s New Green Power has expanded rapidly. Through the project developer and EPC’s partnership with Huawei, Andy Tang, Chair of New Green Power, says that the unique challenges posed by carrying out O&M in Taiwan can be met.

pv magazine: *What is New Green Power’s current project status and market positioning?*

Andy Tang: We are now the leading project development, EPC, and O&M company in Taiwan. Here in Taiwan we have completed around 50 MW of PV, and if we include the projects we have developed in Japan it is 150 MW.

And what is your outlook for 2018?

This year we are aiming to complete around another 50 MW of PV projects.

How would you describe New Green Power’s projects in Taiwan?

Most of the projects are on rooftops, because ground-mounted projects are not easy to develop in Taiwan – due to complicated policy and regulations.

Besides rooftop projects, we are also doing floating projects in 2018 – around 40 MW in total across four or five projects. Some big ground-mounted projects will be started in 2019. There is a 30 MW [project] plus two 20 MW projects, so around 70 MW of ground-mounted systems next year.

Because regulations are quite complicated in Taiwan, investors are looking to work with local partners. One investor we work with is Macquarie Capital, and they are a good example of this.

Taiwan is not such a big island. How difficult is it to find suitable land for ground-mounted PV projects?

Our government has announced some special areas that are not appropriate for agriculture. So our government wants our investors to utilize this kind of land to build up PV systems. Here in Taiwan, there is no really good land for us to build ground-mounted solar PV projects on. Most of the land which can be used to develop solar projects, is not in very good condition.

And how do you deal with this low quality of land?

Most of the time we use concrete piles and enhance the height of the system to around two meters – at least – in order to avoid flooding issues and sinking land issues. Often the drainage systems there are not good.

And installing close to the coast can also be tricky. What do you do there?

Salt problems are another big issue. We have to use a special coating for the modules, which is salt resistant. Recently we used a module that was manufactured in Taiwan, mainly because of the FIT – there is a special FIT bonus if we use a module made in Taiwan.

But the modules we use pass strict and severe tests, and some have received special certificates from Taiwan, to make sure they can cope.

You also partner with Huawei, both for use in your projects but also as a distributor. Why did you make that decision?



In 2018, the company expects to develop around 40 MW of floating solar projects in Taiwan. To date, much of New Green Power's operational capacity has been on rooftops, due to land constraints and regulation in Taiwan.

We work with Huawei because after we conducted a lot of studies, we concluded that their products are very reliable over the long term.

“Huawei has integrated its communications technology into the solar inverter – which is good for our monitoring systems”

What features in particular give Huawei's products an advantage?

They are robust and offer products with multiple MPPT trackers. There is also the ease of installation.

But I think most importantly, Huawei has integrated its communications technology into the solar inverter – which is good for our monitoring systems, and for long-term operations and maintenance (O&M).

At the same time their name brand is very good. They are a big brand.

You mention ‘robust’. There is salt spray, heavy rain, even typhoons and hot, humid conditions in Taiwan. Huawei inverters can survive these conditions?

Yes, that has not been a problem.

You also carry out O&M for your own and other arrays.

How does this work?

Usually, we sign a contract for five years with the plant owner and renew this automatically if nothing special happens. At the moment we provide O&M services for around 70 MW of solar PV.

We integrate the string monitor design into our O&M approach, and from this perspective we can easily check which string is not in good condition and we can check – test – for that string. If our investor partner does not have string monitoring available then it is more difficult to check which string and which panel is going wrong.

You now have a big pipeline for 2018 and 2019 – including floating PV, ground-mounted, and rooftop. Will you work with Huawei on these?

Yes. With most of these projects we will cooperate with Huawei.

You also act as a distributor for Huawei. Do some customers have a preference for home-grown inverter suppliers?

Some customers don't like to use mainland Chinese products. But from our perspective, we use a good product no matter where it is from.

Huawei is a good PV inverter manufacturer, and they are very professional and can respond to our questions in time. We are very happy to cooperate with them. We are their biggest distributor in Taiwan. ◆



Photos: Huawei

Huawei's FusionHome residential inverter installed in a family home.

Homing in on residential solar

Rooftop goals: At Intersolar Europe 2017, Huawei took its first steps in the residential PV sector, introducing its FusionHome Smart Energy solution, with inverter capacities from 2 to 5 kW. After ramping up production of this solution in the second half of 2017, Huawei is now targeting the biggest residential solar markets, and aiming to be a key player in integrating the whole energy system.

Since entering the PV inverter market in 2013, Huawei has more than proven its ability to grow quickly into a major presence, pushing prices down and driving the adoption of new technologies. Already the leader in global inverter shipments for the utility-scale segment by most analyst estimations, Huawei also offers products for the rapidly growing

commercial and industrial space, and is now beefing up its presence in the residential sector.

“We have enjoyed a lot of success in the commercial rooftop markets of Europe, Japan, the U.S., China, and the APAC region,” a Huawei spokesperson told **pV magazine** at the launch of the company’s first residential offerings in 2017.

“So, as requested by our customers, and driven by the development strategy of Huawei itself, we will expand our product portfolio to residential markets. This will be an important year for us to have a global launch of residential products in Europe, Australia, China, and the U.S.”

Huawei states that now is the right time for it to move into the residential PV mar-

ket, thanks to its accumulated experience and proven technology in commercial solar projects, as well as steady market performance and mature channels. According to Huawei's spokesperson, the company's goal for residential PV is "to realize the visualization of energy management, and to build a new, fully digitized home energy system."

Integrated system

Key to Huawei's strategy in residential PV is the focus on building a digitized energy system, and integrating all aspects of home energy – PV power generation, storage, consumption, and system maintenance – into one management system. "Huawei is a new entrant, but we are an innovator," continues the company spokesperson. "We innovate and develop PV technology to be the highest efficiency and the most intelligent. The goal is to open roads to a digital PV world: to bring digitization to every PV enterprise. Huawei will assist home energy management's transition to a new era."

The residential offering from Huawei also aims to focus on the customer, beginning with housing the product in a sleek, smoothly edged white box that would not look out of place in any modern home. The inverter is also 'storage ready' for those homeowners who want to add a battery; or want to have this functionality available for the future.

Like all of Huawei's PV solutions, the residential inverter communicates with users via the FusionHome-NetEco 1000S PV management system, allowing homeowners to quickly and simply monitor their PV system's performance and their energy production. This system allows for easy access via smartphone, with detailed energy yield reports, up to 20 years of data storage, and the option to receive fault alarms via email.

"Managing solar PV, storage, and consumption at home is a different challenge for us. This is why the new inverter is presented as part of our FusionHome Smart Energy Management System," the Huawei spokesperson adds. "Huawei's residential solutions focus more on what people feel and think, to provide the best experience of a home energy system."



After launching new products for the residential market last year, Huawei is ramping up production and preparing to move into major residential markets including the U.S.

Huawei is also rolling out optimizers as part of its residential package, which can help to counter the effects of shading by isolating the effects to just one module, rather than the whole system. They also allow for modules to be installed facing in different directions. Huawei's smart PV optimizer can be mounted to the frame in the warehouse for easy installation, is waterproof (IP68) for outdoor installation, and allows for rapid module voltage shutdown – an important feature given safety regulations for residential PV systems in leading markets including the U.S.

Key markets

After the launch of residential products last year, Huawei initially maintained its focus on China and European markets.

This year, however, launches are planned for other major residential markets, beginning with the U.S.: Huawei has announced a partnership in the U.S. with monitoring and data analytics firm Locus Energy – which will allow it to leverage data centers and other infrastructure within the country.

"Huawei's FusionHome Smart Energy Solution is an important addition to the U.S. residential solar market," said Locus Energy President Michael Herzig. "We

are very excited to partner with Huawei on this initiative, and provide their customers with our monitoring platform, including our unique analytics offerings to help ensure system output is optimized."

China's interest in residential and distributed solar grew substantially in 2017, and this may also have been advantageous to Huawei's plans. "In China, one of the interesting things is that the residential market is starting to take off: That was a key driver for many residential inverter suppliers in 2017," explains Cormac Gilligan, Research Manager Solar and Energy Storage at IHS Markit. "What that means is that they will have achieved volumes in the hundreds of megawatts range – approaching 1 GW in some cases. That will give them a nice cushion to internationalize. With a player such as Huawei, they can just pick out all the data, and look at where the big residential markets are."

