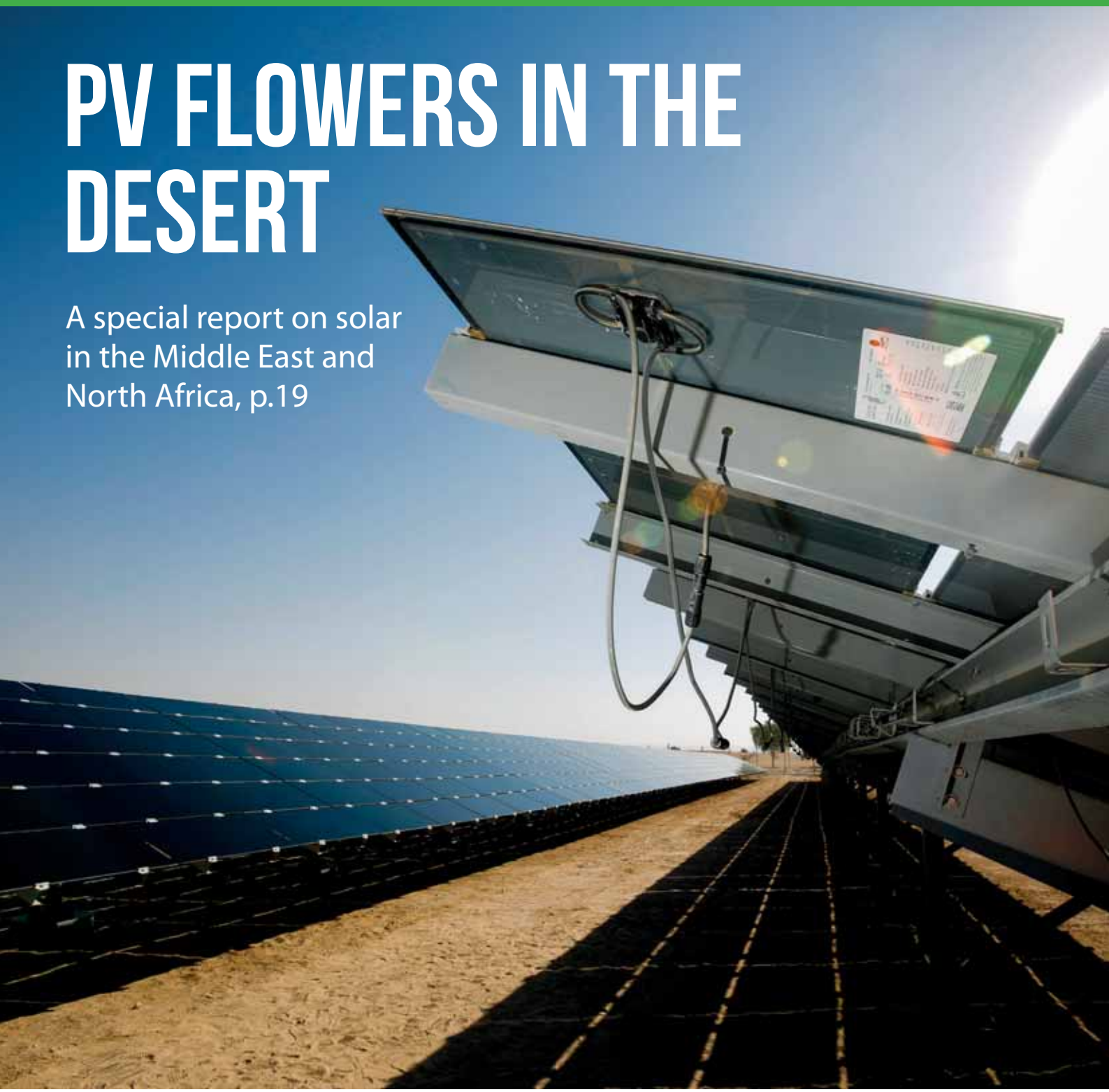
POWER PVTECH

Volume 09 PV POWER PLANT TECHNOLOGY AND BUSINESS December 2016

PV FLOWERS IN THE DESERT

A special report on solar in the Middle East and North Africa, p.19



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About LERRI Solar

A world leading mono-crystalline solar module manufacturer for achieving best LCOE (levelized cost of electricity) solutions.

LERRI Solar is a world leading manufacturer of high-efficiency mono-crystalline solar cells and modules. The company was founded in 2007 and later on acquired by Longi Group in 2014. Longi Group (SH601012) is the largest supplier of mono-crystalline silicon wafers in the world, with total assets above $1.7 billion. (2016)

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PV TECH POWER

Published by

Solar Media Ltd.
3rd Floor, America House,
2 America Square,
London, EC3N 2LU, UK
Tel: +44 (0) 207 871 0122
www.pv-tech.org

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Printed by

Buxton Press Ltd., Derbyshire

PV Tech Power Volume 09, 2016
ISSN: 2057-438X

Cover photograph courtesy of First Solar

Introduction

The Middle East and North Africa has been the next big market for the solar sector for some time. In that period India, Chile and South Africa have eclipsed it. South Korea, Turkey, Mexico, Taiwan and many others are ready to go for growth too. But, as we get ready to start 2017's solar events tour in the Middle East, things appear to be changing.

The days of headlines dominated by big ambitions and lofty targets have given way to news of signed power purchase agreements and grid connections.

We have seen PPAs signed at the tail end of 2016 for 800MW in Dubai, more than 250MW in Jordan and contractors awarded for 170MW in Morocco. Abu Dhabi started work on a net metering scheme, Egypt was ironing out issues with its multi-gigawatt tender and in the summer, Saudi Arabia launched its first PV tender based on the independent power producer model.

The region has huge potential for both utility (p.20) and rooftop solar (p.24). The gradual removal of fossil fuel subsidies for power generation, the falling cost of finance and, of course, improving project performance have tipped the balance of the economics for PV in the region.

Lofty ambitions remain in the region but at least now there is growing confidence that they are achievable.

Elsewhere in this issue of *PV Tech Power*, we take a look at recent market developments in Spain (p.38) and Chile (p.34) as well as our regular round-up of updates from the hottest emerging markets.

Sara ver Bruggen takes a look at the increasing use of mobile PV testing facilities for the monitoring of operational plants (p.71). The increasing arsenal of mobile tools is making a big contribution as asset owners continue to demand the absolute best returns from their projects. Building on that theme, 3E works through the automated fault detection process (p.67). The firm has received EU funding to develop its detection and diagnosis methodology.

Following on from Tesla's suitably glitzy launch for its solar roofing product, *PV Tech Power* sent its own glamour-puss Ben Willis to investigate whether BIPV was set for a rebirth in the wake of Musk's (latest) moment in the spotlight (p.50).

On the O&M front, we caught up with TerraSmart to discuss its innovative 'Mars-rover' style surveying unit (p.54) that it claims can offer huge labour savings.

We also have an in-depth look at tax equity funding in the US. The ITC is supposed to be the silver bullet for us solar but as Danielle Ola reports, not all that glitters is gold (p.46).

Don't miss our coverage of microgrids, encapsulants and the 1500V revolution.

Thanks for reading, we appreciate all your support and we hope to talk with as many of you at PV Expo and Solar Middle East in the coming months.

John Parnell
Head of content

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HUAWEI

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FusionSolar Smart PV Solution
www.huawei.com/solar

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MISSION SOLAR
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EUROPE

Germany raises offering to 160MW in sixth solar tender

Germany's Federal Network Agency has increased the capacity up for grabs in its sixth round tender for large-scale solar PV systems to 160MW. The volume was increased because some bids in the previous round did not pay the security deposit. In these cases, the offered amounts have been moved to the upcoming auction. The cap on tariffs for the sixth round will remain at €0.1109/kWh (US$0.12).

Credit: Conergy

Germany increased the available capacity in its next auction round.

Projects

50MW of PV capacity awarded to Danish companies in cross-border solar auction with Germany

Five companies based in Denmark secured 50MW worth of solar capacity in the first cross-border PV tender in Europe, held in Germany. The 50MW worth of winning bids were awarded with a surcharge of EUR 5.38 cents per kWh. The award price is almost EUR 2 cents per kWh lower than the average supplementary price of the last national call for tender for open-air installations.

GCL-SI to build 1GW solar plant in Chernobyl

GCL-SI, a subsidiary of GCL, is to develop a 1GW solar PV plant at the former contaminated nuclear site in Chernobyl, Ukraine. Construction is expected to start in 2017. It will be located in what is known as the 'exclusion zone' – the 30km^2 guarded areas around the original nuclear reactor hall that exploded in 1986. The plant is part of the Ukrainian government's plans to revive the exclusion zone.

Regulatory

Ireland's first solar auctions not expected until early 2018

Solar developers in Ireland have been told not to expect the first auction in a new government support scheme for large scale projects until early 2018 by the Irish Solar Energy Association. The Irish government recently moved to dampen expectations on the country's solar potential after concerns were sounded over the 4GW pipeline that has developed. It is widely expected that closer to 1GW will ultimately be deployed.

EC rubber stamps exit of five solar firms from MIP

JinkoSolar, JA Solar, Risen Energy, Wuxi Suntech and Sumec (Phono Solar) have been withdrawn from the EU's Minimum Import Price (MIP) undertaking by the European Commission. A primary reason for some leading Chinese producers withdrawing from the MIP is due to the establishment of both solar cell and module assembly operations in countries outside China, primarily in Southeast Asia.

Greentech takes over Conergy Services

Hamburg-based O&M provider greentech has acquired the German O&M business of Conergy, Conergy Services GmbH. This will increase greentech's portfolio of O&M and asset management contracts by more than 100MW combined with another 350MW of monitoring and reporting services in other European markets. Meanwhile, First Solar has sold its PV power plant monitoring, control and supervision systems subsidiary, skytron energy to German business management firm, Liberta Partners.

Secondary market

United Photovoltaics buys up 80MW UK portfolio

Hong Kong-based asset holder United Photovoltaics has acquired more than 80MW of operational UK solar assets. United PV, which will house the assets in its subsidiary Renewable Energy UK Portfolio Ltd, is to acquire the portfolio once debt financing of the portfolio has been completed, paying a maximum equity consideration of £30 million (US$37.4 million). A maximum of £25 million is payable up front, with a further £5 million in conditional payments due if specific targets are met.

EGP and F2i to buy Etrion's 60MW Italian solar portfolio

Ultor, a 50:50 joint venture between Enel Green Power and Fondo Italiano per le Infrastrutture (F2i), has signed an agreement to purchase the 60MW Italian solar portfolio of Etrion Corporation. This will be for an initial cash consideration of €78 million (US$83.7 million) along with the assumption of €221 million of related project-level debt. There may also be further cash earn-out payments of up to €24 million depending on legal and regulatory proceedings.

AMERICAS

Tesla and Solarcity

Tesla/SolarCity merger approved

The merger between Tesla and SolarCity has been approved by shareholders. According to Tesla, 85% of voting shares backed the plan. The US$2.6 billion deal has received mixed reviews from analysts since it was first announced in July. The combined Tesla and SolarCity will deliver Elon Musk's vision for a world-first opportunity to "generate, store and consume energy sustainably, through a suite of integrated products that add aesthetics and function while reducing cost," according to a company blog.

Tesla and SolarCity launch solar roof concept

Tesla and SolarCity launched a building integrated photovoltaics (BIPV) residential roofing system comprised of a range of different tile formats, colours and coatings that aesthetically as possible mirror common conventional tile formats. The solar tiles can be provided as a retrofit option to the replacement of an existing aged tiled roof or as a new build alternative to standard residential roofing systems. Elon Musk controversially claimed the system will cost less than a regular roof without citing any figures.

First Solar

First Solar raises cash with project and skyton sales

First Solar raised cash with the sale of its stake in the 300MW Stateline project for US$329.5 million. The company also offloaded its PV power plant monitoring, control and supervision systems subsidiary, skytron energy to German business management firm, Liberta Partners. Financial details were not disclosed.

Credit: flickr/ Gage Skidmore

Trump

Trump confirms intention to dismantle the Clean Power Plan

President-elect Donald Trump followed his victory with confirmation of his intentions to cancel the Clean Power Plan, in a video message outlining his plans for when he takes office. Trump made several references on the campaign trail of his intent to dismantle not only Obama's Clean Power Plan, but also US involvement with the Paris Climate Agreement and the solar investment tax credit. His latest message stressed his designs in "putting America first" with promises to "bring back our jobs". Trump said he would cancel any restrictions on US energy production – of which the Clean Power Plan is one. "I will cancel job-killing restrictions on the production of American energy, including shale energy and clean coal, creating many millions of high-paying jobs," Trump said.

EPA Chief: Clean energy can't be Trumped

Despite confirmed plans to dismantle the Clean Power Plan, and intentions to withdraw the US from the climate accord and rejuvenate a dying coal industry, president-elect Donald Trump will not succeed in derailing the clean energy industry's progress, according to Environmental Protection Agency (EPA) administrator Gina McCarthy. The EPA is the chief architect of Obama's Clean Power Plan; the cancellation of which is top of the to-do list of the incoming president. Without naming Trump specifically, McCarthy said "the inevitability of our clean energy future is bigger than any one person or nation", but that President Obama used the CPP as "a sign of US commitment" to acting on climate change.

Trump must continue low carbon investment, say US business leaders

More than 360 businesses and investors across more than 35 US states have called on President-elect Donald Trump to maintain the US' commitment to carbon reduction and support investment in a low-carbon infrastructure. "Implementing the Paris Climate Agreement will enable and encourage businesses and investors to turn the billions of dollars in existing low-carbon investments into the trillions of dollars the world needs to bring clean energy prosperity to all," the group wrote in a statement of support at November's climate negotiations in Marrakech, Morocco. "Failure to build a low-carbon economy puts American prosperity at risk." Among the businesses and investors signing the statement were DuPont, Gap Inc., Hewlett Packard Enterprises, Hilton, HP Inc., Kellogg Company, Levi Strauss & Co., L'Oreal USA, NIKE, Mars Incorporated, Schneider Electric, Starbucks and Unilever.

First Solar changes up manufacturing plans

Leading thin-film producer First Solar decided to skip a previously planned migration to its Series 5 module platform, while bringing plans forward to migrate to its large-area Series 6 module technology to 2018. The company has made the radical decision, due to cost competitive issues as global module prices have declined around 25% in the third quarter of 2016 alone. First Solar said that the Series 6 module technology would be ramped to around 3GW of capacity in 2019. This would mean that its current Series 4 product would be completely phased out in this timeframe. The company also noted that it expects lower shipments and project completions in 2017.

Latin America

Latin America surpasses 4GW solar capacity - GTM

The Latin America region had installed 1.8GW of solar PV by the end of the third quarter 2016, already up 400MW from 1.4GW in 2015, according to GTM Research's Latin America PV Playbook for Q3 2016. This brings the region's cumulative total to more than 4GW with much of this deployment in Chile, a country that is expected to surpass 2GW by the end of this year. The industry has progressed well, driven by auctions in Mexico and Chile where solar played a key role and tariffs continued to decline in line with trends across the rest of the world. Argentina had an "impressive breakout year" with auctions making way for 300MW of solar under the RenovAR programme.

Chile reveals plans for 1GW solar park

Chile plans to develop a solar park of between 750MW to 1GW capacity to power the mining industry in the Atacama region, according to a release from Chilean development agency Corfo. This would almost double Chile's current solar capacity having become the first Latin American country to surpass 1GW in January 2016. However, the Chilean renewable energy research institute (CIFES) has not released installation figures for several months. The new solar park, to be known as the 'Solar District', will require investment of US$4 billion and will generate around 3,000 jobs during construction.

MIDDLE EAST & AFRICA

Off-grid

Orange and Engie partner on solar services in Africa

Mobile network operator Orange and French renewables firm Engie have launched a plan to deploy nearly 1,000 solar kits in Senegal, Ivory Coast and Cameroon. The kits include a solar panel and a battery that can store the energy generated and be used to power domestic appliances with electricity in off-grid areas. The kits can be used to replace expensive and dirty lighting solutions such as petroleum or kerosene lamps and diesel-generators. Engie will supply the kits through solar system providers BBOXX and Fenix International but will resume responsibility for the installation and maintenance of the equipment.

Masdar

Masdar doubles clean energy capacity in Mauritania

Abu Dhabi's leading renewable energy firm Masdar has completed eight new solar PV projects in rural communities in Mauritania, doubling the amount of clean power provided to the Islamic Republic nation and powering some 39,000 homes. Now the country's clean energy contribution stands at 31.6MW, and the projects meet up to 30% of the electricity demand in rural communities.

Masdar secures PPA for 200MW Jordan project

Abu Dhabi's clean energy firm Masdar has secured the power purchase agreement for a 200MW solar plant in Jordan. The country's National Electric Power Company has agreed to be the offtaker for the project, which will be the largest in Jordan once it is completed and one of the largest in the region.

World Smart Energy Week 2017

10th Int'l Photovoltaic Power Generation Expo
PV EXPO 2017
8th Int'l Photovoltaic Power Generation System Expo
PV SYSTEM EXPO
8th Int'l Rechargeable Battery Expo
BATTERY JAPAN
7th INT'L
SMART GRID EXPO

Reed Exhibitions Japan Ltd. will be holding the Japan's largest comprehensive show for smart and renewable energy – World Smart Energy Week 2017 from March 1-3 at Tokyo Big Sight, Japan. The show aims to provide a platform for professionals from across Japan, Asia and the world to negotiate and network for the future of smart and renewable energy business. It will consist of nine exhibitions and world-class conference sessions filling up Tokyo Big Sight – the largest exhibition center of the country. The show ranges from power generation to storage, and transmission to distribution technologies. The comprehensive business event is expected to welcome 1,570 exhibitors and 70,000 professional visitors.

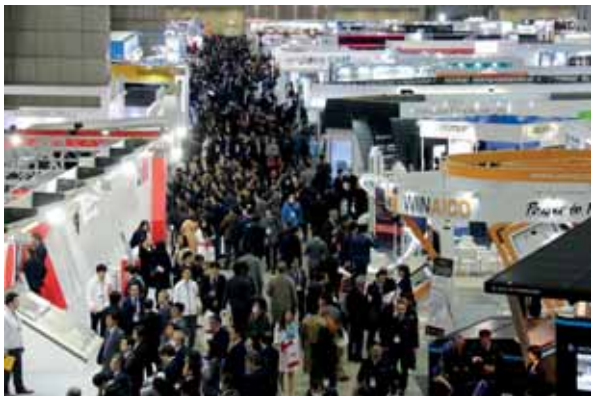
Now is the best timing to enter into Japanese PV market

Japan's largest exhibition for the PV industry will be held in World Smart Energy Week 2017. Four hundred exhibitors will be exhibiting at PV EXPO (Japan's largest PV exhibition specialising in solar cell/module, manufacturing technologies, materials and components) and PV SYSTEM EXPO (Japan's largest exhibition for PV system integration and installation). Many companies from all around the world are developing more high efficiency and high quality products to make a difference from other companies. The world's leading solar cell/module manufacturing companies, such as **HANWHA Q CELLS, JA SOLAR, JINKO SOLAR, PANASONIC, SHARP, TRINA SOLAR, YINGLI GREEN ENERGY** and more will be exhibiting with their latest technologies and products.

One of the biggest highlights of PV EXPO 2017 will be a newly launching BIPV (building-integrated photovoltaics) zone. The Japanese government has set a target year of 2020 to implement Net Zero Energy Building (ZEB) and Net Zero Energy House (ZEH) rapidly as the standard for newly built constructions. BIPV technologies and products are required to reach the target in 2020. Companies offering BIPV solar roofs, windows and more will be exhibiting at BIPV Zone; to name some, **KANEKA** and S**UNTECH POWER JAPAN** will be exhibiting. Including the newly launching zone, PV EXPO is the best gateway to enter and expand your business in the growing Japanese BIPV market.

PV EXPO 2017 and PV SYSTEM EXPO 2017 will be held within World Smart Energy Week 2017 with seven other exhibitions specialising in smart and renewable energy such as smart grids,

Special Events with Renowned Experts


Now is the best timing to enter into Japanese PV market!

energy storage, electricity retail, wind energy and thermal power generation technologies. Participants will be able to build business and network with a vast range of professionals.

Special events with renowned experts

The show will commence with a ribbon-cutting ceremony, inviting over 50 energy industry leaders from Japan and overseas as dignitaries. Ambassadors from France, the UK and Denmark, and senior representatives from major companies in Japan, such as Toshiba Corp., Mitsubishi Electric Corp., Panasonic Corp. and many others celebrated the opening of World Smart Energy Week 2016. Dignitaries for the 2017 opening ribbon-cutting ceremony will be announced in January 2017.

Also, the Executive Party will be held on the first day to facilitate networking among executives of smart energy industries, including executives from exhibiting and visiting firms, organisations, speakers from keynotes and other conference sessions.

The latest market trends from world industry leaders

During the show, keynote and technical conference sessions will be held in parallel to the exhibitions at the Conference Tower of Tokyo Big Sight. Distinguished industry leaders from nine energy sectors will discuss the outlook for their industries, the latest technologies, market trends, national and international energy policies, and various strategies for business. Throughout the show period, 248 sessions will be held in 2017. These will include a World Smart Energy Week keynote session led by the Ministry of Economy, Trade and Industry (METI), Fraunhofer Institute for Solar Energy Systems ISE and Global Solar Council to discuss the "Rapidly Changing PV Industry's Current Environment and Future Market Prospect". Many more interesting sessions are coming up. Check the details of all sessions, which will be announced later in December 2016.

The show has been expanding its scale and the profile of the show by adding THERMAL POWER EXPO and attracting increasing attention from smart and renewable energy related professionals. World Smart Energy Week 2017 is the best place to keep up with the changing conditions of the industry.

Japan's Largest PV Industry Show

420* Exhibitors, 80,000** Visitors

"Largest" in reference to the exhibitor number of trade shows with the same concept. *forecast **forecast including all visitors from World Smart Energy Week 2016.

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Nigeria

Phanes Group to develop 100MW of solar in Nigeria

Dubai-based international solar developer Phanes Group has acquired and will co-develop three 100MW grid-operated PV projects in Nigeria. The ground-mounted projects will boost Nigeria's current solar capacity and play a key role in the Nigerian government's goals to generate 2GW of power from renewable sources by 2020. The projects are located in three areas, including the Mando area of Kaduna, Birnin-Kebbi in Kebbi and Sokoto in northwest Nigeria. The latter – in Sokoto – benefits from one of the highest irradiation levels (2210 kWh/m2/year) in the country and is assisted by one of the 14 recently signed power purchase agreements (PPA) with utility-scale solar power developers – which will collectively add around 1.2GW of solar capacity to the grid.

Nigeria is targeting 2GW of power from renewables by 2020.

Ghana

Eni to develop 20-50MW solar plant in Ghana

Italian oil and gas major Eni has entered into a cooperation agreement with the Savannah Accelerated Development Authority (SADA) for the development of renewable energy projects in Ghana – in particular, for a 20 to 50MW solar plant. The plant is to be located in the Northern Savannah Ecological Zone (NSEZ) and the two companies are to participate in assessing the technical and economic feasibility of the project. Eni has been present in Ghana since 2009, where it operates through its subsidiary Eni Ghana.

ASIA-PACIFIC

Quality

Call for quality to keep solar sustainable from the off in Southeast Asia

Choosing good quality solar equipment will be essential to keep the solar industry sustainable in Southeast Asia, according to Wandee Khunchornyakong Juljarern, chairwoman and chief executive, SPCG, the largest solar installer in Thailand. SPCG has invested and developed more than 36 solar farms, with 260MW of PPAs in the ASEAN region. Speaking at the Solar & Off-Grid Renewables Southeast Asia event in Bangkok, she said that there have been quality issues in Southeast Asia and the market must begin with quality equipment for investors to enjoy high returns in the last 15 years of project life.

Indian PV projects suffering from poor selection of DC cables

Indian solar projects are underperforming because intense pressure to reduce costs is leading to developers and contractors selecting poor quality components and sub-optimal designs, according to consultancy firm Bridge to India. DC cables, used to interconnect modules and to connect modules to combiner boxes and inverters, account for just 2% of project costs, but can impact project output by as much as 15%.

India

Indian solar capacity passes 10GW

India's installed capacity of solar PV has surpassed the major milestone of 10GW, according to consultancy firm Bridge to India. The country is expected to add a total of 5.1GW in 2016, up 137% from last year. Moreover, Bridge to India forecasts additions of between 8-10GW every year from 2017 onwards, which would account for a significant chunk of the ambitious 100GW by 2022 target. Next year, India is also expected to become the third biggest solar market worldwide behind China and the US.

MIP

All China's biggest solar manufacturers now outside the MIP

Europe's price control agreement no longer includes any of China's biggest hitting module manufacturers. Canadian Solar, Lerri, Trina, JA, Jinko and GCL-SI. The Minimum Import Price mechanism was designed to prevent Chinese firms dumping low-cost solar cells and modules in the EU. A quirk of its design has seen the level of the price floor stay more or less constant while global prices plummeted.

Thailand

Thai solar to rejuvenate in mid-2017

Political changes over the last four years and the recent death of King Bhumibol has brought some inertia to the Thailand market, but industry members expect the market will return to strong growth in the second half of 2017. Franck Constant, co-founder of the Sonnedix Group, said it has not been easy to develop policy in the current climate following a constitutional referendum in August, which has made foreign investors hesitate. Far less capacity has come online compared to the 2010/11 period. Constant added: "The country is mourning the late King and there will be a natural slow down situation for a few months. I think that will extend into early next year."

China

China cuts 2020 solar targets

China confirmed a formal reduction in its 2020 PV deployment target from 150GW to 110GW. Parts of China have experienced severe curtailment of installed solar capacity owing to grid restrictions. A surge in connected projects on the government's records saw a huge 22GW of capacity added to the official register in H1 2016. A consultation on a reduction to the country's feed-in tariff was announced in September with utility-scale projects facing possible cuts of up to 31%. Frank Haugwitz, the Beijing-based founder of solar consultancy AECEA, suggested that past experience of Chinese target-setting on solar could well mean that the 110GW is a minimum level. According to AECEA, the 2011-2015 target of 35GW was exceeded by more than 20%.

Credit: United PV

China's rapid project registrations in H1 2016 totalled 22GW but many had been built for some time.

Product reviews

Inverters ABB'S 1500V central inverter complies with latest UL 62109-1 safety standards

Product Outline: ABB has introduced the PVS980 central inverter, one of the first inverters to receive the UL 62109-1 safety certification as well as one of the first 1,500V DC inverters to receive IEEE 1547 grid interconnection certification.

Problem: High power 1,500V DC central inverters have become increasingly popular due to the reduction in unit requirements and balance of system components, improving the LCOE of projects. The new certifications are designed to satisfy local, state, national and international compliance regulations, reducing time to market for next-generation inverters.

Solution: The PVS980 central inverter comes with increased DC input voltage up to 1,500VDC and rated at up to 2000 kVA.

PVS980 inverters are designed for fast and easy installation. The industrial design and modular platform provide a wide range of options, such as remote monitoring, fieldbus connection and modular and flexible DC input connections. The integrated DC saves space and costs as the solar array junction boxes can be connected directly to the fused busbars in the DC cabinet. The PVS980 software includes all the latest grid support and monitoring features, including active power limitation, fault ride-through with current feed-in and reactive power control.

Applications: Utility-scale PV power plants.

Platform: The PVS980 features a self-contained cooling system to ensure endurance in tough environments with minimal maintenance. The cooling system uses phase transition and thermosiphon technology to avoid external air entering the critical compartments of the inverter, reducing the risk of corrosive gases or sand entering the inverter and causing damage. The inverter can operate from below freezing to extreme heat in 100% humidity.

Availability: September 2016 onwards.

Trackers Edisun Microgrids launches first commercial rooftop dual-axis tracker system

Product Outline: Edisun Microgrids has launched the first dual-axis solar tracker designed and built for the commercial and industrial rooftop sector. 'PV Booster' claims to provide higher yields compared to fixed-mounted modules.

Problem: Tracking systems dominate the ground-mount market, and almost 90% of all systems now include trackers because of the strong economic benefits. In contrast, the rooftop market has not been able to take advantage of trackers previously because of weight, size, mounting and wind issues.

Solution: By continuously facing solar modules toward the sun, PV Booster increases the energy production by 30% versus conventional fixed-tilt installations. This significantly enhanced performance decreases installation payback by as much as two years, according to the company; additionally, levelised cost of energy may be lowered by US$0.02 per kWh. PV Booster also provides unique value to utility customers that are subject to escalating time-of-day grid pricing, capturing more energy when time-of-use rates are the highest.

Applications: Commercial rooftops flat; +/- 10 degrees.

Platform: PV Booster is designed for rapid installation and features a gearless, lightweight design that keeps operations and maintenance costs low over the lifetime of the system. The technology has a low wind profile and its embedded intelligence automatically retracts modules at night and during periods of high wind. The trackers are powered by a brushless, low-voltage motor that consumes less than 0.01% of the total installation energy generated and uses a battery backup unit to maintain operations when grid interruptions occur.

Availability: Already available.

Products in Brief

Boviet Solar launches 72-cell 1500 volt multicrystalline module to US market

Vietnam-based manufacturer Boviet Solar Technology has launched a 72-cell, 1,500V DC multicrystalline module, designed for the growing commercial and utility-scale demand in the US for the higher voltage modules. Higher voltage systems are known to enable longer system module strings that reduce combiner box and wiring requirements, lowering upfront capital costs and reducing installation times. Larger, 72-cell modules also reduce installation times for a given system size, due to lower unit requirements. The 72-cell 1,500V DC modules were said to come with a 12-year workmanship warranty and a 25-year power output warranty.

Ingeteam's 1,500V inverter features 'smart cooling system'

Inverter manufacturer and EPC firm Ingeteam's newly launched 1,500V INGECON SUN PowerMax B Series inverter family features a 'smart cooling system', which makes it possible to optimise and reduce auxiliary services consumption. Furthermore, the inverter's latest-generation electronic components are housed in an IP66 (NEMA 4) protected compartment, which prevents condensation and lengthens the useful life of the power electronics. Additionally, the new improved inverter design facilitates installation and wiring tasks (on both DC and AC) in addition to maintenance and repair work. Reliability of the product has been proved on the Bankability and Reliability report issued by Black & Veatch.

Product reviews

Inverters — GE's advanced silicon carbide technology at core of next-gen 1,500V central inverter

Product Outline: GE Power Conversion is introducing silicon carbide (SiC) technology into its next-generation 1,500V PV inverter product line. The LV5+ Solar Inverter is the first multi-MW, utility scale inverter based completely on SiC technology.

Problem: PV project developers, EPCs and power plant owners continue to demand greater reductions in the levelised cost of electricity. The growing adoption of 1,500V DC systems, in themselves a major cost saving, is expected to drive demand for higher efficiencies, less power loss and improved opex.

Solution: GE's LV5+ Solar Inverter has an efficiency rating of 99% weighted at EU

level, which allows for higher annual energy production when compared to today's traditional inverters. Higher output per square meter enables customers to reduce investment cost by using fewer panels, thus less land, for the same energy output. Calculations with solar PV plant simulation tools have confirmed incremental benefits of an average 1% of annual energy production (AEP) at the global level. According to GE, 1% more AEP enables up to ~US$2.5 million per 100MW worth of revenue compared to its previous system, the LV5.

Applications: 1,500V PV power plants.

Platform: The use of SiC power electronics enables the LV5+ inverter to adopt a highly efficient air cooling system with air-to-air heat exchangers instead of filters, for hot and harsh environments, reducing operating costs by a claimed US$300,000 over the lifetime of a 100MW solar plant and results in low maintenance. The LV5+ eHouse solution – putting the entire solar skid into a container – comes with a 'sleep' feature, avoiding nighttime energy consumption (dependent on grid code requirements) of a claimed US$820,000 over the lifetime of a 100MW solar plant.

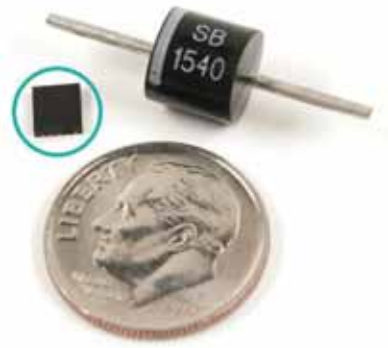
Availability: Already available.

Balance of system — Maxim's analogue IC integrated cell-string optimiser replaces bypass diode limitations

Product Outline: Maxim Integrated Products has introduced a new cell-string optimiser technology that allows PV panels to harvest significantly more energy and simplifies design complexity for solar installation projects.

Problem: Unlike conventional bypass diodes, solar cell optimisers do not bypass weak cell strings. Using bypass diodes in solar a solar panel that experiences shading/soiling at any point within a string limits the maximum current rating to the lowest performing cell in the string.

Solution: Maxim's cell-string optimisers are integrated DC-DC converters that replace the bypass diode and perform maximum power point tracking (MPPT) of the PV panel (from six to 24 cells). By replacing each diode (three) with a MPPT device, the on-off response to



performance mismatch is eliminated; every cell-string contributes maximum power without interfering with the power production capability of others. This enhanced degree of flexibility leads to increased energy production; eliminating collateral performance loss due to module mismatch, degradation, soiling, localised shading, and row shading loss mechanisms. A PV system designer can reconfigure a system design to allow for more inter-row shading that is claimed to deliver 10 to 20% more energy density than a conventional system design. Effectively, the system can maintain the same kWh/kWp as a conventional system, but with higher ground coverage ratios.

Applications: PV module integrated replacement for bypass diodes.

Platform: The Maixm cell optimiser's MPPT function works alongside the string inverter MPPT, to ensure that the system output is optimal under any environmental conditions. The module includes three Maxim solar cell optimisers, which replace the three diodes found in a conventional module junction box.

Availability: Already available.

Products in Brief

Mission Solar gearing up its PV module portfolio in US

US-based PV module manufacturer Mission Solar Energy is introducing its new 'Apollo' module, a 72-cell module capable of producing 360W of power. The module utilises passive emitter rear cell (PERC) technology and four busbars to drive module-level efficiency greater than 18%, and is 1,500V compliant. Meanwhile, the 'Mercury' module is Mission Solar's first product designed for the rooftop market, a 60-cell panel capable of producing 300W of power. In addition, the module's black-on-black design makes it ideal for commercial and residential rooftop installations, according to the company. All products will be available to in early 2017.

