Using string at scale

String inverters: Heralded by some developers as a way to reduce O&M costs and meet the challenges of optimizing park design, large string inverters for PV power plants have made headway in some markets. And as solar spreads to harsher and more remote regions, string's strength is coming ever more to the fore.

When working in hot and dusty conditions, time is of the essence. It takes a maximum of two trained installers to fit a typical three-phase string inverter on to a row of ground-mounted modules. Depending on the size of the system, this translates to a few hours' work, especially when compared to the heavy duty nature of a typical central inverter install. With shorter DC cables, no need for string combiner boxes and no allocated truck path snaking through the array, the job of installing hundreds – maybe thousands – of string inverters is often far simpler than fitting a single central inverter. And as solar spreads its tentacles into ever more remote regions, it pays to do things quickly and effectively.

Decentralized EPC specialists Asunim speak from a position of experience when they extol the virtues of string inverters at large scale. With a current focus on developing ground-mounted solar systems in Turkey, Egypt and Portugal, Asunim has accrued a weighty scrapbook of dos, don'ts and best practice when constructing solar plants in such regions.

"Large string inverters make our job as an EPC a lot easier," Asunim Group Director Andreas Schuenhoff told **pv magazine**. "By using string, we can install large-scale systems on what would usually be deemed difficult terrain. Even with modules facing different angles, or exposed to different orientations or temperatures, by using a decentralized string inverter solution you can minimize the negative impact of this mismatch."

This tends not to be the case, argues Schuenhoff, with central inverters, which tend to operate to the efficiency of the worst-performing module. "When using central inverters, often the slowest module leads, as it were," he says. "There are smarter central inverters on the market that make accommodations for this effect, but you end up paying almost the same as you would if using string."

And whether an EPC is building a megawatt-scale solar farm in the remotest corner of eastern Turkey, or a large rooftop array in the heart of a German city, cost remains king, with performance and reliability the ever-present prince.

Photo: Huawei

China's Huawei has been a pioneer in using string inverters in large-scale solar installations, developing plants in Germany and other parts of Europe, and is currently working on a 2 GW site in China.

Why string, and why now?

The traditional method for converting the sun's energy into alternating current (AC) at large scale had largely followed the central inverter approach. Large and unwieldy they may be, but once installed a central inverter would operate quietly at the fringes of the array, handling all or half of the entire DC energy produced by the solar modules.

But in recent years smaller string inverters – typically used in residential and commercial-scale applications – have

begun to eat into this segment. As costs have fallen and features have improved, three-phase string inverters have become a viable option for large solar plant owners. "The threshold to what string inverters can achieve at large scale is continuously being raised," said IHS senior solar analyst Cormac Gilligan. "Today, most PV inverter suppliers are very comfortable installing string inverters in an installation up to 20 MW, for example, and really there is no limit – China's Huawei, for example, is currently building a 2 GW solar plant in the country using string inverters."

Asunim's Schuenhoff believes, far from there being a 'sweet spot' for string inverters' efficacy, there is in fact no upper limit, no optimum plant size for string inverters. "I don't see a limit," he said. "People are constantly crunching those numbers, but I would happily build a 100 MW array with string inverters."

Schuenhoff is quick to stress that the situation is not simply one of 'central inverters bad, string inverters good', but rather, as solar installations are increasingly commissioned in more remote areas, logistically and technically it is often easier to ship, install and maintain string inverters rather than central inverters.

Why is this the case? Ask any string inverter manufacturer or EPC and the answer will be the same: A decentralized approach offers greater modularity, design flexibility and scope for innovation. IHS' Gilligan agrees, noting that there is a subset of key benefits that make string inverters an attractive proposition for the large-scale solar market.

"Spare string inverters can be stored in a warehouse or a stockpile on site, allowing rapid and cost-effective replacement of failed inverters," he told **pv magazine**. "In difficult terrain or hard-to-reach locations, this is an obvious benefit. String inverters are also lighter and can be quicker to install, and can now be attached to mounting and tracking systems so that they have a reduced footprint on-site."

Many proponents of string inverters claim that the technology offers more reliability than a central inverter, the argument being less a case that the components themselves are more durable – failure is failure – but that the downtime, i.e., the negative impact of a faulty string inverter, is far less injurious than with a central inverter.

"In the more remote areas in which the solar market is growing, often, as an EPC, you are dealing with sub-contractors that have very little or no solar experience," explains Schuenhoff. "In central Europe or the U.K., the majority of large-scale solar plants have been installed with central inverters. And that's not a problem because the chief suppliers there have 24-hour response times and dedicated, experienced O&M teams close by.

"This is not the case in some of the more emerging solar markets. If we were to install a 10 MW solar farm in eastern Anatolia, for example, not only would we have to deal with customs and face importation issues on spare parts, but we would be dealing with much longer response times from the central inverter manufacturer in the event of a failure."

Schuenhoff believes that a faulty central inverter in locations as remote as this could equate to a realistic downtime of two to four weeks for a typical solar plant – a stint offline that would not sit well with the vast majority of investors.