Changing tack

It is also important to note that operating in the residential sector requires very different methods of doing business in comparison to utility projects, where Huawei has already made a name for itself. "It's a different customer base – you're dealing more with distributors and installers, and thousands of systems," explains Gilligan. "In these markets for residential you need to partner with big distributors – it can be very fragmented. Huawei, in terms of strategy, is going after what are perceived to be some of the big markets – Germany, Australia, the U.S., China."

As Huawei moves into competition with established players in the residential sector, the company's experience in consumer electronics could help it to gain an advantage. "Residential is almost like B2C, it's more hands on than utility-scale," adds Gilligan. "There is a higher quantity of customers to deal with, you need more people for sales, service, and installation, etc. Through its sister divisions in smartphone and telecoms, Huawei has a history in high volume customer-based approaches that it will be able to leverage. So far it's early days, but they will have very aggressive targets." ♦



Photos: pv magazine/Emiliano Bellini

A small country with a dense population, lack of suitable space represents a major challenge for the energy transition in the Netherlands. However, the country's rooftop segment has remained stable, thanks to homeowners opting for PV, as well as energy efficiency policies for new buildings.

Aiding the Dutch energy transition

Huawei residential solution: The Netherlands is a country with one of the highest population densities in the world and, as a consequence, it has constrained availability of surfaces and land for all kinds of purpose, including the deployment of rooftop solar power generators. Residential PV could really help the country implement its challenging energy transition, which is to reach its almost impossible RES targets for 2020.

Dutch citizens and homeowners seem not to have been discouraged by the challenges ahead for the country's energy transition, because the number of residential rooftop PV projects developed and installed under the country's net metering scheme has risen tremendously over the past few years.

Sometimes, however – particularly atop the peculiar rooftops of a city such as Amsterdam in which the historical buildings in the center represent one of

its most valuable assets – the lack of viable space seems to pose an insurmountable challenge for the installation of a PV array, even of the smallest kind.

But not all homeowners in Amsterdam are being deterred from adopting solar power. One proud Dutchman has decided to install a PV system using solar modules provided by South Korean electronics group LG, and connected in combination with the Huawei FusionHome Smart Energy Center (inverter).

The roof of this gentleman's apartment, which consists of a small standalone building located in the center of a courtyard surrounded by much higher apartment buildings, presented a serious problem regarding shadowing during certain hours of the day, as well as a few issues for the project's logistics.

However, an ingenious solution was developed, in order to ensure that the installation process was in fact quite simple.

Jayant Parimal, CEO of Renewable Energy at Adani Enterprises – one of the largest project developers operating in the Indian market.

Photos: Adani

Scaling string in India

Partner interview: Jayant Parimal is the CEO of Renewable Energy at Adani Enterprises, which has developed more than 1 GW of PV projects in India in partnership with Huawei. Recently, **pV magazine** caught up with Parimal in India to discuss the massive opportunities in the country, and Adani's switch from central to string inverters.

pV magazine: *As India's largest solar power developer, what are your strategic business objectives in clean energy for 2018 and 2019? Given India's unprecedented growth in solar energy recently, how has your performance been in 2017?*

Jayant Parimal: Last year was good for us, and for India too. India installed almost 10 GW of solar, and we completed around 1.4 GW solar. Now, our portfolio stands at 2 GW of solar. There is a lot of competition in the market, several solar developers and EPCs have taken punts on falling module prices. A lot of innovation is happening, there is no doubt about it. However, predominantly the focus is on module cost.

In 2016, module prices really fell, that encouraged lot of people to take a punt, reduce bid prices and continue with aggressive numbers. We do not know how practical it is, but anyway, the prices fell.

We are also seeing opportunities outside of India, like we are already executing some projects in Australia and the United States, and planning to explore the Far East and African markets.

Adani started to team up with Huawei in 2016 and there is more than 1 GW of PV plants commissioned. Huawei's ICT history set the company in good stead to grow rapidly in the inverter space. How did the firm's background help Adani identify Huawei as a preferred partner?

In 2016 we were developing large projects using central inverters, and the same year Huawei entered the Indian inverter market. They came and presented their proposition. At that time, it was difficult for anyone to digest the fact that string inverters can be a good solution for grid-scale PV. But, somehow, they were able to convince us that we should look at it. We did some pilot testing, and then we took a plan and ordered almost 1.25 GW. After that we built our plants using only Huawei inverters. In 2018, we do not have any PPAs, otherwise we could have procured more from them.



In recent months the Indian solar market has seen a raft of record-low PPAs signed for large-scale solar. While cheaper solar is good for many parts of the PV chain, it does pose a problem for O&M providers. How is Adani hoping to tackle and overcome this problem of squeezed O&M margins?

We maintain our plants ourselves. So, whatever 2-2.5 GW we have, they are reasonably priced. We have sufficient capital for O&M. However, looking forward we see very aggressive assumptions on O&M. If any of the assumptions do not hold true, then people will end up with losses. It is a very big challenge. In fact, people are taking aggressive action. Everybody is under pressure to reduce their cost. Thus, somewhere you might be inadvertently compromising your quality, which will haunt you later. We are avoiding this, at least until now we have not fallen prey to that.

The 50 MW power plant located on Mahoba using the Huawei FusionSolar Smart PV Solution was already commissioned a few months back. Is there any experience you would like to share with us?

FusionSolar Smart Management is a software product which is well above standard string inverters. It has better monitoring flexibility. So Huawei have offered us, and we have taken one sample, which we are right now experimenting with in one of our plants.

It is a good platform to monitor assets, and there are features not available elsewhere. If you can control your plants better, then you can monitor them better. With this feature you can ensure

that all your strings are in optimal working condition. As soon as there is any failure, it will notify you. That way the plant availability is good – performance ratio is good, so it helps. Otherwise, the inverters are everywhere, so this is only one incremental factor, which is compatible to their inverter.

What are the benefits of using Huawei's string inverters at scale? Is it simply a case of better opex versus capex?

String monitoring can also be done with central inverters. It is just that you must install the string monitoring facility – you have to add additional equipment. Thus, some of our plants uti-

lize central inverters with string monitoring facilities. However, string inverters are slightly better in terms of performance, because there is more maximum power point tracking (MPPT) for every megawatt of modules. Since the biggest risk in any solar plant is mismatch loss, having more MPPT helps you to reduce risk.

Nowadays, there are up to 3.5 MW in a single central inverter, but only one MPPT. If the terrain is flat and everywhere receives uniform irradiation, it is fine. But if terrain is not so flat, irradiation varies from one place to another, and it may perform sub-optimally compared to a string inverter. String inverters, I

Photo: Adani Enterprises



This 100 MW solar park in Telangana, India, was developed by Adani and utilizes string inverters from Huawei.



Photo: Adani Enterprises

Adani has announced plans to expand its cell and module manufacturing capacity in India to 2 GW.

believe, offer 1 MPPT for every 12.5 kWp. Every 100-200 m² you have MPPTs, so performance is better.

Additionally, with multiple string inverters, even if one fails only a few kilowatts are affected. That way availability would be slightly better – that is another advantage. Although you have to install so many of them, so it gives you a slightly tougher time during installation. However, once they are installed, it is fine. In opex, we have been told there will be better performance in terms of availability, etc. For instance, we are operating them for six to seven months. We have good experience: Until now we did not get any serious issues. However, six to seven months is too small a period compared to 25 years' plant life. But we can say that their system does provide greater monitoring and control.

How is the prospect of the solar industry in India?

Good, I say. Now, solar prices are falling far below the average grid price. I am sure solar, as well as wind, will grow. Resistance from the distribution companies (discoms) to sign more PPAs should reduce – they should be willing to sign more. Another problem was that, because prices were falling, some discoms thought the more you delay, the cheaper power you will get. That also slowed the process of bidding. Once prices stabilize, then I am sure the discoms will sign more deals.

There are vast opportunities in the Indian solar market right now. But with growth and opportunity come challenges. What are the major pressures when operating in the Indian solar market?