Silfab Solar debuts 300Wp 60-cell solar module

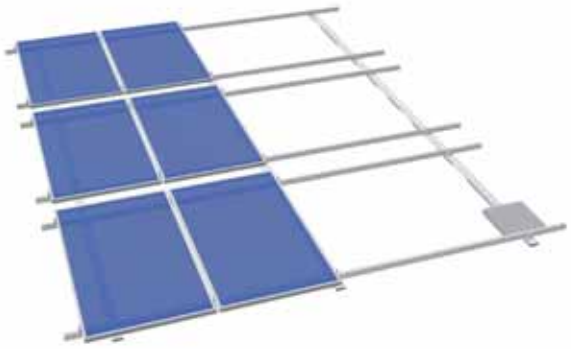
Canada-based PV module manufacturer Silfab Solar has launched its most advanced 60-cell solar modules with a maximum power rating of 300Wp. The new 'SLA-M 300' module utilises p-type monocrystalline PERC cell technology and is aimed at the ground-mount and rooftop installation market where space constraints and architectural designs are a factor. The module comes with positive tolerance of -0/+5W and 100% EL testing guarantee with a 25-year performance warranty. Reduced weight accommodates low load bearing structures while maintaining highly durable mechanical characteristics including a maximum loading of 5,400 Pa.

Racking | S:FLEX has developed a new low-ballast pitched roof system for non-penetrative installations

Product Outline: S:FLEX now offers installers a new, aerodynamic installation system for residential and commercial buildings. 'Flat Direct' can be used on pitched roofs with up to 30° slope and guarantees short installation times with its pre-assembled components.

Problem: Non-penetrative installations of PV systems on pitched roofs with composite shingle and other roofing materials places high demands on the substructure, especially on commercial buildings with low load-bearing reserves.

Solution: Flat Direct is useable on a variety of roof types with various roofing materials and framed modules arranged in a portrait or landscape setting. If required, secure anchoring is achieved by a minimal number



of mechanical attachments or counter-weights over the roof ridge. A special ridge angle joint has been designed for installations on pitched roofs, which can be easily adapted to each site specific situation. The system solution was designed to meet the specifications of snow loads up to 50psf and wind speeds up to 130mph. Ballast stone clamps are available for installations where project-specific parameters require additional ballast. Aerodynamic functionality is achieved through air gaps between the modules that produce a suction effect towards the roof and an optimised air flow throughout the solar array.

Applications: PV systems on pitched roofs with composite shingle and other roofing materials.

Platform: The Flat Direct, which was developed in cooperation with PMT (Premium Mounting Technologies), offers also optionally available covers for the cable channels integrated into the bottom rails. This way, string cables are protected against permanent and harmful environmental influences.

Availability: Already available.

O&M | skytron energy's PVGuard 2.4 supervision platform provides fleet management advances

Product Outline: Version 2.4 of skytron energy's PVGuard Fleet Manager system enables system owners and operators to monitor the technical performance of PV power plants, inverters and alarms across their entire fleet in a single view.

Problem: As PV portfolios grow in size and geographic diversity, PV power plant owners and operators need to gain a single-point administration of an entire global portfolio of power plants that enables roles and responsibilities to be clearly defined.

Solution: The new version of PVGuard provides a completely new way of obtaining a summary view of an entire fleet. The geographical representation of sites and plant states allows operators a quick system overview at all times for any plant in an account. The overlaying of data for the various normalised parameters allows the comparison and evaluation of plants at different sites that use differing inverter concepts or module technologies. All of a customer's monitored inverters for example can be seen in one place, irrespective of

plant. The graphical display can be sorted according to the performance ratio of each individual device. In this way, any poorly performing inverters become immediately obvious. Added to this, the alarms from all power plants under supervision can be brought together and processed in a single place.

Applications: O&M of utility-scale and commercial PV power plant fleets.

Platform: The Fleet Manager is being made available in both the PVGuard Supervision Platform and in the PVGuard Mobile Apps. A separate HTML version will also be available that can be embedded on a big screen in a control room or on a tablet PC.

Availability: Already available.

Schneider Electric 'Conext SmartGen' inverter records and stores its own operation and service history

Schneider Electric has launched 'Conext SmartGen', an intelligent, cloud-connected 1,500V utility-scale power conversion system, as well as a suite of supporting software solutions called the 'Power EcoSystem'. Conext SmartGen inverter records and stores its own operation and service history. It has self-diagnostic capabilities and can send predictive maintenance warnings and reports through the cloud. Housed in a water- and dust-sealed corrosion-proof enclosure, it is designed to deliver up to 2MVA of power for 30 years. Its wide operation range, combined with best-in-class efficiency and unprecedented service life maximise its energy generation lifetime.

Yaskawa - Solectria Solar's 1,500V string combiners offer HALT reliability

US commercial PV inverter manufacturer Yaskawa - Solectria Solar has added the DISCOM 1500, a 1,500V DC string combiner, to its DISCOM string combiner line. The combiners have gone through Highly Accelerated Lifetime Testing (HALT), guaranteeing all components are carefully vetted for reliability. Key features include a high gloss white painted finish to keep the electronics cooler in higher temperatures and reduce extreme thermal cycling, adding to the product life. Multi-Contact MC4 or Amphenol H4 Connectorized Wire Whips reduce installation time and costs. These string combiners are being deployed in utility-scale projects in the US from 50-200MW.

Product reviews

Modules — SunCulture Solar launches breakthrough integrated high-efficiency solar rooftop system

Product Outline: US-based start-up SunCulture Solar Inc. has come out of stealth mode and launched a fully integrated residential and off-grid solar system. 'SolPad' Home combines multiple patented technologies into a single device, including breakthrough solid-state battery technology, an innovative inverter system and intelligent software to enable real 'plug and play.'

Problem: Labour and technical soft costs are seen to be the hardest problems to solve when it comes to integrating solar and storage with software for residential rooftop applications and have traditionally been purchased and installed separately.

Solution: SolPad Home combines solar and smart home components that have traditionally always been bought and installed separately, reducing the system's installed cost by 50%, according to the company. Each SolPad device is equipped with its own 'solar micro-storage' solid-state battery at the panel level. This battery technology is said to be inherently safer than standard lithium-ion-based batteries.

Applications: Plug-and-play residential rooftops.

Platform: SolPad Home's 'flexgrid' inverter is flexible enough to account for the many different power environments that exist can automatically detect when to charge from the sun or charge from the local utility grid, adjusting for cloudy or rainy days, as well as changing local electricity rates. Flexgrid will also detect when there's a power outage or blackout and safely disconnect itself from the grid. Once off the grid, SolPad automatically forms a personal solar micro-grid that will keep delivering power to specific lights and appliances. The SolPad Home 'Connect' system is a wire-free system that links two or more SolPad Home panels together, eliminating the need for any complicated cabling or wiring.

Availability: Second half of 2017.

Inverters — Sungrow launches world's first 1500V string inverter

Product Outline: Sungrow has launched the world's first 1500V string inverter. The SG80HV has a power output of 80KW rated at 1,500V DC, with a 2.5MW PV power block design and the ability to lift the maximum efficiency to 99%.

Problem: 1,500V solar systems are expected to dramatically reduce system costs and improve power generation efficiency. The solar industry has long demanded a 1,500V string inverter to reduce the levelised cost of electricity for commercial- and utility-scale PV power plants.

Solution: The SG80HV has a power output of 80kW rated at 1,500V DC. With a 2.5MW PV power block design, DC side cabling costs can be reduced by 30%. Sungrow's patented five-level topology design enables SG80HV to lift the maximum efficiency up to over 99%, even at a 1,500V DC voltage rating. Also, SG80HV is able to operate at 1.1 times overload in temperatures as high as 45 degrees Celsius, while avoiding power losses caused by temperature de-rating. At a 1,500V DC rating, the SG80HV is also able to reduce balance of system costs in addition to the high power generation yield it offers.

Applications: Commercial- and utility-scale PV power plants.

Platform: The SG80HV is designed with a next-generation film capacitor designed to prolong the lifetime of the inverter. Its patented PID protection and repair function enable SG80HV to work stably. In addition, the inverter's power factor can be continuously adjusted from 0.9 lagging to 0.9 leading when it is operating at full active power with the support of stronger reactive power.

Availability: Already available.

Products in Brief

SolarEdge offering highest wattage power optimiser for commercial projects

SolarEdge's highest wattage power optimiser – the P800 – allows installers to connect even higher wattage modules in a 2-to-1 configuration in commercial projects, reducing installation time on the roof, lowering part count and increasing system energy production. The expansion also includes new monitoring capabilities to improve PV asset management with the launch of a new commercial cellular solution that directly integrates with weather stations and Revenue Grade Meters (RGMs), available from SolarEdge. Enabling monitoring via GSM networks and display of revenue-grade data, the solution is designed to improve connectivity and data accuracy for commercial sites using the SolarEdge monitoring platform.

Solar Data Systems enhanced 'Solar-Log' metering solution offers adaptable options

Solar Data Systems has enhanced the design of its 'Solar-Log' commercial revenue-grade solar metering solution. The new design offers adaptable options including SCADA integration through DNP3 or Modbus protocol. These additional communication protocols plus compatibility with over 100 inverter brands provide power management tools for control of inverter production, power factor, VAR and grid export. As part of the enhanced product redesign, the non-fading polycarbonate and ABS plastic enclosure now features a swing frame to accommodate more options in a compact package.

Trackers — SunLink's 'TechTrack Distributed' single-axis tracker controls damping and stiffness of the array

Product Outline: SunLink's TechTrack Distributed single-axis tracker introduces 'dynamic design', providing site flexibility and reductions in total project costs.

Problem: The ability to control the damping and stiffness of a single-axis PV array in real-time conditions could increase generation and reduce the risk of harm to the power plant. Providing damping when the single-axis PV array is unlocked would increase system natural frequency.

Solution: Central to the system's innovation is a dynamic design feature called 'Dynamic Stabilisation', through which the characteristics of the tracker are changed depending on real-time, sensor-observed environmental conditions. Beyond simply adjusting tilt, SunLink's TechTrack Distributed incorporates control over the damping and stiffness of the array, opening a new solution space for increasing energy output, maintaining structural integrity and lowering cost. The system solves the challenge of monitoring the thousands of electromechanical parts that make up a distributed tracker system via SunLink's 'VERTEX Project Intelligence Platform'.

Applications: Ground-mounted utility-scale PV power plants.

Platform: TechTrack Distributed has enabled the maximum system torque be reduced by 67%, resulting in a stronger, lighter and more cost-effective tracker. Continuous tables and 120° tracking yield improved power density and generation, according to the company. Communication is via secure, proprietary mesh network. SunLink also offers PowerCare installation and O&M services for TechTrack projects, making it possible for EPCs and developers to take on more projects successfully.

Availability: Already available.

Modules — Sunpreme's 'Maxima' bifacial modules offer 380W and impedance matching performance

Product Outline: Sunpreme has launched the Maxima GxB380 SM, 380W, touted as the most advanced high-efficiency bifacial panels, using its proprietary 'Hybrid Cell Technology' (HCT) platform and featuring an integrated Tigo optimiser.

Problem: Bifacial modules respond to the growing demand for high-performance and high-yielding PV modules by absorbing light reflected light from a roof or ground surface, boosting module output. Such systems also operate better with optimiser technology.

Solution: Sunpreme's GxB380 SM Smart Bifacial modules are claimed to be the highest performance bifacial modules on the market. They boast impedance matching technology, improved reliability and durability, shade tolerance and longer strings at the system level. A peak string level AC/DC ratio of 0.95+ reduces LCOE and boosts lifetime yield. The GxB380 SM offers increased flexibility, as modules with optimisers can be easily installed with complex rooftops or shading from trees, chimneys and other obstructions.

Applications: Bifacial modules can be used in a variety of BAPV applications such as carports outside conventional utility-scale ground mount and commercial and industrial (C&I) rooftops. Sunpreme recommends a 15 degree tilt mounting frame for C&I rooftops.

Platform: Sunpreme's Smart GxB380 SM is a 72-cell module that maximizes energy yield and peak string level AC/DC using impedance matching technology. The module components work together to communicate wirelessly through a gateway and meet the new NEC 'rapid shutdown' safety' standards. The panels are double glass for durability and aesthetics, and come with -0.28%/C thermal coefficient and fire class rated A.

Availability: Already available.

PHP Systems/Design re-launches its 'PHP Solar Panel Mounting System'

US-based PHP Systems/Design (PHP), a designer and manufacturer of rooftop pipe and equipment support systems, has re-introduced its 'PHP Solar Panel Mounting System' which is designed to support a wide variety of solar panels. The system's base is made out of injection-moulded, high-density polypropylene with UV-inhibitors and antioxidants, and carbon steel framing that is hot-dip galvanised per ASTM A 123. PHP's system can be used most types of flat or low slope roof and is ideal for commercial and industrial buildings. Seismic and high-wind applications are available for all solar support applications.

Risen Energy offers 1500V series panels for lower LCOE

Module manufacturer Risen Energy has introduced a mainstream multicrystalline 60-cell 1500V series PV module for commercial and utility-scale applications. The RSM60-6 module comes in 250W through 270W configurations using four-busbar technology and 16.5% maximum conversion efficiencies. In 1,500V DC system format the efficiency performance ratio can be expected to be improved by 1.5-2%, according to company. 1,500V modules can potentially increase string length by 50%, lowering balance of system costs and overall LCOE. The modules come with class-A requirement of IEC61730 and 12-year product warranty and 25-year linear power warranty.

Product reviews

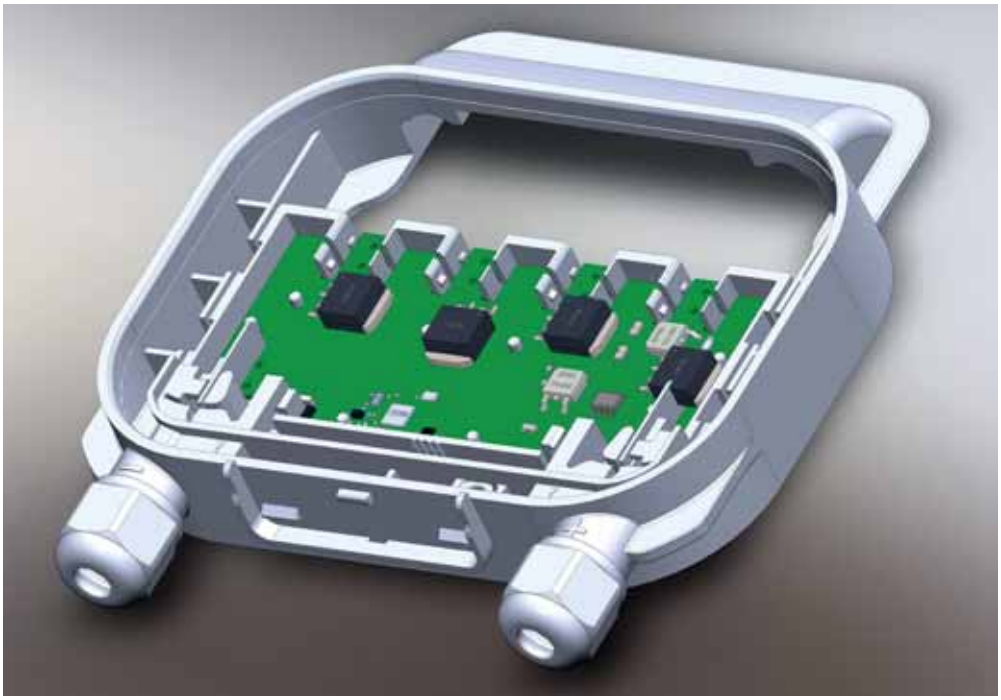
Balance of system | SunSniffer adds rapid shutdown function to solar module-level monitoring system

Product Outline: SunSniffer is to launch its first junction boxes with a special monitoring sensor and a rapid shutdown function for solar modules.

Problem: In 2017, a revised version of the US National Electrical Code (NEC 2017) comes into effect requiring module-level rapid shutdown. SunSpec Alliance reacted on that and drafted specifications for the communication signal supporting module-level rapid shutdown (Communication Signal for Rapid Shutdown, SunSpec Interoperability Specification).

Solution: SunSniffer has developed a sensor that not only provides the special and unique module-level monitoring system, including module-level temperature measurement, analysis via artificial intelligence and a simulation engine, but additionally is able to rapidly shut the system down according to the requirements of NEC 2017. LEONI and QC Solar together with SunSniffer developed the respective junction boxes with the embedded sensor.

Applications: PV module junction box sensor for US rapid shutdown.



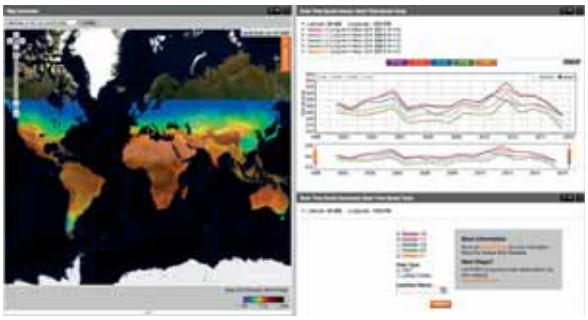
Platform: The SunSniffer sensor measures voltage and temperature at each single module, and the simulation engine in combination with artificial intelligence allows the system to detect even the smallest error – with an accuracy of under 1%, according to the company. The SunSniffer system not only detects errors, it analyses and identifies them, provides detailed instructions to operators on what needs to be swapped or repaired, and ensures complete documentation.

Availability: From December 2016.

O&M | Vaisala's online 'Solar Time Series Tool' enables in-house irradiance measurements

Product Outline: Vaisala's 'Solar Time Series Tool' allows solar project developers, operators and engineering teams to minimise long-term resource risk and improve energy estimates.

Problem: To date, the solar industry has either used publicly available irradiance datasets based on single models or relied on third-party providers of resource data to carry out evaluation of the available sources. As margins on solar projects worldwide get tighter, it is increasingly critical that asset owners are able to understand and manage the impact of long-term production variability when undertaking financial planning. In order to do so, access to reliable resource data and models is essential. While the number of high-quality datasets available to the industry is steadily growing, each model uses different inputs and methods of irradiance calculation – and therefore carries inherent uncertainty.



Solution: Vaisala's online Solar Time Series Tool enables subscribers to compare results from up to five models for any given site, via a visual interface that enables side-by-side analysis of long-term trends. The availability of multiple datasets gives users the ability to conduct resource risk evaluation and energy modelling. For developers, this could help avoid dramatic shifts in project value. In turn, portfolio owners and operators will be able to use Vaisala's resource data, which is updated monthly, to weather-adjust project performance at multiple sites. Independent engineering firms will also see the benefit of using these high quality datasets as they look to improve the reliability of their energy estimates.

Applications: PV power plant and fleet irradiance measurements.

Platform: Both time series and Typical Meteorological Year (TMY) data can be downloaded directly from the Solar Time Series Tool and are delivered within 24 hours. The dataset is based on visible satellite imagery observations via the broadband visible wavelength channel at a 2 arc minute resolution.

Availability: Already available.

POWER PVTECH

SPECIAL REPORT

Solar in the Middle East and North Africa

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Staying on top of the soiling problem, p.28

Credit: franckreporter/Getty Images

MENA means business

Credit First Solar

Market overview | A number of false dawns have so far prevented solar from living up to its full potential in the Middle East and North Africa. But as Danielle Ola reports, with all the right ingredients in place, and an increasingly competitive business environment, the prospects in the region look better than ever before

The Middle East and North Africa (MENA) region has been the next big solar market for a very long time but never seems to quite make it. Despite confidence in power demand and in the solar resource, questions over financing and political risk remain. The differing energy demand requirements, economic status and generation capacities found across the region mean the prospects for clean energy potential in the Middle East are far from uniform.

However, as oil prices worldwide plummet alongside the cost of renewable energy technologies, the latter are poised to play a significant role as a cost-competitive alternative to conventional power. Indeed the first sign of things to come are already well in evidence, with solar already starting to play an increasingly important role in Jordan, Morocco and the UAE. Potentially the region's biggest solar market, Saudi Arabia, has started to show signs of life, while across the Red Sea in Egypt there is optimism that recent political hurdles can be overcome to reignite what at the outset looked like a very promising new solar market.

This article looks at some of the dynamics shaping the fortunes of solar in the MENA region and its prospects in a part of the world where it arguably makes most sense.

Stop-start Saudi

Saudi Arabia is at the centre of the region's plans to become a renewable energy heavyweight. Despite having first outlined plans for a renewable energy transition back in 2010, Saudi has faced severe delays in implementation.

The King Abdullah City for Atomic and Renewable Energy (KA CARE) procurement programme was launched in 2010. The original target of 41GW of solar energy was less than successful and subsequently pushed back. The reasons for the failure of the programme are still debated, but possible explanations include a lack of competitiveness against heavily subsidised conventional power and a lack of government implementation. "There was no clear responsibility and clear authority in one place for the programme and it kind of just fell apart with all the different centres of power," says James Kurz, senior consultant at Apricum - The Cleantech Advisory.

Chris Ehlers, newly installed CEO of Saudi-based ACWA Power's renewable energy division ACWA Power RenewCo, agrees that the false start could be down to a lack of coordination from stakeholders: "We must not forget that these are huge programmes that are being rolled out and that there are a variety of stakeholders involved. It is also part of a transition from the historical form of providing energy and shifting the focus to renewables. That is a huge transition for any country."

Record-low bids are one reason for optimism over solar's prospects in the MENA region

However, in late April of this year, the Saudi government approved the 'Saudi Vision 2030', a concerted attempt to reduce the kingdom's reliance on oil and transition into a clean energy future. Vision 2030 is a complete economic overhaul as well as an ideological one, with wide-ranging economic diversification and designs to rein in government spending. Specifically, for the renewable energy sector, it sends out a long-anticipated signal to developers and other industry stakeholders that Saudi's 'sleeping giant' is finally awake.

"Obviously we had a bit of a false start but it now looks like things are finally moving," says Mhairi Garcia, vice chair of the Clean Energy Business Council and energy counsel at law firm Ashurst. "Everyone is quite excited about Saudi."

Whilst no specific mandates have been set for wind and solar procurement, the 'initial' target of 9.5GW of renewable energy by 2023 is much more definitive than the previous 'wait and see' approach to renewables that Saudi has taken so far.

In addition to this commitment, a recent and radical Saudi government reshuffle under the 'King Salman Renewable Energy Initiative' adds new legal and regulatory frameworks for the deployment of renewables. In May 2016, oil minister Al-Naimi was replaced by Khalid Al-Falih, who was made the head of the new ministry of energy, industry and mineral resources, which now assumes sole responsibility for electricity.

Garcia believes that this new government focus is its own driver for renewables deployment in Saudi: "Now I think there is a real commitment from the ministerial level in Saudi to move things along; obviously they've got their own drivers in terms of oil price and so on, but that will be what gets things off the ground."

Nevertheless, although the Saudi Electric Company has begun with a request for proposals for the upcoming tender, no other plans for long-term procurement are in place, causing Apricum to forecast an outlook of 'uncertainty' for the region.

"[Saudi] has not clarified a framework for development, whether that will be larger tenders done by SEC or whether Saudi Aramco will be involved somehow," says Apricum's Kurz. "What about KA-Care: does it still have some role to play in renewable energy development? It's not exactly clear yet. We know that the major players are trying to decide on what the framework will look like, but there is some risk that agreement is delayed or it could be that what they decide is smaller than expected.

"But we expect that by 2020, this will be a PV market that will be installing between 500, 600MW-1GW."

Jordan

Saudi could learn from the model in Jordan, where generating capacity is expanding. Despite relying on imports for around 95% of its energy needs, Jordan's lack of conventional energy resources means that there is a clear opportunity for renewables. While it is not the most politically secure region, it has mandated a very clear commitment for renewables with the government's tailor-made renewable programme.

"It is in a sense really leading the region because it has a regime in place; it has a renewables slot and it has a price list and its third round of tendered projects has been announced," says Garcia. "It is not doing projects in the same scale necessarily as in Dubai and Abu Dhabi. But there is that real commitment and because there is a real need for [renewables] as part of their energy mix, diversification is a key requirement."

Jordan holds targets of 1.8GW of wind and solar by 2018, with a promising pipeline of projects already underway to achieve this. Direct proposal submissions have just opened for the third round of tenders for 200MW of PV and 100MW of wind.

Despite being limited in size and experiencing higher electricity prices than most countries in the MENA region, Jordan has nonetheless made an opportunity for development. "The fact the projects are smaller means more private developers could come in, despite trying to get them to take a bit more risk perhaps, as has been the case in conventional independent power projects. It's quicker to get 20MW or 50MW up and running, rather than 800MW," says Garcia.

Jordan has also proved a resilient player, overcoming its electricity network's struggles to support bidder appetite for renewables. "Everybody wanted to build a solar project in Jordan but the network kind of prevented it," says Keith Bullen, senior legal consultant at DLA Piper's F&P team in Dubai. "They fixed that through the Green Corridor and will soon be supplementing that with a very robust transmission line that will be able to support renewable projects close to it."

Egypt

Less of a role model for the region is Egypt, whose tumultuous energy sector has been buffeted by political and social turbulence. Now that the climate has settled down, the need for a stable and secure power supply is on the books, with solar and wind power expected to be instrumental in creating this.

Tahboub believes that for Egypt to repair its internal damage, the country should reach to external sources: "Government stakeholders need to revise their plans and put in place a more sustainable mechanism to invite international developers to come in, invest and develop green energy."

It may however not be that straightforward, as Egypt's energy sector currently faces two significant barriers: one pertaining to currency and the other to dispute resolution with the government insisting on local arbitration.

The arbitration issue was triggered by competition elsewhere in the region. The original Egyptian 4.3GW FiT programme began at a relatively high price of US$0.014/kWh for 20-50MW PV projects. This price was in stark contrast to the competitive bids happening elsewhere in the likes of Jordan, Abu Dhabi and Morocco.

"The Egyptian government was like, wow, why are we paying two or three times the price in Egypt? So they put in additional clauses to the PPA that would basically make it almost impossible to finance these projects – the local arbitration rule," explains Kurz. "The requirements also stipulate that 85% of the financing be from international sources. The whole idea was that they would push these projects with this higher PPA to another round with a lower FiT rate so that they could save on costs. Of course, that is doing huge damage to the Egyptian government's credibility."

Kurz estimates that of the 2GW from the first round, representing 40 projects, around 10 of those found a PPA. "But as for how many of those 10 projects actually get built – I don't think it will be all of them. In our assumptions we think about half of them have a chance, so that would be about 150-200MW," he adds.

MESIA takes the view that a "low percentage" of the original tender will get built, with the onus falling on developers to engage with the government to get through the issue. ACWA Power, however, remains optimistic – particularly since a second phase of tenders was announced 28 October at a price of US$0.0840/kWh with a 30% and 40% local content requirement for solar and wind projects respectively.

Indeed, Egypt is home to the second-largest economy in Africa, creating a high demand for energy. The content requirement offers opportunities for both local and international companies, and the new incentive structures give Egypt the chance to redress its former discretions. Moving forward, the Egyptian energy ministry has outlined three options for participants: to carry on with Phase 1 of the original tender, transition to Phase 2 or to withdraw completely and recover costs paid through the Cost Sharing Agreement.

Finance

The MENA region is characterised by some of the lowest tariff prices globally for solar PV projects. The Abu Dhabi Water and Electricity Authority (ADWEA) received what are said to be the lowest bids ever for solar PV, for its 350MW Sweihan plant. Coming in at just US$0.0242/kWh, JinkoSolar and Japanese conglomerate Marubeni Corporation submitted the lowest bid – even lower than the bids in Dubai that were at the time hailed as the lowest tariffs ever received.

"What we have seen in Dubai and Abu Dhabi are factors coming together," says Ehlers. "Obviously, these are factors that cannot be replicated in each and every country; however, there is potential to scale

if demand is there, so I don't see a reason why other markets cannot be on a similar – I'm not saying on a lower or the same – but on a similar level."

The question remains whether it is feasible for similar prices to be replicated in other countries, given unique market dynamics and differing drivers. For example, PV in Saudi is not the same as PV in the UAE; each has differing climatic conditions and solar irradiation which will determine whether one achieves a more favourable price. Secondly, the confidence of banks in that particular jurisdiction will determine how cheap financing can be. That being said, Apricum's Kurz believes the adjusted levelised costs of energy renders prices incommensurable regardless:

"There's a bit of a misconception with the Abu Dhabi tender. What came out in the press is this 2.4 cents/kWh figure and everyone is saying this is an all-time record. But this is not an adjusted levelised cost of energy. Unadjusted, it was around the same as the Dubai bid. The way it was adjusted gave 60% higher value to all energy generated during the summer months, which actually reduced the LCOE by about 20% if you take the whole year into account."

Sustainable pricing?

What can be agreed is that the region as a whole is experiencing favourable pricing conditions. Even Egypt, for all its political woes, experienced a price drop to US$0.078/kWh from US$0.136/kWh for 500kW-20MW projects and from US$0.14/kWh to US$0.084/kWh for 20-50MW projects under its FiT.

The low prices are not questioned, but the sustainability of such prices is. In fact, in the summer several developers including Enel Green Power, ACWA Power and ALJ pulled out of the bidding for Dubai's 350MW solar tender due to the fear of prices plummeting to new lows.

This begs the question whether such prices are feasible for reliable execution. The general consensus, despite the risk, appears to be that they are.

"Yes they can be – as evidenced by what is going on in Abu Dhabi and what is going on in Dubai," says Garcia. "That has of course brought increased pressure on the banks and EPC contractors to come up with lower prices."

Input of commercial banks and government authorities also has a lot to do with whether certain prices are feasible in certain regions. For example, security and diversification are at the forefront of driving Jordan's market, so it has garnered the support of the likes of the IFC and the EBRD. On the other hand, the UAE has the support of its off-takers, making low-priced projects feasible.

"In Dubai the mandated minimum return on a project was set at 10% and in Abu Dhabi it was set at 7% so DEWA was already investing 50% in the project and ADWEA was also investing 60% in their projects," says Kurz. "7% is not a super high return, but the project should be profitable based on what the bidders are proposing."

Subsidies (or lack of)

Something a lot of the MENA countries do have in common are subsidies for conventional sources of power such as oil and natural gas. There is however a movement spreading across the region for the phasing out of such subsidies, which would be an additional driver for renewables. "It makes it more transparent to see how competitive renewables are directly compared with conventional power," says Ehlers.

"It's quite a sensitive issue because [phasing out subsidies] in turn pushes up the cost of power for commercial and private usage, but the upshot is that conventional energy has been subsidised for years, which makes it very difficult for renewables to compete," agrees Garcia, who also feels this movement could open a converse question of whether all renewables can indeed compete or whether some in fact need subsidising.

Notwithstanding, Abu Dhabi and Dubai achieved US$0.03/kWh or less for PV. So it is undeniable that PV is extremely competitive – even without subsidy. In fact, all countries in the MENA region have at one point or another proved their competitiveness for PV and other renewable technologies, including wind and CSP. Although the financial and political situation remains vastly varied, the common thread remains that a region once dominated by oil is becoming famous for a very different type of energy. ■

Morocco, MENA's unsung hero

While the focus is on solar's prospects in the big economies of Saudi, Egypt and the UAE, there is the opinion that Morocco is quietly blazing a trail for the rest to follow.

"Morocco clearly is one of the early starters," says CEBC's Mhairi Garcia. "It was one of the first countries to push forward on solar farms and has of course has been a leader on CSP. Now it's got PV projects and wind projects. It's got a lot of ambition."

Morocco has a target of 2GW of solar by 2020 and has recently chosen a consortium to build the 170MW Noor PV I scheme, representing its first significant PV deployment. As has been the case elsewhere in the region, Morocco has seen some competitive pricing for PV, with the winning bid for Noor coming at around US$0.06/kWh.

"Morocco is really taking the lead not only on renewables from a programme implementation and speed point of view but also from the solar part of it. We have seen now in the past that these programmes having specified CSP and then specified PV, but that is going to change in the future and I see Morocco driving that and complementing both technologies," says Chris Ehlers of ACWA Power, which is leading the Noor PV I consortium.

Already a leader in CSP, Morocco is now beginning to embrace utility-scale PV

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Widening the net

A shortage of roof space in urban parts of the Middle East is one impediment to the rollout of distributed PV

Credit: Richy_B/Getty Images

Distributed PV | The first substantial barriers to rooftop solar in the Middle East are being eroded but a host of other challenges remain. Many are familiar, some are unique to the region. John Parnell reports

What's wrong with this picture? Dubai is a modern city-state within a wealthy nation-state. It has first-class infrastructure, from telecoms to the power grid to transport. Yet in the main image of this story, the sun is beating down on concrete rooftops, satellite dishes, air conditioners, pools and helipads. But there isn't a solar panel in sight.

Dubai has taken action to address this with an ambitious goal to have solar on every rooftop by 2030 and the introduction of the 'Shams' net-metering programme by the state monopoly utility, the Dubai Electricity and Water Authority (DEWA). Neighbouring Abu Dhabi is holding a consultation on its own scheme and the Jordanian programme was enabled by regulations passed in 2012. Plans are also afoot in Oman, Kuwait and Qatar.

Previously there have been a number of substantial obstacles to the take up of rooftop solar. While some of these remain, major hurdles have been removed.

Policy

With the Middle East dominated by state-owned monopoly utilities, there was no legal framework for individual businesses or consumers to be compensated for solar power generated on their roof. Jordan cleared that hurdle with its 2012 policy package. Dubai followed suit and others will inevitably follow.

The subsidisation of conventional energy in oil and gas producing countries kept the price of electricity artificially low. With the price of a barrel of oil well below US$70 for the last two years several Gulf countries have eased up on those subsidies, sending consumer's bills upwards.

"The old economics of retail energy cost were a huge barrier to the rollout of distributed solar," says Sami Khoreibi, CEO of UAE-based developer and EPC Enviromena. "Very simply, traditional prices were heavily subsidised and there were no such subsidies implemented for renewable technology. Under previous frameworks it was virtually impossible to make an economic case for solar to the end user. They had to be making a green statement, or want to know how it would behave on the grid," he explains.

These are the circumstances under which Enviromena built 16 rooftop systems in the Emirates outside of any support scheme.

"The DEWA programme is just over a year old in terms of being allowed to connect to the grid in the net metering fashion. The programme started with a couple of dozen projects that have already occurred. Typically what we are seeing are some government buildings as well as a few commercial and industry rooftops, and some residential systems. Usually it is the owner of the building that is taking the initiative to have a solar power system," explains Khoreibi. "This is one of the fundamental bottlenecks right now, it's not a very challenging bottleneck but nonetheless, in the UAE the tenant is rarely the owner. It has been a bit of a challenge to find people who have lease terms long enough to justify the installation of a solar power system that will typically have a payback period of seven to nine years."

Khoreibi is right to describe this as a surmountable bottleneck. Many markets have had to deal with the tenant-landlord issue within their own legal framework. The transient nature of the population in the Gulf can exaggerate this problem, particularly when looking at the residential sector.

"Enviromena alongside some industry partners have started developing some standardised rooftop leases. We need to understand the underlying legality of who owns the roof and the underlying framework from both property law and a banking perspective, to getting everyone comfortable that a solar power system, even if a new tenant comes in, will continue to be valuable as a source of power saving," he adds.

"A lot of the slowdowns we have felt in the past 12 months in terms of the rollout of rooftop solar have been a function of a lack of standardisation. It's a nascent industry. So we're working on a lot of the administrative and legal side of it today in order to hit the ground running," he said.

Prices

With utility solar pricing in the region garnering plenty of attention, it could be easy to presume that the economic argument for rooftop solar is a no-brainer. The numbers are already favourable and there are changes that could be made to promote solar further, beyond the removal of fossil fuel subsidies.

"The new reality is that solar continues to be unsubsidised," says Khoreibi, "but subsidies have been lifted for conventional energy in terms of power generation so now we are comparing apples to apples. If you take a look at the average cost of baseload electricity production in the UAE, it is around 6-8 cents for conventional sources. Solar is at the lower end of that and it has gone as low as 2.42 cents. Rooftop solar could go to 5-6 cents and it will be way below retail cost."

"So with net metering people can pay off their system in less than 10 years and in many, many cases less than seven. The underlying economics are quite compelling for the end user and also for an owner selling power to an end user," he adds.

The Abu Dhabi utility-scale tender that solicited a 2.42 cents per kWh bid, includes a 60% premium for power generated in the summer months, when it is desperately needed to cope with peaks generated by air conditioning use.

These same peaks also drive up the cost of generation. Khoreibi points out that Saudi Arabia relies on diesel and fuel oil peaker plants in the summer months at a cost of nearly 20 cents per kWh.

"Legislation which allows individuals or businesses to offset their power production with solar would be a tremendous opportunity"

Net metering

Dubai has had the benefit of Europe's experience, and mistakes, when it comes to encouraging the take-up of rooftop solar. It was no surprise to see it go

Credit Enviromena

down the net metering route. There are currently no grid charges as the utility also operates the network. This has been a bone of contention in the US. Jeremy Crane is CEO of distributed solar developer Yellow Door. The company is part of private equity investor Adenium Energy Capital which has already funded 57MW in Jordan and has another 10MW in construction.

"At this point it is really simple. There is no compensation to the utility company. You just dial it in. You produce something, you consume something and you net it out. The utility is somewhat on the hook for managing that but at the scale of production will be positive as it will help to meet peak demand," says Crane.

He believes that the implementation of time of day billing, which is widely mooted, could be a boon to distributed solar. "I would assume time of day billing would be structured so that daytime prices would be higher and therefore if the price goes up and solar becomes more competitive. I think that would be very positive but who knows if that will happen next year or four years from now," he says.

The Jordanian programme has been widely praised and has one distinct advantage over others in the region, the so-called wheeling provision.

"Wheeling is the ability to generate in one spot and consume it somewhere else, so to leverage someone else's, usually the grid company's, transmission lines to move power for you," explains Crane. "The Jordanian legislation only allows you to generate for yourself. So you generate outside the city on some cheap open land, you pay the grid company to move the power. The fee structure is 1 cent per kWh then you forfeit 6% of the power as losses. Between those two items you can generate somewhere and use it somewhere else. This opens the opportunity for a collective with 100 homes taking a small share but so far, we're seeing telcos, banks, hospitals and hotels," says Crane, who believes Yellow Door to be the largest provider of third-party funded distributed solar in Jordan.

Enviromena's Khoreibi says the lack of wheeling option in Dubai restricts the scope of the programme as there is only so much solar Dubai's roofs can support. Rooftops are typically home to a number of building services, particularly air conditioning units. This, the dense nature of the city and the penchant for tall buildings reduce the potential for a building to house enough solar to substantially offset the demand it creates.

"Today what we see is a number of systems are limited due to a lack of available space," says Khoreibi. "In the UAE we have an abundance of what you would call cheaper land in the desert, which has relatively close access to grid infrastructure. Given the opportunity, or if legislation takes place which allows for individuals or businesses to offset their power production utilising offsite systems, there would be a tremendous opportunity and we think it would create a massive influx of additional solar being installed on to the grid."

Ubiquitous rooftop solar

Issues with rooftop space, the absence of a wheeling provision and standardisation of contracts are still creating obstacles in Dubai but these are being addressed. Between the efforts of the industry and the continuing position of governments in the region to reduce their independence on oil and reduce costly subsidies on fossil fuels, solar is well-placed.

Achieving some of the authorities' loftier ambitions could prove difficult.

Rooftop PV is starting to be deployed in parts of the Middle East such as Abu Dhabi

"The goal of the government of Dubai, the very ambitious goal, is to have solar on 100% of rooftops by 2030. That is an incredibly ambitious goal and probably a very challenging one to achieve but even if we get half way there, or 20% of the way there, that is a huge market opportunity for solar companies. It is also a huge challenge to ensure some of the lessons from other markets are not repeated here. Truth be told, our expectation is that the delivered cost of electricity in the UAE won't go lower than solar power production costs."

Looking at the alternative options for generation – new nuclear, increased gas imports – it is difficult to see such a scenario emerging. On the off chance that it does, Khoreibi would like to see a mechanism in place to ensure that those tied to solar contracts at a price point above a notional rock bottom price are insulated from that risk.

"It's a scenario I have difficulty explaining because the reality is that as we see a continued decline in the cost of solar, it is difficult to see the delivered cost of electricity to the consumer being cheaper than that in the next ten years."

Developing a rooftop market from scratch when there is no appetite for feed-in tariffs and far lower electricity prices than other net metering-dominated markets like the US and others seems challenging. The fundamentals in the Middle East are in place: nicely matched demand and solar generation profiles, growing demand for power and rising prices. Early movers in the region developing workable contract structures, financing and laying the groundwork for O&M support could find themselves well placed to take advantage as more governments open the door to net metering. ■

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Perspectives on soiling

O&M | Keeping on top of the impacts of dust and sand on power output is crucial to making solar a viable option in desert regions such as the Middle East. A fierce debate is currently raging over which methods are the most effective. Ben Willis listens to some of the arguments

Credit: PI Berlin

The strong, plentiful sunshine in the Middle East and North Africa makes the region particularly well suited to solar power. But the flipside to that coin is that the dusty and often humid conditions found in this part of the world can create all kinds of headaches for plant owners and operators who must contend with the significant and unpredictable effects that the soiling of PV modules can have on a project's performance.

When PV was first suggested as a solution to meeting the Middle East's spiralling appetite for power, critics said that soiling – the collection of dust, sand and other particulates on a module's surface – would make it unviable. But as the rush of large-scale, price-beating solar development currently underway the region clearly demonstrates, the predicted problems have so far failed to materialise.

"There's been a lot of emphasis on soiling – to the extent that it will kill PV in the Middle East. And that's proven to be not true – it's not the deal breaker or destroyer of performance that it was portrayed by some experts to be," says Raed Bkayrat, head of business development in the Middle East for US integrated PV firm First Solar.

The reason for this is not that soiling is not an issue – far from it. According to Bkayrat, First Solar's experiences in building and operating some of the first large-scale PV plants in the Middle East demonstrate that soiling, if not managed properly, can have a significant impact on the performance of a plant. What's more, it's unpredictable, varying from season to season, site to site and even within individual sites.

"With DEWA 13 we've seen soiling as low as half a percent per day, which if it accumulates then it's 15% per month," says Bkayrat, referring to the 13MW project First Solar completed in Dubai in 2013. "And we've seen soiling as low as 0.1% per day, which is less than 5% per month. So we've seen those two extremes. And it varies over the year: in winter we see very low soiling – less than 5% per month, for sure. In summer it could be 10, 12% easy. If you have a sandstorm you could have soiling of 20%."

All of which highlights just how difficult a problem soiling is to manage. The fact that soiling has so far not developed into the problem some feared it would be is testament to the ingenuity of plant operators such as First Solar in understanding the nature of the soiling problem and finding ways of keeping on top of it.

Unless managed properly, dust and sand on modules located in desert regions can significantly reduce a project's output

But with the size of projects about to get very much larger in the Middle East, and with new parts of the region with varying soiling characteristics opening up, so too is the scale of the soiling issue. Below we present four different perspectives on the different technologies and strategies emerging for contending with the soiling issue.

Understand the problem

For Bkayrat, the key to managing the impact of soiling on PV performance is first to understand it in order to be able to predict it and thus put in place the most cost-effective management regime. That will become particularly crucial given the increasingly cut-throat nature of the prices being tendered for projects in the Middle East, where the difference between a successful or unsuccessful bid can come down to as little as US$0.001.

He says First Solar's experience in the Middle East, in the UAE and other countries such as Saudi Arabia, has taught the firm that the level and type of soiling found in different areas can vary hugely and require different responses. "Humid deserts would require a different frequency and method of cleaning compared to, for example, dry deserts," Bkayrat explains. "The composi-

tion of the dust itself varies, the size of the particles varies, as does the adhesive capability for the dust: if you're in a coastal area you get the sticky kind of dust that falls on the panel, there's some kind of organic content, compared to dry deserts where it's very loose, you can just wipe it with your fingers and feel how loose it is."

He cites the example of DEWA 13 in Dubai, where the comparatively humid conditions and more regular rain in the winter months help minimise the impact of soiling by naturally cleaning modules. "If we took the approach that we would not do anything [with DEWA 13] we would have a soiling loss on average of about 6% – which is interesting; you might think it should be 20, 30% but actually it's only 6%. And people ask me would that be the case in Riyadh, no, it's probably going to be higher in Riyadh."

First Solar has so far relied on manual, waterless cleaning for its projects in the Middle East – waterless because of the scarcity of this resource in this arid region, manual because First Solar's calculations have shown this to be the most cost-effective method, for now at least.

"I think you can do manual cleaning up to 30-40MW roughly. But if you have 100, 200MW large-scale projects then you have to automate, because managing the labourers will go up and it becomes logistically difficult. So you have to introduce automated or semi-automated cleaning solutions – be it robotics or cleaning machines," Bkayrat says.

In anticipation of the larger projects that are set to emerge in the Middle East from next year, Bkayrat says First Solar is working on developing an in-house automated solution. He doesn't reveal further detail of this, but says this is a response to the company's view that none of the automated cleaning solutions currently on the market are yet fully bankable. The main issues he has with products currently on the market are their cost and the fact they often require modifications to modules to make them compatible. "That ties you to that specific solution; if that company disappears, then you're sitting on thousands of robots you have to dump or fix, or change your frame to put another company's robot on there. We continue to evaluate them but we haven't seen anything yet that ticks all the boxes, in my book at least."

Nevertheless he is confident that new cleaning products will appear that give the peace of mind First Solar is looking for. Another promising solution he believes could emerge is an 'anti-soiling' coating for modules, which use nano-technology to prevent the build-up of particulates. Bkayrat highlights the work being done by the likes of Fraunhofer in Germany to develop solutions that combine anti-reflective and anti-soiling properties. "This is the 'super coating' if you will – a coating that has optical properties that improve light transmission, but which also prevents the accumulation of dust. And I think we're close probably to seeing a commercial coating whereby it minimises your frequency of cleaning."

Through technological developments such as this, and through continued good practices in monitoring soiling and proper cleaning, Bkayrat's main message is that although soiling certainly is an issue in the Middle East, it should not be seen as a terminal one as far as PV is concerned: "We want others to believe soiling is not a big deal – a few years back there were people fighting PV saying it's not going to work with the soiling in the ME. And it's proven to be a point of consideration, but it's manageable."

The future is automated

As chief executive of Ecoppia, the Israel-based supplier of waterless, robotic cleaning solutions, Eran Meller unsurprisingly is of the view that the future of anti-soiling efforts is automated. As plants get bigger, Meller's belief is that manual cleaning will become unviable.

"Maintaining 2, 3, 4, 5MW sites is one thing; maintaining those large utility-scale solar plants is almost impossible to do manually," he says. "The quantities of water are quite significant, and with the gigawatts the Middle East, India and other places are talking about, it's really unsustainable."

Another factor militating against the future use of manual cleaning is the consistency of results that can be achieved. "Unlike robotics, human beings one day can clean one way, the other day they can clean another way," says Meller.

Some of the manual techniques, he argues, also damage the anti-reflective coating (ARC) found on modules today, undermining their performance. "Currently the anti-reflective coating provides an additional 3% uplift per year [in output] and according to many studies that were conducted, some with us but also by the major movers and shakers, they have found out that with six manual cleanings the anti-reflective coating will be destroyed."

Meller claims the Ecoppia solution gets around this problem by employ-

Credit First Solar

First Solar's DEWA 13 project in the UAE has been a test-bed for its approach to managing soiling

Credit Ecoppia

ing a specially designed soft brush that minimises the abrasion visited on the module. Another advantage of automated cleaning he says is its responsiveness to sudden soiling events such as sand or dust storms. Ecoppia's solution is operated via the cloud, with sensors at the site keeping a constant check on particulate levels, and issuing instructions to clean if they pass a certain threshold. That means cleaning can be underway in next to no time.

"Once a dust storm arrives within less than two hours your site will be crystal clean; with manual technology it takes in many cases two days even to detect the problem and then another two weeks to clean it – so you're talking 16 days of sub-optimal production. And in many areas this could be negative 30-40%."

Like First Solar's, Ecoppia's solution is waterless, a factor that Meller believes must define the industry's approach to controlling the impact of soiling in water-stressed parts of the world. "Once you use water, even a little bit of water, you need water infrastructure, you need high-quality of water, you need reverse osmosis, you need storage for water," he says. "We strongly believe that our mission is to make green energy even greener and by not using water we're doing that."

Simplicity is key

Another automated cleaning solution making its way to market is the NOMADD (NO-water Mechanical Automated Dusting Device). Developed over the past three years by engineers at King Abdullah University for Science and Technology near Jeddah, Saudi Arabia, the NOMADD solution is shortly expected to see its first applications in commercial installs in the Middle East.

NOMADD's chief technology officer, Georg Eitelhuber, explains how the NOMADD solution came into being. "Lego was my prototyping tool! I was playing around with Lego for about 12 months to get a mechanism for waterless automatic cleaning. And I discovered this quite funky mechanism by accident that seemed to make a huge difference to the effectiveness of the cleaning. I took the model to the tech transfer department here and they said 'we're going to back this, here's some development money'. And it all went from there."

The NOMADD machine is now in its seventh version and has been extensively trialled in the harsh desert conditions found in Saudi Arabia. With the kingdom now finally looking to embrace solar after several years of stop-start interest in the technology, Eitelhuber is excited that his technology's time may soon be about to come. "It's getting to be a big deal now," he says.

Ecoppia believes waterless, fully automated cleaning is the future for desert solar

The effect of dust on PV in Saudi Arabia can be particularly acute; "background soiling" can cause a loss of output of between 0.4 and 1.1%, Eitelhuber says. If there's a dust storm, the problem can be much worse. Eitelhuber cites one recent storm that lasted two hours and caused a 60% loss of power from a test site. "The problem with that is that they will stay at [40%] output until you clean them. And if you're relying on a scheduled, manual-based cleaning method, where you've got an army of fellas out there and they start at one end and take days to get to the other end, you're only producing at 40% output for a long time."

As others have, Eitelhuber and his team concluded that automatic, waterless cleaning was the only way to go in the Middle East. Aside from the consistency issue highlighted by Meller where manual cleaning is concerned, another drawback of this method noticed by the NOMADD team was that the bottom rows of panels in arrays were getting mysteriously damaged. "We couldn't work out why at first," Eitelhuber says. "But it turned out the fellas cleaning the panels got exhausted and were sitting on the panels on the bottom row and they were breaking."

The development of the NOMADD system he says was based on the two principles of cost-effectiveness and reliability "It's got to be cost effective – and we are: we've got a payback period of a couple of years compared to traditional cleaning methods. And we can also provide assurance that the array will be performing optimally at the touch of a button."

Credit NOMADD

The NOMADD cleaning system has been designed to withstand the rigours of the desert environment

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The NOMADD system works by running a cleaning unit along individual rows of modules. Each unit contains a long brush powered by a direct-drive motor that runs diagonally across the modules. The essence of the design is simplicity, says Eitelhuber: "Anything that's complex will not survive in the desert. And the art of the engineering around NOMADD has been about how we get this as absolutely simple as possible. When we talk about robotic cleaning, people think of something highly complex and futuristic. NOMADD is not like that, it's more a power tool than a robot. We see machines out there now; some of them have up to five separate electric motors on them, doing complex mechanical processes. That's a recipe for disaster – there are so many failure modes you're introducing to your machine."

The NOMADD team is now in discussions with developers of projects in the Middle East, Latin America and Australia about commercial deployment of the technology. He is particularly hopeful that the first wave of projects in Saudi Arabia will deploy the system.

Indeed, Eitelhuber believes manual cleaning will soon – and quite rapidly – become a thing of the past as the industry recognised the advantages of technologies such as NOMADD. "I think it'll be almost overnight," he says. "The majority of projects going through the tendering process in the next six months in dusty regions will all have automated waterless cleaning on them – this is going to be industry standard, pretty much instantaneously. The economics add up, the value proposition adds up. The future of cleaning is waterless, automatic systems."

Know your costs

One company that still advocates water in cleaning is SunPower, via its Greenbotics automated cleaning system. SunPower acquired Greenbotics as a start-up in 2013 and now uses the system in its Oasis utility-scale power plants.

At a presentation at Intersolar Europe in June, Kyle Cobb, co-founder of Greenbotics and now a senior product manager at SunPower, described the considerations in deciding on the best cleaning strategy for PV plants – whether manual, semi-automated, fully automated, with water or waterless. With each of these decisions there are trade-offs, Cobb said.

Taking water, for example, he said not using it could result in poor cleaning of panels. "[If] you use no water, you put yourself at risk of coming across a soil type that doesn't respond well to dry cleaning, not fully restoring a module to 100% cleanliness," he said. "So I'd argue that there's a sweet spot, and it took us a long time to figure out that there's a semi-automated cleaning method that uses low water and low labour to reach the maximum return on investment for your cleaning activities at a power plant." The Greenbotics solution uses a small amount of water per panel to achieve what he said was the optimum cleaning result.

SunPower advocates small quantities of water in module cleaning to achieve optimal results

In deciding whether to go for manual or automated cleaning methods, Cobb said again there were trade-offs, with the generally lower cost but greater inefficiency of manual set against the greater efficiency but also much higher cost of full automation. "The important questions to ask yourself are: what is the true benefit of the cleaning technology you're exploring; make sure you look into the details about the efficacy of the cleaning. The second is what is the true cost? You could go down the route of paying the higher initial installation cost and perhaps lower O&M down the road on those fixed robots, or you could also make the trade-off to do a semi-automated cleaning method which gives you more flexibility and has lower up-front cost. Spending a lot of money up front on a robot might not be the right decision – you might decide that it's better to use a semi-automated, lower-water, low-labour cleaning solution that requires a lower upfront investment and around the same operational cost."

For now, no clear winner in the cleaning debate has emerged. But as more and more solar is installed in areas where managing the soiling problem is vital, no doubt the best solution will eventually become clear. ■

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Credit: ACERA

Chile plots path to two-cents solar by 2025

Market update | Chile has long been a strong contender for PV deployment with a growing economy, great solar resources and plenty of land. But as Tom Kenning learns, the market has several challenges ahead on its path to two-cents solar

Chile looked set to become a front-running market for solar investment in 2016, with a transmission law upheaval to combat solar curtailment and the promise of its largest ever power tender. However, the parameters of the power auction meant that PV ended up taking away just 6.8% of the capacity available in a nation where solar resources are pretty much second to none. This was a huge disappointment for the industry, particularly since Chile has launched a national programme to try to reach astonishing solar tariffs of just US$0.02/kWh by 2025. Even so, the auction did award what was temporarily the lowest ever solar tariff anywhere in the world and Chile remains the standout market in Latin America, on course to reach 2GW of deployment by the end of this year. This article investigates what went wrong in the auction, but also why the impending completion of major transmission lines might just pave the way for robust, curtailment-proof solar deployments in years to come.

Chile's new energy minister, Andrés Ignacio Rebolledo Smitmans, who succeeded Maximo Pacheo, used his first speech in October to highlight the importance of distributed renewable energy generation for the local electricity markets. This was followed by Spanish firm Acciona Energia connecting the largest solar plant in Latin America, the 246MW El Romero project, to the grid. The government then announced plans for a 750MW-1GW solar park complex spanning PV, thermal solar power and energy storage. Clearly, there is

How solar fits into Chile's energy mix, as of September 2016. *Source CNE*

- Total installed power capacity 20,740MW
- Renewable energy installed 3,607MW
- Installed solar capacity 1,395MW
- Solar generation 223GWh
- Targeting 70% electricity from renewables by 2050
- Targeting 68% reduction in the levelised cost of energy for PV by 2025
- Attracting 100 companies to the solar industry value chain by 2025
- Bringing US$800 million of private and public sector investment by 2025

impetus across all the different solar-related segments and technologies.

PV thwarted in auction

Yet, as with many markets, the spearheading solar segment has been utility scale. In August, the Chile National Energy Commission (CNE) enacted the country's largest ever energy tender with 12,430GWh of power on offer. As the auction was 'agnostic' in terms of technologies, there has been a lack of transparency around which technologies won capacity. Endesa, which grabbed about 47% of capacity available, will mostly build conventional power plants, but there are strong indicators that this may also include a small amount of existing wind and solar plants. Indeed it is highly likely that just one new-build solar plant was awarded with Spain-based firm Solarpack to supply electricity at a record breaking low price of US$0.0291/kWh at its 120MW Granja Solar plant.

Bart Doyle, general manager, Chile, Mainstream Renewable Power, a firm that bid for both wind and solar capacity in the auction, says that the biggest setbacks were in solar and new gas. Gas could not compete against wind, while solar struggled to bid in the 24-hour blocks.

Most capacity was tendered in these 24-hour blocks, but only 1GWh was set aside for projects in separate hourly blocks for day, night and evening categories. With solar all but married to the daytime category, its ability to bid for large capacity was particularly restricted.

"The view is still that you can't bid solar into the 24-hour block," says Doyle. "You are going to be trailing for 16 hours of the day.

"That's a big problem for Chile because it has a much better solar resource than it has a wind resource. PV on the PV belt in Atacama and Antofagasta has a capacity factor of 28-32%, which is a fantastic solar resource and yet only one new project won 4% [of the capacity] and the other 2.8% is for existing solar and that's a disaster for Chile."

Dozens of solar developers were competing for that small capacity available in the daytime block, but Mainstream, which happened to put in the second lowest bid for solar in the auction, still missed out. To add to frustrations, the median price for all technologies in the auction was US$0.0476/kWh, far higher than the sub-3 cents tariff for the one solar project.

"The Chilean customer is not going to get the benefit of that great solar resource and those great solar prices because of the way the tender rules are structured," adds Doyle.

Credit: ACERA

Finat is confident that the Solar District will help developers deliver on low prices.

Any attempt to prevent so many PV firms missing out in future auctions will also be dampened by the fact currently planned tenders are far smaller than the one this year. CNE will soon enact another tender for 3,800GWh to start delivering power in 2023. Another auction of 7,200GWh will take place in 2017, followed by 8,900GWh in 2018.

To vex the solar sector further, wind power also dominated the last tender with at least 45% (5,781.6GWh) of the capacity, despite having inferior resources.

Solar District promise

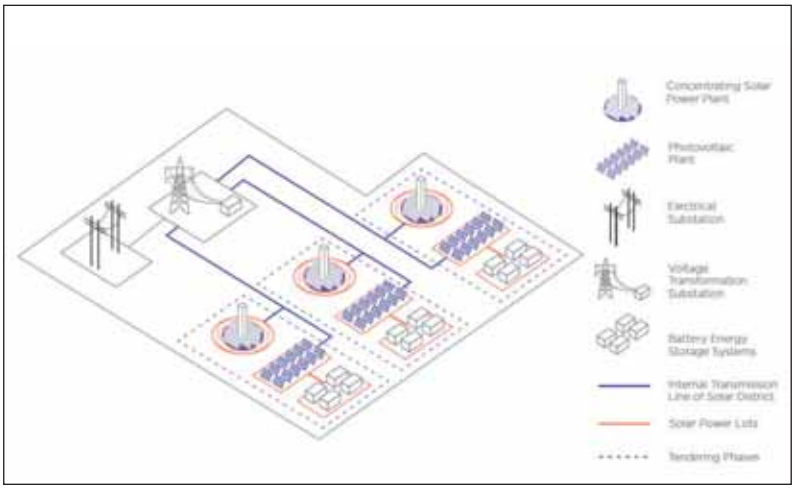
A governmental plan to develop a brand new 750MW-1GW solar park, however, will have raised the spirits of the industry. The so-called Solar Technology District will have its permits and approvals pushed through by the government and portions of the park will then be tendered, says Carlos Finat, executive director of the Chilean Renewable Energy Association (ACERA). Connection to the transmission system is part of the offer of the project and economies of scale are expected. Finat also understands that land for the project has already been allocated by the Ministry of Public Lands.

The US$4 billion park, also involving CSP and energy storage, will require 3,000 construction workers and will mainly power the mining industry in the Atacama region. Mining in the Atacama has been Chile's main productive and economic sector for over a century, since its soils hold the world's largest copper and non-metallic minerals reserve.

The solar district enterprise is part of a bigger initiative that is intended to obtain a very low cost of solar energy in Chile, says Finat. The Programa Energia Solar (PES) will focus on reducing PV costs by 25% using the extremely favourable conditions of the Atacama Desert, aiming to reach prices of just two dollar cents per unit by 2025. However, Chile has competition on the lowest price rankings from the Middle East.

"The world record of Solarpack only lasted for a few days, as a new low happened in an auction at Abu Dhabi," says Finat. "Based on prices that have been seen in other places and on the ever decreasing cost inversion of solar PV, we believe that with the right regulatory and contractual framework, PV projects at low prices will have no problem to be implemented successfully."

Another aim of the PES programme is to adapt and develop new materials, components and O&M services for PV systems that will ensure their durability and performance under the harsh desert climate conditions native to the PV Belt.



Credit: PES

The Chilean government has promised a new 1GW 'solar district'

Transmission cure

Of course, without enough demand or suitable grid capacity, it doesn't matter how cheap solar can go. Both solar and wind projects in the central northern region of Chile have been experiencing curtailment for some time now, since October 2015. One of the main causes is the weak Chilean power system. Previous attempts to resolve the requirements of the transmission system have also experienced major delays.

However, the Chilean Congress passed a major law on electricity transmission in July, which is expected to benefit the entire power sector while speeding up the connection of Chile's main grids – the SING in the north and the SIC in the south. Solar projects tend to be concentrated in the north of the country near the Atacama Desert, which has world-beating levels of irradiation, but lacks transmission infrastructure and demand. The grid interconnection will allow solar power generated in the Atacama region to power the major electricity demand centres such as Santiago in the centre.

Another key connection, the Cardones-Polpaico transmission line, is also being constructed by Colombian utility Interconexión Eléctrica (ISA), again helping to alleviate any PV overcapacity on the grid.

Several solar energy developers have gone ahead with developing projects in the central northern region in the full knowledge that curtailment is happening, says Finat. Meanwhile, others that are already experiencing curtailment would have factored it into their business plans. This is because they will have anticipated the SIC and SING grid interconnection and will expect to benefit from the exchange of energy between the two grids once complete.

"I would say that almost all the companies that have won energy blocks in the last two tenders in Chile and will build new renewable energy power plants, are trusting that the new transmission infrastructure will be available on time," says Finat. "It´s progressing as per the schedule that was committed by the government and the dates established in the law itself."

However, he stresses that the interconnections must be completed together to help solve curtailment. There is also no way of speeding up the process. GTM Research reports that the SIC and SING connection is more than 60% complete.

Under the new law, Chile has also appointed five directors for the board of its Independent Coordinator of the National Electric System. Finat says this is critical to ensure transparency, independence and technical adequacy of the operation of the electric system.

At the time of the law passing, minister of resources Victor Osorio said: "The main objective of the bill is to ensure that the transmission favours the development of a competitive market, to facilitate the transport of energy from clean sources to consumption centres, and to contribute to lower energy prices for households and businesses, allowing more competition and the incorporation of new players."

Ultimately, strong solar resources and the various initiatives to improve solar technology and attract investment make Chile a market to watch out for, but Finat insists that until energy storage becomes competitive, the capacity to introduce high levels of PV will continue to be limited by transmission capability. If grid interconnections are completed on time in 2018, curtailments could be drastically cut with room for plenty more deployment, but the framework of the power tenders will need to be more accommodating for solar to win big. ■

A philosophical manoeuvre for Chilean transmission

Bart Doyle, general manager, Chile, Mainstream Renewable Power, explains the paradigm shifting transmission upheaval:

"The transmission law helps wind and solar particularly because for the first time, it allows renewable generation to be factored into transmission planning. It is not something the Chileans really did before; they allowed the market to look after transmission lines.

"They did not build new transmission lines specifically for new renewable energy projects before. Renewables were a tag-on to an almost purely conventional or thermal-based system. With the new law the government will make more of an intervention, identifying which zones could cater for a lot of generation, be that hydro, wind, solar or conventional power and then planning the transmission lines in advance for those areas.

"That is a big philosophical change in how they run their market with the Chile National Energy Commission (CNE) taking a more active role in future transmission planning. It is also recognition that it wasn't working before. Renewable energy plants take two years to build, while transmission lines take up to 10 years to build. There was a big mismatch there.

"There used to be two system operators, one for the northern grid, SING, and one operating southern grid, SIC. They have now been made into a single entity controlling the whole system and the directors have to be independent. Previously all of the directors were management people from incumbents. This made things challenging if you had a dispute with a connection for example.

"The two systems, SIC and SING, will also be interconnected from mid-2018. Even if it is delayed another six months or a year it will still be finished well before the offtake day for the last PPAs. Winners of the latest power auction are not expected to provide energy for consumers connected to the SIC and SING grids until 2021.

The Cardones to Polpaico connection, a 500kV upgrade from Santiago right up to the top of the SIC, will also be crucial. If you don't have that in place, the SIC and SING interconnector hasn't got that much value because the power just gets stuck at the top of the SIC. There would not be enough capacity to get the power down to Santiago. You really need both projects completed at the same time and definitely before 2021."

There is optimism that the degree of grid network planning can smooth the path for greater PV deployment

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Solar wars: a new hope for the Spanish PV market

Market update | The Spanish photovoltaic market, once the darling of the global industry, has been ailing for almost a decade. But a new government finds itself with a mandate to build capacity, repeal taxes and redress the balance. James Blackman polls the market on its hopes for a new start

Credit Fotowatio Renewable Ventures

Changes in Spain's government have raised hopes of a second coming for the country's once-flourishing PV industry

The Spanish parliament's vote at the end of October to finally allow the conservative People's Party to form a minority government, after gaining tacit support from its socialist counterparts, might yet see the country's troubled solar market reborn.

Indeed, certain undertakings on energy and climate change appear to have emerged out of the political deadlock that preceded the new administration taking power. Principally, the government finds itself tasked with a wave of new energy tenders, as well as repeal of the country's controversial 'sun tax'.

However, for investors to take the plunge, and gamble anew on a market that has been so disrupted by retroactive policy, uncertainty needs to be stamped out, and fast, reckon market watchers.

"If Spain wants to attract new investment, the government has to restore legal certainty promptly, and develop a plan to foster renewable energy in the medium to long term," says José Donoso, general manager of UNEF, the country's photovoltaic union.

Regulatory stability is the key condition for the Spanish solar market to regain its buoyancy and catch the eye of investors, it seems. The problem is investors have been burned already; the challenge to regain their confidence will be hard fought, reckons Patxi Otamendi, chief executive at solar panel manufacturer Tamesol.

"It won't be easy for either local or foreign investors to come back in," he says. "There have been continued violations by the Spanish state in the field of renewables. The positive side is that the good location and hours of sunshine make Spain a country with great opportunities for [solar] electricity generation."

Retroactive policy

It might appear simplistic to talk about the weather, in the context of such intrigue and disarray, but it is instructive when considering Spain's solar credentials and the repercussions of its regime change. It also allows us to consider briefly how the market has fallen.

Spain, with a raft of persuasive renewable energy subsidies, was one of the 'darlings' of the global photovoltaic market through the first part of the last decade. By 2008, it was responsible for half of the world's solar power facilities in terms of wattage. Its forecast looked sunny.

But the global financial collapse exposed the structural weakness of the country's economy, heavily reliant on domestic demand and property development. Its subsidy model for solar unravelled – the cost of generation went up, the cost of consumption went down, and, within five years, the government's energy deficit stood at €4.5 billion (US$4.7 billion).

In response, it introduced a mess of legislation that forced individuals and enterprises with solar to connect to the main grid, and pay an inflated premium for energy they took from their own panels. In parallel with this so-called sun tax, the government also imposed a ceiling on the profit achievable from grid-scale solar projects, limiting returns to 7.4% before tax, and around 5.5% after tax.

"Trust has been totally destroyed," remarks Daniel Pérez, an attorney at legal firm Holtrop, which has joined together many of the local market's complaints against the country's retroactive solar cuts.

But new initiatives, mooted with the recent regime change, might just see the Spanish solar market heat up again. The new government indicated at the end of October a tender for renewable energy production will be finished before the year is out; two further auctions are expected in 2017. Details are hazy, but commentators expect up to 4GW of energy capacity across the three acts.

Meanwhile, a majority in the Spanish parliament voted in March, right in the middle of its constitutional stalemate, to remove the country's sun tax within 100 days of a new government being formed. The starting gun has now been fired, even if the conservative party, which authored the original measure, has returned to office, albeit in a somewhat reduced form.

Investment risk

UNEF will apply pressure on immediately. "We will get back to our conversations with all the political parties, and ask them to keep their word and put new 'self-consumption' regulation on the table," says Donoso.

The market is primed, he reflects. Its local protagonists, productive during the sector's salad days, and expansive ever since, have hardly been idle: "The Spanish solar market has important and valuable know-how because of the work it has done in research and development, and it has continued to bring expertise to other countries, where regulation is more favourable."

The prospect of Spain hitting its 2022 target of 20% renewables had looked to be receding. But a late re-orientation of energy policy, which sets the market on a progressive course, will see home interest return. "If current regulation is changed, the market at home could flourish. The sector is alive. It is ready to contribute to the country's clean energy targets and to the job market," says Donoso.