All developers right now are facing the issue of duty uncertainty. Plus we have a lot of issues on PPAs: Some of the distribution companies do not honor their PPAs at times, and there is pressure for the renegotiation of PPAs. Two years back, INR 5-5.5/kWh (\$0.075 - \$0.082) was a great tariff – everybody was happy. Today it is INR 2.5/kWh. So the fellows who had signed the contract at INR 5/kWh – they want to renegotiate. Solar plants are predominantly capital, where O&M is hardly anything. Falling module prices later are not going to give us any benefit, once we have already installed our plant. Discoms do not realize all of these things, and so pressure unnecessarily. Therefore, the sanctity of the contract becomes an issue. It is unfortunate – you do not expect such behavior from some government-controlled entities. In addition, there may be delays in payment, etc. due to the poor health of the discoms.

Plus, some of our older PPAs, which are at higher tariffs, face other risks of curtailment. Although in theory they cannot curtail, but in the name of technical reasons, they will. So, it affects our financial viability.

Huawei has also come up with module-level power electronics. What's your thought on this?

They have come up with some viable propositions – we will be interested in that. Using string inverters or string monitoring devices, you can monitor a string. Roughly, each string has 22 modules. Thus, you are monitoring an average performance of 22 modules. Now, we are trying to go below 22 modules, and maybe every module.

They will be monitored and should send their performance data every few minutes. Thus, we can recognize which panel is doing what.

We have now set up our central control and command center, where we collect all our data and we are centrally monitoring

our plants. Moreover, all the big data from the plant which are sent to the cloud – we will add an Artificial Intelligence tool to them.

This will go through whole swathes of data and send some of this to analysts to rectify, in case of any errors. ♦

India's Solar Revolution

Prime Minister Narendra Modi is driving India to implement a solar revolution. The grand strategy has been well articulated and regularly reinforced since Modi was elected in a landslide in May 2014. Four years on, the impact is clear, the government conviction unquestioned, and the capacity to implement is building rapidly. It helps that the economics are now compelling. With both wind and solar tariffs both halving since 2016, new renewables are seen as the low-cost, deflationary source of new capacity. From being a major fossil fuel importer, India is now negotiating solar export contracts, a remarkable transformation. There are plenty of obstacles, but with constant technology innovation, the opportunities are clear.

India's National Electricity Plan 2018 forecasts a near doubling of India's installed capacity by 2027 to 619 GW. Within this, thermal power is forecast to see its share drop from 67% in March 2017 to just 43% by March 2027. Excluding hydro, renewables' share of capacity will rise from 17% in 2017 to 44% by 2027 (solar at 170 GW as part of total renewables at 275 GW). Renewables are targeted to provide 40% of electricity generation by 2030, mirroring the transition path already evident in China and

the United States, but at twice the speed, benefiting from the compelling deflation solar is providing.

The evidence to show this path is on track can be seen in the chart below. Where India was installing 20 GW annually of thermal power in the four years to 2016, net thermal adds in the last two years dropped by 75% to just 5 GW annually. Solar installs doubled to 10 GW in FY2018, doubling cumulative installs to 22 GW. April 2018 saw the Chief Minister of Gujarat, Vijay Rupani, announce plans for a 5,000 MW industrial solar park in the Gulf of Khambhat. Little more than a headline at the moment, the economics are very supportive, given Gujarat is heavily reliant on expensive coal imports as its source of electricity, and solar tariffs of \$40/MWh are half the required rate needed to make imported coal viable. Also, the levelized cost of solar is well below \$40/MWh, given that this includes a flat nominal/declining real price tariff contractually for 25 years. On the back of this, India and Bangladesh are negotiating a ground-breaking 2 GW solar electricity export contract.

Solar technology innovation is still fast evolving, and an ongoing source of cost deflation driven by improved output and higher utilization rates. India is looking at commercial deployment across a range of opportunities, from floating solar to solar irrigation pumps and hybrid wind-solar-battery utility-scale combinations. India has the largest single location rooftop solar installation to-date in

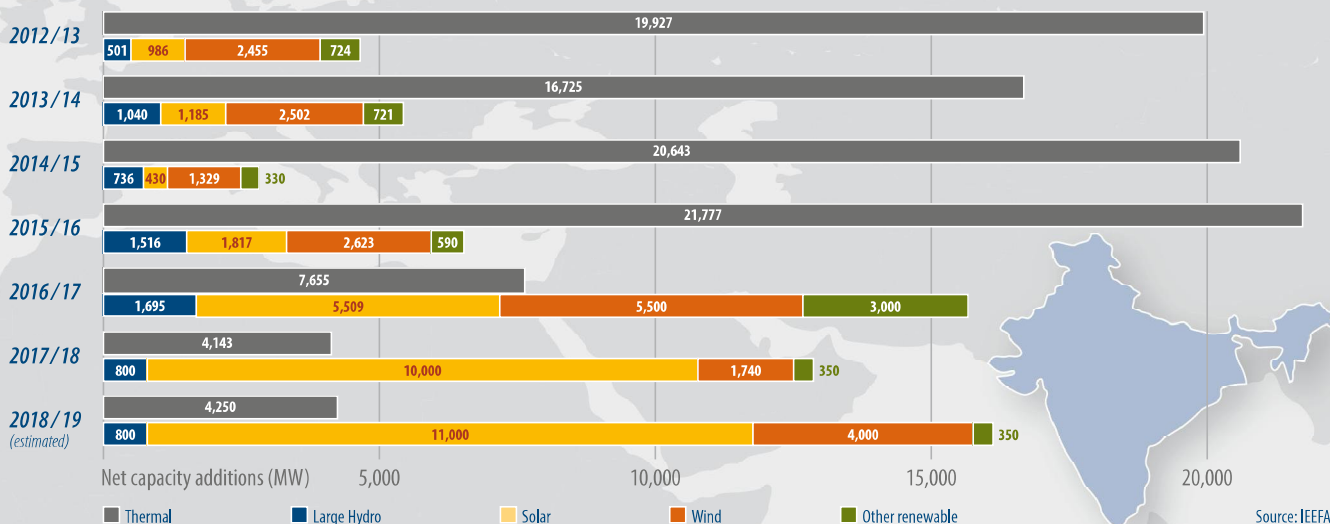
operation with 19 MW at a campus in Punjab. India is also leading the world in financial innovations like bundled solar-thermal power purchase agreements, where national power company NTPC Ltd is looking to scale down coal-fired power generation during midday solar peaks and substitute solar generation instead, allowing fuel savings but also in a clear acknowledgement that base load coal power is becoming an outdated concept. December 2017 saw the Solar Energy Corporation of India request expressions of interest for 10 GW of floating solar across the country. This follows the mid-2017 commissioning of the world's largest floating solar project in China at Anhui Province by Sungrow. China is due to commission two separate 150 MW floating solar projects in mid-2018. To conclude, concurrent with massive ongoing deflationary cost trends, solar is also rapidly expanding in scale. In IEEFA's view, technology innovation will see a clear global transformation of electricity markets, at the same time as electric vehicles are clearly disrupting traditional players in the automotive sector. A solar revolution is underway, deflationary, unstoppable, and accelerating.

Tim Buckley, IEEFA



Photos: Rays Power Infra

IEEFA: India renewable and thermal power capacity additions



Graphic: pv magazine/Harald Schütt



Photos: Enviromena

Sami Khoreibi is the CEO and Founder of Enviromena, which is one of the leading EPC firms operating in the Middle East & North Africa region.

Local knowledge, global scale

Partner interview: Enviromena is a leading EPC company operating in the Middle East and North Africa region. The company's CEO and Founder, Sami Khoreibi, discusses the advantages of working with an experienced company offering intelligent solutions.

pv magazine: *To begin with, can you provide us with a brief outline of Enviromena's main activities, markets, and strengths?*

Sami Khoreibi: Since Enviromena Power Systems was first created in 2007, we have grown year after year to become one of the region's leading engineering, procurement, and construction (EPC) companies in the solar PV sector.

In November, we were acquired by Arjun Infrastructure Partners, which will allow us to continue our focus throughout the Middle East and North Africa (MENA) region. But we will also expand further into being an owner of assets targeting the large-scale commercial and industrial space. We are looking to deploy more than 100 megawatts in the near-term.

As a player that has been around for more than a decade, we understand the different dynamics at play in the MENA region, from varying legislation and targets to local culture.