The auction of new capacity and the repeal of old policy cannot come soon enough. "We are waiting for those modifications to be taken by congress – not just so we can reach 20% in 2022, but so we have a system that is generally less dependent on non-renewable energies," says Otamendi.

Financial interest in the Spanish solar market could hardly be less, observes Lourdes Álvarez, a lawyer at Spanish legal firm Evolutiza. "Investors are afraid," she suggests, describing the last government's retroactive policy changes as "so damaging".

The fact the new regime has only just muddled through a long transition hardly helps, when stability is considered the only baseline to get the party jumping again. One-step advances may not be sufficient to sway cynicism, remarks Pérez at Holtrop. "Legislative changes have happened before. There is no guarantee they will not be changed in the future," he says.

Improving hardware costs, bright sunshine and pent-up demand make Spanish photovoltaics as attractive as German solar, he suggests, but Brussels needs to set a precedent.

"Investors want higher returns in Spain because the risk is higher – high levels of [solar] radiation on one hand, are offset by mistrust. Spain is as attractive as Germany, which has less sun but higher investor confidence. If the European Court declares the cutbacks contravene EU law, there is a chance their confidence will be restored," says Pérez.

Capacity auctions

The forthcoming auctions for new capacity are expected to be technology neutral, and to spark competition between large wind farms in the windy north and solar projects in the sunny south. Will there be wariness, at all, about bidding for solar capacity and building utility-scale solar facilities?

"We will see, but no new capacity has been built in the past years, and Spanish photovoltaic companies are determined to make the most of the tender process. It is a valuable business opportunity, especially as solar costs have decreased significantly," says Donoso.

"Investors want higher returns in Spain because the risk is higher – high levels of solar radiation are offset by mistrust"

Pérez agrees; business is business, after all, for well-heeled establishment providers, at least. "Those who bid will be those trying to build plants anyway – and I am talking here about big photovoltaic plants of over 100MW, developed by utilities," he says.

Most market watchers fear smaller developers will be squeezed out of the process. Otamendi at Tamesol makes the point the tenders are "public and large-scale", and "essential" for Spain to reach its 2022 targets, but worries for a lack of diversity in the mix-up. "We hope they are open and public, and aren't 'tailored' to the large Spanish electricity companies," he says.

The bidding is expected to follow the same structure as the January auction for wind and biomass capacity, where, alongside a lack of subsidies, offers were made on an 'investment cost', rather than a kWh tariff basis. "They're based on the costs of the project and not, as has happened until 2012, on a Royal Decree," says Otamendi.

He echoes the default prediction, about on-grid supply without subsidies. "From now on, most projects will be without aids [subsidies], and be connected to the grid, and without batteries," he says.

Álvarez at Evolutiza reckons the government needs to put in place financial incentives to reignite competition in the local market. "There aren't any at the moment, but it is necessary for the development of the country, and I hope the government sees that and approves the subsidy," she says. "Spain has a problem; the big electricity companies have a monopoly."

For his part, Donoso says the solar market is mature enough to compete with fossil fuels, and stand on its own feet. "The photovoltaic sector doesn't need subsidies to grow. It just needs a well-functioning electricity market," he says.

'Self-consumption'

Pérez brings it back to the theme of market stability, achieved through progressive legislation. The challenge for the solar industry in general is to navigate local fluctuations in electricity prices, which vacillate between €20/MWh and €60/MWh, depending on the availability of wind power.

"When there is wind, prices go down drastically," he says. "It makes it difficult to invest in long-term projects. Even if subsidies are not needed, market reform to provide more stable and real prices to photovoltaic [supply] would be very useful."

What is clear from the new government's in-tray is that repeal of the country's taxes on 'self-consumption' will give the residential and commercial sectors a shot in the arm. "If the sun tax is finally eliminated, the residential and commercial sector will go up," remarks Otamendi.

Private solar generation stands to be the most resurgent sector. Beyond the nitty-gritty of long-term planning, removal of this single, well-hated regulatory device is the single chink of light the solar industry in Spain craves. "This will be the great opportunity we've waited so long for," Otamendi adds.

Donoso rejoins, picking up a general point about opportunities in the commercial sector. "Companies would benefit from an increase in competitiveness as their electricity costs decrease. The public sector could also benefit from PV self-consumption, if collective installations are permitted, as they could be implemented in schools and council buildings," he says

It is the kind of vision that is being made real in weekly news announcements in other countries, which once looked to Spain as the frontrunner in the global market. ■

James Blackman is a freelance journalist

Emerging market briefing

Tom Kenning profiles some of the emerging solar markets around the world that look set to gain momentum in 2017

Solar surprises in Argentina auctions

Argentina is a latecomer to the explosion of solar across the globe, having been tarnished with an awkward reputation among foreign investors and boasting just 8MW of PV installations to date. However, a new pro-business president and the launch of two well-handled large-scale tenders could well catapult Argentina into a respected solar market. A previous attempt at tendering renewables nose-dived with zero project completions, so the big question will be whether any of the latest awards translate into solid projects.

As the third largest economy in Latin America, Argentina is only just taking off with renewables since the previous administration led by Cristina Fernández de Kirchner was not receptive to foreign technology or capital, says Carlos St. James, managing director of financial advisory firm Santiago & Sinclair, and co-founder of the Argentine Renewable Energies Chamber (CADER). She wanted to build renewables but no one would invest or lend money.

"It was just not a credible market," adds St. James. "They did an auction in 2010/11 called GENREN, when they sought 900MW and it was well oversubscribed with a lot of interest, but in the end nothing got built, even though the prices were really attractive."

Now with the arrival of President Mauricio Macri, development banks and other financiers are finally looking to invest.

Credit Solar -GIS

Argentina looks set to build on promising tenders held this year in 2017, despite some concerns over financing

RenovAr 1

A new energy ministry swiftly organised a competitive bidding auction for 1GW of wind and other technologies, setting aside 300MW for solar PV under 20-year power purchase agreements (PPAs).

"Solar ended up being far more oversubscribed, even than wind, which I think caught them by surprise, because Argentina always tends to think of itself as a wind country and I think they just weren't aware and didn't realise that solar is really kicking everyone's ass," says St. James. "Solar is taking over everywhere."

In response, the Ministry of Energy and Mines (MEM) increased the solar portion by awarding 400MW at an average price of under US$0.05975/kWh. St. James says this was "pretty good given that Argentina really has no credibility and is technically still in default as a nation".

Jujuy province-owned developer JEMSE took away three projects of 100MW each, while Spain's Fieldfare in partnership with Isolux took a 100MW project. St. James notes that China was a particular winner in the auction given that three quarters of the winning solar projects will involve Chinese technology and capital.

Developers that missed out on the first round were told they could bid again in the second tender for 200MW, named RenovAr 1.5, but at a ceiling price of US$0.05975, which is the same as the average price in RenovAr 1. Again the tender was oversubscribed three-fold.

Trouble building

Whether projects get built is a real concern, says St. James, since bankers still remember getting "screwed royally" after the GENREN tenders and losing a lot of money. On the flip side people recognise Argentina as the world's 25th largest economy and see potential for making a lot of money.

The ministry wants to get all the projects built in 12- to 18-month timeframes, but St. James is sceptical of such tight deadlines, due to logistical constraints. "Everything will take longer than they want to and in the meantime while everyone was very enthusiastic, there's some heartache coming up here," adds St. James.

"I don't think anyone can make a blanket statement that all of the awarded projects will be built," agrees Juan Payeras, chief investment officer at the infrastructure and natural resources department of the International Finance Corporation. "It's a combination of tariffs, technology, location, returns that are expected by the sponsor and conditions imposed by the banks."

With significant deployment in some other large Latin American markets and some very large experienced European players engaged in bidding, Argentina should benefit from the collective experience of the solar industry in executing large utility-scale solar PV projects, adds Dana Younger, chief renewable energy specialist at IFC. Experience gained to date in engineering, procurement and construction, and other contractual arrangements should be an advantage.

Beyond the RenovAr tenders

It is expected that any forthcoming tenders will have a similar pattern of putting the ceiling price at the average of the previous auction. Furthermore,

given the surprising high interest in solar, it is likely to be given a larger role to play in each tender. St. James says that people thought wind would dominate as there is so much high-quality wind resource in Patagonia and the southern half of the country, but solar has turned out to be extremely attractive as well.

"Law requires that [Argentina] get to 10GW of renewables over the next decade," says St. James. "That's a whole lot of investment and if they pull this off they are going to be doing auctions for 1,000MW every year for the next decade or so."

Argentina will still have to learn from other countries in terms of transmission risks. Grids are expected to be capable of handling the capacity additions of the first two tenders, but after this the ministry will have to become choosy and only approve deals based on substation locations in order to avoid congestion. St. James says stakeholders should keep an eye out for whether Argentina does start investing money in additional transmission grids, because if they do not they are "going to run into a wall".

St. James compliments the MEM for its handling of the first auction as it approved projects not just on price but according to what nodes developers were intending to connect to. It shows they knew in advance where there might be traffic jams and where there won't be.

For now St. James says: "Everyone who gets approved for these projects in 1 and 1.5; they know they have plenty of room on the transmission grid."

The enthusiasm for deploying solar in Argentina is undeniable and the major hurdles of gaining investor confidence and obtaining financing seem to be easing. But with a paltry installation base so far, the industry will look on keenly to see if the first projects start getting built.

Financiers return to Argentina

The IFC's Juan Payeras explains who will finance the tendered projects in Argentina.

"The current administration has undertaken a large number of reforms with special care during the design of the RenovAr auctions precisely to ensure the financial viability of these projects.

"While the benefits of the programme resulted in an oversubscription situation, the issue remains as to whether the financing will be in place. Commercial banks have shown an interest in Argentina quite superior to anything that was exhibited before the current administration; however maturities are still at levels that would be difficult for these kinds of projects.

"We have heard that maturities from commercial banks right now are in the range of seven years or thereabouts, however, there is quite extensive interest on the part of multi and bi-lateral financiers in Argentina and in there you can count on institutions like IFC, IIC, FMO, EEC, EKF etc. There is a healthy number of multi and bilaterals that are actively considering financing projects that were awarded under RenovAr 1 and will be awarded under RenovAr 1.5.

"We are looking to finance projects that are as large as possible for economies of scale reasons."

Taiwan embarks on its 20GW target

Taiwan's solar deployment has been slow to kick off in comparison to its mature and bustling PV manufacturing industry.

A year after a new government played its hand by targeting 20GW of solar by 2025 – driven by a desire to avoid adding more nuclear capacity – movement remains relatively pedestrian with 980MW of cumulative installations at the end of August. However, Taiwan looks set to break into the top 10 solar markets in terms of capacity additions around the world in 2017, according to EnergyTrend, a division of TrendForce.

To kick off the 20GW programme, the short target was to reach 1.52GW deployment within two years, including 915MW for rooftop and 610MW for ground mount, says Hung-Sen Wu, deputy division director of the non-profit R&D organisation Industrial Technology Research Institute (ITRI).

Credit Taitra

Chen Chien-Jen, vice president of the Republic of China (Taiwan), addressing PV Taiwan. Taiwan has been forecast to be among the world's top 10 solar markets in 2017

Much of the 20GW is likely to be set aside for utility-scale solar, but in one of the most densely populated countries in Asia land acquisition will be a real challenge. Uncultivable and salty land has been made available for solar development. However, this includes so-called 'sinking land' where groundwater has been withdrawn to the extent that the land is liable to sink in various locations. This means robust solar equipment will be essential for a well-performing plant.

Eric Wang, Asia Pacific sales director for Chinese inverter firm Huawei, says the government must also open up industrial space and even agricultural areas, especially land near the big substations. Most sinking land also happens to be located far away from quality transmission lines.

Module choice is also important since the Taiwan market has been negatively affected by typhoons.

"The typhoons are very scary here," says Sascha Rossmann, vice president, solar global sales at module manufacturer Winaico. "There is a lot of damage to the PV systems here because of the poor designs of the panels and also the mounting system. If the mounting system resists the wind speed, the panel must resist the vibration."

Mexico boasts Latin America's largest pipeline

Mexico has continued its strong push for renewables following the liberalisation of its energy sector.

With private entities now able to participate in the energy market, the country was able to hold its second long-term renewable power auction. After an impressive first auction, Mexico followed up with 2.4GW of solar in September's round and PV is expected to continue winning large capacities in years to come.

Mexico now has the largest contracted solar pipeline in the Latin American region.

GTM Research has also deemed Mexico as having the greatest potential for distributed generation given the recent reforms. This market reform sought to end the monopolies held on the electricity sector by the Comisión Federal de Electricidad (CFE). In doing so, it would open up Mexico's energy sector to new players, investment and new technology.

A total of 23 winners out of a pool of 57 eligible bidders were selected in the latest auction, obtaining long-term energy contracts and clean energy certificates (CEL) to build 2,871MW of renewables projects at a cost of US$4 billion. The average price for clean energy was US$0.03347/kWh.

Credit SPG Solar

After a strong 2016, Mexico's burgeoning PV market looks set for further growth in 2017

Solar dominated once more by securing 54% of the 8.9TWh annual power supply awarded and 53% of the 8.9 million contracts in the auction. Out of the 23 winners, 14 have secured plans for PV projects across 15 Mexican states. Successful bidders included Enel, Engie, Acciona, Iberdrola, Zuma Energia, IEnova, OPDE, Tuto Energy, Grenergy, X-Elio Energy and Fotowatio, among others.

Ministry leaders subsequently confirmed that the country's third long-term power auction is scheduled for April 2017.

The International Energy Agency (IEA) has also put out a special report predicting that Mexico will hit between 30-40GW of solar PV deployment by 2040 under various scenarios modelled. It also forecast that its auctions will lead to more than half of the country's new power generation capacity installed between now and 2040 coming from renewables.

Jordan readies next large-scale tender

Jordan saw the commissioning and financing of multiple utility-scale projects over the last three months, while also unveiling the Middle East's largest solar plant.

First Solar took centre stage by completing the 52.5MW (AC) Shams Ma'an PV project, but other developers can look ahead to the 300MW renewables tender announced by the government, of which 200MW will be for solar PV again in the Ma'an area.

Elsewhere, Dubai-based solar financing company Adenium Energy Capital and California-based renewables firm RAI Energy International in September started commercial operation of a 20MW PV project north of Amman in Mafraq. At the time, REI president and chief executive Mohammed Alrai said: "The Jordanian solar power sector is poised for explosive growth."

At about the same time, Norwegian integrated independent solar power producer Scatec Solar also completed a 22MW plant, its third in the region.

Developer confidence will also be buoyed by the securing of financing for several large-scale projects. In November Acwa Power secured two separate loans each of US$27 million from the European Bank for Reconstruction and Development (EBRD) and the Netherlands Development Finance Company (FMO). These were for a 60MW plant for which it successfully bid in the second round of the country's PV tenders with a bid of 0.043 Jordanian dinars (US$0.061/kWh).

Credit First Solar

Completion of the Shams Ma'an project has fired the starting gun on Jordan's emergence as a utility PV market, with more in the pipeline

The International Finance Corporation (IFC) and the Canadian government have also partnered up to finance a US$76 million solar plant. The 50MW project is to be built by FRV, part of Abdul Latif Jameel Energy (ALJ) in Mafraq.

Meanwhile, Abu Dhabi's clean energy firm Masdar secured the power purchase agreement for a 200MW solar plant, which will be connected to a sub-station just outside the capital Amman.

Demand for power is growing in Jordan and solar can play a big role in adding to its generation capacity. Moreover, the country is actively upgrading its high-voltage distribution network in order to integrate more renewable generation into the grid. ■

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Due diligence for financing of PV assets

Project finance | Minimising risk to lenders is vital in ensuring the solar industry continues to have access to adequate sources of finance. Simon Turner and Paola Piazzolla outline the key ingredients for the technical due diligence needed to give peace of mind to investors

Credit OST Energy

Technical due diligence for financing PV projects is becoming increasingly important as solar finds its way into new markets and environments

Financing renewable energy projects has been key to the successful growth of the industry. In 2015 approximately US$286 billion was invested [1], a new record high. In total 118GW of new wind and solar PV installed capacity was added in the same year and renewables (excluding hydro) made up 54% of all newly installed generating capacity, the first year renewables has beaten thermal. With the size of projects and portfolios now being financed and the constant search for lower costs of finance, it has become increasingly important to ensure that appropriate diligence is undertaken before making investment decisions.

OST Energy has worked on over 30GW of solar and wind projects globally. We have advised numerous international development institutions and commercial banks on the risk of financing renewable energy projects in the role of Lenders' Engineer, working on over 50% of utility-scale UK solar projects and 40% of all utility-scale African solar projects, and have forged a reputation for providing advice synonymous with a positive financial return, even on the most complex transactions. Understanding, quantifying and mitigating technical risk through the due diligence process is critical to the financing process.

Below is a high-level summary of the process undertaken during due diligence. The general process is similar both for financing of new-build projects and refinancing of operational assets, however some risk allocations will be different depending on the stage of the project at which the analysis is undertaken.

Process outline

The general process undertaken to support lenders and investors in the identification and mitigation of renewable energy project risks can be summarised below:

- Risk identification
- Risk assessment
- Risk mitigation

All renewable energy projects have to deal with a certain amount of risk, since they are unique undertakings based on assumptions about the future, affected by many factors and subject to the influence of multiple stakeholders. Controlling the project risks has a positive effect on the control of project costs, timeliness, quality, and performance.

The scope of work for a Lenders' Engineer covers any aspect of the project with a technical input, including review of permitting, grid connection, construction and operation contracts, power purchase agreement (PPA), project participants, site conditions, lease, yield, design, construction schedule and financial model. The output is to provide the lenders and other stakeholders with an overview of the technical risks and how to mitigate them in order to reduce the risk profile of the project. Technical risk mitigation needs to involve all the advisors, not just technical. Early engagement of all the legal and financial advisors is key to ensuring a timely transaction.

The approach to due diligence is based upon a methodical risk analysis, accounting for mitigating controls and residual risk.

Figure 1. Approach to due diligence

					Probability				
	Reputation	Time	Capex	Revenue	Very unlikely	Unlikely	50/50	Likely	Certain
Impact	Slight	Days	<0.1%	<1%					
	Project	Weeks	0.1 - 0.9%	1-2%					
	Local	Months	1 - 2.4%	2-5%					
	National	Years	2.5 - 4.9%	5-10%					
	International	Permanent	>5%	>10%					

Major and residual risks

There is a different approach to mitigating major risks and residual risks. Major risks are those that are more likely to have a big impact on the debt terms from a lender's perspective and are mitigated through the implementation of a risk response strategy. For the major risks, the Lenders' Engineer evaluates occurrence probability and impact severity to quantify the risk exposure of the project. Residual risks are generally mitigated through contractual arrangements and contingency values that are included in the financial model.

In the risk response strategy a qualitative scale is used to evaluate probability and impact. Probability scale is defined by using a 1 to 5 range that classifies the probability of occurrence as very low, low, medium, high and very high. We also use a "five value" range to define impact as a percentage on revenues and capex. Time impact and reputational impact are also considered in our analysis.

The lowest scale points for probability and impact are set to a level of risk exposure which is regarded as negligible. Higher scale points define risks that lead to significant consequences on the project.

Additionally, we identify whoever is best able to manage the risk at the lower cost as 'risk owner'.

Dealing with risk

The level of the overall risk exposure changes over time throughout the project, as a result of actions taken regarding the project or due to other external events. Some risks are relevant only during specific phases of the projects, such as construction and delay risks for new-built plants that are no longer relevant during a due diligence process for refinancing of operational assets. Similarly, should longer term operational yield data be available the uncertainty associated with performance modelling will be reduced with a refinancing compared to a new build.

Risks can be mitigated, transferred, avoided, or accepted. Lenders are risk-acceptance adverse and the only risk they accept in a non-recourse financed renewable energy project is the resource risk (even so a P90 or even P99 downside to yield is investigated). All the other risks have to be managed and allocated to the other parties involved in the transaction. Technical risks can be mitigated in three areas:

- Technical
- Financial
- Legal

Technical due diligence in practice

OST has worked on hundreds of lenders' due diligence exercises across the world advising on project risks. Our main areas of expertise are ground-mounted and rooftop solar and wind. We have selected a few case studies, related to the refinancing of the assets, where we acted as Lenders' Engineer and helped the client to mitigate any issues which could have had a detrimental effect on project value, in order to help ensure lasting financial viability for the buy-and-hold nature of the investment.

OST carried out a technical due diligence on a floating PV plant in the South of England. We identified a number of technical risks, chief amongst them being the structural element underpinning the entire project, namely; the anchoring system. The anchoring system plays an integral role by ensuring the floating platform on which the PV modules are placed remains fixed in position and withstands the effects of wave and wind action. We carried out a structural analysis of the anchoring system using our in-house civil and structural engineering experts. We recommended European and international standards to which we expected the system to be designed, and identified tests to increase confidence in the chosen system. We also analysed the installation methodology of the anchoring system and commented on H&S risks. OST successfully guided the development team through the planning stages of the design and construction of the floating plant and its anchoring system. The project is now fully operational and was the first of its kind to secure European Bank financing.

OST has conducted the technical due diligence of an existing operational portfolio of under 50kWp rooftop and ground-mounted sites in the UK. Inverter warranties were not available at the time of our review so we had to assume that the components were out of warranty. To mitigate this issue, we needed to size a suitable MRA in conjunction with the review of the O&M contracts of the project. At the end of the process, the portfolio was accepted by the lender.

Although the Lenders' Engineer will co-ordinate the mitigation of technical risk, each advisor must input into each area.

Technical mitigation includes any design or operational changes to the original design. This could be related to planning, grid connection or to the plant design itself. These risks are normally highlighted to the EPC/O&M contractor and discussions held to try and resolve potential areas of concern.

The Lenders' Engineer should review the technical inputs to the financial model. Financial mitigations are related to these inputs and assumptions and include irradiation studies, yield studies, availability of the plant, degradation, capex, opex, MRA and downside sensitivities. The lender determines the financial requirements of the debt. The Lenders' Engineer should work with the financial advisor to maintain the project financial model within these parameters whilst maintaining an appropriate technical risk profile.

The Lenders' Engineer should also review all the project contracts from a technical perspective. These include the EPC and O&M contracts, PPA, land lease, manufacturers' warranties and other technical agreements. These documents are reviewed in conjunction with a legal review. Any technical risks are highlighted and negotiated with the relevant counterparty. If this is not achievable the risk will have to be mitigated in one of the other areas. Insurance is also included in the legal mitigation area, although usually only relied upon as a last resort or in the case of factors outside of the stakeholders' control, for example force majeure events.

In some cases a combination of two or even three mitigation measures is required. For example underperformance of the projects is normally mitigated through the EPC contract by means of liquidated damages; a legal mitigation in terms of obligations under the EPC contract that is calculated based on the required coverage of lost revenues from the financial model.

Moving forward

The sector is set to grow over the next years and decades, and we believe that Lenders' Engineering will cover an increasingly important role in the future as new types of money enter the market and projects become increasingly complex as renewable penetration increases, storage becomes a commonplace addition, networks become more strained and new business models enter the marketplace. There is a shortage of available projects in mature markets such as Western Europe at the moment so new opportunities are being sought out. Newer markets and applications represent a challenge for all parties involved in the transaction as they tend to have a higher risk profile, therefore a specific risk analysis conducted by a reputable and experienced Lenders' Engineer will help the lenders to mitigate those risks effectively. ■

Authors

Simon Turner holds a first class MEng (Hons) degree in mechanical engineering and is a member of the Institute of Mechanical Engineers. He has extensive experience across a wide range of renewable technologies, specialising in solar PV. Simon co-founded OST Energy in June 2008 and, in the role of Lenders' Technical Advisor, he has evaluated the technical and commercial risk of purchasing numerous solar PV plants.

Paola Piazzolla holds a BSc in engineering physics and a Master's in engineering, contracting and project management from the Politecnico di Milano, Italy. She is a Technical Advisor with experience in supporting lenders and investors in the identification and mitigation of project risks associated with utility-scale and portfolio renewable energy projects. Paola joined OST Energy in April 2015.

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Everything that's wrong with tax equity

Project finance | The importance of the investment tax credit in stimulating solar development has become an article of faith in the US, and its extension at the end of 2015 was welcomed as a vital lifeline. But as Danielle Ola hears, complexity, tightening supply and inefficiencies mean tax equity has a growing number of critics

When the investment tax credit (ITC) was first extended, it was hailed as the saviour of US solar. But whilst tax equity has undoubtedly been a key factor behind the extended period of solar capacity growth seen in the US in recent years, it has not been without its critics.

Despite being the most popular financing mechanism for solar in the US, tax equity is also one of the most complex out there when compared with its debt and sponsor equity counterparts. Greg Jenner, the former acting assistant secretary of the US Treasury for tax policy describes tax equity as "not optimal by any means".

"Right now I would describe it as necessary – and maybe not a necessary evil; but it's not optimal by any means," Jenner says. "The problem is that Congress has chosen to provide incentives [for solar] in the form of tax benefits. The only way that many developers can use these benefits is to use tax equity because they don't have their own tax liability. The lost value to developers is because tax equity doesn't invest dollar for dollar, it invests with a substantial discount. It's a high-priced cost, but it's cheaper than anything else – it's cheaper than debt, it's cheaper than equity. They've got to use it, but nevertheless it's an inefficient system. The transaction costs are high. From a policy standpoint it's incredibly inefficient. It would be much better if there were some alternate incentives."

Complexity

To those in the know, the various processes do not pose a problem. But for new market entrants or for the inexperienced, it can pose a significant barrier even to the point of being off-putting, according to Akamai Technologies' senior director of environmental sustainability, Nicola Peill-Moelter.

"The ITC, while I think it's great and some companies are doing really well with it, for the companies that don't really understand the renewable energy market and what advantages they could have, it's a very complicated model for procuring renewable energy. It might look good financially, but a lot of companies don't have the financial or accounting expertise or they are not experts in the power market. For those that do not have in-house expertise, it's a very complicated way to procure renewable energy. Most companies just see it as too complicated and too risky.

Tax equity has been crucially important for solar in the US, but some believe alternatives are now needed

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"For the companies that do understand the benefits and have in-house expertise, it's great that they can take advantage of it. But I do think those companies are few and far between."

John Berger, CEO of rooftop solar provider, Sunnova, expresses a similar concern: "At some point you've got to call the ball, and ask of that complexity associated with tax equity that a lot of these institutional investors have to get their head around: is that going to change? It doesn't look to me like that is going to change. That doesn't mean that some won't get into it and do some of it, but as the market becomes bigger we really need that investor base to come into it.

"It just seems hard for me to get my head around, that you're going to have a material impact or influx of capital as long as that tax equity structure is in the way. It just seems to be holding back the industry. Tax equity is the biggest hold back for the market by far."

'The benefit of the few'

Further to its being a difficult mechanism to grapple with, the effort may not even be worth it as the net benefit that filters down to the end user is significantly diluted. As the ITC is effectively divided between all parts of the supply chain, it could be questioned how material the end saving is that a solar customer would receive.

"The subsidy has to be shared by the developer and the consumer in order for the pricing mechanism to work," says Jenner. "The developer is going to want a piece of that subsidy because it is intended to help them develop an asset which doesn't necessarily have market parity yet.

"At the same time, you need to create an incentive for the ultimate consumer to use solar. So there's got to be a split. If you throw tax equity into it, developers are going to get their split first – so tax equity dilutes the benefit to the developer and the developer dilutes the benefit to the consumer; but that's just the system we have."

Not only does the average solar customer have a significant benefit from the ITC sliced in the process, but the overall pool that benefits from tax equity is limited, says Greenwood Energy CEO Camilo Patrignani.

"Aside from not resulting in a material cost saving to the end user, the other very important issue with the ITC is that it really is for the benefit of the few. Only really large solar companies can do this and a lot of local installers as a result are basically in a position of weakness," he says.

Much like the point about complexity, the exclusionary nature of tax equity means that it likely causes a barrier to market competition. According to Roundrock Capital Partners managing partner Matt James, the market has traditionally been dominated by banks and other financiers. The inclusion of corporate bodies and other entrants would help to diversify the marketplace and increase competition. "What the market could use is a much more diverse corporate base of tax investors," he adds.

"It just seems hard for me to get my head around, that you're going to have a material impact or influx of capital as long as that tax equity structure is in the way. It just seems to be holding back the industry. Tax equity is the biggest hold back for the market by far"

"There are only really 10-15 serious tax equity providers for larger projects and that is very little," agrees Patrignani. "It is mainly for those few that have the benefit of a strong balance sheet that can provide the right set of indemnities and can provide at least 10MW on an installation. It really sets a lot of barriers to entry that otherwise would enable the market to be more competitive and perhaps grow faster."

Limited supply

Not only is the number of individual tax equity providers arguably lower than would perhaps be desirable, the actual amount of capital available too is limited. If the government is providing a subsidy in the form of tax benefits, the only way that subsidy can be tapped into is through the market and market providers. If there is a limited supply of investment capital in the tax equity market, the consequences are evident. "Particularly as new entrants try to get into the field, if tax equity providers already have claims on the amount of money they are willing to invest, it becomes brutal for new entrants," says Jenner. Indeed, new market entrants from Europe, or even small and medium-sized domestic developers, still have problems accessing the vast amount of tax equity financing needed to complete their new-build projects, according to Scott Reising, managing director of Baker Martin Capital.

In addition, the lack of providers is preventing a lot of secondary liquidity from flowing through the industry, according to Berger. "We've got to have more players. It's a little difficult to have a lot of liquidity when you have six firms, maybe 10 at the most, existing in all the US."

"There is still a lack of capital in tax equity," agrees Reising. "Those who have it can kind of play a little bit and be more efficient with their projects. Those that don't, don't have to worry as much because they can hold on to that project for several years and just wait it out a little bit until they actually get the financing put together.

"You're going to see a lot more M&A […] so people think, let's see who survives the next four to five years with the tax credit and maybe there are going to be some mergers going on with only a few big players. And then after that, the world is their oyster; the big players who have survived will now have to survive on their own with no tax equity investment, no tax incentives (at least the major federal ones) and you'll potentially see a lot of major state ones go away as well because they'll follow suit of the federal players, and they may not see a need to have any sort of state or local tax credit."

A slow-down

The limited supply results in increased demand, which in turn causes an increase in cost. But stretching a limited supply among a disproportionate amount of partakers also has other downsides, namely in a prolonged delay in projects being executed.

As is well-known, the ITC extension at the end of 2015 meant many developers would delay projects so they could source better tax equity. "While it was good to have the extension, it did slow things down a little bit because the extension took the pressure off everything being done by Q4 of this year," says Reising.

A further impact has been on the

development of a secondary PV market in the US, as the widespread sale of operating assets can only really happen once the tax equity period is over. But according to Stacey Hughes, partner at solar development and finance specialist, SunLight General Capital, the barriers that tax equity is causing in regards to slowing down progress in solar should be looked at in context, as it may not be creating any more of a barrier than other factors.

"It definitely varies by segment," Hughes says. "With regards to utility, [the tax equity period] will reduce the number of utility plants that come online, but just as big of a constraint would be the availability of land. In the C&I space, tax equity doesn't tend to be really utilised so it probably doesn't make a huge difference. I think other forces will be ultimately more relevant than the decline in tax equity."

The future of tax equity

Due to the issue of demand caused by the ITC being extended at the end of 2015, this year has been a rough one for most developers, particularly the second half, as most tax equity providers had insufficient capital to last the entire year. The silver lining is that some of that volume should shift to 2017. Next year, the landscape should become easier to navigate. "There is a possibility that tax equity supply could ratchet up a little bit," says Santosh Raikar, managing director of renewable energy investments at State Street Bank. "We have seen a number of players entering the market over the last couple of years and there are a number of institutional investors stepping in. If there is an opportunity for this, there won't be as much constraint on capital."

Whilst it still has its road bumps, tax equity is no longer a wholly unknown entity and applicability is a lot easier than it was two or three years ago. However, Patrignani highlights the need for "smarter alternatives" to tax equity that are better able to cope with the fast-changing dynamics of the solar market.

The difficulty lies in finding an alternate mechanism that is simpler but still provides that same access to equity for solar developers. One alternative that has been suggested is some form of cash grant that is better geared towards a rapidly growingly market like solar that attracts many new entrants. Until such a mechanism is found, the industry will just have to sit tight and wait and see what happens once the ITC extension eventually expires for residential projects and drops to 10% for commercial and utility projects after 2023.

An optimistic view comes from Altus Power CEO Tom Athan: "Once the ITC runs out, solar will just exist in the same way it does now, if not better. It'll be a simpler investment for people to make without having to deal with tax equity. It'll 100% be easier; nobody questions that – it is just a question of whether or not the yields that you can get will be enough for investors. If you took the ITC away today, people probably wouldn't be comfortable with the yields. But if you lower the cost of the solar panels and the installation, and you got investors more comfortable in the next five years with solar as an asset class, then you will probably see when the ITC goes away that people are comfortable investing even in those yields." ■

Living up to expectations

Building integrated PV | Despite plenty of hype, BIPV has remained a niche segment in the solar business, held back by a combination of high costs and low efficiencies. But as Ben Willis hears, the high-profile entry of Tesla on to the BIPV scene could herald the start of a new era for the sector

Credit: Tesla

In late October, with all the usual fanfare that accompanies an Elon Musk announcement, the CEO of EV and battery storage manufacturer, Tesla, took to the stage to lift the lid on a heavily trailed new product. Most of Musk's recent utterances on energy have been about storage, particularly Tesla's high-profile foray into the world of stationary storage through its Powerwall battery system. But this was something a bit different – a building-integrated PV (BIPV) product designed to emulate various kinds of roofing tile and eliminate the need for clunky conventional roof-mounted modules once and for all.

Critics were quick to pick holes in Musk's BIPV play. They pointed to a landscape littered with the carcases of companies that had been lured to the sleek looks and theoretical logic of BIPV only to come unstuck when they found the market – for many reasons including cost, technical challenges and the general complications of integrating two different industries (solar and construction) – just wasn't there yet. Why, the pundits asked, should Musk and his Tesla/SolarCity machine presume to be able to crack a market that so far has evaded all attempts at mainstreaming?

That may well prove to be a pertinent and prescient question. For sure, BIPV so far has remained very much a niche segment of the solar business, beautiful but confined to signature projects where the client most likely sees the designerly incorporation of PV into a building as an effective way of expressing green credentials. All of the negatives cited by Musk's detractors are perfectly valid as they have so far been the main reasons why BIPV has yet to hit the big time. And of course, details of the Tesla/SolarCity BIPV offering are still sketchy to say the least, and fall well short of a full-blooded product launch.

Yet for some seasoned BIPV observers, Musk's announcement is symptomatic of a general shift in the market that could see BIPV take a step up to a new level of deployment. A convergence of technical, cost and regulatory factors point to potentially fertile conditions for the solar industry's great underachiever to finally flourish.

Adel El Gammal is director of the Becquerel Institute, the Brussels-based solar market research and consultancy. He has been involved in BIPV in some shape or form since 2008, when he founded architectural BIPV company, Ecotemis. From what he has seen of this segment over the years, El Gammal believes BIPV's time is coming. "We know what has happened with BIPV but based on the experiences I have had we are certainly approaching the moment where we can expect to see BIPV really ramping up maybe for the first time as a mainstream market segment," he says.

Tesla CEO Elon Musk has unveiled a new solar roofing product to combine with is Powerwall battery

Policy

El Gammal's assertion is based on the fact that, particularly in Europe, the drivers behind solar are changing. Broadly speaking, the solar boom that began in Germany in the previous decade and subsequently spread to other countries was driven by subsidies that deliberately encouraged volume production as a means of driving down costs rapidly. In that aim it was successful, but at the expense of BIPV, which although a good idea on paper, was by definition a more specialist product unable to compete with standard rooftop or ground-mount deployments.

But that environment is now changing. "We can see clearly in Europe that the market will be stagnating or even decreasing in coming years, as a result of basically mostly all subsidies being cut or significantly decreased," says El Gammal. "This means there will be little case for continuing to build big ground-mount systems in Europe. There are markets that are much more attractive outside Europe for ground-mount systems."

As that change happens, some, including El Gammal, are hoping that so-called 'prosumer' policies – that encourage self-

consumption of own-generated, primarily solar power – will fill the gap left by subsidies. He concedes this is by no means a given, but says it could favour BIPV if it does.

"BIPV could become very interesting if we see prosumer-friendly policies gaining ground. It's very uncertain at the moment; if you look at the landscape in the EU, almost every European country has a different approach to self-consumption, and there are as many regulations on self-consumption as there are PV markets in Europe. But we can see clearly that the commission is very interested in pushing that concept forward.

"And I believe we will see the market in Europe growing again based on the pure competitiveness of PV under prosumer-friendly policies. This of course doesn't mean that rooftop installation will be competitive at any price. But we can see with the tremendous decrease in the cost of production of cells it becomes realistic to build more customised products at costs which are still compatible with profitability on rooftops in general conditions in Europe."

Another promising driver on the policy side is the growing interest, not just in Europe but around the world, in buildings designed to minimise energy consumption. This takes different forms in different areas – dubbed variously zero net energy, net-zero energy, nearly-zero energy or energy-plus buildings. Whatever the name, BIPV is seen as potentially having a great deal to offer in helping realise the general aim of reducing the emissions from buildings, a significant contributor to global greenhouse emissions. The European Commission's 'Energy performance of buildings directive', for example, stipulates that all new public buildings must be 'nearly zero energy' by 2018 and all other new buildings from 2020.

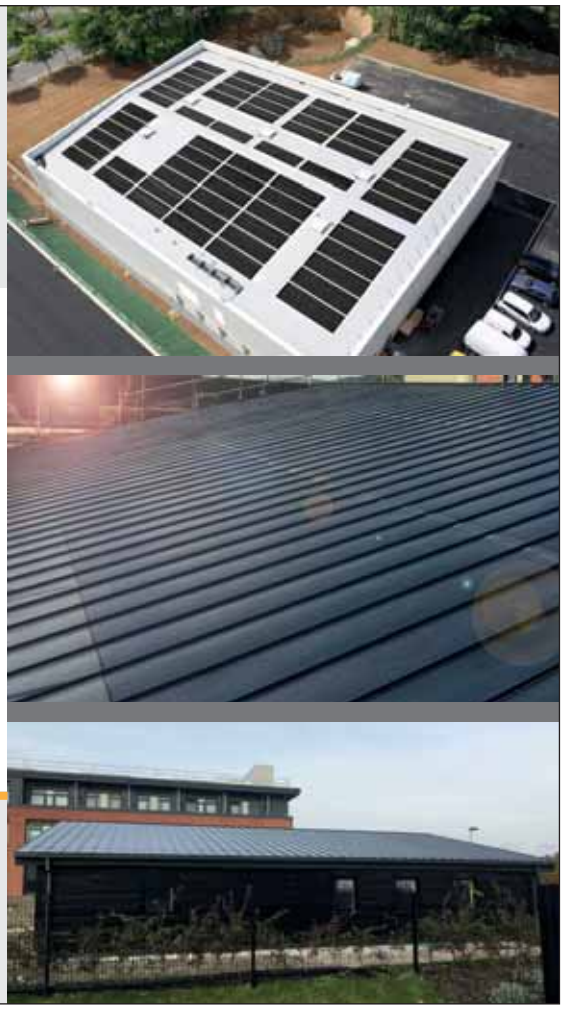
"In Europe and the US there's a big push towards net-zero energy buildings, so you need to have solar that will offset your energy usage," says Anil Vijayendran, vice president of sales and marketing at MiaSolé, the California-based CIGS thin-film specialist acquired by China's Hanergy in 2012. MiaSolé recently launched what it described as a "next-generation" range of flexible CIGS products aimed at BIPV applications. "It's mostly on homes, so those homes need to be aesthetically beautiful; the traditional panels may not cut it, so you'll start to see more and more use of BIPV in order to meet some of these net-zero challenges. In France they're talking about a net-zero policy, in the US there are certain areas with net-zero compliance. I think those things are going to push adoption."

Lower cost, higher efficiency

Exactly how those policies play out in the current climate, with an incoming US president who has already made clear his hostility towards clean energy, the unknown consequences of Brexit and a European Union that looks politically ever shakier, remains to be seen. But other countries such as Canada and Japan have policies in place, and there is discussion of heavy hitters such as China and India taking steps towards net-zero energy buildings.

And aside from the vagaries of policy, one immutable fact is that on cost and performance BIPV has made some significant advances in recent years. These two areas have traditionally been BIPV's biggest Achilles heels, the generally lower efficiencies achievable with most BIPV products and the relatively greater costs compared to regular crystalline silicon products together acting as a significant barrier to adoption.

Vijayendran says that in the past, leaders in the BIPV field were only able to muster



performance efficiencies of around 8%. "There were some nice products, but if you needed to use two to three times as many solar panels to get the same amount of power the economics don't work out, and frankly there's just not enough space on the roof," he says. Now, MiaSolé's CIGS product is able to achieve efficiencies of more like 16-17%. "Once you get to that level of efficiency you can start to play from an economic standpoint," Vijayendran says.

Alongside the greater efficiencies, Vijayendran says MiaSolé has been able to significantly reduce its costs. This is in a large part thanks to a new proprietary tool the company has developed that allows it to deposit all the layers of the PV film in one hit. "It allows us to deposit thousands of different cells per hour," he explains. "So we can go through many different recipe types to fine tune the efficiency in an hour – having 10 different tools for each process step, it would take you 100 times longer to do the optimisation and testing."

New products

Of course, BIPV products are still not at the point of being able to compete directly with regular crystalline modules. MiaSolé is driving its costs down, but expects the best cost of a system using its products still to be 10 to 30% higher than one using standard modules. But where BIPV comes into its own, and will increasingly do so if the regulatory environment tightens, is in buildings where standard PV is not applicable.

One of MiaSolé's collaborators is the UK-based company, BIPVco, a spin-out from Swansea University in Wales that produces metal roofing products incorporating its US partner's CIGS cells. Its CEO Daniel Pillai agrees that the significant advances in efficiency achieved by MiaSolé have enabled his company to develop products that although still more costly than regular crystalline silicon modules offer the sort of return on investment that makes them competitive. And crucially, given the lightweightness of MiaSolé CIGS cells, they can be applied to buildings where regular panels would be too heavy.

For Pillai, with the likelihood that BIPV products will be unable to compete with their mainstream c-Si counterparts for the foreseeable future, this is where the real opportunities in BIPV now lie. "There's a clear need [for BIPV products] in the sense that traditional PV cannot address huge chunks of buildings," he says. "The existing technologies can't meet the need, so BIPV offers a solution."

Another exciting development on the horizon is the possible emergence of new BIPV products manufactured by construction material companies as opposed to PV manufacturers. There have been some attempts at this, but they generally haven't worked for the reasons already highlighted. Clearly, however, the successful manufacture of BIPV products by companies with both knowledge of and clout in the construction materials business could be a significant boost to the adoption of BIPV.

El Gammal reveals that he has been consulting with two such companies, which he says are close to launching BIPV products. "These are both actors who have traditionally been outside of the PV sector and are very, very significant players," he says. "They are at the very point of commercialising pure BIPV products, which have been designed starting from a building construction material perspective on which, by different technologies, you apply a PV functionality. And this is a totally different approach which I believe is very effective, because it means you don't need to change much in the manufacture, in the distribution and implementation process – because it's basically fitting the material you are used to fitting with a PV component. All you need is an electrical connection. It's a very different approach."

Working together

This represents a potentially important step forward for BIPV. One factor that has hitherto been a hindrance for the sector has been the lack of success by the PV and construction industries to collaborate on developing solutions that work optimally for both the energy-production and construction functions that BIPV must necessarily perform.

Earlier this year, a new association, Allianz BIPV, was launched in Germany with the specific intention of uniting the disparate spheres of expertise that fall under the BIPV umbrella. Among its members so far are research bodies representing the solar and construction industries, architecture firms, solar technology companies and building material companies. Its chairman, Sebastian Lange, a Potsdam-based lawyer specialising in climate change and renewable energy, explains the thinking behind the venture.

"We had a very long, intense discussion about whether or not to found a new organisation," he says. "There are so many organisations with some connection to BIPV; we wondered if it really makes sense to set up another. But the view actually was that there is a gap between all these organisations; BIPV really is in the middle of so many different aspects – you have the building aspect, you have the energy industry… you have the architects and the ones who are ordering and paying for the buildings. That led us to the conclusion that there's actually a missing link between all these organisations. So we have the intention not to be in a way another organisation but build up these missing links and work together."

The aim of the organisation, which Lange says will not be limited solely to BIPV in Germany, will be to undertake research, collect and disseminate information on best practice and help develop the right regulatory frameworks for BIPV, as well as generally helping raise its profile in the public's eye. Lange says the alliance has just completed its first piece of work, an exercise to document the knowledge available on how to install BIPV in a new building, from the perspective of an architect or planner. "We are working on documents which will be helping tools for the ones who are thinking about BIPV and investing in it – what does it cost, what are the benefits – but also for the ones who then have to plan and build it – what do they have to know about the new technologies?"

From initiatives such as these, it would seem that the will is certainly there to coax BIPV out of the niche it has occupied so far. The conditions look better than they ever have for BIPV to take off, and coupled with recent developments on the technology front, there are reasons to feel optimistic this could happen. On top of that, Elon Musk's announcement in October will have helped further the cause: BIPV is now firmly in the public's mind, and who knows, it may even turn out in time that Musk has chosen the right time to back a winning horse.

"The fact you see a highly respected businessman, considered as a visionary, linking together e-mobility, electricity and storage and PV, this is absolutely essential in terms of the credibility of the story and the credibility of BIPV as a solution for the future," says El Gammal. "The fact that he's looking at it as well means there will be an economic case for BIPV otherwise he wouldn't announce it. It was exactly the same with storage - he has made his very bold announcement on the price of storage, and now we see it happening. This announcement is fundamental in terms of awareness in the general public and in industry, but it proves the economics of BIPV will soon be there to make it a truly attractive case." ■

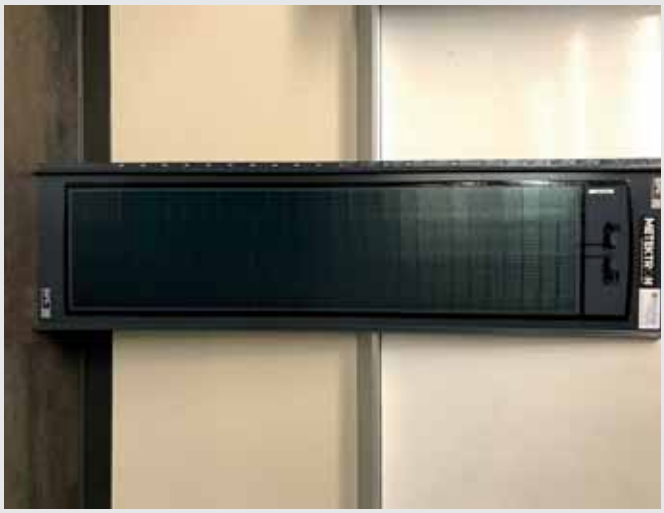
Next generation - BIPV technologies to watch

CIGS thin film

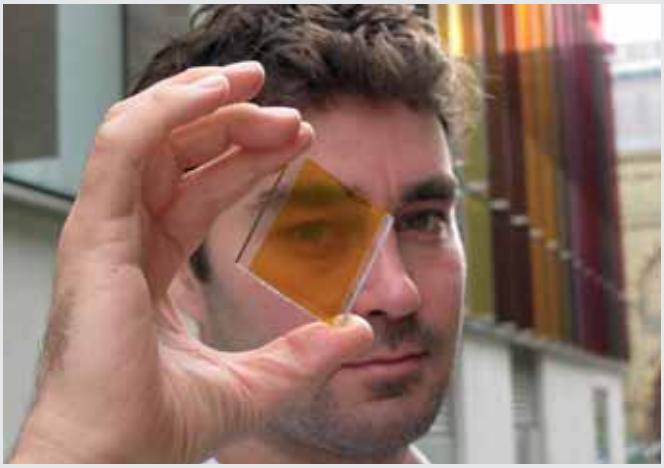
By virtue of its light weight and flexibility CIGS thin-film technology is particularly well suited to BIPV applications. Following the launch in September of its next-generation CIGS products, MiaSolé announced a partnership with American roofing manufacturer McElroy Metal to produce a range of solar roofing materials. As well as BIPVco in the UK, MiaSolé is also partnering with General Membrane, an Italian firm specialising in bitumen roofs to develop BIPV roofing products.

Another attribute of CIGS is its transparency, which makes it suited for use in solar glass. In September the German thin-film specialist Avancis announced a partnership with French PV glazing manufacturer SunPartner to produce semi-transparent solar glass incorporating Avancis' CIGS cells.

"We are quite sure the BIPV market will grow quickly," says Avancis' head of business development and sales, Jochen Weick. "There is more and more manufacturing work going on in this field, and there are a lot of requests from architects and planners [for BIPV]. And there is demand due to zero-emissions buildings."



Credit: MiaSolé



Credit Oxford PV

Perovskite

Perovskite, the new solar 'wonder material' being developed by the likes of UK-based Oxford PV, has frequently been touted for its potential in building-integrated applications. Oxford PV itself recently took the first steps towards commercialisation by acquiring a former Bosch PV production line in Germany to begin pilot-scale production of its technology.

Speaking to PV Tech Power, Oxford PV's chief technology officer Chris Case says that for the time being the company is focusing on producing its perovskite technology for use in tandem with regular silicon solar cells – the latter having the greatest market presence at the moment and thus offering the greatest opportunities for scaling up perovskite. However, he says that in the fullness of time, applying perovskite to BIPV is still a big strategic objective for Oxford PV, as it had been when the company first came into being.

Perovskite is also making progress in combination with CIGS technology. In October a team from Belgium's imec and Germany's ZSW and KIT research institutes achieved a 17.8% conversion efficiency with a tandem perovskite/CIGS module. A combination of perovskite and CIGS would be particularly suited for BIPV applications, given the latter's proven attributes in this area.

Other companies working on perovskite solutions include Australia's Dyesol.

Organic PV

Organic PV (OPV) uses carbon-based semiconducters to produce power. OPV cells are printed, meaning, like CIGS technology, they have the flexibility to be applied to almost anything – glass, building materials and even clothing and other small-scale products.

Germany's Belectric, under its 'Solarte' brand, is one of the leading names working on OPV technology and claims to have put into operation the world's first grid-connected OPV project – a 0.2kW installation at the Frankfurt base of German energy supplier, Mainova.

In October, in a press release published to mark four years of operation of this installation, Belectric declared it a success, claiming it had exceeded the simulated energy yield by 7%. In conjunction with its partner, Merck, Belectric declared OPV a next-generation PV technology to watch.

"Four years trouble-free operation, with no apparent degradation, a higher energy yield than expected and Mainova a satisfied partner, are confirmation of our good work. Finally, the system was built to the 2012 level of technology. Since then we have made great progress in terms of performance and integration. With our current possibilities, such a project would look different, even better, and achieve higher yields. With the knowledge that OPV technology development is continuing to advance, we are in a good position to meet the future," said Hermann Issa, director of business development at Belectric OPV.

Other companies working on OPV technologies include Germany's Heliatek, which recently received an €80 million investment boost to expand production capacity for its 'HeliaFilm' OPV technology, which is used in the building and automotive industries.

Credit Belectric

Surveying the scene

Surveying | All parts of the PV supply chain are under pressure to reduce costs and boost the competitiveness of solar. A new rover vehicle developed for site surveying work promises to help significantly reduce labour costs in the construction of large-scale solar projects. Danielle Ola reports

TerraSmart, a Florida-based provider of turnkey ground-mount PV solutions, has introduced the US solar industry's first fully autonomous precision survey rover (ASPR) to perform survey stake-out functions. The robot, which is a gas/electric hybrid, more than triples survey speed and accuracy, and is scheduled to be followed up by a larger model with added drilling capabilities. TerraSmart Systems design manager Chase Anderson caught up with *PV Tech Power* to discuss how the rover will revolutionise the game.

What exactly is the rover and what it does?

The APSR was designed and built not to replace a human surveyor, but to give them a more accurate and a faster tool to do their job with. It's a machine that locates on a large field exactly where all of our foundation products need to be installed. It does this completely autonomously using various algorithms and high-accuracy GPS technology. The purpose of it was to speed up what traditionally is one of the slowest parts of the installation of a solar project.

When designing the robot to be used as a tool, we had to make sure that they didn't sacrifice any of that reliability and accuracy and it turns out that we ended up with a machine that can be more accurate and more reliable than a human can.

Why specifically is this a useful technology for solar?

There are many industries where survey is used, but in solar specifically, you have thousands and thousands of foundations in a grid-like pattern just due to the sheer scale of these projects. We've done projects with over 100,000 foundations that have had to be manually surveyed for each and every single one of them. So you can imagine the benefit of a machine that could do that for us, both quicker and more accurately.

In solar specifically, it is such a good application because of the sheer quantity. Any type of solar installation has – even the small projects – thousands of foundations. The average-sized projects have anywhere from 5-20,000 foundations and the really big ones have over 100,000. In our day, we have to locate thousands of points underneath the solar panel; and that is a common thing with all solar companies and all solar products. It helps us get our job done better and faster with less possibility for error.

How significant are the speed and accuracy you describe in cutting overall project construction costs?

When we can survey more points in a day, it still only takes the one man to do it; so his eight-hour day is now four times more efficient, so there's a little bit of cost reduction there in labour alone.

The robot has different attachments, and one of them is a micro-drill that will drill a small hole into the ground, and we call it the pilot hole. When there's a pilot hole, the team that are installing the ground screws behind the survey robot can use the pilot hole to install the ground-screws easier and faster, which can also reduce the cost.

The biggest savings are on the really large projects. When we know that our survey is going to be reliable, we know that our foundations are going to be in the right place, the installations of the solar racking becomes so much easier because it is more precise from the get-go. When things get easier for field crews who can start to be more efficient, not just in the survey but in the ground-screw installation, in the racking installation, the electricians have an easier time putting the modules on, just because everything fits together better.

How much difference does the APSR make in reducing the levelised cost of electricity in projects?

I don't think that I have a good answer for that one. We've just recently released it; we've used it in a couple of places here in the north-east, but it's a little too early to tell exactly, to put a hard number to it.

What sort of demand have you experienced for the vehicle and what sort of wider uptake do you foresee?

It is currently just available in the States. We've had interest from clients in the north-west US such as Nevada, Oregon and California, and we have a very large footprint in the north-east. We are very excited to be not only using the three that we currently have, but building more to meet the demand in both sides of the States.

We have deployed three but they are booked up for a while for TerraSmart use so that's why we are busy on developing more. Our goal is to move towards a system where we are using this on every single site, just for consistency. So we would like to have one for every single survey team that we have.

What would you say the limitations of the APSR are at the moment – whether that is in terms of terrain, speed, inclines and so on?

So we designed it to handle up to 45 degree slopes, so there are not too many challenges in terms of moving up the side of a steep hill – that was a key design consideration. So far, in all the sites and the testing that we've done, it has run extremely well in all conditions.

But as with any GPS technology, when there's too much cloud cover or a really terrible storm, you will lose that signal from the satellite. That's certainly a limitation but typically on days like that,

not too much is happening anyway, so it's not too big of a loss.

The tyres that are on the machine are designed to work in the snow. We have yet to run it during the winter season, but we are pretty confident that it will work. And if doesn't, the tyres can be swapped out for tracks within a few moments.

What is the application like for considerably larger PV sites i.e. 100MW+?

One operator has the ability to control multiple units from a single handheld device using long-range wireless communication. On a large site, say 100MW, we would definitely be able to run not just one but maybe three or four units at the same time and guarantee that our robots are well ahead of any phases that are starting after it.

Based on the velocities that I've seen, I would put two on a 100MW site; on some of the previous larger projects that we've done that had very compressed timelines, we were already behind schedule and we had to finish sooner. But realistically, on a traditional timeline, one would have been more than enough to support the standard course for 100MW. If we need one, we can send one, if we need two, we don't have to send any more people; we just send another robot and one person can do both.

What other results can you share from the field?

We've done trialling on multiple sites. We sent a survey crew behind the robot to verify on these sites that it is putting in accurate, reliable foundation locations – and every single time we were unable to locate any that weren't correct. It kind of has a fail-safe in the software that will move the robot into the correct position and only when the robot is 100% certain, based on all the sensor data, will it allow that point to be placed. And if at any point during the placement the robot detects that it has moved, or some environmental condition has changed, it will redo that point; or it will mark that point as incomplete and the operator can choose to come back at a later time.

TerraSmart's ASPR is claimed to be able to stake out the foundations for large PV arrays in a fraction of the time it takes humans

Credit: TerraSmart

A lot of the numbers that we've posted thus far have been based on our official stats. My survey crew can view between 200-250 survey points in a day accurately. They certainly can do more, but we usually see a loss of accuracy if they do that. The APSR has proven to do over a thousand and in one case, what was just over 1,200 points within the same amount to time; and of course the accuracy…

What attributes are going to be improved on the new model, other than size?

We are going to scale up – and the reason for this is to build a machine that not only can survey but can rock-drill at the same time. A lot of the projects that TerraSmart does are in locations where right beneath the grass or the top level of dirt is solid rock. So if we have a quicker, more accurate, more automated way to drill the holes that we need through that solid rock, installation times of our entire process will be greatly, greatly reduced. What used to be three phases will be down into one phase; survey, locate and rock-drill all the points of our sites for us. We usually drill between a six to eight-foot hole, with a diameter anywhere from three to five inches for our foundation product. That will now be automated.

The bigger model will also have eight wheels and those wheels will also be interchangeable with tracks. It is quite a bit bigger; not only are there eight wheels, but the wheels are almost twice the size. It will be at least six times the size of the current APSR.

Do you see any other applications for the APSR beyond site surveying, such as operations and maintenance?

I've never really thought about the O&M side – but I'm sure we can spin our wheels a little bit to come up with something.

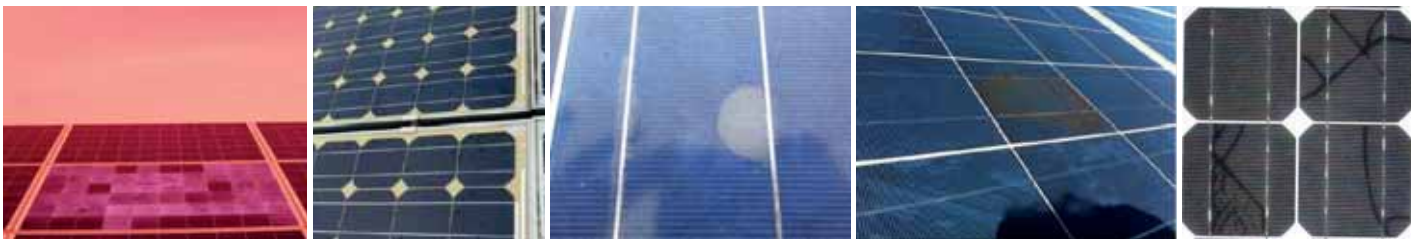
Our guys have the ability to use the robot when it is not surveying as a tool to aid them in their construction; and we have incorporated a few things on the robot to help this – things as simple as a trailer hitch. You would be surprised how many times we need to move a small trailer from one side of a muddy site to the other and your typical truck can't make it through. So your APSR is both heavy and rugged enough to tow the trailer from one end of the site to the other. We actually can use it to move material around if needed; and you can take manual control of the robot to do that.

In addition, the entire front assembly – I call it the attachment – is interchangeable and designed to work with the pilot hole drilling attachment that I mentioned, we also have a spray paint application. It can mark and spray points on the ground and another one will clip flags in the ground.

We can also use the robot to drive over an empty field and create a topography map using the on-board sensors. Before a project starts usually they'll send a surveyor out to use GPS equipment and make a 3D model of what the terrain looks like. We can actually run the robot in a grid pattern across the same field and produce the same result and we can create this really nice 3D terrain model that be used by engineers to make the shading plans and the various solar installation layouts more efficient. ■

Properties of encapsulation materials and their relevance for quality control and recent field failures

Module defects | The properties of module encapsulant materials are coming under closer scrutiny as their role in a number of common field failures becomes better understood. Juliane Berghold and Tsuyoshi Shioda report on new testing methods being developed to analyse the composition of encapsulants and improve the quality control of this crucial material



An increasing number of frequent and energy yield-relevant field failures are not covered by IEC testing. In this context the properties of the encapsulation material are coming increasingly into the focus due to their impact on the long-term stability of solar modules in the field. Furthermore, in the future the majority of PV installations worldwide will be exposed to more stressful conditions, since the market share of installed PV in desert-like and tropical surroundings will further increase in the coming years. Accordingly, the long-term stability of the encapsulation material will become crucial. For instance electrical and chemical properties of the encapsulation material have been shown to play an important role for the occurrence and avoidance of various module field failures, such as potential-induced degradation(PID), 'browning', delamination, corrosion and 'snail trails' (from left to right in Figure 1).

Relevance of encapsulant for field failures

The vast majority of PV panels worldwide are still produced with ethylene vinyl acetate (EVA) as the encapsulation material, although there are also other promising materials (e.g. POE) with desirable properties entering the PV market. The impact of the EVA material on frequently observed field failures can be either indirect or direct, which shall be shortly illustrated here.

Indirect impact of the encapsulant

As 'media' for charge carrying and mass transportation within the PV module the electrical properties of the selected EVA material determine the level and distribution of leakage current. The leakage current and the resulting ion transport in a PV module is very relevant for field failures such as PID. In Figure 2 the leakage current distribution is shown for two different EVA materials – with very high and very low volume resistivity.

For PID as one of the frequently observed module field failures today, the leakage current distribution in PV modules is crucial and it is not only impacted by the encapsulant but also by environmental conditions the PV module is exposed to (such as temperature and humidity). As a result the specific 'failure pattern' for PID that is observed in a PV plant can be very different as illustrated in Figure 3.

Figure 1. Different module field failures with indirect or direct influence of encapsulation material

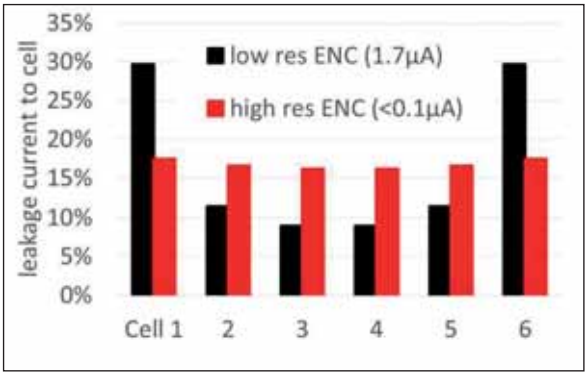


Figure 2. Leakage current distribution depending on kind of encapsulation material (high volume resistivity (10^{15} Ωcm) versus low volume resistivity (10^{13} Ωcm)) [1]

Direct impact of the encapsulant

Furthermore, components or decay products (e.g. acetic acid) of the EVA can also serve directly as a 'reaction partner' for chemical processes within the PV module resulting in visible failures such as corrosion. Moreover, the additives in the EVA – with the purpose of securing specific material properties – could be unstable, added in insufficient concentration or simply missing altogether, causing module failures such as delamination or browning.

As a result it turns out that the specific formulation of the EVA material – which is usually unknown (to the end customer but mostly also to the module manufacturer) – has a very direct impact on the likelihood of certain module defects at specific locations.

An example of the impact of different EVA formulations on the trend for yellowing/browning is given in Figure 4. The difference for the yellowing index is highlighted for 17 and 27 years of outdoor exposure for a location in Japan. However, the difference for these two EVA formulations would be even more

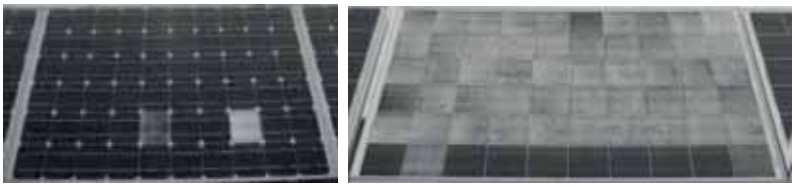


Figure 3: electroluminescence images from PID-affected modules in field: 'surface' PID (left) and 'frame' PID (right) depending on different leakage current distribution in PV modules [1]

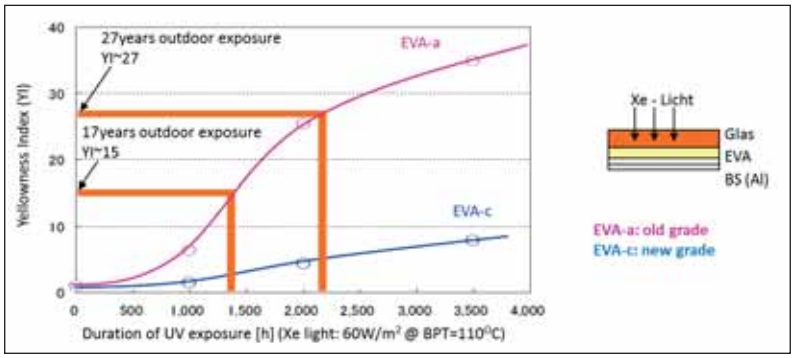


Figure 4. Different trends for the yellowness index for two different EVA formulations

Figure 5. Snail trail formation in indoor experiment and outdoor exposure depending on chemical agents and additives in the EVA (red: clear snail trails; orange: light snail trails) [2]

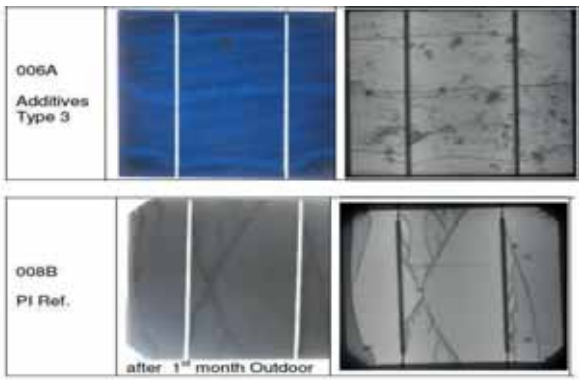


Figure 6. Different visual appearance of snail trails depending on additives in EVA [2]

pronounced for locations with very high irradiance, such as Chile.

Another example of the direct impact of the encapsulant is the frequently observed so-called snail trail formation on PV modules in solar plants. Snail trail formation was investigated for its dependence on the specific EVA formulation, including specific chemical agents and additives. The results of indoor and outdoor experiments (Figure 5) revealed that the formation of snail trails was dependent on the presence of certain additives in the EVA material.

Also the visual appearance of the snail trails was found to be different depending on the specific additives involved (Figure 6).

Quality control and failure analysis

For avoidance and root cause analysis of module field failures related to the encapsulation material different analysis methods are applied by PI Berlin

Additives	Type	Fresh EVA	Cured EVA
Curing agent	a	Detected	Detected
	b	Detected	Detected
	c	Not detected	Not detected
	d	Not detected	Not detected
UV absorber	e	Detected	Detected
	f	Not detected	Not detected
Light stabiliser	g	Detected	Detected
	h	Not detected	Not detected
Anti-oxidant	i	Detected	Detected
	j	Detected	Detected
	k	Not detected	Not detected
Coupling agent	m	Detected	Detected

Table 1. Comparison of the results of the qualitative analysis of selected additives for two EVA samples ('fresh/uncured' (e.g. taken from an EVA roll in production) versus 'cured' (e.g. taken from a PV module in field))

Figure 7. EVA sampling for finger print test during quality control for PV plant

– including volume resistivity measurements, peel testing and gel contents determination.

Furthermore, recently a powerful tool for chemical analysis was developed in cooperation with Mitsui Chemicals – the 'finger print test' for EVA materials. This test procedure includes qualitative and quantitative chemical analysis of selected additives in the EVA material and therefore allows for all sorts of applications relevant for practical purposes – such as quality control, root-cause analysis in case of module defects and resulting reclaim processes.

One straightforward application is for example the confirmation of the 'bill of materials' (BOM) of commercial PV modules. With the finger print test it is now possible to evaluate if the specific EVA in commercial PV modules (in a specific solar plant) is the 'correct' material and therefore in accordance with the 'agreed' BOM or specification (e.g. for a solar project or for a production slot manufactured by an OEM supplier etc.). In Table 1 the comparison of the qualitative chemical analysis for 'cured EVA' (taken from a commercial PV module) and the 'fresh/uncured EVA' (according to BOM/specification) is demonstrated for selected additives.

Furthermore, with the finger print test 'critical' EVA compositions can also be identified. This can be used for the identification of module failures in field. For example if a specific additive (e.g. the coupling agent) in the EVA is missing ('not detected') or found only in insufficient concentration, this can then be identified as a root cause for observed delamination of the PV modules in field.

"In the future the majority of PV installations worldwide will be exposed to more stressful conditions, since the market share of installed PV in desert-like and tropical surroundings will further increase within the next years. Accordingly, the long-term stability of the encapsulation material will become crucial"

Examples for finger print testing

In the following two examples from praxis shall be given for the confirmation of the BOM/specification ('correct' EVA material) introduced in section III.