How vital is it for a company like Enviromena to have a firm grasp of the culture, language, laws, and customs of the MENA region? What benefits does this bring?

Having local insight, no matter where a company operates, is always an advantage. There is no one-size-fits-all answer for the region, so for us the key is to be on the ground to ensure the most efficient solution is deployed to best fit the needs of the client and community.

In the past decade, we have built the largest team of local solar experts, who speak the same language and understand the uniqueness of operating in the MENA region.

MENA has rapidly accelerated its embrace of renewables – particularly solar – in the past few years. What is driving this trend? Is it a desire to move away from fossil fuels and be more environmentally minded? Or is it a cost-driven trend?

I believe the region's solar ambitions derive from the need to diversify, as well as the cost competitiveness. It is never good to

have all eggs in one basket, and with the plummeting oil prices that began in 2014, it was evident that a change needed to happen. However, the deal is made even sweeter with the price of solar PV falling thanks to more efficient technology.

What are the specific challenges of building large-scale solar plants in the harsh environments of MENA?

Although the MENA region has favorable conditions for solar generation, the main challenges arise from the harsh climate. Enviromena's vision is to ensure that our solar plants are engineered and built to last their lifetime, by selecting components that are capable of withstanding the harsh environmental conditions that prevail in our region.

Our approach to our customers has always been that we are here to stay. We stand behind our plant's performance by offering long-term operations & maintenance (O&M) services, ensuring that our customers see the returns on their investment and the value added by working with Enviromena.

A specific challenge that we have overcome in the past decade is the intricate detail of designing the plants to withstand the corrosive atmospheric and soil conditions, rating for high operating temperatures, ensuring the redundancy measures for uptime, and developing sustainable and effective cleaning solutions.

With that in mind, selecting the correct components – from modules and mounting structures to cabling and inverters – is extremely important. Can you describe how Enviromena identifies certain components for certain projects? What factors shape your decision?

The first step that Enviromena always takes before designing a system is understanding the site conditions and local regulations of each project. Our engineering team undertakes several studies on the various site-specific conditions right from the start. After gathering all technical parameters, the engineering



team creates detailed specifications and designs the solar plant around these results by working together with top-tier suppliers on customized components that fit the purpose. With over a decade of experience, we realize how important it is to dictate the specifications of all components that make up our plants, rather than relying on the suppliers to provide their off-the-shelf solutions. We run simulations to test the modifications for each of our projects in order to arrive at the sweet spot for optimal operation.

A vast solar farm in a remote desert will obviously be a great source of energy, provided it is performing optimally. What benefits does working with a company like Huawei bring in this case, in terms of energy yield, monitoring, and O&M?

There are a number of aspects which pertain to a plant running optimally and the inverter, being the heart of any solar plant, is extremely important. Enviromena works together with reputable suppliers such as Huawei, to ensure that the system is designed to maximize output not only in the short-term, but also to predict long-term operational behaviors. We ensure that the DC side into the inverter is sized to optimize the output of each panel, bearing in mind long-term degradation and temperature effects, and that the AC side can support the dynamic behavior of the demanding grid conditions.

What Huawei technology does Enviromena typically work with, and can you explain the relationship the company has with Huawei?

Our teams have frequent face-to-face meetings to work on finding the right solution for each project. Huawei's strength stems from its experience in the communications industry, which Enviromena has leveraged by integrating the solar plant not only with Huawei's inverters, but also with their monitoring, communication, instrumentation, and control solutions in a harmonious environment.

The company has built a number of large-scale solar plants; can you give us an insight into which ones were built using Huawei string inverters, and how their performance compares to centralized solutions?

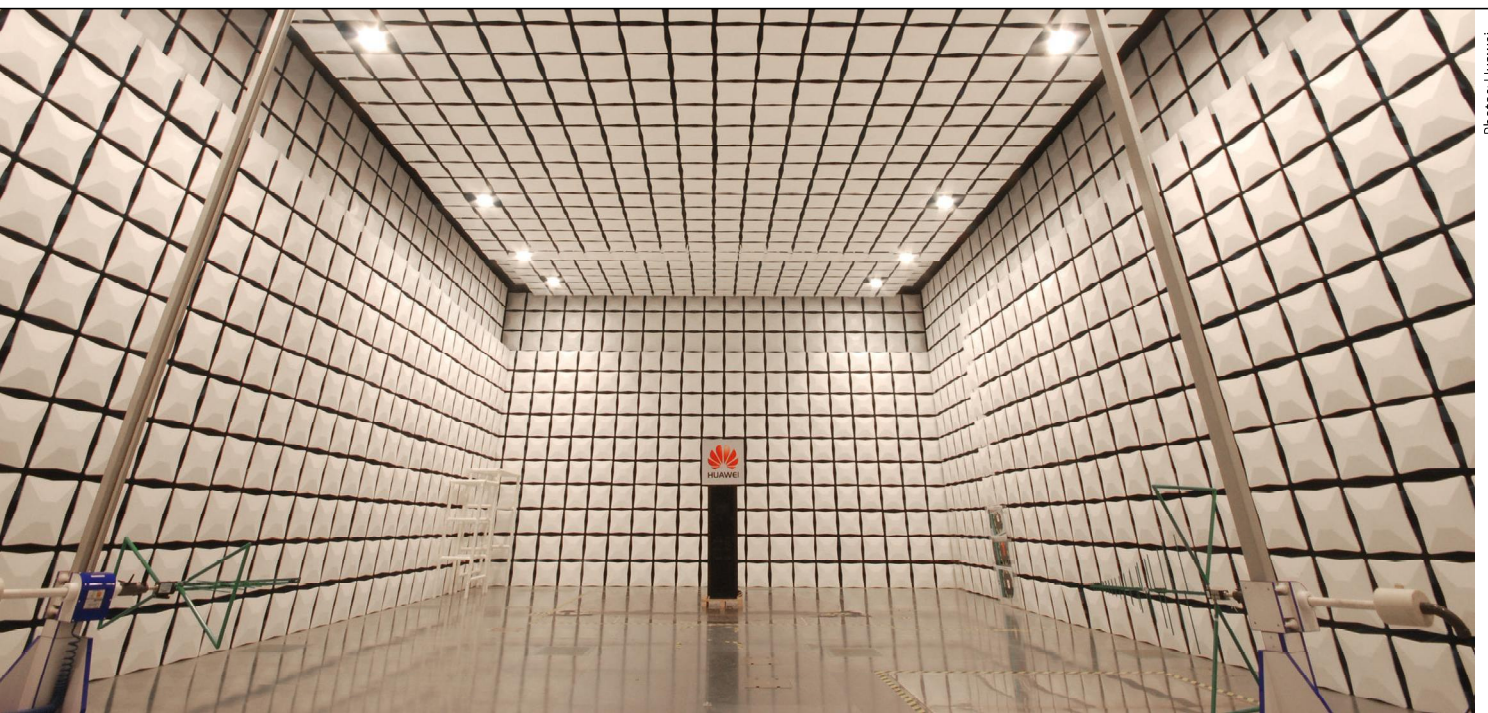
Enviromena has been working closely with Huawei on bidding for large-scale solar power plants in the MENA region. To date, Enviromena has executed a 1 MW rooftop system in Dubai with Huawei's inverters, which has proved that their string inverter solutions are performing optimally and with high reliability.

“We understand the different dynamics at play in the MENA region, from varying legislation and targets to local culture”

What, specifically, does a plant owner in the MENA region gain by operating a string inverter-controlled solar farm?

String inverters offer a few distinct advantages, a key one being that they optimize the overall performance of a solar plant by subdividing smaller sub-arrays of module strings, thereby reducing mismatch losses from inherent differences between solar module strings. This subdivision of the solar plant extends into further benefits over central inverters, where if there is excessive soiling from dust or shading effects such as clouds covering a particular part of the array, only that portion of the solar plant is affected.

Other benefits include reduction in downtime in case of failure, ease of replacement in remote areas without the need of skilled personnel, reliable operation outdoors under high ambient temperatures and granularity in monitoring of the plant behavior. ♦



Photos: Huawei

Huawei's 10x4 meter semi-anechoic chamber, at the Global Compliance and Testing Center in Shanghai.