Example 1: Quality control for 20MW plant in Japan

PI Berlin carried out the quality control for a 20 MW plant in Japan in cooperation with Mitsui Chemicals – from production audit and quality control testing of the modules in China until the construction and commissioning of the solar plant in Japan. During the production audit in China EVA samples were taken from a designated EVA roll in production (as specified according to BOM).

For the verification that the modules shipped to the site in Japan were manufactured with the same materials, EVA samples were taken from the PV modules during the QC sampling test in China and finger print testing was conducted with the fresh EVA sample from production and the cured EVA sample taken from the modules desig-

Module number	Status	PMMP (W)	Power deviation (%)	PID quality category (PI Berlin)
1	Initial	205.0		C
	After PID	Not detectable	-100	
2	Initial	205.6		C
	After PID	Not detectable	-100	
3	Initial	204.2		C
	After PID	Not detectable	-100	
4	Initial	205.8		C
	After PID	Not detectable	-100	
5	Initial	205.2		C
	After PID	Not detectable	-100	
6	Initial	205.7		C
	After PID	Not detectable	-100	

Table 2. PID lab results for modules from OEM supplier

nated for shipment to Japan (Fig ure 7).

In this case the finger print test revealed the nonconformity of the two samples. For selected additives the concentration of selected additives were drastically different – for the reference material from production compared with the EVA material utilised for the production of the PV modules for the solar project in Japan.

Example 2: Reclaim regarding xMW of production capacity of an OEM supplier

This case started with first warranty claims from end customers of PV modules (manufactured by an OEM module supplier) at different locations worldwide. PI Berlin was instructed as technical adviser and confirmed PID sensitivity of the modules in lab testing and also progressed PID in different solar plants and locations.

As the PID sensitivity of these modules was found to be extreme with no detectable power after testing (see Table 2), the aim of employing the finger print test for these modules was to evaluate whether or not the EVA material used was in accordance with the specification/BOM agreed with the OEM supplier of these modules.

However, in this case the fingerprint test results confirmed that the utilised EVA was in accordance to the agreed specification.

Summary and conclusion

Long-term stability aspects of the encapsulation material are becoming increasingly important as more and more module defects in field are found to be correlated to the EVA material. In the root cause analysis for different field failures (snail trails, delamination etc.) the specific chemical composition of the EVA – which is mostly unknown to module manufactures and end customers – is moving into focus. The relevance of the chemical composition – including the type and quantity of certain additives – will further increase also in more stressful climates (in terms of radiation, temperature and humidity).

The finger print test is an innovative new tool for quality control, root cause analysis and reclaim processes for PV modules. ■

Authors

Juliane Berghold received her Ph.D. in physical chemistry in 2006 from Freie Universität Berlin. She has more than 15 years' experience in PV technology, including R&D, consultancy and management. She currently heads the PV module technology and R&D services business unit at PI Berlin.

Tsuyoshi Shioda received his M.Eng. degree in electronics in 1997 and his Dr.Eng. degree in chemistry in 2005 from Tohoku University, Japan. In 1997, he joined Mitsui Chemicals, Inc. He has been an expert of Japanese NC of IEC/TC82/WG2 where standardisation for PV modules has been discussed. He has conducted researches related to reliability of PV modules and PV materials since 2008. Now he focuses on running new businesses concerning diagnosis of a PV power plant and a PV module utilising his expertise.

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High voltage, low costs

System architecture | As the solar industry continues to squeeze out cost reductions, 1,500V architecture is tipped to make its mark in 2017. John Parnell looks at the potential pitfalls and likely winners as utility-scale plants dial up the voltage

Credit Sungrow

The cost per kilowatt hour of solar projects will continue to fall. Take a look at the value of some power purchase agreements signed of late. NV Energy will be paying just US$0.0387/kWh for power from First Solar's Playa Solar 2 plant. If power purchase prices are going to keep falling, the industry is going to need to keep finding savings.

This is not news to project designers and engineers. But if solar does not continue to remain competitive on price, it doesn't have a future.

This task is not solely the responsibility of the module manufacturers. As the biggest cost component of any project, modules get the lion's share of attention when it comes to reducing that crucial per-kWh figure.

Walking the halls of any of the major trade shows in 2015 and 2016, bifacial modules, PERC, energy storage and ever-simplified trackers were competing for attention. A growing number of vendors were also displaying 1,500V products.

With certification arranged by Trina Solar, SMA, Canadian Solar and many others, the starting gun on the 1,500V transition has been fired. Analysts firm GTM expects "wide-scale adoption" in 2017. The rest of the industry seems to agree.

Not tech tokenism

Gabe Cantor is director of plant architecture and plant technology at developer and EPC firm Strata Solar. "When you are talking about transitions from one technology to another, that's what I live day in and day out," says Cantor.

"We have several tens of megawatts under construction with 1,500V equipment; this is happening, it is not just vendors shouting loudly about it at SPI [Solar Power International]."

Cantor isn't quite convinced that 1,500V will become the dominant architecture in 2017 but acknowledges that it will certainly be far more than a token part of the market. "It's going to be a substantial portion," he says. "A lot of our projects are actually constrained by what has already been submitted in our interconnection requests to utilities. In some cases it doesn't make sense to re-study those with a new inverter. In a lot of cases the study process with the utility can take 18 months or even two years. So it really depends but I think some projects are more flexible than others."

1500V PV power plants, such as Sungrow's 50MW project in Datung, China, are expected to become a more common sight as the industry shifts to the higher voltage

That will apply across the US and in other markets where network operators are involved in the process. Projects in the pipeline not marked down for 1,500V will likely remain that way. As they are joined by fresh 1,500V-based proposals the outlook for future project development will most certainly evolve into one dominated by the new architecture. The speed of the switch to 1,500V requires numerous pieces of the puzzle to be in place and is constrained in a way that shifting to new module technologies, for example, would not be.

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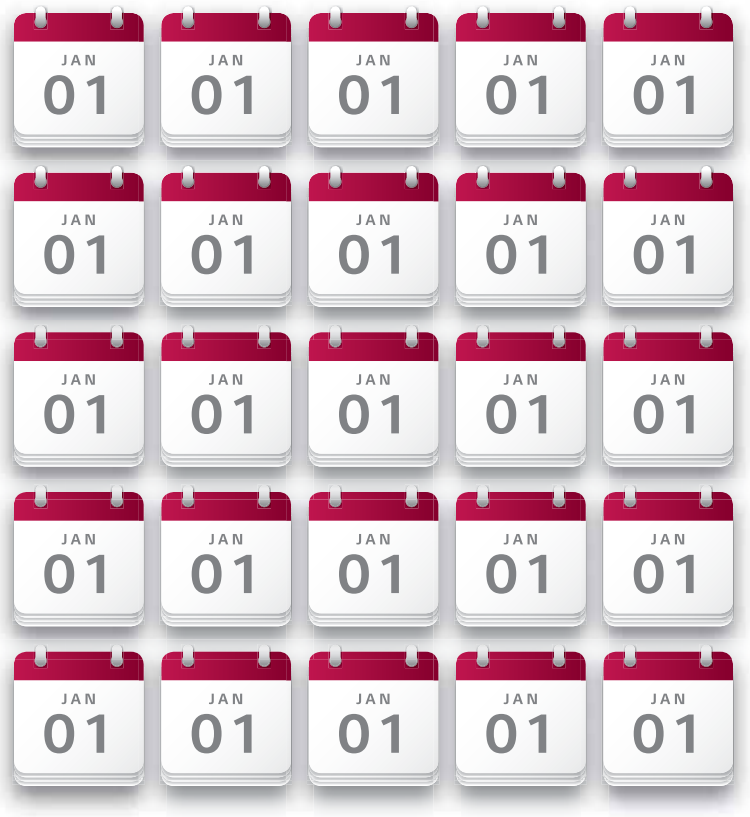

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Cantor oversaw the company's switch up from 600V to 1,000V and is confident that lessons learned during that process should make things smoother this time around. "There are some lessons we learned there and some mistakes that we made that we are trying not to repeat this time around. The main difficulty with the transition to 1,000V was not really technical, it was more regulatory.

"A lot of our projects are inspected by local inspectors who like to see UL or other nationally recognised testing laboratories' kite marks on all of the equipment and at the time that 1,000V inverters first came out, the modules still had to catch up on the listing aspect.

"This time around, our first 1,500V projects are larger than we were doing for the last transition and they are what we would consider to be 'behind the fence' [utility owned and operated], so the local inspector element is not an issue."

One surprise element that impacted Strata during the 600V to 1,000V changeover was the field tools its installers use. That is likely to be the same again with the 1,000 to 1,500V transition, although, as before, the impact of that will be tempered to a degree by the fact that much of the componentry will remain the same.

"In the last transition we had to retool to make sure we had the right multimeters and tools for measuring the string current and open circuit voltages. A lot of our equipment at that time was rated to 600V and we needed to buy that equipment for 1,000V. Things like that aren't completely obvious when you're first looking at the project; you have to get into the nuts and bolts of it to find all of those issues and shake them out," says Cantor.

"The combiner boxes and connectors and cabling are all basically going to stay the same. It's not any substantial change. We're going to be building plants with basically the same methods and materials as before. The cabling that we use currently is rated to 2,000V so this isn't an issue either," he adds.

Inverters

One obvious component that has to change in the 1,000 to 1,5000V transition is the inverter. The main area of debate here is the appropriateness of string inverters versus central inverters for 1,500V projects.

"We advocate the logic of varied designing for various conditions," says Dr. David Zhao, senior vice president and president of the PV production division at Chinese inverter manufacturer, Sungrow. "Generally speaking, for solar power plants on flat ground, central inverters are the best choice for 1,500V system designers. One obvious reason is that such a plant requires fewer central inverters than string inverters and thus maintains a reasonable number of command and control interfaces.

"There are some lessons we learned there and some mistakes that we made that we are trying not to repeat this time around. The main difficulty with the transition to 1,000V was not really technical, it was more regulatory"

"When it comes to an irregular terrain where structure shades or inconsistent array directions may lead to loss of power production, string inverters with more MPPTs become a more reasonable choice," explains Zhou.

Strata's Cantor agrees and points out that in some instances, making the jump to 1,500V might not even be the best decision. "If you have an array and a piece of land that is big enough for one and half arrays with one inverter size and one that is big enough for two arrays with a smaller inverter size, you will be better off with the smaller inverter," he offers as an example.

But where the choice of 1500V makes sense, Cantor believes that string inverters will certainly have their place, as long as the right considerations are given to how the system is configured.

"With a 1,000V string inverter we have 480V output and that combination of voltages pushes you to move your inverter into the field because you get fewer losses on the 480V output than on the string," he explains. "But with 1,500V string inverters, they tend to have a 600V output so it's a lot lower proportionately to the string input voltage. That pushes you, at least if you're analysing it on cabling, it pushes you to centralise those string inverters and cluster them near your medium voltage transformer, so effectively you'd be building a plant that looked like it was using central inverters but it's just got a number of independent string inverters that are co-located."

A big advantage Cantor sees to string over central inverters is in the relative ease with which they can be replaced in the event of failure. One of the larger risks with central inverters is the risk of an inverter manufacturer not being there in 10 years to support the product. "We have seen it with Satcon, Advanced Energy, and central inverters tend to be very specific in terms of the output voltage they require for the transformer and the general arrangement of where the cabling goes in," he says. "Replacing a central inverter with a compatible unit from another manufacturer is usually an impossibility so going to string inverters I think de-risks the project in the long term and can have an availability effect as well."

This is similar to the way Sungrow sees string inverters being utilised for 1,500V projects. Zhao refers to it as a "virtual central inverter", a concept that makes use of the company's 125kW 1,500V string inverters.

"[It] combines the flexibility of string inverters and the cost effectiveness and command and control advantages of a central inverter. This virtual central inverter concept is adaptable to irregular terrain so it works perfectly for system designers who are in great need of flexibility. We believe, as the cost reduces and the capacity increases, our virtual central inverter concept will catch on quickly."

Lior Handelsman, co-founder of inverter manufacturer SolarEdge, and the company's head of product strategy, believes that the shift to 1,500V will help central inverters remain competitive. "1,500V as a concept was born and defined for reducing balance of system (BOS) costs. I agree that in a central inverter architecture you can reduce a lot of BOS by going into 1,500V because you have a lot of strings. Every string has a go and a return cable and combiner boxes with longer and longer cables. With 1,500V you reduce the cost of cabling and BOS by around 50%. The benefits with string inverters are lessened by [the additional] combiner boxes and better for the DC cabling but

The 1,500V club

PV Tech has been reporting on the release of 1,500V modules since 2013 when Suntech showed off a frameless module at SPI that year. At this stage German system integrator Belectric had already connected the world's first 1,500V system. It used central inverters from GE for the installation. Since those early years a great deal more suppliers have joined the fray. Below are some of the products launched by leading suppliers to service the growing 1,500V market.

Hanwha Q CELLS, Q.PLUS L-G4.2
The panel is specifically optimised for large-scale deployment with power classes of up to 340 Watts and is UL and IEC 1,500V certified. The utility-scale module incorporates Hanwha Q CELLS' proprietary Q.ANTUM technology based on the rear side passivation of solar cells and utilises additional features to optimise the efficiency and performance of the PV cells to reduce the LCOE for the US market. It was launched in June 2016.

Canadian Solar, Diamond CS6X-P-FG
The 72-cell, 1,500V PV module with heat-strengthened double-glass configuration for commercial and utility-scale applications was designed for high-voltage systems of up to 1,500V. By replacing the traditional polymer backsheet with heat-strengthened glass, the Diamond module is claimed to have a lower annual power degradation rate than a traditional module and offer better protection against the elements, making it more reliable and durable during its lifetime. The company claimed the module had a first year annual degradation of 2.5%, each subsequent year 0.5% and an 85.5% power output at year 25 and 83% power output at year 30. It was released in the last quarter of 2015.

ABB, PVS980
The high power outdoor central inverter has DC input voltage of up to 1,500V and a high power rating of up to 2000kVA. One of the key features trailed by the company is its self-contained cooling system. Based on development from the ABB ACS800-38 low-harmonic drive's innovative cooling system, the PVS980 uses phase transition and thermosiphon technology to avoid external air entering the critical compartments of the inverter. The inverter can operate from below freezing to extreme heat in 100% humidity without jeopardising functionality. The high DC input voltage, high efficiency, proven components, compact and modular design and a host of life cycle services that also includes the standard grid support features of PVS series inverters such as active and reactive power control including night-time reactive power support. It was launched in late 2015.

Schneider Electric, Conext SmartGen
Conext SmartGen is an intelligent, cloud-connected 1,500V utility-scale power conversion system, according to Schneider. It has a suite of supporting software solutions called the 'Power EcoSystem', including the cloud-based monitoring and control solution 'Conext Advisor 2'. The Conext SmartGen is the new approach for large-scale renewable power installations. It provides greater efficiency in power generation which Schneider says results in lower short-term and long-term costs, and a far longer service life. The integrated solution features built-in sensors and intelligence for connectivity to the entire plant, and optional monitoring and control using Schneider Electric's SCADA system, Conext Advisor 2. The system is claimed to lower capital expenditure due to its 1,500V DC configuration resulting in the need for fewer inverter stations, less equipment and less wiring. It was launched in October 2016.

overall there is value for string inverters as well," he says.

"I think central inverters are becoming less competitive with string inverters for many other reasons. 1,500V will help them keep up but for systems that are not very, very big, in my view, string inverters will win."

Modules and markets

In a period of module overcapacity, fretting about the availability of modules may seem like a strange thing to do, but one question that has been raised in connection to the transition to 1,500V is whether there will be sufficient modules on the market to meet demand. Cantor is sanguine on this, pointing out maintaining close links with modules suppliers should ensure developers and EPC firms are left short.

> "The only way solar energy can push through is if we continually shave inefficiencies and cost out of it"

A more specific cause for optimism is that whereas, as Cantor highlighted, in the shift from 600V to 1,000V the listing of 1,000V modules lagged behind the introduction of 1,000V inverters, UL already has a number of major manufacturers listed as holding certification for 1,500V modules including First Solar, LG, Jinko and Trina, suggesting the industry is better prepared this time around to make the leap up in voltage

Sungrow's Zhou expects 1,500V to have a 20% market share in the utility sector in 2017.

"In terms of specific markets, 1,500V projects will first thrive in North America in 2017 and then Asia will overtake the Americas in 1,500V shipments sometime between 2017 and 2018. EMEA will also follow this trend but at a much slower pace," adds Zhou.

SolarEdge's Handelsman envisages the shift hitting the US first. "One of the markets that will benefit from this is the US market because the electrical code requirements in the US create more cost into the system design. You need more fusing and more combiner boxes than in other markets. If you have more than two strings in parallel you need combiner boxes and fuses that you don't need in some markets. So the more strings you have the more cost you have. Longer strings have a greater impact on reducing cost in the US than anywhere else," says Handelsman.

An added factor skewing early development of 1,500V systems towards markets like the US is the cost of labour. Reducing BOS requirements naturally means a proportional reduction in labour. Markets with a high cost of labour such as Japan and the US will benefit even more from making the switch.

Switching to 1,500V is not a trend for the sake of the industry offering something new so people upgrade. It's not the latest iteration of a smartphone with a marginally better camera and ever so slightly different shape. Handelsman offers a reminder of the real drive behind the transition and need for all sections of the solar value chain to embrace it.

"The only way solar energy can push through is if we continually shave inefficiencies and cost out of it," he says. "1,000V architecture is creating more cost, more combiner boxes, more strings, more return cable. We need to streamline design, we need to streamline installation, we need to shave cost out." ■

Project briefing

MIDDLE EAST'S LARGEST PV PLANT LANDS IN JORDAN

Project name: Shams Ma'an
Location: Ma'an, Jordan
Capacity: 52.35MW

Huge solar parks with world-beating prices are under development in various parts of the Middle East, but no plant on a massive scale had been completed in the region until the last quarter of 2016. Settled in the desert conditions of southern Jordan, the Shams Ma'an solar PV plant was developed and constructed by US-based integrated PV firm First Solar. Standing at 52.35MW (AC), it is not only the largest solar plant in Jordan, but also the entire Middle East, and it will pave the way for future large-scale developments in this part of the world where irradiation is strong and land relatively plentiful compared to other regions.

A ground-breaking ceremony attended by the prime minister of Jordan, Hani Al-Mulki, took place in early October, 14 months after construction began. The plant is owned by a consortium of investors consisting of Diamond Generating Europe, Nebras Power Q.S.C. and the Kawar Group. After divesting its stake, First Solar was appointed the engineering, procurement and construction (EPC) contractor.

Local conditions

Both weather and soiling stations were put out to measure irradiance for as long as possible before getting deep into project development, says Raed Bkayrat, vice president of business development for Saudi Arabia and Middle East at First Solar. The land was not ideal for fixed installations so single-axis trackers were chosen to accommodate the shape of the land.

King Abdullah II bin Al Hussein set his sights on improving the infrastructure of southern Jordan with the creation of the Ma'an development area, an economic development zone that will feature new housing and amenities for locals, facilities for pilgrims on their way to the holy cities of Mecca and Medina, a major new industrial park and finally substantial new volumes of solar power. Land owned by Ma'an development Authority (MDA) has been shared out between around eight solar developers for phase-one projects.

All the projects are co-located and connected to the same substation around 20 kilometres away; this can handle around 180MW capacity, which is the equivalent of the combined capacity of all the planned solar projects. While the plant that First Solar constructed stands at 52.35MW, others are between 10-20MW in size.

This fact may have provided some valuable lessons to the off-taker, Jordan's main utility National Electric Power Company (NEPCO), which has a signed 20-year power purchase agreement (PPA) for this solar energy. "Doing tendering on project sizes for projects of less than 50MW becomes a headache to the off-taker and the utility," says Bkayrat, "You really lose on economies of scale once you go below the 50MW mark so I think now all the utilities in the region consider 100MW and up in terms of project size."

The point is that engaging just one or two developers would be much more streamlined and efficient, but it is unlikely of course that smaller solar firms would feel the same way. "That's a big lesson learned that the bigger the better," adds Bkayrat. "You have to maximise your value and your benefit from economies of scale otherwise it's very hard to achieve the very low tariffs that we see in Dubai and Abu Dhabi."

> "They see more and more solar coming online and the sky is not falling"

The southern part of Jordan is relatively poor so after obtaining the necessary permits with more or less no issues, First Solar assigned a CSR budget to focus on employment, training and job creation. The core team, the subcontract workers and labour, were all Jordanian. Meanwhile, construction workers were almost all locals from the Ma'an province or the Ma'an city. The social impact of the PV project is one of its outstanding features, says Bkayrat.

That said, First Solar had to manage expectations within the local community over the number of jobs the project would create. There can be a sense in new markets that the solar industry will create thousands of jobs. At the peak of the project's construction, there were 600 workers on site, but with operations and maintenance (O&M) there will be 20-30 long-term jobs.

Access to the site was relatively simple. First Solar's manufacturing is primarily located in Kulim, northern Malaysia. The modules were then taken by ship from Penang, the closest port in Malaysia, and transported on to the port of Aqaba. From this point at the top of the Gulf of Aqaba in the Red Sea, it took only two hours to get to the site using trucks.

Grid connection

To progress with the first plus-50MW solar plant in Jordan, First Solar had to prove its advantages. "We had to convince NEPCO about the friendliness of utility-scale PV plants to the grid," explains Bkayrat. "NEPCO was a bit conservative in their assumptions and in their grid interconnection requirements. They've imposed standards for interconnection that went above and beyond what's customary in the US or Germany and so on. We had to abide by that."

In terms of transmission, First Solar also had to provide three 33kV medium voltage feeders from its plant to the substation, built by NEPCO. "Meeting the expectations; creating an impact for the community – that had to be handled carefully," adds Bkayrat. "Other than that it was smooth sailing in the sense of the execution, the technology and so on. This is all proven."

Explaining how the company went about convincing NEPCO about the plant, Bkayrat says there were a lot of discussions. NEPCO went ahead with revising its grid connection code and a second version was released after it had signed the PPAs, however, these were very conservative in terms of the demands on

By Tom Kenning

compensation and voltage ride through.

"Everybody agrees that it's a bit of an overkill but that's where they stand right now", adds Bkayrat. "I think in the future they see more and more solar coming online and the sky is not falling. I think they will be more inclined to relax some of these requirements a little bit."

Components

First Solar used its 110W Series 4 modules for the entire plant. "Obviously the value of thin-film technology in the desert is well proven from a temperature co-efficient standpoint and from a yield standpoint," says Bkayrat.

The single-axis trackers have an east-west design and each mechanical table of the trackers holds 60 modules: four high, 15 wide. "Each table has an actuator like a piston that moves and rotates it bearing east and west. It's a customary First Solar propriety design for trackers."

The Ma'an region enjoys good Global Horizontal Irradiance (GHI) and Direct Normal Irradiance (DNI) at the same time, which means trackers are particularly suitable. The output of the plant shoots up from around 10% to its rated output of 52.35MW(ac) at 9am and then flattens out and stays flat as late as 4pm in the afternoon, before dropping again.

"It is quite significant and I haven't seen that before," says Bkayrat. "Literally you get a rectangular output. That is the value of the thin-film with the high DNI and the single-axis tracking."

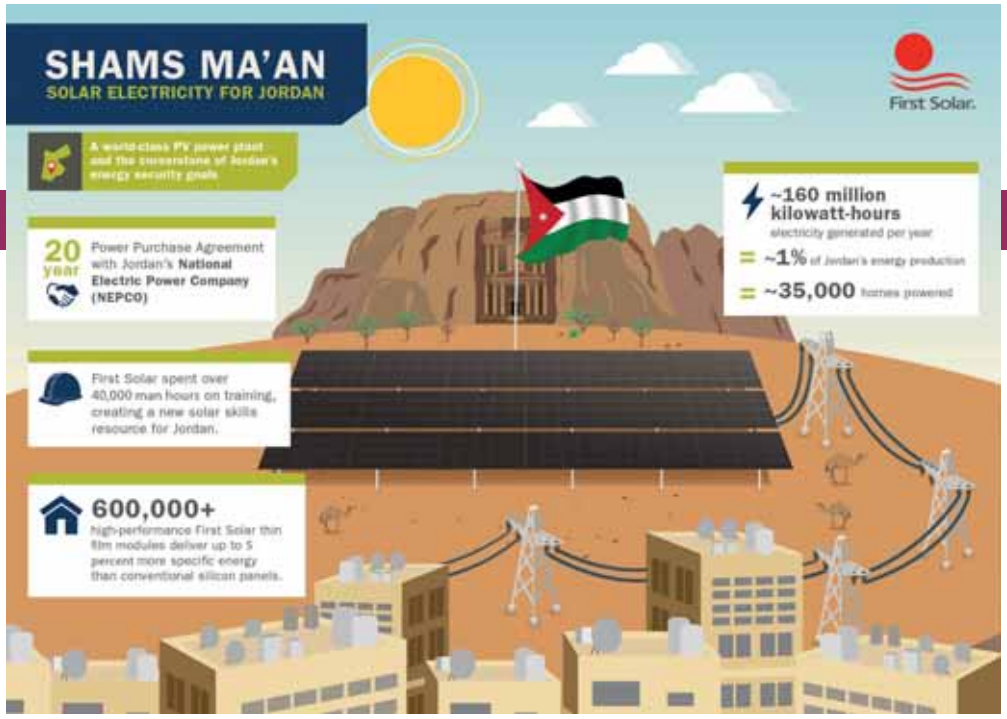
The plant also uses 800KVa island inverters, switchgears and satcoms from major PV inverter manufacturer ABB.

"We are very happy with the execution. The quality is what it needed to be. I think the performance of the plant is already turning heads as it is, and hopefully will continue to do so. We also have the O&M contract for the project so we are looking forward to publishing results at some point once we have enough data to summarise the performance and the output."

O&M

While not as dusty as a sand dune desert environment, the site still needs regular cleaning. The company opted to use manual dry cleaning techniques without water or robots. It is likely that a group of 10-12 workers will clean in six-hour shifts every night from around 6-7pm. They clean a portion of the plant and within two weeks they can clean the whole plant and start again from the beginning. A special tool for this is still being tweaked. This is a trolley-based brush, which does not have any rotating parts or electric motors. It has stationary brushes and is simply dragged over the surface of the modules, as has been used by First Solar for almost three and a half years on its 13MW Dubai solar plant known as DEWA 13.

Only for a site well above 50MW would



the firm consider using robotics for cleaning.

Finance

The project is jointly financed by Mizuho Bank, Japan Bank for International Cooperation (JBIC), Nippon Export and Investment Insurance (NEXI) and Standard Chartered Bank (SCB).

"At the time, Shams Ma'an was the largest solar PV project to be financed in the Middle East and the only one to be financed by commercial bank lenders," says David Short, a director at Mizuho Bank. "This is a good example of how project finance can be effective in the region and shows how renewables transactions in the region are viable; and it shows that the economics of it are actually competitive with other forms of power available".

Across the Middle East, the next project to compete in size could come online mid-2017, a single 200MW plant in the Mohammed bin Rashid Al Maktoum Solar Park in Dubai from developers TSK and Acwa Power, with modules supplied by First Solar. There will also be another 100MW plant in Jordan towards the end of 2017, developed by Spain's TSK and a partner in the UAE.

The government of Jordan recently announced the opening of its third round of competitive bidding for renewables tenders, with a further 200MW of solar on offer for the Ma'an area. The Public Security Directorate (PSD) also announced 60MW of 'autonomous' solar projects for its on-site facilities.

"We have already an extensive experience and local presence in Jordan so we don't mind being involved again, be it as a developer or an EPC or as an O&M provider," says Bkayrat. "I'm pretty sure we will be participating as well." ■

Lessons for the Middle East

Raed Bkayrat, vice president of business development for Saudi Arabia and Middle East at First Solar, explains two lessons from the Shams Ma'an project.

"One learning for the Middle East at large is that utility-scale solar PV power plants can have a positive impact on the grid. Rather than negatively impacting performance such as destabilising the grid, on the contrary, it actually contributes to the stability of the grid. Once the utilities start commissioning and turning on these power plants and they engage them and connect them to their network operation centre, I think that value will be demonstrated.

"A second lesson is that utilities across the Middle East are new to solar and they keep comparing solar with dispatchable power plants. I think now they are beginning to appreciate the value of adding forecasting capability to help integrate solar PV. Even in Jordan, NEPCO is asking for forecasting functionalities out of the developers an hour ahead. They demand a certain level of accuracy, but so far it hasn't been contractual. In time they will realise that this information can help them plan their generation. I was hoping this lesson would be adopted or accepted faster, but I think they are still learning as they go and not using the optimal approach. PV can actually participate in the load generation planning."

Data mining for automatic fault detection and diagnosis from photovoltaic monitoring data

Asset management | The timely and skilful interpretation of performance data from the monitoring of operational PV power plants is vital to improving the management and thus profitability of those plants over their lifetime. Achim Woyte shows how data mining and artificial intelligence can serve the management of solar assets

Professional photovoltaic plants today are virtually always monitored. Asset managers collect operational data from heterogeneous portfolios of plants. The data originates from on-site sensors and inverters. They are recorded by local dataloggers and sent to a central monitoring platform. Such platforms include a database, dashboards for supervision, operations and maintenance (O&M) and reporting purposes, analytical tools and data export functions.

3E operates the hardware-independent performance monitoring and reporting platform SynaptiQ. From the monitoring data of our customers we see that, on average, their PV plants perform as well as expected. SynaptiQ lets them continuously improve the plant availability and performance while streamlining their business processes. At the same time, performance ratios (PRs) are widely spread, even for plants from the same portfolio. Although monitored, many plants perform far below expectation (Figure 1). Obviously, these plants are not managed as well as they could be.

Monitoring is more than collecting data and aggregating them into contractual and financial key performance indicators (KPIs). Probably, the bottom tier plants in Figure 1 are followed by an operator and their KPIs are reported regularly. To the asset manager, their overall performance must look weak but not yet alarming.

Performance monitoring allows O&M contractors to increase their business efficiency through fast fault detection and focus on actual faults and solutions. It serves asset managers to see what's going on at the plant and device level and how fast their O&M partners intervene. In case of component failure or module degradation, they can identify and prove causes for warranty claims.

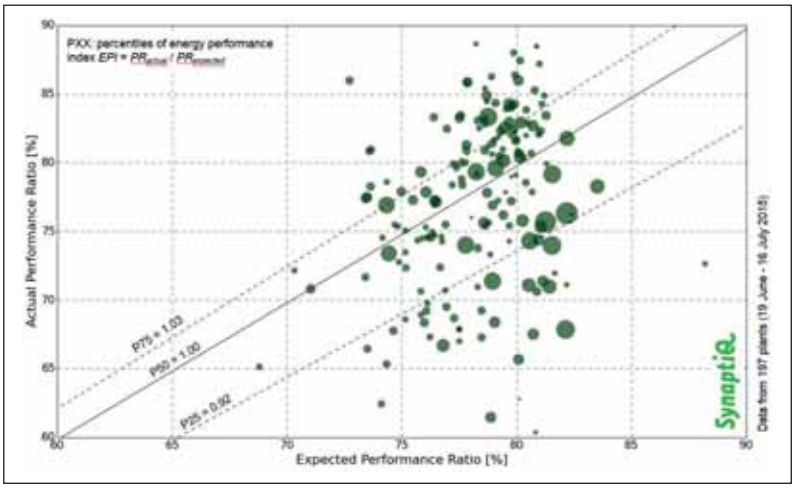


Figure 1: Actual performance ratio (PR) from monitoring versus expected PR based on plant specification and real weather data for 197 PV plants in Europe; the worst 25% perform more than 8% below expectation; the dot size represents the size of the PV plant

Back in 2012, 3E launched an extensive programme to introduce automatic fault detection and diagnosis into its monitoring tools. Today 3E offers the PV Health Guard as a monthly or quarterly fault report to their SynaptiQ customers as well as a one-time Historical PV Health Scan, e.g., before the end of the warranty period or for plants changing ownership.

Approach

Asset managers can easily implement automatic fault detection and diagnosis functions themselves as a step of data post-processing. The data is exported from the monitoring database and can then be mined with spreadsheets, scripting tools or dedicated data mining packages. However, particularly for large portfolios, plants with many inverters or with string monitoring, this task becomes quite challenging due to the complexity of the underlying data structures as well as the sheer size of the data sets.

3E uses the Python programming language. The application programming interface (API) of SynaptiQ allows the user to directly query SynaptiQ's monitoring and plant configuration databases with Python. The API can be made available to customers.

Automatic fault detection and diagnosis are common activities in the condition monitoring of industrial processes and machines. The energy conversion process we want to monitor is illustrated in Figure 2. The different measurements as indicated may be interpreted as external process variables. The PV Health Scan for

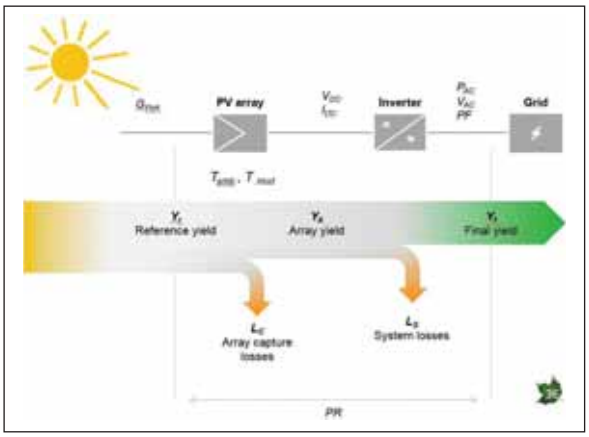


Figure 2: Energy flow in a grid-connected PV system; with measurements of plane-of-array irradiance (GPoA), DC voltage and current (VDC, IDC), AC power, voltage and power factor (PAC, VAC, PF), ambient and module temperature (Tamb, Tmod); yields (Y), losses (L) and performance ratio (PR)

this process consists of the steps analysis, fault detection and diagnosis. Analysis allows the plant operation to be reviewed in detail but it does not include any evaluation or decision step. Fault detection tells us whether anything is wrong, what is wrong and where it is wrong. And diagnosis tells us why it is wrong and how we can solve it.

Analysis

We start the analysis step with a data integrity check, removing outliers and identifying periods of missing data. Local irradiance sensors are validated by comparing their measurements to satellite-based irradiance. We then compute the high-level KPIs, performance ratio and energy-based availability for the PV plant and its individual arrays/inverters. In a second step, we compute the losses over the energy conversion chain for the plant and its arrays/inverters. We show how these loss components behave over time and whether they differ for the different arrays/inverters. If the plant contains string monitoring, the different loss components are also computed for each string.