Outdoor endurance

Testing standards: Solar PV systems need to be able to withstand at least 25 years of outdoor operation, and investors require proof that components can live up to these expectations before a PV project can get underway. Huawei's Global Compliance and Testing Center has developed a rigorous set of standards to prove the endurance of its inverters and components.

As solar PV technology spreads into more and more global regions, the systems must withstand all kinds of extreme weather conditions, from scorching desert heat to bitter cold winters, and everything in between, including sand storms, heavy rain, salt mist, high humidity, and high-altitude conditions, to name but a few.

To ensure that this level of reliability can be achieved without the need for frequent, costly maintenance, each component in a system requires comprehensive testing and optimization for operation in any type of environment.

Huawei's inverters are put through their paces at the Global Compliance and Testing Center (GCTC) in Shanghai, where a comprehensive set of laboratory-based and outdoor tests has been developed to ensure the endurance capabilities of Huawei's inverters.

GCTC was set up in 1996 and operates as a subsidiary of Huawei, with the objec-

tive to "use true and objective data, and serve customers sincerely." The lab provides testing and certification for many of Huawei's products. It now has more than 180 employees, and is accredited by TÜV Rheinland and Underwriters Laboratory.

The lab divides its testing into four key areas: safety, environment & reliability, regulation compliance, and electromagnetic compatibility. It conducts testing in each area based on the global standards set for electronic products by the International Electrotechnical Commission (IEC), the International Organization for Standardization (ISO) and other key testing standards bodies.

Inverter testing process

The reliability tests Huawei inverters are put through cover many real-world scenarios, such as high humidity, rain, salt spray, wet dust corrosion, solar radiation, fast changing temperatures, lightning strikes, high altitudes, and extreme

temperatures (from -40°C to over 100°C). Tests are split into long-term and short-term reliability testing, with long-term testing involving continuous operation for more than 1,000 hours, and some tests even taking more than a year to complete. The testing process for Huawei inverters at GCTC is run as follows.

HALT testing

Highly accelerated life testing (HALT) comprises a stepped high temperature limit test, stepped low temperature limit test (instant cooling of liquid nitrogen), stepped vibration test, and combined (temperature shock + vibration) stress test to reveal weak points in the design. The high temperature limit is 110°C, the low temperature limit is -60°C, and the vibration limit is 40 G acceleration. The test generally lasts three days. Inverters are powered on with loads throughout the process and the operating status is closely monitored.

Ice testing

This test places the inverters in temperature conditions down to -40°C , and lasts more than one week. After three days of freezing, the inverter is thawed, and then frozen again. This is conducted twice during the testing period. In the process, the inverter is powered on and off, with and without loads, and the examiners repeat the operations several times to test all of its functions.

Heat dissipation limit

Next comes the heat dissipation limit test. This test places the inverter in a contained lab at high temperatures. Air ducts on the top of the inverter are stuffed with leaves, to simulate real world conditions, and the inverter is positioned at different angles to better determine performance.

Low pressure test

This stage is designed to ensure operability in high altitude conditions. The low pressure testing checks the operating status of grid-tied Huawei inverters at altitudes of 4,000 meters, 4,500 meters, 5,000 meters, and 5,500 meters.

EMC test

GCTC's electromagnetic compatibility (EMC) testing is conducted on world-class instruments, including semi anechoic chambers, one fully anechoic chamber and five shielding rooms. GCTC's expert team conducts an in-depth test of the inverter's lightning protection interface, enclosure shielding, on-site earthing, and other related areas. Testing meets the legal safety standards of various regions, including the EU, Japan, Australia, Russia, India, and others.

Wet dust test

Developed by Huawei, wet dust testing is an integrated test of temperature, humidity, and corrosive dust (the formula of the dust is customized for different regions of the world), designed to verify the adaptation of Huawei inverters to work in high temperature, humidity, and dust environments. The test casts dust on the inverter in the dust box, and then increases the temperature and humidity to check the anti-dust and anti-sand capability of the equipment.

Vibration test

A Huawei inverter is fastened on a large vibration test platform. During the test,

the inverter is powered on with full loads and monitored. The vibration test measures anti-vibration capability in a simulated environment of its actual use. Effects of vibration can include structural damage, impaired function, or loosening/damage of connection points and screws.

High temperature rain

The high temperature rain test simulates the scenario that it rains suddenly on a day of high temperature and humidity, and then the temperature drops dramatically. This test is designed to check whether Huawei inverters can adapt to the environments of a tropical rainforest, and check their capability to protect against moisture ingress.

Powered on temperature cycle

Solar PV systems work in the daytime and stop working at night, so inverters have one temperature cycle every day. In a 25 year lifetime, this means 9,125 cycles in total. At GCTC, Huawei has implemented the most stringent testing standards: 1,500 times; lowest working temperature: -40°C ; highest temperature: 70°C ; temperature variation: $15^{\circ}\text{C}/\text{minute}$).

High temperature and humidity

In many countries inside the tropics, high temperature, high humidity conditions are a common occurrence. This stage aims to test the adaptation of Huawei inverters to such environments, and the anti-corrosion and insulation capabilities of inverter boards and shells.

Inverters are left in a box at 70°C and 95% humidity for more than six months.

Outdoor exposure

This test is conducted at a location close to the equator, which is frequently hit by typhoons, and with temperatures exceeding 40°C during summer. The outdoor test presents a typical scenario of high temperature, humidity, and salt. Tests are also conducted on an offshore platform, and at altitudes of 350 m and 1,000 m.

Lightning attraction

GCTC conducts lightning tests in the field, using a tall tower to attract lightning during a storm. This stage tests the surge protection capability and safety of Huawei inverters. The company designs its inverters with the aim of 25 years' reliable operation without maintenance in mind. Inverters are built to the IP65 standard (protected against dust that may harm equipment and protected against water spray from all directions), to ensure a stable environment for components and minimizing the influence of external conditions on component lifespan.

Fragile components such as fuses and fans are eliminated from the design, according to Huawei, so as to minimize maintenance requirements. "Drawing on the design and quality management experience of massively delivered products and the product deployment from Huawei communications base stations," Huawei tells *pv magazine*, "the components and the whole system adopt designs of high reliability and long service life to ensure the 25 year life cycle." ♦



Outdoor testing of Huawei inverters is conducted at a location which is frequently hit by typhoons and sees temperatures exceed 40°C during the summer months.



Photo: Marubeni

Takaharu Mori is General Manager at Marubeni Techno-Systems Renewable Energy Business Division.

Big in Japan

Partner interview: Japan is traditionally a tough market for international players to crack, thanks to a sense of pride in its own technological capabilities, and a strong preference for locally made electronics. Huawei, nonetheless, has seen plenty of success, as explains Takaharu Mori, General Manager at Marubeni Techno-Systems Renewable Energy Business Division, a Japanese company with experience up and down the solar supply chain, which has partnered with Huawei since 2016 on multiple PV projects.

First, please can you explain how the division Marubeni Techno-Systems differs from what we generally know about Marubeni?

Marubeni is famous as an IPP player in solar. While we as Marubeni Techno-Systems focus just on the trading. So for Huawei, we are a distributor of their products. Our USP is our background in the machinery industry.

This division has unique properties because we have different faces, as an IPP player, and as a distributor for modules and power conditioners. Besides that, we have another face as an assembly machinery supplier, especially to the large module manufacturers. We still provide production equipment to these tier-1 companies.

There are five groups within Marubeni, and each group has a different business model. In terms of PV industries, each has its own business model and functions upstream and downstream in the PV supply chain. For example, The Power Project Group is purely focused on power supply, and does not specify any particular source – solar, conventional, anything that is suitable for the market, and that is demanded in each region. One example is the Mega Solar project, which is well known in Saudi Arabia. Marubeni Techno-Systems is 100% owned by Marubeni. We cover a broad cross-section of the PV supply chain- not only assembly machinery but also backsheet, glass etc- which are important key points for module quality.

In the early 2000s, we started to export Japanese PV modules outside of Japan. This is when we saw Europe's PV market begin to grow. We delivered PV modules we were involved in making into Europe. The yen was weak against the euro at that time, which made it hard for us. But luckily this was also when the Japanese market began to boom.

We also make and have expertise in module production lines, as well as module supply and racking system supply – we have contacts and logistics here. This is our USP: Rather than building vast plants, we began with smaller plants, built and supplied by us, monitored by us, and we have learned from that.