Moreover, we review the correlation of measurements for the individual samples recorded. Finally, if the dataset contains several years of data, we also review the structural degradation over time.

In short, the analysis step largely relies on the detailed allocation of losses over the energy conversion chain, over the different instances of each component type (e.g., strings, arrays, inverters) and over time. It creates value for the user through the quantitative details and their visual presentation.

For the analysis, we build further on the conventions, guidelines and recommended practices from IEC 61724 [1], the European Joint Research Centre in Ispra [2], the International Energy Agency's Photovoltaic Power System Programme (IEA-PVPS) [3] and SolarPower Europe's O&M Best Practice Guidelines [4].

Fault detection

Our approach to fault detection is model-based: we compare the process variables as measured in the field to their expected reference values based on a model of the process. A simple and frequently used method to do this is limit checking of the measured variable. The measured value is compared to the reference value. If a certain range around the reference value is exceeded, this indicates a fault.

For PV monitoring, evaluating the process variables directly as they have been measured over time is not very effective due to the often high noise. Instead, it is more promising to work with derived indicators that correspond to different parts of the process. These so-called features should be representative for the underlying process and uncorrelated with each other. When a feature is evaluated positive, i.e., a threshold is exceeded, we call this a symptom.

For the PV Health Scan we have developed several feature sets for different parts of the work flow. Features for the 'Data Integrity Check' are the daytime recording fraction, i.e., the fraction of the monitoring period during daytime for which measurements have been recorded, and the fraction of outliers over the total number of measurements. For the 'Solar Sensor Check', we use features to check the clock setting, the sensor orientation and its calibration (see example in Table 1). For the 'Performance and Loss Analysis' on plant and component level, we have defined features in line with the different loss components. For the 'Degradation Analysis' we use annual degradation rates.

The threshold values for the different features can initially be set based on expert knowledge. A better way is to compute the feature sets for a sufficiently large sample of healthy plants and then chose, e.g., the P5 and P95 percentiles for each feature as thresholds. Finally, by applying fuzzy logics for decision making or machine learning based on classification, it is possible to evaluate the features more gradually in line with their severity. This should contribute to improving the overall selectivity of the fault detection algorithm.

Diagnosis

While automatic analysis and fault detection are relatively straightforward, the diagnosis step is the most challenging. We look for a conclusion on the underlying root cause through a comprehensive analysis of the different symptoms. In practice, we see that the symptoms from different parts of the workflow, e.g., Data Integrity Check, Solar Sensor Check, Performance and Loss Analysis and Degradation Analysis, complement each other. A human domain expert can synthesise these symptoms and draw a conclusion based on human experience. The challenge is to make the machine evaluate and synthesise from the symptoms and return a few probable suggestions on the root cause.

Notably, the obvious analogy to the medical world is not solely semantic but also practical. A blood test returns a feature set consisting of concentrations of lipids, glucose, hormones, etc. If the reference range for any of these features is exceeded, this is flagged as being 'abnormal'. Medical imaging devices come with post-processing tools that check features like minimum thickness of a layer of tissue or optical density and raise a flag as well if the reference range is exceeded. Both tools perform a fault detection; however, the diagnosis is left to the physician.

We can apply different approaches to move from fault detection to diagnosis. 'Inference-based methods' are suited if the link between root causes and symptoms can be expressed through a known set of logical rules, referred to as knowledge base. By means of the knowledge base, a so-called inference engine can then compute the most probable root causes. In artificial intelligence, this kind of systems is commonly called 'expert systems'. Setting them up requires a realistic translation of domain expertise into the knowledge base, which easily becomes quite tedious.

'Classification methods' are suited if a sufficiently large empirical dataset is available for training. They are a family of machine learning methods. For the case of PV fault diagnosis, this would ideally be a set of monitoring data from many plants over several years along with detailed maintenance logs. Classification

methods can be applied without explicit knowledge of the underlying causalities. However, the preparation of a meaningful training set can be quite tedious as well. For a practical overview of the advantages and drawbacks of different machine learning algorithms, we recommend the documentation of the Python machine learning package scikit-learn [5].

Currently, 3E is exploring inference-based as well as classification methods. Inference-based methods work well for simple causalities. For example, in Use Case 1 below, the slope of the sensor calibration is significantly too low. In this situation, the sensor should be cleaned or calibrated. Other common faults like near shading or a wrong orientation can be excluded since they would cause a different set of symptoms. This reasoning can easily be formulated in logical rules. For the example of Use Case 2, deciding whether a reduction in array current is due to a disconnected string, module degradation or inefficient maximum power point tracking is less straightforward. The symptoms for these faults are quite distinctive and a PV expert should be able to read them. Nevertheless, it looks much more promising to implement this intelligence through machine learning than through an explicit knowledge base.

Both approaches are potentially very useful for fault diagnosis in PV. At the same time, their limitations become clear from the medical analogy. Artificial intelligence and data mining can point towards possible root causes; however, asset managers and O&M contractor will still rely on their domain experience and personal judgement for a long time. Automatic fault detection and diagnosis can simplify this work and help them to manage large and heterogeneous portfolios much more efficiently.

Use case 1: radiation sensor calibration

Case description

A 860kW rooftop installation in Belgium returned an annual PR of 82% which appears to be a normal performance. A Solar Sensor Check was run for the on-site irradiance sensor over the annual data set from June 2015 to May 2016.

Fault detection and diagnosis

The Solar Sensor Check evaluates the fault illustrators (features) as listed in Table 1. Where the fault illustrators are situated in the normal range, the observation is labelled 'OK'. Where this is not the case, a symptom is triggered. Finally, a human expert verifies the textual description.

	Fault illustrator [unit]	Fault illustrator value	Observation
Data recording: plausibility of maximum irradiance	maximum Irradiance [W/m^2]	1037	OK
Data recording: plausibility of minimum irradiance	minimum Irradiance [W/m^2]	0	OK
Data recording: completeness	daytime recording fraction [%]	99.98	OK
Total irradiation	Mean bias error [%]	-9.4	Measured irradiation too low
Clock setting	approximated time shift [min]	-15	Deviation in clock setting
Sensor orientation	estimated azimuth & tilt [degree]	4°, 13° -> 6°, 13°	OK
Sensor calibration: linearity	non-linear term	1.037	OK
Sensor calibration: offset	sensor offset [W/m^2]	-3.88	OK
Sensor calibration: slope	sensor gain	0.922	Slope of calibration is too low

Table 1. Example of fault illustrators (features) and diagnosis for a solar radiation sensor installed in Belgium, data from 1 June 2015 to 31 May 2016

Of the three symptoms indicated in Table 1, the low value of 'Sensor calibration: slope' is the decisive one for the diagnosis. The sensor systematically shows 92.2% of the satellite-based irradiance only. Accordingly, the linear regression line in Figure 3 approximates the real calibration of the sensor. Consequently, the measured irradiation over the period is 9.4% too low. This deviation may be due to severe soiling or bad calibration.

Moreover, a deviation in clock setting is observed. However, the clock setting error of -15 minutes is in the order of magnitude of the sampling period and does not disturb the measurement as such.

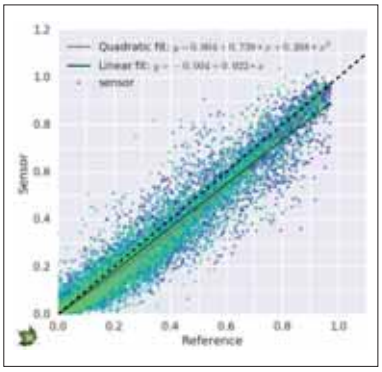


Figure 3. Sensor irradiance versus satellite-based reference irradiance with linear and quadratic regression; the slope is 8% too low; 860 kW site in Belgium, data from 1 June 2015 (blue) to 31 May 2016 (green), orientation 30° south

Economic impact

In line with the mean bias error as listed in Table 1, the sensor in this use case recorded 9.4% too little irradiation over the year. Accordingly, the performance ratio as computed with this reference yield is 10.6% too high. While the real PR for this year was a low 74%, the O&M contractor could report 82%. For the 860kW plant built in 2011, this over-optimistic performance evaluation hides a loss of €40 000 per year. With recurrent monthly sensor checks, this faulty calibration would have been detected after one month.

Use case 2: disconnected strings

Case description

After five years of operation, a 250kW rooftop plant in France was checked on behalf of a third-party investor. The plant contains three central inverters and no string monitoring. Amongst other things, a PV Health Scan revealed that, for one inverter, several strings had been disconnected for more than a year.

Fault detection and diagnosis

Figure 4 shows the high-level KPIs and losses per array/inverter. The overall PR of this plant for the study period of one year is low at 69%. The current-based losses are too high for all arrays/inverters, and especially for Inverter 1 with current-based losses of 17.8%. Accordingly, threshold checking of the overall losses triggered a fault for this array; however,

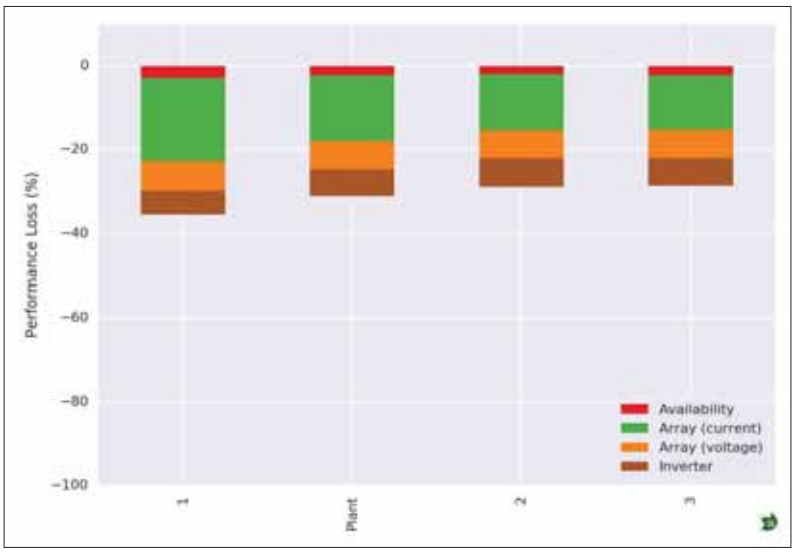


Figure 4. Performance losses split into loss types and stacked for each array/inverter and the entire plant, sorted in ascending order; particularly the current-based losses (green) are generally too high and worst of all for array/inverter 1; the losses are normalised to the reference yield. Data from 1 July 2015 to 30 June 2016

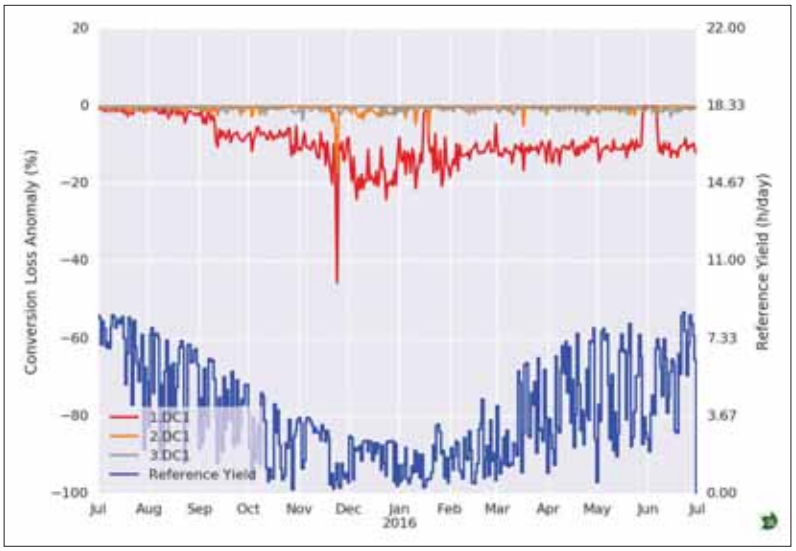


Figure 5. Conversion loss anomaly for current-based array losses per day, comparing the conversion losses of all arrays/inverters to the best in class of each day. The blue line shows the reference yield and hence the available irradiation for each day. Starting on 11 September 2015, the losses for inverter 1 (red) are much higher than for the others

it is insufficient to conclude on a root cause.

Figure 5 reveals that the conversion loss anomaly for current-based losses is almost constant over time. We can identify two distinctive events: on 11 September 2015, the current losses for array/inverter 1 dropped by -5.5% below the others. On 27 October 2015, the losses dropped further to -11%. This situation persisted until the end of the study period.

Array/inverter 1 counts 18 strings of modules. Accordingly, a disconnection of one or two strings would lead to a systematic power loss of 5.5 and 11%, respectively. These distinct conversion loss anomaly values, together with their relatively sudden changes, point towards one or two disconnected strings at this array/inverter.

Economic impact

Obviously, in the given case the O&M contractor did not see these string faults. Their effect on the overall performance is quite small, namely 11% on an array/inverter level and 3.7% on a plant level. Moreover, the O&M contractor did not act on the overall low performance of the plants.

For the owner, only the string faults caused a loss of approximately €6,000 per year. With recurrent monthly Health Scans, the string faults would have been detected and repaired after one month.

Outlook

Data mining and machine learning can boost the revenues from PV plant operation by up to 10% simply by making O&M more agile. Already today, readily available solutions for automatic analysis and fault detection can be plugged into the PV performance monitoring platforms.

The step from fault detection to automatic diagnosis is still challenging. The machine can suggest probable root causes for common faults and formulate recommendations. However, for the final interpretation and formulation of remediation actions, we still rely on human experts for now. ■

Acknowledgement

3E's work on automatic fault detection and diagnosis has received funding from the European Union under the Horizon 2020 programme, contract 662189 – MANTIS – ECSEL-2014-1 as well as from the Brussels Capital Region – Innoviris under the MANTIS project.

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Mobile revolution

Testing | The past two years have seen a boom in the deployment of mobile PV testing laboratories. Sara ver Bruggen reports on how technological advances are helping investors and developers in new and emerging solar markets get the best from their assets

Credit Kirchner Solar Group

Mobile module testing equipment is seeing booming demand in PV markets worldwide

The notion of being able to test PV modules in the field can be traced back to the last decade, when the PV market really began to take off and a flood of cheap modules from China first sparked concerns over quality. But it is really in the past 18 months that the concept has taken off.

Several companies – mainly European – now offer mobile PV testing services. And it looks like an area that is set to grow still further, fuelled by a combination of ongoing pressure to ensure quality and the increasingly stringent demands of plant owners and operators to maximise the value of PV assets in the field. Add to that the burgeoning demand for solar in emerging markets worldwide, where developers are keen to avoid the mistakes made in pioneer markets, and it looks as though this is an idea whose time has come.

"Quality assurance monitoring of PV panels, from production to installation, will always be a key factor determining a PV plant's overall performance," says Erik Lohse, managing director of mobile testing specialist MBJ Services. "Testing of panels in a stationary lab has been the traditional method. Mobile testing, thanks to improvements in technology, is becoming more popular. It provides banks and insurers with assurances that PV modules, which comprise 30-40% of a plant's total cost, installed at site, are without flaw.

"With the increase of the installed base, keeping all the gigawatts of PV operational at the optimal performance is and will be a major challenge for O&M and this is where mobile testing will be deployed more widely in the coming years."

It's the tech

One key factor that has helped the mobile testing concept take off and will likely underpin its further expansion is the improvement in mobile testing technology. Advances in the sophistication of equipment used for testing in a mobile environment means the quality and standard of testing is on par with diagnostics undertaken by independent testing and quality monitoring firms and agencies, such as Fraunhofer ISE and TÜV Rheinland.

When Hamburg-based MBJ Services launched its second-generation mobile PV testing lab, an initial customer was independent quality assurance services provider Intertek. In 2015 Intertek, in partnership with the Center for the Evaluation of Clean Energy Technology (CECET), launched a mobile platform for testing modules in situ. The Mobile PV Testcenter complements Intertek's wider range of quality assurance services for solar products and installations usually carried out at fixed laboratories on the US east and west coasts. The lab is used to identify underperforming modules.

MBJ Solutions, a leading producer of electroluminescent (EL) inspection equipment for PV module factory lines, set up MBJ Services as a subsidiary five years ago. The first generation of mobile testing labs commercialised by MBJ Services was based on a simple light emitting diode (LED) flasher, for sunlight simulation, as well as EL technology.

"We saw that a certified lab-level flasher was needed for greater accuracy and to provide testing in the field equivalent to PV testing in stationary labs," says Lohse.

Xenon flash lamp technology, widely used at the time in stationary PV labs and production lines, was deemed insufficiently robust for use in the field. MBJ Services started developing an LED flasher, the basis of its second-generation lab, which the company is now commercialising.

"As the spectrum range of LED lamps has improved LED flash lamps are today at least as accurate as xenon," says Lohse. "More widely across the industry LED flash lamps are replacing xenon flash lamps and sun simulators because the technology is as accurate, but is more robust and compact."

Credit MBJ Services

MBJ Services' mobile electroluminescence testing in operation

Driving up quality

The biggest impact that mobile module testing has had to date is in driving up module manufacturing standards.

"In the past, before mobile testing was possible, many manufacturers did not care about quality because nobody knew what was going on," says Thomas Hemmenstädt, head of service at Kirchner Solar Group, which operates a subsidiary business for testing PV modules in situ, called PV Mobilab.

Lohse adds: "Mobile testing gives our customers the means to be able to scrutinise what module suppliers claim they are producing. The growth in mobile PV testing has forced module manufacturers to improve quality."

In 2012 Kirchner Solar Group launched its PV Mobilab. The lab offers IV curve measurement at class A+A+A, real standard test conditions (STC), electroluminescence testing, thermography inspection of the entire system, identification of hot spots and inactive modules, and on-site random sampling and documentation of issues and faults found. The range of testing that can be administered means mobile PV testing can be used during several stages of the PV panel's lifecycle.

"It is critical to carry out in situ testing but as part of a wider quality control programme, which starts at the module factory, and even during module supply contract negotiations," says Álvaro Velasco, global business development executive at renewable energy consultancy, Enertis, in Spain.

Mobile PV testing can be deployed in various downstream stages to ensure quality, identify faults or damage and protect investments in PV plant assets, from pre-shipment inspection of PV panels after leaving the factory, to post-shipment inspection of modules at the harbour, before customs, to when the panels are unloaded from the delivery truck at the project site. Post installation, it can be used to verify the final status of the PV panels as part of plant-level inspections, as well as during the plant's operational lifetime to identify or estimate degradation.

"This provides the entire picture of what may have happened to panels, and can help settle warranty disputes and apportion responsibility correctly," says Velasco.

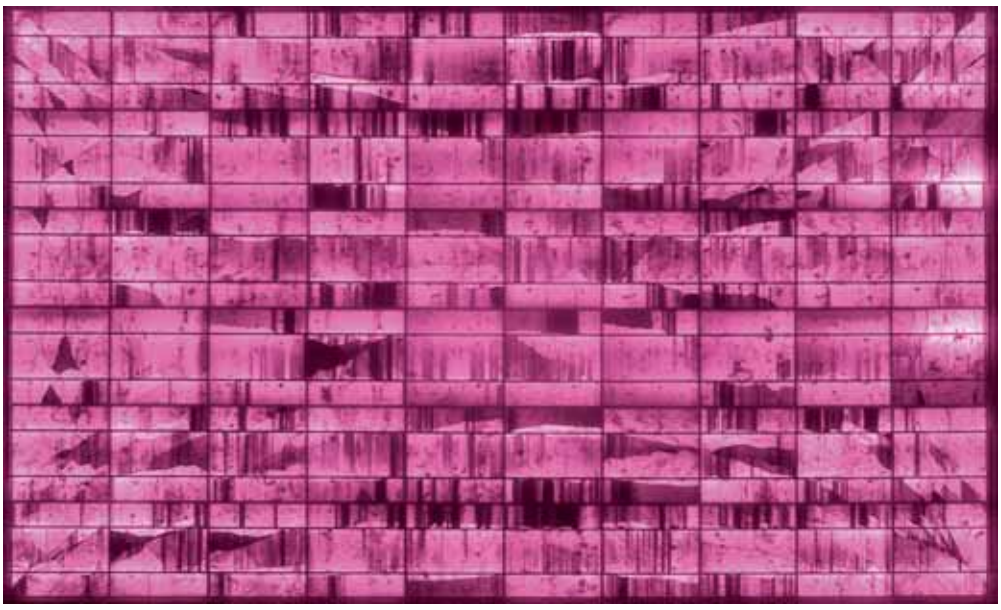
Enertis provides a full range of PV testing. "We provide services covering the full cycle of the project, based on our own laboratory capabilities, as opposed to being just a supplier of mobile PV testing laboratories," says Velasco.

Markets

The company's third and latest mobile PV testing laboratory is expected to be deployed by December in the northern part of Chile, where much of the country's installed solar capacity is based. Enertis opened a local operation in Chile two years ago. All three generations of the mobile PV testing labs include A+A+A LED solar simulators.

Enertis launched its first mobile PV testing lab in Europe in late 2012 and it remains one of the first mobile labs still used in the industry. Over the past four years it has been transported around Europe's main PV markets, including Spain, France, Italy, Germany, the Netherlands and the UK.

The growth in demand for utility-scale PV means the lab has been widely deployed in the UK over the past two years. Due to the significant role investment funds play in the UK PV market, there is demand for Enertis' quality control services and those provided by the mobile lab in the operational phases, as



Credit PI Berlin

EL imaging from mobile testing highlights inactive cell areas in modules in the field

well as in the installation phases of plants.

Valesco says: "The secondary PV market in the UK is evolved, where there is a high level of activity transferring assets from one owner to a new owner. On the one hand, the existing owner of the plant wants to be able to check how the asset is operating with the view to selling these on, but the buyers of assets also want our services to be able to do due diligence on PV plants they are seeking to purchase."

Enertis deployed its second mobile lab in the US two years ago in New Jersey and in San Francisco.

"In the US, we have to focus on where the lab can be deployed. Though there is demand at all stages, including the construction of PV plants, where we are seeing growing demand is for the operational stages of PV farms. Typically, we might deploy it when a plant's output or yield is impacted and we can test modules in the field and identify degradation causes, such as potential-induced degradation (PID), hotspots and so on. The US is a highly competitive and mature market, so plant operators and owners want to be able to quickly identify any problems that impact a plant's output and, therefore, its earnings," says Velasco.

Enertis' mobile lab can test up to several dozen panels in a day, though actual quantities tested per customer depend on the size of the PV farm itself. In some cases the company has tested 50 modules in a PV farm, but in others the requirement has been up to a thousand.

"It does not make economic sense to test every panel, so we use a sampling approach, which is standard practice of PV module testing in the industry," Velasco says.

According to Lohse, certification bodies such as TÜV Rheinland and Fraunhofer ISE will use mobile testing as part of PV plant testing and certification services, particularly in emerging markets where it does not make economic sense to have panels shipped over to Germany for testing.

MBJ Services has several partners in local markets around the world, including five in Japan and one in the US. The company is qualifying its first local partner in South Africa, which is also looking to provide mobile PV testing services throughout the African continent.

"This approach makes sense as the mobile testing lab can cost in the region of €200,000, whereas investing in the setting up of a stationary testing lab costs at least €1 million," says Lohse.

The local partner must not only have access to the local PV market but must also employ lab engineers. While the operation of the mobile lab can be done by technicians with training, the interpretation of the results has to be done by properly qualified solar PV engineers.

"The South African partner was already operating a mobile service for calibrating sensors for PV modules installed in the field, so expanding its service to include inspection of PV panels was a logical step," Lohse says.

Other partners include Adler Solar, a Bremen-based provider of independent technical services for the entire lifetime of a PV plant, including operation and maintenance services on behalf of operators, and which also has a subsidiary in Japan.

To date MJB Services has sold 20 mobile labs. Six of these are the company's second-generation version, which is the version Intertek is using. It uses a certified A+A+A LED flasher. The first-generation labs, which use simple LED flashers only, are still being used, though they cannot carry out certified PV lab-level inspections.

Emerging solar markets

This year MBJ Services has refined the lab further by building a containerised version, which is smaller and more compact, and is also air conditioned. Lohse says: "It is more suitable for shipment by truck and plane, which makes it ideal for emerging markets, such as Africa and Latin America."

In line with growth in utility-scale solar PV, MBJ Services expects more demand for its labs to come from emerging markets.

"This is not because local investors and developers are requesting this

How mobile PV testing is being deployed in the field

Back when production of PV modules boomed and panels started shipping to Europe, failures were thought to be due to damage during shipping and transportation.

In one case, a PV module producer supplying panels to Europe had issues with 50-80MW-worth of panels shipped. Initially problems were found when MBJ Services' mobile testing equipment was used by a customer – an investor – and revealed a high rate of cracked panels after the journey from China to Europe. The issue was traced to the panels being too sensitive to mechanical loads.

In the end, however, the PV module producer also employed MBJ Services' equipment to test panels at various ports in Europe and the producer was able to track back through the production process to the root cause of the problems and the producer was able to adjust and modify its production processes accordingly.

"Investor-owners are most interested in using mobile testing, as opposed to developers, as investors want to ensure that any risks are minimised by good quality control. Sometimes investors procure panels directly for a project," says Erik Lohse, managing director of MBJ Services.

However, some developers will also use mobile PV testing for quality control, especially if they plan to sell the asset once operational. "Here, developers want to minimise the risk in knowing the status of the panels they will use," he says.

Suncycle is now offering its mobile testing services through an O&M partnership with Cobalt Energy in the UK

Credit: Suncycle

Three years ago Kirchner Solar Group's PV Mobilab tested modules at a solar farm comprising 36,000 modules, following a thunder and hail storm. About 120 modules were damaged by hail. Broken glass was visible, however the tests picked up broken cells that the naked eye could not detect.

"It depends on the transport costs and what price the customer is willing to pay. But we can test around 500 modules per day," says Thomas Hemmenstädt, head of service at Kirchner Solar Group.

Meanwhile, Cobalt Energy has joined forces with German solar firm Suncycle, which offers a mobile test lab, to launch a joint venture bolstering its operations and maintenance service to UK customers. The addition of the German company's operations to the UK arm, known as Suncycle Ltd, means clients will now be offered advanced O&M techniques such as mobile electroluminescence, flash testing and aerial thermography analysis as well as standard maintenance services.

John Davies, managing director of Suncycle Ltd, says: "By combining Suncycle's extensive experience across Europe in testing and servicing with Cobalt Energy's well established solar operation and maintenance service, we will be able to offer unique professional and technical expertise and services."

Following the reduction in government support in the form of cuts to feed-in tariffs and ROCs, Suncycle believes the UK market is transitioning towards an O&M market following a highly active period of construction. This is further supported by the fact that many solar PV installations are soon to come to the end of their warranty periods.

type of testing, but because where European and North American investors and developer partners are involved, they are educating partners in new markets because they want to see the earlier mistakes in Europe – when the absence of mobile testing made it hard to pick up faults from PV installed in the field – avoided," Lohse says.

Today, he says most demand for mobile PV testing is for the pre-operational stage of the project. Stationary PV labs will always be required but it is likely that in future their services will be deployed for certifying new types of panels. The individual testing of panels which are checked by testing and certification agencies on behalf of investors and PV plant owners will be done in the field, as will any testing as part of O&M activities. "It makes no sense to ship hundreds of panels from one country such as South Africa to a lab in Germany due to the risk of damage and the logistical cost," says Lohse.

Future demand

But as global PV markets continue to mature, the O&M side of the industry is evolving in order to be able to adequately service the growing quantity of operational PV assets. That's where providers of mobile PV testing labs and associated services see growth opportunities.

Enertis, which provides a whole suite of PV quality control services, wants to work with third-party O&M service providers, as well as engineering, procurement and construction firms, owners and asset managers on a collaborative basis, as opposed to selling its PV mobile testing labs to customers such as independent testing and service providers.

"Operators are in a tough position as they have to take responsibility for an asset they didn't build or specify components for. We can offer comfort, because our testing service can identify the root of the problem, such as whether it was due to faulty or poor quality modules in the first place."

Whether through partnering with firms like Enertis, or leasing or purchasing mobile PV testing labs, O&M service providers are able to offer their clients, the owner-investors, peace of mind that the PV asset will operate profitably over its lifetime. The ability to provide lab-level testing could be a valid differentiator for independent service providers as the O&M market grows. ■

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Large-scale storage gains toehold in the UK

Grid services | The potential for storage to help stabilise the grid has finally been recognised in the UK, where battery projects took all of the 200MW on offer in a recent frequency response tender. David Pickup looks at the evolving role of storage in the future grid and how further policy support can help it flourish

Energy storage is big news and, thanks in part to some high-profile companies such as Tesla, has got people in many different industries very excited. And rightly so; as the costs have fallen, for lithium-ion in particular, large-scale storage systems are becoming viable across the world and have the ability to revolutionise power networks.

A number of global trends explain the long-term strategic importance of storage. First, renewables (solar and wind in particular) are reaching cost parity with conventional centralised generation, and this trend is set to continue. Secondly, the move towards a low-carbon energy system, accelerated by the Paris climate change agreement that came into force on 4 November, is now a priority for governments across the world. While the timescale for achieving these aims is up for debate, the direction of travel is clear.

The combination of these political and technological drivers means decentralised renewables are set to dominate the world's energy supply; renewables' global capacity has already overtaken coal and new installations in 2015 outstripped all fossil fuel sources. Supporting variable renewables through greater system flexibility is increasingly important for the development of an efficient, low-carbon and secure energy system.

The Solar Trade Association (STA) is the UK's representative body for the solar industry, representing both solar PV and thermal. The STA has been looking at storage for over a year, culminating in the report 'Solar + Storage = Opportunity' published in September this year.

The mutual benefits between solar and storage are obvious. For end users it allows solar to be available around the clock; in 2015 41% of new solar PV systems in Germany were tied to storage, showing remarkably quick adoption. However energy storage systems are not commercially economical for all customers yet, and more work needs to be done to support continuing cost reduction. The STA's immediate focus will be on laying the foundations for a strong, sustainable, solar + storage market. Globally the solar + storage market alone is predicted to be worth US$8 billion by 2026, with the storage sector as a whole worth even more, according to Lux Research.

Credit Renewable Energy Systems

The potential for large-scale battery storage to support grid stability is to be given its first significant test in the UK

The UK's position as an island, with relatively old grid infrastructure, increases the potential value that flexible and smart grid infrastructure such as storage can deliver. Last December the UK's former Department for Energy & Climate Change (DECC) published a policy paper covering the challenges that the energy system faces over the coming years and focussing on how to deliver affordable, clean and secure energy through a smarter system. DECC said that the benefits of a smart grid include: less investment, reduced balancing costs and a reduced need for curtailing generation. Each unit of energy generated can be used more effectively, leading to a cheaper, greener, more resilient energy system.

Ofgem, the UK's energy regulator, is working with the new Department of Business, Energy & Industrial Strategy (BEIS) in this area, specifically leading on enabling new business models and in facilitating the transition to new roles for distribution network operators and industrial or commercial users. However Ofgem's position paper admits there needs to be clarification of the legal and commercial status of storage.

In October 2015 the Treasury set up the National Infrastructure Commission (NIC) to advise on long-term strategic infrastructure. The NIC's first report in March 2016, 'Smart Power', found that £8 billion (US$9.95 billion) could be saved annually by 2030 through increased flexibility from a combination of additional interconnectors, energy storage and demand-side flexibility. The report specifically said the UK should become a world leader in storage through reforming the regulatory and legal status of storage, and removing barriers. BEIS is expected to consult on smart networks this autumn, although that consultation had not been announced at time of writing.

There have been many positive signs for the storage industry in the UK; in October Baroness Neville-Rolfe, the minister responsible, said "making energy storage more commonplace means stability" and "we are actively supporting the UK storage industry through our innovation programme". However there has also been some uncertainty, such as the merger between DECC and the Department for Business, Innovation and Skills into BEIS, as well as the vote to leave the European Union. These may have an impact on the timelines, but neither changes the fundamental reasons why energy storage is so important.

While storage can offer a host of services for the grid, it is with intermittent renewables such as solar where it can make the biggest difference. In a world with high battery penetration into the grid the intermittency of renewables moves from a cost on the grid into savings, as the extra flexibility helps smooth peaks and troughs of production.

The STA recently commissioned a report into the costs associated with intermittency from independent researchers Aurora Energy Research. The report found that current intermittency costs equate to around £1.30/MWh, and rise to £6.80/MWh with the central forecast of 40GW of solar by 2030. However in that same future scenario but with high battery penetration the costs drop to £-3.70/MWh, delivering actual savings. This means that within this system solar production is actually more beneficial than a baseload equivalent output profile.

Domestically there are already a number of companies launching products; there is a lot of excitement around new products from high profile brands such as Tesla, Nissan and E.On, for example. The drivers are obvious: solar energy is largely produced during the day while people are at work and demand remains after the sun has gone down; storage allows you to use solar power at night.

The system can be that simple, however there is no reason why the business model for solar + storage need be the same as solar-only models. Peer-to-peer trading at a local level could provide value for a domestic customer. An aggregator-owned approach would allow an aggregator to provide balancing services to the grid through a large number of small domestic batteries. Another model could be a large-scale battery installed as a "bank," allowing people to deposit excess generation and other consumers to withdraw on the same basis.

At a large scale, solar farms and energy storage seem intuitively a perfect match. Grid connections are typically underutilised due to the variable nature of solar generation and lack of sun at night. Space is typically available and planning permission either already granted or relatively simple to obtain. They can also offer further services than just energy generation, including frequency response.

Storage and frequency response

In the summer the UK government announced the outcome of its Enhanced Frequency Response (EFR) tender, with eight contracts between £7-12/MW/hr (see box, above). EFR can react to frequency changes in under one second, helping maintain the grid at the requisite 50Hz. Battery sites featured heavily in the bidding process and all eight of

Low Carbon's move into energy storage

Renewable energy investor Low Carbon was the biggest winner in the National Grid's recent EFR tender. Investment director, Ian Larivé, discusses the company's contract wins and expansion into energy storage

Low Carbon is a UK-based renewable energy investor committed to mitigating the negative effects of climate change. We invest in renewable energy projects leveraging proven technologies including solar PV, onshore wind, combined heat and power, anaerobic digestion and concentrated solar power. The latest addition to Low Carbon's portfolio of renewable energy investments is large-scale battery storage.

National Grid's EFR tender

Low Carbon has long been evaluating the potential of large-scale energy storage. Submitting responses to National Grid's Enhanced Frequency Response (EFR) tender process was a natural extension of this work.