How did the partnership come about? For how long has Marubeni Techno-Systems worked together with Huawei?

Back in 2014, we knew Huawei as a string inverter supplier. At that time, we still believed that a centralized [inverter] solution is necessary. We hesitated to work with them at the time. It was not until 2016 that we began to partner with Huawei.

Marubeni Techno-Systems' trade partner is first and foremost Trina Solar. We began in solar at almost the same time, in 1997, communicating with CEO Jifan Gao. They used to be our customer, but now they are our important partners. We still provide production machinery to them, while we buy their modules to sell into the Japanese market.

Trina Solar has a high end production line, and recently it has been improving the line by installing new equipment, and it is growing at a far faster rate than before.

In 2013, the boom in Japan had already started. Many players jumped into the market at a time when Japanese module brands were strong. Chinese firms still had a weaker reputation, even if the quality was good. So Marubeni decided to work with Trina, and still today we purchase modules from their dedicated factory and lines under Trina's QC regulation. This is Marubeni's expertise.

Trina were always cooperative and with a view on growth and quality, not just profit. They gave us confidence selling Trina modules into the market with the Marubeni's eyes.

So knowing about Marubeni's unique sales scheme and strong presence in the market, Huawei came again to Marubeni, and gave a presentation about their string inverter. At that point, our industrial machine department was designing a new solar plant. We always naturally opted for central inverters and Japanese brands, because of our reliance on EPCs who were cautiously conservative.

But then we went to visit Huawei's factory to witness and discuss the inverter. This visit was the turning point for us. We started to evaluate an entire string inverter – cost, output, installation, maintenance – all evaluations possible. It was like a scoring or ranking system, and Huawei came out best, in comparison to a lot of Chinese, Taiwanese, and Japanese inverters.

For 30 kW to 40 kW inverters, they're hard to find from Japanese suppliers at that time. This size was ideal for our projects, and we were impressed.

Huawei were very new, with little in terms of field data to assess. What type of assessment and testing were you able to do when making your decision, particularly in terms of post-installation O&M and service?

Well, service is very important. But the funny thing is, Huawei's inverters don't need service – they changed the game! That was really shocking. Honestly, I was taken aback, to slowly realize that Japanese manufacturing expertise cannot beat Huawei. Quality control is high class, and they know Japanese standards and regulations, they thoroughly study and respect these important key factors.

Japan is famously proud of its technology and ways of doing business - and rightly so. When it comes to making things, we Japanese are proud to see ourselves as number one. Based on this viewpoint and measurable success, we went to Huawei to organize and consult with them, and without knowing the history or country of origin of the inverters, we saw the technology and how it requires no maintenance, is competitive on price, and we could not help but be impressed and happy with the decision to partner with Huawei.

We had operated several mega solar sites, and every week we had a report of what the electrical output was, the performance, etc... The reports always indicated central power conditioners requiring a change of fuse, cleaning of the filter etc... so we found that the maintenance cost for power conditioners is very sensitive, even though its cost is not huge.

We then thought that Huawei inverters could help us to remove those costs, because of their five-year warranty program, which can extend to a total of 20 years. And also, the message I wanted to instill throughout our team was: "Don't just rely on Japanese products, let's go with Huawei."

Therefore, my message to the clients was: Although Huawei is new to the market, their products can help to improve the performance of your projects, from technical as well as commercial aspects. That is why initially we began by explaining the general advantage of string over central, because the market at that time was still skeptical.

Nowadays, this trend is well recognized. So our message has evolved. We chose Huawei as a partner and began distribution work. Now, are proud to supply high quality products: Trina Solar modules and Huawei inverters.

When you were approached by Huawei, what else beyond the production quality and performance convinced you to partner with them? How much of an impact did Huawei's digitization capabilities have on your decision?

Their development speed was impressive. The reason why the industrial machinery division is strong is that the market always adapts. Yesterday's product is not high end today. So we have to stay on the pulse. With Huawei, we saw how 10% of their annual turnover goes towards R&D – it's nice to know, sure. But the reality is that they develop new systems and products including storage, an electric vehicle charger, and residential applications. And this gives us the confidence that Huawei shares those same values, and maybe Marubeni can support them on their journey. For the next-gen business we thought we can be their partner. They don't need our support in the mobile phone space of course – we are just a customer – but for power electronics, we see opportunities to work together.

Are your clients who now use Huawei products also sharing such enthusiasm?

It was difficult to penetrate the market, because Japanese players dominated. The door for the newcomer is a bit hard to open, because every decision by the management reflects what the Japanese manufacturer said. All regulation stems from here. So as a user they hesitated, and questioned it. We decided we would be a fast initiator, and lead by example.

“Rather than building vast plants, we began with smaller plants, built and supplied by us, monitored by us, and we have learned from that.”

The message I'm getting is that quality, transparency, and speed is important to you.

Huawei's new larger inverters come quickly, and their intention is always to pursue new markets, and they do this because they keep a close eye on market trends. That gives us confidence that they look for and know what's going on in the market; and prepare development items to fit this. As a distributor, this makes our job very easy.

Now you have field data of Huawei inverters, so are you finding that your initial impressions are being proved correct?

Our first customer bought 10 MW of Huawei inverters – built in 500 kW blocks. They feed back entire data and they indicate above-expectation performance throughout. We have sold many inverters in the market, and this is good. We haven't yet had to respond to any emergencies or problems with Huawei, so we cannot assess the level of their service yet – because there have been no failures so far! ♦



Photo: Huawei

Tony Xu is President of Huawei's Smart PV Business.

The smartest way forward

Interview: For this special edition, Tony Xu, President of the Smart PV Business at Huawei, shares with **pv magazine** his views on the digitization of the energy system, and Huawei's leading role in this transformation.

Recognition of the benefits offered by synergies between solar PV, the Internet of things (IoT), and digitization is growing day by day. Can you begin by outlining the main goals and aims of Huawei's FusionSolar Smart PV Business, and how it works with renewable energy?

The physical and the digital realms are undergoing profound integration. Innovation in digital technologies, represented by 5G, IoT, cloud computing, and artificial intelligence (AI), will continue to help all industries to prosper.

As an essential trend and inevitable path for the global energy industry, digitization paves the way for technological development and reshapes the entire PV industry. In 2018, Huawei's vision is to bring digitization to every person, family, and organization and build a fully-connected intelligent world. As for the energy industry, Huawei is committed to bringing digitization to every PV plant, and every new energy enterprise, while helping partners to lead the Smart Era.

What does the phrase 'Smart PV' mean to you, and to Huawei?

'Smart PV' is a convergence and innovation of PV power generation and digital information technologies. The Huawei Smart PV Plant solution is the innovation and optimization of the whole process, from plant construction to operation & maintenance

(O&M), by integrating digital information, IoT, and PV technologies. This lowers the initial investment and O&M cost, increases the energy yield, and improves the rate of return on investment. It can be adapted to various scenarios, including large ground plants, hillside plants, and solar-integrated farming and aquaculture.

'Smart' indicates less human intervention in favor of automated, unattended operation. That is, faults can be automatically detected, diagnosed, and rectified so as to improve the energy yield, reduce maintenance costs, and increase system incomes. Automation, informatization, and big data analytics are the three essential phases in the development. Automation means that there should be less manual work at the PV plant. The system is made of sturdy parts that don't require maintenance. Experts are seldom required for on-site troubleshooting, and personnel are no longer required on site to rectify faults. Informatization refers to high-precision smart PV string monitoring. It ensures the high-speed, reliable, secure, and low-cost transmission of information, and implements reliable storage and monitoring over background data. Big data analysis makes possible the proactive identification of problems before they occur. The system draws on big data to make O&M suggestions. The remote mobile O&M facilitates remote expert guidance and reuse of expert resources. The expert O&M system implements

preventive maintenance, and the automatic report system provides automatic data reports of different levels.

Digitization of solar plants has become extremely widespread across most major markets and is offered by a range of companies. How do you ensure that Huawei continues to innovate and stay ahead of the competition?