The tender process was very involved with many intricacies. As participants to the tender process, we were required to provide comprehensive details for each of our proposed projects including: site details and land arrangements, grid connection details, full construction and technical details including technical proposals from equipment suppliers and build contractors, response parameters of the proposed system and timetable for delivery. To be successful in the process we were required to demonstrate the forecast performance of each project as well as show our ability to finance the construction and commissioning of the projects.

Preparation and proposed projects

Based on a comprehensive set of selection criteria, the National Grid awarded eight significant energy storage contracts, as part of its inaugural EFR service tender. Low Carbon is one of just seven businesses to be awarded tenders – and the only business to be awarded two contracts. The two Low Carbon sites, Cleator in Cumbria (10MW) and Glassenbury in Kent (40MW), will give the National Grid the ability to access 50MW of this unique grid stability service – greater capacity than any other provider named. Both sites will make use of large-scale battery storage technology in the form of lithium-ion batteries.

What the future holds

The UK energy mix can be broadened and secured through a series of complementary generation and storage solutions. Supporting domestically sourced energy solutions is also the key to securing the UK energy supply now and in the future. Low Carbon is targeting both projects to be operational during 2017. We recognise the tremendous potential of energy storage technology and will continue to look for opportunities to grow our portfolio in 2017 as part of ongoing mission to help mitigate the negative effects of climate change.

the successful contracts were to storage systems.

EFR is important because of the potential for savings it offers – National Grid predicts approximately £200 million in reduced costs – so other nations will be watching with interest. The price for the successful bids was also unexpectedly low, below even Fast Frequency Response (FFR) that has a timescale of 10 seconds. This demonstrates the ability for battery systems to compete in the marketplace.

One of the reasons that the price for EFR could fall so far was the contract length. At four years the contracts on offer were much longer than traditional FFR ones; this enabled lower financing costs as investors had greater security. For renewable technologies looking to go subsidy-free this provides useful information on how changes to the business landscape can affect the viability of projects.

There is clearly a bright future for storage technologies. The grid of the future will have large amounts of renewables on it, with storage helping to even out the peaks and troughs. However, government needs to act to provide the right environment to help the industry flourish: currently there is no clear regulatory framework for storage; the industry will remain limited until that issue is solved. This is especially important for multi-use sites such as solar + storage.

Currently storage is treated as generation, and subject to network charges on that basis. Any electricity stored is therefore charged twice: firstly for importing and storing the energy and secondly for discharging and using that energy. If charges were levied on final consumption and not all consumption this double-charging problem would be solved and level the playing field for storage.

To fulfil storage's potential new marketplaces for services must be made. Distribution Network Operators (DNOs) are network operators, not distribution system operators. As a result they are unable to procure and tender for services to ensure the stability of the grid in the way that National Grid can: we couldn't have an EFR tender at the local level, for example. This means that a significant amount is spent on passive grid reinforcement even if by spending a lesser amount DNOs could procure storage services that would mean upgrades are not required.

Storage, along with solar, has a major role to play in the transformation of the UK's energy system into a truly smart grid fit for the 21st Century. The UK is making progress in this area, but more can be done; the potential benefits from such a system are too big to pass up. ■

Authors

David Pickup is policy manager at the Solar Trade Association, responsible for economic modelling and policy analysis. He provides in-depth guidance and briefings to STA member companies, as well as developing the STA's view on wider policy issues. David is also the lead at the STA for storage, and authored the recently published STA position paper on energy storage.

The analyst's view

By John Parnell

Sam Wilkinson, senior solar analyst at IHS Markit, discusses the winning companies, likely technology choices and chances for a second round of bidding in the UK's Enhanced Frequency Response tender

PV Tech Power: What did you think of the pricing of the winning projects?

Sam Wilkinson: Our analyst team did some preliminary work on what to expect. The final results were fractionally below what we thought they would be. There was a reasonable spread there too. One thing to remember is that the enhanced performance that this provides would allow the batteries to command a premium over the conventional gas-fired solutions that are providing frequency response as well.

How advanced do you think the winners will be with their procurement?

I would imagine that as they are bidding in with prices, they would already have provisionally selected technology suppliers to provide all the components and the systems. I'd be very surprised if they had gone ahead with pricing in the bid if that wasn't at least provisionally established.

The timeframe looks relatively short considering the experience that we have so far building utility-scale storage projects. I think the biggest [in the UK] is 6MW at Leighton Buzzard and some of these projects are in the range of 40MW; that's a significantly larger project than we have ever tackled before. Given some of the uncertainties, it does look like a pretty aggressive time frame to get those projects completed in time for the contract start date. I would say that the winners will start moving quickly so that they can allow the maximum amount of time for issues that may come later with, for example, siting, grid connection or permitting.

A second EFR tender round is widely expected. Could that happen sooner rather than later given the interest in round one?

To me it would follow that we would expect these projects to go into operation and get some preliminary feedback on how well they perform and how much they live up to the expectation placed on them, before they go ahead with a potentially larger tender. To me it would seem unusual to launch a second tender just because the first is so oversubscribed.

Which battery technologies do you expect to win out?

There are very few technical details available but I would be amazed if they are not lithium-ion batteries. That is the technology to beat right now for battery-based frequency response. They are very good at high-power situations; typically frequency response is in periods of 30 minutes or shorter and Li-ion is typically chosen because of its ability to respond extremely quickly and inject high amounts of power.

What else was interesting about the results of the tender for you?

The winners were predominantly renewables EPCs and developers. That strengthens the link between the renewable industry and the battery industry. At the same time, there are three extremely established utilities there that have already got a lot of expertise in providing services like frequency response and they also have a lot of assets built out, and the fact that they can then site these batteries there at these existing grid connections, allows them to lower costs compared to building a site on a brand new piece of land and a grid connection just for that one battery project.

To find out how storage is being primed for a key role in the UK's future power system, turn to page 80

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Storage up front

Policy | The UK government and energy regulator recently outlined initial proposals for overhauling the country's energy system. Andy Colthorpe speaks to Anthony Price, director of the Electricity Storage Network trade group, about how the long-awaited document has been received and the key role it envisages for storage

In addition to excitement around the UK's Enhanced Frequency Response (EFR) tender, as outlined on the previous pages, the biggest topic in the UK as far as storage is concerned is the publication in November of a "call for evidence" on power network reform, published jointly by the national energy regulator, Ofgem, and the UK's Department for Business, Energy and Industry (BEIS). The pair has evaluated what it considers to be all of the issues around building a smart power system fit for the future – putting storage at the forefront of a flexible, low-cost and hopefully low-carbon network. Stakeholders have been asked to respond to the document by mid-January.

PV Tech Power: This call for evidence has been promised for some time. Have Ofgem and BEIS got it right?

Anthony Price: It's actually quite a good document in that it explains the situation as Ofgem and BEIS see it and asks for information to support or contradict their views from industry. This has been probably one of the longest running document launches of all time. First talked about almost a year ago, back in January, ministers were talking about launching this early in spring and then we had hold-ups because other things were happening in the political world.

We are very pleased it has come out. We are disappointed it has taken so long but very pleased that actually it is going to address a number of important issues to do with flexibility and specifically put storage right up front.

The document talks about creating a competitive market for flexibility, including storage where possible – to what extent is that ironing out the kinks in the regulatory system versus an overhaul of the system?

What you need to do is to identify all of the areas where there's a concern and I think we've got most of them on the table already; there are bound to be a few more that need to come out. There does need to be a massive overhaul of the whole sector. We are still dealing with issues or precedents that have been set a long time ago on the basis of old technology, and old methods just don't reflect the current changes in commercial activities and the change in technologies.

Is there enough recognition of storage to benefit the network versus storage to benefit individual users? Should the call for evidence be able to capture that?

That's one of the things we need to bring out, because primarily storage should be a system asset, and if you don't have a plan for storage and you don't have a strategy and a means of implementing that strategy, you are going to end up with unintended consequences. You could end up with a lot of stranded assets, with things that are not doing what was intended. That could have nasty implications for the system and these things will happen very, very quickly.

Currently UK distribution network operators (DNOs) aren't allowed to own storage assets. Why is that and what's your position?

The argument against the network operating storage is that they would then be involved in buying and selling electricity, which seems to be counter to their distribution licence, but this of course is just to my mind a little bit of a red herring because everything that a network operator does concerns the movement of electricity. The network operators are trying to operate their network at the lowest cost because that's a condition of their licence; they need to offer best value to their customers and if by putting storage in they can lower the whole cost of operating the network, that's something they should do. There seems to be an argument that says, the network operator shouldn't be allowed to do that because he's got access to low-cost capital, he's got preferential planning rights, he can do things which a private developer couldn't do. Well my answer to that is, why hasn't a private developer already done it?

I am not saying that DNOs only should be allowed to put in storage, I'm not saying DNOs will put in the majority of storage but we are saying DNOs should be able to put in storage because it's a network tool which they need to have in their portfolio. To write it out now, we will live to regret it in 10 or 20 years' time when we go through the next iteration of market rules.

The call for evidence covers everything from a smart meter rollout to potential time-of-use electricity pricing to then much higher order things such as legislation and double-charging of storage asset. Is it perhaps a bit too wide ranging?

It is a huge call for evidence but the nature of the electricity industry is that it's a huge undertaking and you can't do things in isolation. To give you another example, if we had real time-of-day pricing with dynamic charges, we wouldn't be having an argument about getting more storage on the system: everyone would put storage in to insulate themselves against price changes. ■

Electricity Storage Network director Anthony Price

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Microgrids on the cusp

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Microgrids | The technology and financing of the remote microgrid market are maturing. Now improved sales and marketing methods are needed to commercialise the huge potential on offer in this burgeoning market segment, writes Thomas Hillig

Microgrids are one of the hottest topics in the renewable energy world. Solar and wind energy are changing the paradigms of electricity generation toward more decentralised solutions. The utility microgrid segment is mainly driven by autarky and security of supply. The biggest market is in the United States, where an ageing grid infrastructure requires large investments into the grid. Here microgrids are sometimes a more economical alternative. Investments in local generation assets mean in conjunction with microgrids that the improved reliability will have benefits that are felt locally. In case of larger blackouts, the microgrid can "island" certain consumers and continue to provide them with electricity. This could be attractive for communities, utilities and commercial and industrial end-users.

In an international context, microgrids are even more successful in the off-grid or extreme-weak-grid environment. Due to steadily falling prices, solar and wind energy have become very competitive for applications in areas that are not or insufficiently connected to the grid. In these areas, heavy fuel oil and particularly diesel are the main sources for power generation. The business case in this segment is mainly driven by cost reductions and involves replacing expensive diesel or heavy fuel oil by relatively inexpensive solar or wind energy. In remote locations, diesel is an extremely expensive source for electricity generation. The fuel must be transported in trucks to remote sites, taxes apply and losses or theft are a common issue. Renewable energy is typically competitive without additional incentives.

Microgrid concepts

Solar or wind power plants are built in the proximity of existing diesel gensets. The easiest concept consists of a light microgrid without energy storage. When there is enough solar irradiation or wind speed, the power is mainly generated by renewable energy resources. However, the diesel gensets are the grid-forming element and must run constantly to quickly provide spinning reserve for periods of sudden power drops from shaded solar arrays or unsteady wind speeds. Sometimes wind and solar are combined for diesel reduction. Regarding the intermittency question there are some advantages as solar and wind power often correlate inversely in many conditions of weather changes. Light microgrids are the most widely spread plant type in remote power generation.

Remote mines are just one of the many applications for renewables-powered microgrids

This is still due to the relatively high prices for energy storage systems. In more advanced concepts, energy storage is added. This allows for partly switching off the diesel gensets when the weather conditions are favourable. In this scenario, the batteries can also be grid-forming. One of their main functions is to bridge shorter time periods that are needed for starting gensets when unpredicted adverse weather changes occur. Energy storage increases the share of renewable energy sources in the system. The size of the batteries needed for this bridge-to-back-up is relatively small. As energy storage prices have fallen significantly in the past

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years, we also see more and more applications in this area. Many off-takers are however reluctant to invest large sums in their power generation infrastructure. For many communities and commercial and industrial consumers, power generation is not a core competence. They are used to paying for their electricity by the kilowatt-hour or by litres of diesel.

The most advanced concept for off-grid power generation involves the addition of long-term storage devices that allow for shifting solar and wind energy consumption to times without solar irradiation or wind speed. For example, solar power that is generated during daytime can be shifted with the help of energy storage systems to the night. For energy shifting, the batteries must be much larger than for bridge-to-back-up applications. At the same time, different battery technologies might be taken into consideration. For example, flow-batteries are hardly adequate for short-term applications, but have advantages in long-term applications because of their scalability regarding capacity.

Market innovation

The market for remote microgrids is maturing rapidly. Many new solutions are being introduced in this quickly growing market segment that has been identified by many experts as highly attractive in the mid-term and long-term future. Traditionally, diesel gensets are optimised for operating in the high load range. For balancing intermittent renewable energy generators, the requirements change. Low-load diesel gensets that can be run at lower loads, which enables them to provide more spinning reserve, are one of these developments. Improved local irradiation, wind velocity and power generation forecasting are also helping with the case for microgrids by making the intermittencies of solar and wind power more manageable, if not eliminating them altogether.

Finally, there are several innovations regarding the transportability of microgrid components. As the generator is linked to a limited number of off-takers, a certain degree of mobility ensures that in case the off-taker does not exist anymore or stops paying, that the solar or wind plant can be moved to another site. In this group of innovations, we see containerised solar power plants, batteries or mounting systems that are easier to relocate.

Innovation is not restricted to technology. We also observe business model innovation. External investors are feeling more and more comfortable with financing off-grid installations. The risk is higher, because of an increased counterparty risk. In case the off-taker does not pay, typically there are no other off-takers close by in remote locations. In addition, many areas with no or weak grids are in developing countries. That means that the country risk is an additional factor to be considered. We see a large number of independent power producers (IPPs) entering the off-grid markets and offering PPAs to remote off-takers. There is also a limited number of companies that offer leasing solutions. These financing options mainly address the issue that many off-takers do not consider power generation as one of their core competencies and are hence not willing to make large investments in their own microgrid systems.

Many IPPs and leasing companies prefer to finance large-scale off-grid renewable energy assets. Most of them have a background in financing grid-connected solar and wind parks and they are used to large-scale investments. For funds, the project due diligence and transaction costs are often too high for small-scale projects.

A high potential for large-scale projects can be found in the mining industry. Electricity consumption is much greater than for most other applications and diesel prices are especially expensive as mines are often remote and do not always have a good transportation infrastructure.

Smaller hybrid projects can be found in the tourism industry with remote island resorts as a flagship. Storage is more common in the hospitality sector, because switching off diesel gensets has advantages beyond cost reductions. Hotel guests see additional value when solar avoids hazardous diesel emission or noise. A third interesting sector is telecommunication. Remote telecommunication towers present an interesting business case, though the power consumption is rather small. Intelligent bundling of projects also allows third-party financing as typically there is a huge number of towers in a country that belong to one telecommunications operator or tower company. Other examples of sectors are agriculture, where powering irrigation systems plays an important role, food processing, commercial real estate such as shopping centres and finally rural electrification.

Microgrid projects in rural electrification are mainly driven by aid or international development organisations. Development cycles are normally much longer than for private sector projects. This is one reason investors tend to focus more on private sector projects. Another reason is that the governments or public utilities involved typically do not have a very high credit rating.

Commercialising microgrids

Many companies from the renewable energy and finance sectors have entered the remote microgrid sector lately. The supply side of the market is relatively mature as far as technology and financing are concerned. The number of remote microgrid projects however is still rather limited. One reason is the crash of world market oil and diesel price in recent years. Another reason is also that many renewable energy companies

are focusing on the engineering rather than commercial aspects of projects. Technology seems to be the focus of their entrepreneurial efforts. European renewable energy companies, in particular, have gained much of their experience in feed-in tariff-driven projects, where the core competencies were securing land, organising the feed-in tariff, legal organisation and financing. There was no industry or commercial end-customer to address. This has changed completely for microgrid projects. Commercialising the renewable energy solutions toward the off-takers becomes a key success factor. At the same time, marketing and sales gain importance.

For many engineering-driven companies the necessary organisational modifications become an insurmountable challenge. With that in mind it is no surprise that more and more component suppliers actively market their products. They do end-customer marketing and put end customers in the focus of their sales activities. A good example is storage providers. They see that microgrids are often the most attractive business case for storage applications. After having identified and pre-developed promising projects they involve project developers under the condition that they can deliver their storage solutions into the projects. The project developers continue the development process.

As the market is maturing, but competitive at the same time, it often is a good idea not to act alone, but to join forces. Many players have formed or are in the process of forming partnerships. There are two main targets for partnerships: market access and technology enhancement by pooling complementary solutions. Table 1 shows some of the recent partnerships that have been forged to focus on the emerging microgrid market.

On the technology side, ABB has teamed up with Samsung and Ideal Power with LG Chem and Aquion Energy to provide tailor-made microgrid solutions featuring energy storage systems. The inverter manufacturers Fronius and Victron have also joined forces in a strategic partnership for smaller microgrids. For larger plants, Schneider Electric has developed a control solution in cooperation with DEIF.

Sometimes the objectives of the partnership are twofold. For microgrids, Caterpillar has lined up with First Solar. From a technology perspective, Caterpillar covers diesel genset expertise, while from a market perspective, Caterpillar is a leading supplier in the mining industry – a key target sector of many microgrid players. First Solar contributes photovoltaics expertise.

Partner	Partner	Year	Partnership focus
Schneider	Green Energy Corp	2014	Technology
Caterpillar	First Solar	2015	Market access + technology
ABB	Samsung	2015	Technology
Northern Power Systems	ELVI	2015	Market access + technology
LG Chem	Ideal Power Inc.	2015	Technology
WindStax	Aquion Energy	2015	Market access + technology
Enerdeal	Henri Fraise	2015	Market access + technology
KACO New Energy	Nixon Power Services	2016	Market access + technology
Fronius	Victron	2016	Technology
ViZn Energy	Jabil Inala	2016	Market access + technology
Renova	CleanSpark	2016	Market access + finance
Aquion	Ideal Power Inc.	2016	Technology
JuWi	KPS (Pacific Energy)	2016	Market access + technology
Schneider Electric	DEIF	2016	Technology
GE	LSIS	2016	Technology
Wärtsilä	Greensmith Energy	2016	Market access + technology
IBC Solar	DHYBRID	2016	Market access + technology

Table 1. A selection of recent major microgrid partnership announcements.

In other instances, the collaboration goes beyond pure strategic partnerships. The French utility ENGIE has invested US$6 million in the California-based company Advanced Microgrid Solutions (AMS) targeting utility microgrids. The French oil and gas major Total SA has acquired majority and minority stakes in several renewable energy and storage companies that cover key aspects of the microgrid value chain. Among the investments are SunPower, Saft, Aquion Energy, STEM, LightSail Energy, EnerVault, Ambri, Offgrid Electric, Powerhive, and DP Energy. It will be interesting to see if Total SA intends to integrate these investments in the future.

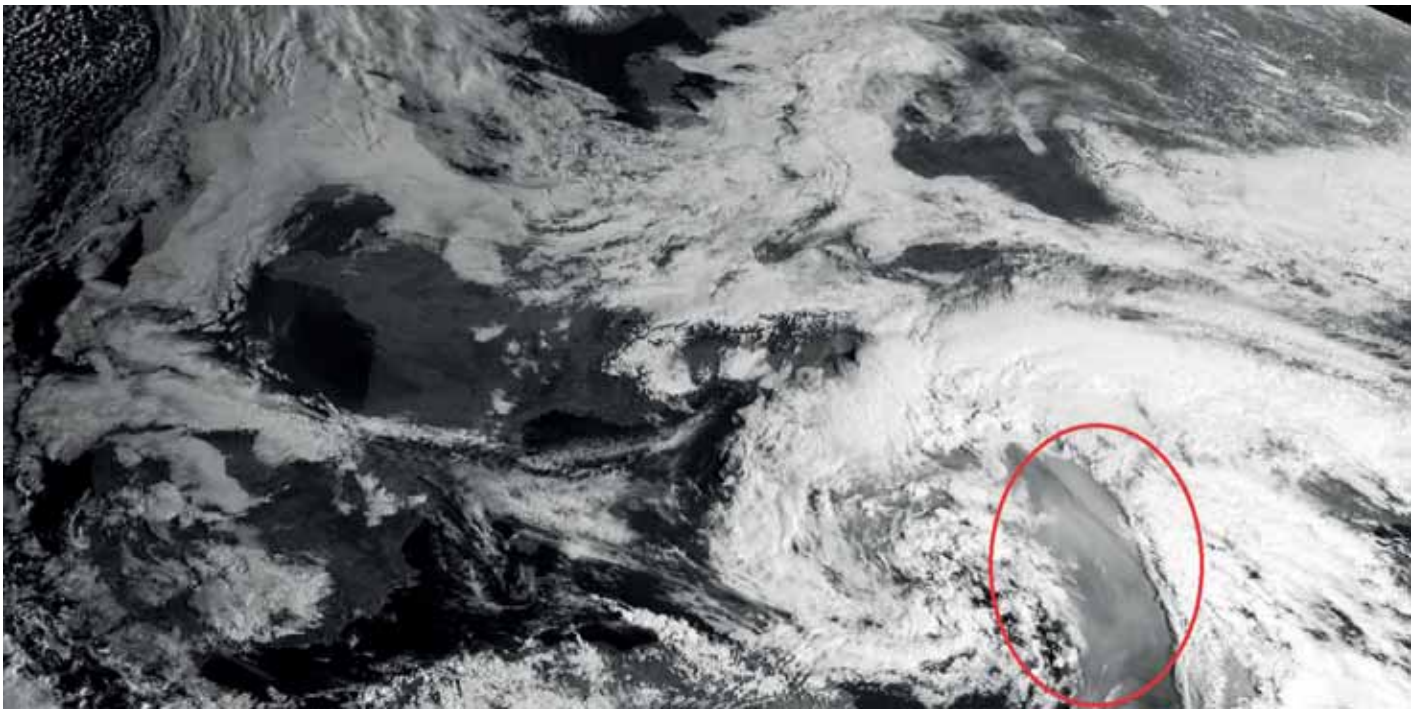
THEnergy has been working with several companies in screening the microgrid market landscape for potential partners and assisted them in setting up partnerships. Especially for smaller players, strategic partnerships are an important vehicle for entering new markets. THEnergy is constantly looking at growing our network of microgrid players in emerging markets. At this stage, many European and American companies intend to access new markets through strategic partnerships. THEnergy also helps them to design and implement these new partnerships. Often the beginning of a partnership paves the way for how successful the collaboration will be long term.

It can be expected that microgrids will be play an increasingly important role in the future. Mature, tailor-made solutions for microgrid optimisation are being developed, new business models are evolving and more and more renewable energy players are entering this market segment. The only remaining gap is sophisticated sales and marketing concepts. When this burden is overcome or if oil and diesel world market prices increase slightly, it can be expected that the market for remote microgrids will boom and that decentralised, off-grid energy generation will be a serious competition for grid extensions in many developing countries or sparsely populated regions such as Western and Northern Australia or Northern Canada. ■

Author

Thomas Hillig founded THEnergy in 2013 as a specialised consultancy focusing on energy generation for industrial and commercial consumers. Main areas covered are renewable energy microgrids and remote hybrid power plants for sectors such as mining, tourism, telecommunication, or agriculture. THEnergy combines Hillig's previous experiences working at Alstom Power in conventional energy generation and at Innotech Solar. At the beginning of his career, Hillig consulted leading companies from the transport, telecommunication and construction sectors.

Getting a grip on Saharan dust



Credit Meteosat

Forecasting | A poor understanding of how European PV arrays perform in Saharan dust outbreaks can have a crippling financial impact on grid operators. Christian Kurz and Lucas Richter of meteocontrol describe a major new research project underway in Germany to improve the forecasting of dust outbreaks and their impact on PV power output

Germany's electricity market is highly affected by volatile renewable energy generators. German policy is seeking to eliminate atomic power, reduce CO2 emissions and also to become more independent of fossil energy sources, as a model for other countries to follow. The aim is to increase the portion of renewables incrementally from approximately 30% now to 35% in 2020, to 50% in 2030 and to 65% in 2040.

Due to the higher proportion of renewables in the energy mix and their volatility because of the variability of weather conditions – and until recently no possibility of electrical storage – renewables can endanger the stability of the grid. If there is too much electricity in the grid either renewables will be curtailed in their power output or the overflow of electricity is delivered to other countries, which are not always pleased by the prospect of having to absorb the additional power in their own grids. Otherwise if there is too little electricity in the grid the deficit has to be compensated for by generation from conventional power stations.

Thus we can see that the integration of renewables does not work all the time. In the case of photovoltaic power stations and their expected aggregated contribution to the electricity grid, tricky situations are mainly a consequence of low stratus cloud, extended convection with cloud building and Saharan dust outbreaks, the latter of which is considered here in more detail. Power forecasts help to maximise the integration of renewables and minimise the costs. On sunny days the contribution of photovoltaic power to the entire energy consumption can reach up to 80%. During Saharan dust outbreaks single PV sites can lose over 80% in comparison to the forecasted power generation of a numerical weather model, and the aggregated sum of regional PV sites can lose up to 50-60%.

The lost output from PV power plants during a Saharan dust outbreak can have a detrimental effect on grid stability

For such situations the grid operators have to hold back special energy in the form of gas power stations, which is demanded instantaneously and which is very expensive. So Saharan dust outbreaks can lead to economic damage for the German grid operators – around a high two-digit million amount in euros per year, figures supplied by the grid operators suggest. There are

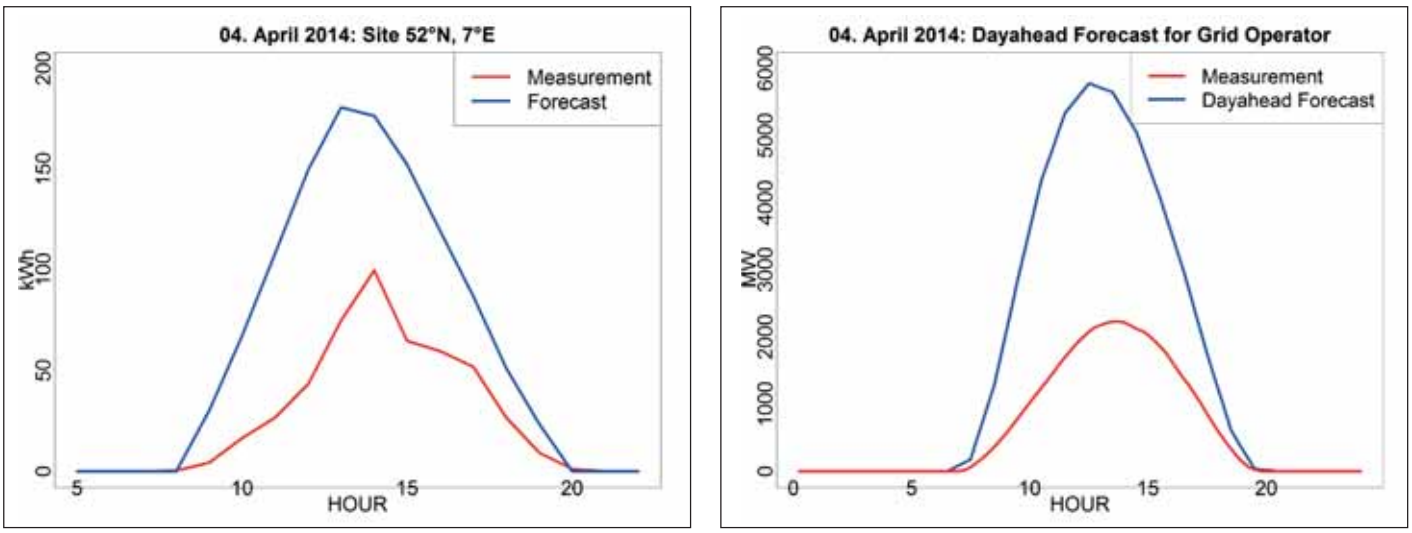


Figure 1. The difference between forecast and actual production during a Saharan dust outbreak for a single site (left) and at a grid level

four grid operators in Germany. Each of them has a certain level of electricity demand dependent on the time of day, day of the week and also day of the year due to holidays. As a result they all have to plan the energy generation from conventional power stations to react to the forecasted power generated by the renewables and to ensure grid stability. During Saharan dust outbreaks this procedure can be very difficult.

The Saharan dust problem

Over 50% of the tropospheric aerosol content consists of mineral dust particles of which over half originate from desert regions. For the transport of Saharan dust to Middle Europe there have to be special weather conditions and a certain circulation pattern over North Africa and Europe. At first the dust has to be blown up into the air by turbulence and high wind speed to rise high up in the atmosphere. If the dust gets into the stratosphere it can remain there for several weeks until it sediments on the ground or falls back into the troposphere and is washed out by precipitation.

For the dust to be carried from the Sahara to Europe requires a strong longwave upper-level trough in the west of Europe, equivalent to a low pressure area. Because of an anticlockwise rotation of low pressure systems in the northern hemisphere, Saharan air mass is moved by a great southern wind current to Europe. The frequency and intensity of such an event is different from year to year, but it occurs mostly in spring and early summer in the cycle of the year. The content of aerosol in the atmosphere can be twenty times higher than usual and in mean there are five to 15 events per year with an aggregated duration of 10 to 60 days.

In terms of solar radiation and PV power output levels, Saharan dust can have various different effects. Firstly aerosols can reflect solar radiation directly or indirectly by tuning the development of clouds: cloud development requires a surface on which water vapour can condense; if there are more dust particles there, more droplets and thus more clouds will be formed. Otherwise photovoltaic power output is reduced by deposition of dust on the module surface. Furthermore the occurrence of Saharan dust in the atmosphere leads to less precipitation and this leads also to a longer pollution

of the PV module.

For grid operators, the Saharan dust phenomenon is problematic because at the moment the variability of aerosol content in the atmosphere is not included in numerical weather models. They use a climatology of aerosol content, which only gives its average.

To solve this problem, further work is required to better understand and predict performance of PV systems during different levels of pollution by Saharan dust. Real PV measurements have to be investigated to create an appropriate algorithm which approximates the photovoltaic output to the higher aerosol content, its duration, the occurrence of precipitation and at last the assumed module surface pollution.

Subhead

With this in mind, a consortium of DWD – the German Weather Service – the Karlsruher Institute of Technology (KIT) and weather services company meteocontrol earlier this year launched a joint research project, PerduS, to examine how dust affects the output of PV systems. The aim of the project is to expand DWD's numerical forecast with an improved dispersion forecast for desert dust; this enhanced modelling will offer insights into the likely reduction of sunlight by simulated dust distribution. Meteocontrol is in close contact with grid operators and other users, and as such recognises the urgency of this issue. As a PV power forecast provider meteocontrol is mainly a user of the radiation forecast of DWD; it is highly interested in the improvement of the numerical weather models and sees much potential in this research. It uses the radiation forecast in its own PV power forecast model and hopes to enhance regional and single site photovoltaic power forecast quality during Saharan dust outbreaks. The expected soiling of photovoltaic systems by the deposited Saharan dust will also be estimated, and how soon the dust will be washed off by rain later on.

The key step forward offered by the PerduS project is that the current aerosol content is included in the numerical weather models. As well as improving radiation forecasts, this new modelling approach should find application in numerical weather models to advance weather forecasting more generally. In summary the main motivation of this project is to get a reliable radiation and module pollution forecast during Saharan dust outbreaks. Ultimately this should offer an economic benefit to grid operators trying to maintain grid stability and also to electricity consumers.

In the first step of the project, the shift of the particle content distribution has to be modelled and to be compared with real measurements in respect of the great weather circulation, its wind speed, temperature, humidity and the origin of the air mass. The parameterisation of the particle model is then found by a sensitivity study, which will be carried out by KIT and simulate parameters such as the aerosol content, density and distribution as it moves from the Sahara to Europe.

In the next step, DWD will examine the interaction between the particle size distribution and cloud micro physics. The higher the aerosol content, the smaller and lighter the cloud droplet is. In consequence the cloud lifetime is longer than clouds with the usual aerosol content. This is because with fewer particles in the atmosphere, the entire water vapour condenses on this number of particles. In consequence the cloud droplet will be greater and heavier than cloud droplets where water vapour condenses on many more particles – as in a dust outbreak. Thus the radiation retrieval algorithm out of the numerical weather model has to be adapted to this special case.

After the correction of the radiation algorithm, the photovoltaic module pollution has to be approximated with an appropriate model, which will be developed by KIT and meteocontrol. This can be done by comparing the simulated PV power output based on real radiation measurements with the help of real photovoltaic power measurements. The KIT has a test field with PV plants of different orientations and meteocontrol monitors over 40,000 photovoltaic sites with a high temporal and spatial resolution. Most likely there is a significant dependence of the module pollution on the real aerosol content in the atmosphere. At this point you have to be careful with the duration of pollution considering precipitation and in consequence the washout of particles on the photovoltaic module.

After finding a good approximation to reality several case studies can be investigated. For example, each of the four German grid operators has recorded days in history when a Saharan dust outbreak and poor day-ahead solar power forecast have coincided. The new algorithm can now be used to recalculate historical forecasts and then compare them with real photovoltaic power feed-in. The three project partners DWD, KIT and meteocontrol, hope to reduce the forecast error by more than a half. Especially for future scenarios when there is an even higher photovoltaic penetration in the German energy market, the new model will offer numerous advantages. For example if there is one and a half times greater installed photovoltaic capacity, the forecast error would scale linearly with recent numerical weather models. So this new model adapted to Saharan dust would help promote an extension of PV power in the German grid.

The new model could also be used to simulate PV power output for other regions, in general for desert regions. Following the UN climate conferences in Paris last year and in Marrakesh, Morocco this year, the majority of the countries have ratified the new global agreement to reduce greenhouse gas emissions significantly and finally to limit the increase in global temperatures. For this the expansion of renewable energies is necessary. Due to the climate in desert regions there is much potential in solar energy, but also great effort in forecasting module pollution and finally solar energy during sand storms.

With support from Germany's ministry of economy and energy, the PerduS project is expected to be complete by the end of 2019. ■

Authors

Dr Christian Kurz is head of prognoses and data mining at the energy service provider meteocontrol. After his studies of atmospheric physics at Munich University he worked at the German Aerospace Center (DLR) for many years, mainly on the parameterisation of clouds and cloud-irradiation interactions in a global atmospheric circulation model. Since 2007 Dr Kurz has been responsible for the development of renewable energy power forecasts for grid operators and trading companies at meteocontrol.

Lucas Richter studied atmospheric physics at Frankfurt University. His master's thesis was about the variability of solar radiation in Europe. Now works in the department of quality services at meteocontrol, where he is responsible for the validation and improvement of forecast quality.

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