In order to stay one step ahead of the competition in terms of technology, Huawei has consistently invested heavily in R&D. In 2017, 14.9% of Huawei's global sales revenue was reinvested into R&D. The path leading us to an intelligent world is the path of innovation. Thanks to its deep involvement in global competition and customer-centered innovation policy over the last 30 years, Huawei has developed chips, mathematical algorithms, and architecture design processes. Based on these technologies, it now possesses excellent capabilities in telecommunication, computing, and storage. Huawei can continuously enhance its competitive edge from one product and solution to the next, as each inherits the successful technologies of its predecessors. This momentum can be used to drive the digital transformation of all industries. We will continue our investment in R&D, promote digital innovation in AI, 5G, cloud computing, and IoT to provide competitive solutions that integrate new energy sources for better user experience.

“The physical and the digital realms are undergoing profound integration”

Can you describe the LTE wireless network currently used by Huawei for solar plant monitoring and data analysis? How can system owners be confident that the network is reliable, secure, and user-friendly?

The wireless 4G eLTE technology is widely and securely applied in major fields such as energy, transportation, finance, and government. It ensures security by means of 128-bit keys for bidirectional encryption and unscheduled updates, multiple application encryption protocols to ensure secure transmission for end-to-end businesses, secure environment build between wireless base stations and security gateways, and access control, logs, and alarms.

In the PV industry, the terrain often complicates the construction of new plants, as PV plants may be built on mountains, rooftops, or the surface of a lake. PV plants may be built in areas where the geology poses unique challenges. Due to its convenience, eLTE technology is witnessing broader application in PV plant construction and O&M. The technology is safe, reliable, and simple to deploy. In terms of plant construction and O&M, no optical fibers or trenching for optical cables are required, and faults can be easily located and rectified. With regard to management, the synergy of mobile Internet, smart PV terminals, drones, and remote experts improves the O&M efficiency.

Digitizing the energy system is certainly a path that much of the world is heading down; what are Huawei's ambitions on this front? Do you hope to eventually be instrumental in

all residential, commercial, and industrial solar markets globally?

As I mentioned earlier, Huawei's vision is to bring digitization to every person, family, and organization and build a fully-connected intelligent world. Digitization is also a major trend within the energy industry. Digitization has become the core competitiveness of energy enterprises. The advancement of digital technology will accelerate the drop of the levelized cost of energy (LCOE) for PV plants and ultimately achieve grid parity. Intelligent algorithms, intelligent diagnosis, and intelligent convergence not only improve the energy yield by 0.5-2.0%, but also provide fault warning and self-diagnosis, O&M team performance evaluation, asset and solution implementation evaluation, and fishery-agriculture system analysis and control for maximizing the benefits of the PV plant throughout its life cycle for customers. Today, one-click scanning of the Huawei Smart I-V Curve Diagnosis 2.0 technology enables the scanning of all strings in a 100 MW PV plant in just 25 minutes. Compared with traditional inspection, customers save CNY 10 million (\$1.56 million) in the 25 year life cycle of the PV plant.

Remote monitoring, predictive analytics, and big data – these terms are no longer new to the solar industry. So how does Huawei hope to push the boundaries in the coming years? What types of innovations – both digital and in terms of hardware – can we expect to see?

Based on Huawei-developed chips, digital power generation of Huawei smart PV system implements high-precision digitization for the devices in the system so that they can be sensed, connected, and controlled. This lays the data foundation for later big data mining and analytics, fault prediction, and proactive and preventive maintenance. ♦



ALL-DIGITAL SMART-ECO PV PLANT

In summary, the all-digital smart-eco PV plant launched by Huawei boasts the following features:

- All modules, trackers, and devices can be sensed, connected, and controlled – high-precision (0.5%) string-level information and full device information.
- Zero touch design concept: A reliable digital system takes us from “people serving machines” to “machines serving people.”
- Digital integration and system interaction: Smart PV controllers and trackers converge seamlessly. Multi-level intelligent optimization on the same platform facilitates optimal adaptation to bifacial PV modules. Based on abundant data and big data platform analytics, Huawei has developed an industry-leading smart design toolkit for bifacial PV modules. The toolkit combines the all-scenario “bifacial PV module + tracker” smart algorithm that features auto-adaptation and self-teaching with the most efficient PV panel maximum power point (MPP) intelligent tracking algorithm. Compared with conventional solution designs, the toolkit can help reduce the unit electricity cost and improve the energy yield by more than 3.9%.
- Digital transmission: full-coverage network – full access anytime and anywhere
- Digital management platform: open platform, expandable applications
- LTE wireless private network: secure, remote, and mobile O&M
- Digital brain: end-to-end analysis for the PV plant operation, fault warning, smart diagnosis and troubleshooting suggestions, per capita efficiency up by 50%+



A PV project on water featuring bifacial modules and Huawei inverters. Depending on the surface albedo, bifacial modules can boost performance by between 5% and 39%.

More than two sides to new technology

Working with bifacial: Bifacial modules are gaining ground in the PV market, thanks to their potential for high efficiency and performance without major changes to the module production line. These efficient modules need to be used with the right inverter in order to maximize value. Based on empirical data collected by Huawei, this article describes the best inverter features needed for integration into a project with bifacial modules.

The cell technologies used in bifacial solar modules which are currently on the market include p-type passivated emitter rear contact (PERC), n-type passivated emitter rear totally diffused (PERT), and heterojunction technology.

In addition to receiving solar radiation from the front, the rear of the bifacial module can also receive scattered light from the air, reflected light from the ground, and direct solar light coming from the rear during the morning and evening. Therefore, the power generated by a bifacial module is greater compared with the standard PV module designed for the same PV plant.

Huawei has tested standard and bifacial modules with the same structure for a long period of time. The energy yield gain from the rear of the bifacial module varies depending on the scenario, and the energy yield has been shown to increase by anywhere between 5% and 39%. In addition, the bifacial module can further increase the energy yield by 2–6% based on its excellent performance in low light conditions, and low power loss under high working temperatures.

The right inverter

The table on page 39 lists some parameters of a bifacial module with 300 W out-

put on the front side from a well-known manufacturer. As the bifacial module gain increases, open-circuit voltage and peak power voltage remain unchanged, while the peak power and peak current of the PV module increase. In this case, system designers need to select a more appropriate inverter with a larger DC input current based on the actual power gain.

The current of each maximum power point tracker (MPPT) circuit of the Huawei SUN2000-75KTL-C1 inverter for bifacial modules is 25 A (Note: SUN2000-75KTL-C1 is the best match string inverter for bifacial modules in China).

This fully meets the requirements for the increased output current from bifacial modules.

MPPT granularity

Rear radiation of the bifacial module is uneven. Consequently the overall output power of the PV module is different, and the current discrete rate of the PV module reaches more than 5%.

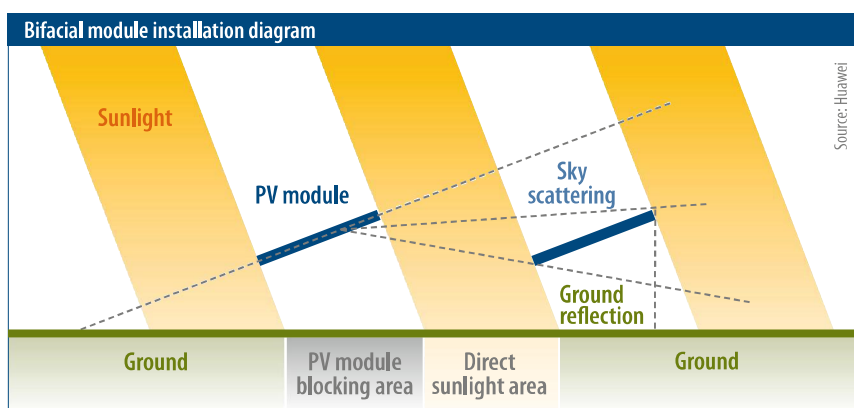
In this case, the MPPT granularity of inverters should be finer. In addition, the mismatch loss caused by inconsistency should be avoided when the string is designed and when it connects to inverters.

Every two strings connected to the Huawei SUN2000-75KTL-C1 inverter form one MPPT circuit, which means that the inverter has the finest MPPT granularity in the industry. This minimizes the mismatch caused by bifacial modules. Based on simulations, it has been found that the mismatch loss caused by inverters which form one MPPT circuit for every two strings is 1.1% lower than that caused by common inverters in a system using bifacial modules.

Accurate algorithm

Since the mismatch of the bifacial module is high, its I-V curve is more complex than that of a standard PV module, and its power-voltage curve will generate multiple peak values. This places higher requirements on the detection precision and MPPT in inverters.

Huawei string inverters have multiple MPPT units, which can greatly avoid energy yield loss caused by string mismatch. The detection precision of a string reaches 0.5%. In addition, Huawei inverters use the most efficient maximum power point (MPP) intelligent tracking algorithm in the industry. The inverter utilizes adaptive MPPT technology. When irradiance is stable, the MPP of the PV module can almost be reached. When the irradiance rapidly changes in cloudy weather, the inverter can quickly respond and track the maximum power



point in real time, so it can adapt to the bifacial module accurately.

In addition, as the bifacial module has multiple peak values, the inverter can intelligently identify whether the maximum power point has been reached. The high-speed multi-peak scanning algorithm is enabled to ensure that the inverter is always operating at the maximum power point of the PV module, thereby effectively improving the energy yield of the bifacial module.

Protection design

The fuse failure rate increases as the current increases: The current of the PV module is affected by radiation and temperature, so it cannot be controlled. When the fuse has a low-current overload, the fusing time becomes longer. When the fuse is almost blown, it is in a high-temperature heat balance state, or the insulation between the cable and the fuse box is damaged. As a result, fire accidents may occur. The output current of a bifacial module is even larger, which is more likely to cause low-current overload. The fuse can then be blown and this can even result in fire due to such high temperatures.

The fuse of a single specification cannot adapt to current mainstream PV modules: Currently, the maximum reverse current capabilities of bifacial modules from mainstream vendors are 15 A and 20 A. In this case, a DC combiner box or a string inverter with built-

in fuses cannot adapt to PV modules of another specification, regardless of the fuse specifications. This is because the built-in 20 A fuse cannot protect the 15 A PV module, and the built-in 15 A fuse is blown frequently due to the large operating current.

Every two strings in Huawei SUN2000-75KTL-C1 inverters dedicated for bifacial modules form one MPPT circuit and adopt a fuseless security protection solution. The design ensures that no overcurrent will occur, protects PV modules, and improves system reliability. In addition, security risks, frequent fuse replacement, and energy yield loss caused by fuse faults are avoided.

Physical model

A physical model needs to be set up for evaluating the energy yield of bifacial modules. Research personnel from the National Renewable Energy Laboratory (NREL), Sandia National Laboratories, and Fraunhofer Institute for Solar Energy Systems (ISE) in Germany have conducted a lot of research into this. They focus on ray-tracing and view-factor models, which can accurately describe the gain of the bifacial module from the rear.

The two models are based on 3D modeling. Although more details can be displayed, algorithms are complex and computing is time-consuming, which does not meet the actual requirements of engineering applications.

Huawei has simplified and optimized the two models, and launched an industry-leading intelligent design tool for bifacial module systems. The tool can find the balance point between the calculation speed and design details, and accurately and quickly calculate the optimal configuration of the bifacial module system.

Parameters of a bifacial module				
	PV module peak power (W)	Open-circuit voltage (V)	Peak power voltage (V)	Peak power current (A)
Standard PV module	300	39.6	32.9	9.11
Bifacial module gain (5%)	315	39.6	32.9	9.58
Bifacial module gain (10%)	330	39.6	32.9	10.04
Bifacial module gain (20%)	360	39.7	32.8	10.98
Bifacial module gain (25%)	375	39.7	32.8	11.44

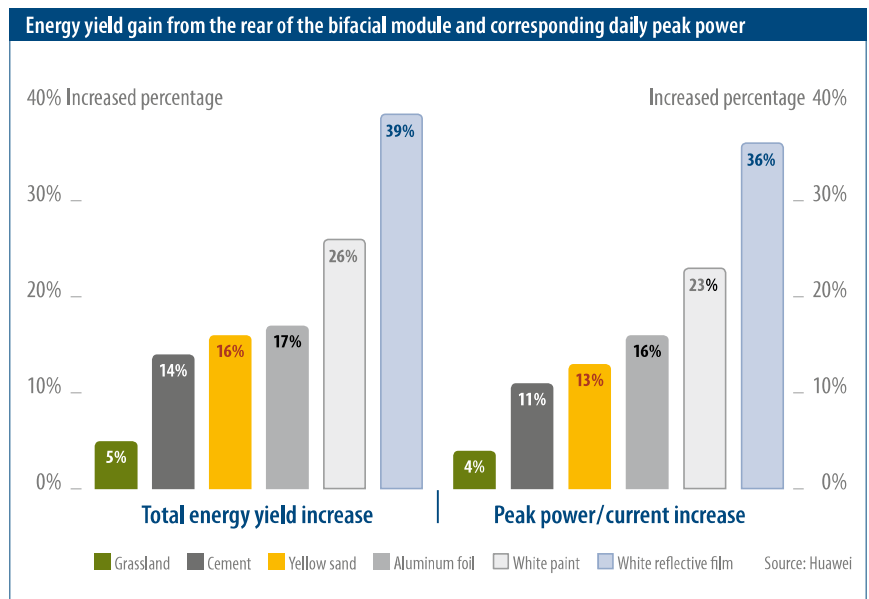
The intelligent design tool for bifacial module systems integrates full-scenario, adaptive, and self-learning intelligent control algorithms to accurately output the optimal design solution. This increases the energy yield by more than 3%, compared with solutions provided by other standard design methods. Currently, this tool is the only accurate design tool for bifacial module plants in the industry, and has been verified by a large amount of data.

In addition, the higher complexity of the I-V curve of bifacial modules makes the intelligent diagnosis of string faults easy to misjudge, which causes inconvenience to operations and maintenance activities. Huawei's latest Smart I-V Curve Diagnosis function 2.0 uses a new intelligent string diagnosis algorithm. Based on big data analysis and AI algorithms, it can automatically learn and evolve. Based on the built-in database, it can quickly master the input and output feature curves of various PV modules, and automatically filter out the noise that causes misjudgment. It supports bifacial modules and provides an intelligent solution for the increasing number of PV plants incorporating this technology. To sum up, Huawei compared the Huawei Smart PV Solution with other mainstream inverter solutions currently available, as shown in the table below.

Huawei inverters have the following features:

- Higher input current and efficiency
- Finer MPPT granularity
- Highly adaptive – the most accurate and efficient MPPT
- Secure and reliable protection design

These smart tools make Huawei invert-



ers an excellent match for bifacial modules. In fact, solutions made up of Huawei inverters and bifacial modules have already been widely applied in solar power plants across various markets and scenarios.

Summary

The bifacial module has started a new round of technology replacement for the solar industry.

The application of these new technologies requires the development of other supporting technologies, such as higher inverter input current, finer MPPT granularity, more accurate MPPT algorithms, and smarter design tools for bifacial module plants.

Based on the preceding analysis, Huawei is proud to be the provider of one of the most adaptive PV inverter and solution designs in the industry. ♦

“The bifacial module has started a new round of technology replacement for the solar industry.”

Comparison of solutions for bifacial module scenarios			
Comparison item of bifacial modules matching different solutions	Traditional centralized solution	Traditional string solution	Smart PV solution
Increase of the DC inverter input	Good: The number of combiner boxes is reduced.	Poor: The MPPT input current is not increased.	Excellent: The MPPT input current is increased.
Inverter MPPT granularity	Poor: Hundreds of strings form one MPPT circuit.	Good: Multiple (more than two) strings form one MPPT circuit.	Excellent: Two strings form one MPPT circuit.
Inverter fuse fault	Poor	Poor	Excellent: Two strings form one MPPT circuit and there is no fuse.
Inverter MPPT algorithm	Poor	Poor	Excellent: Most efficient algorithm in the industry. The algorithm is intelligently optimized based on the complex and multi-peak I-V curve of bifacial modules.
Bifacial module solution design	None	None	Excellent: Currently, the industry's unique intelligent, self-learning, and adaptive design tool for bifacial modules is used in various complex scenarios.
Bifacial module analysis tool	None	None	Excellent: Based on big data analysis and AI algorithms, the smart I-V curve 2.0 is the optimal choice for O&M of bifacial module plants.