"With string inverters, failures are swiftly rectified without the need for the customer or EPC to get back in touch with the manufacturer, which is a strong selling point for the technology," said Schuenhoff.

Cost and maintenance

Why install many when one will do? A trump card long held by central inverters at such scale was cost. In 2015, IHS calculated that the average global price for three-phase high power inverters (those larger than 99 kW, i.e., central inverters) was 30% lower than three-phase low-power inverters (<99 kW, i.e., string inverters). Equate that saving over a megawatt-scale plant and central inverters certainly have the upper hand.

But solar installation costs are far more nuanced than the initial capex would suggest. Increasingly, string inverters actually deliver lower balance of system (BOS) costs for the plant owner, and

Photo: Asunim

In terms of post-installation monitoring and maintenance, many EPCs prefer string inverters.

in most of today's markets cost parity between the two has been reached. Factor in shipping, labor and logistics costs in those remote areas that are embracing solar power with such gusto, and the string approach becomes the cost-effective approach.

"You have to look at the full picture of the PV system setup," explains Christian Buchholz, head of product management at REFU Elektronik, the German manufacturer of RefuSol string inverters. "With string inverters you eliminate the need for combiner boxes, but on the other hand you do need AC combiner boxes. However, overall we see that it at least equals out – and not just for the developer. Pro-string arguments account for the customers as well – string opex is taken into account, and the concept of being independent of the manufacturer [in terms of O&M] is attractive."

Exploring that last point, Buchholz remarked that central inverter suppliers typically insist on a maintenance contract with their customer, which is usually subject to an annual fee. "With string inverters," he said, "plant owners can organize their own service as and when required – usually because there is no on-site repair necessary."

From an EPC's perspective, Asunim's Schuenhoff adds that post-installation O&M for solar plants managed by a central inverter can leave plant owners at the mercy of the supplier's cost structure and – increasingly in the volatile world of solar – oftentimes dealing with firms that have either left the industry or gone bust.

"I don't believe that the majority of central inverter manufacturers on the market today will be around in 10 years' time," said Schuenhoff. "The same of course applies to string inverter manufacturers. But let's say you have a 40 kW string inverter in your plant and the supplier goes bankrupt: You can simply buy a comparable replacement product from another supplier. It is not so easy to do this with central inverters."

Schuenhoff cites Asunim's dealings with a central inverter supplier that closed its solar operations but continued to run a lucrative maintenance and spare parts business. "We were completely exposed to this company's price fluctuations. They dictated the price and there was nothing we could do. That is what turned Asunim away from central inverters and led us to explore building megawatt-scale arrays with string inverters."

For innovation, decentralize

Perhaps the strongest argument in favor of string inverters at scale lies in plant design. By decentralizing the solar system setup, EPCs can identify terrain that previously may have been considered challenging. From hilly topography to asymmetrical plots, string inverters can adapt to the most optimum plant design, and not the other way around.

This, believe both Schuenhoff and Buchholz, is string's main strength. "Whether solar panels are installed at different angles, exposed to different temperatures or shading, a decentralized solution minimizes the negative effect. You can solve topographical constraints more elegantly with string inverters because you can basically group modules together," said Schuenhoff. "Let's say you have a square piece of terrain. You can group your string inverters across the field, leading with AC cables to the transformer. And if that terrain has an unusually shaped annex, you simply group those inverters on the extreme side where it leads to your transformer. Sometimes you don't even group the inverters. It's a question of design."

Asunim has calculated that large-scale solar systems it has developed with string inverters consistently deliver a 3% higher yield than central inverter-controlled plants. "This is not a simulated result but actual performance," Schuenhoff stresses, pointing to the extra energy harvested by string inverters boasting multiple maximum power point trackers. "Another point to remember," adds Buchholz, "is that with string you essentially get monitoring for free because you do not need additional smart string combiner boxes because in a multi-megawatt system you have hundreds of string inverters, each monitoring the string input automatically into the portal."

Whether market or technology-driven, or a mixture of both, the trend is apparent. String inverters have proven their worth at large scale, convincing EPCs and plant owners of their efficiency, cost and monitoring benefits. "It's now a virtuous cycle," concluded Buchholz. "EPCs have begun to rethink how they design PV systems, and have adopted a more open-minded approach. Previously their default setting was to use central inverters, but a growing number are now changing their minds and are more open to the possibilities offered by string inverters." ◆

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HUAWEI POINTS THE WAY

Chinese ICT firm Huawei exclusively manufactures string inverters and has already completed a series of large-scale solar farms around the world. Its latest project promises to show that there really is no upper limit to the efficacy of string inverters.

Site size and location: 2 GW once completed, located in Yanchi, Ningxia, China.

Inverters used: Approximately 55,000 Huawei SUN2000-40KTL string inverters will be installed on the site once it is completed.

Benefits of string at scale: "Our string inverters can make real time string detection with a high accuracy sensor at up to 0.5%," said Huawei's Yan Jianfeng. "That is six times higher than what a DC combiner box can manage. Furthermore, the string inverters can detect both the current and voltage.

"Our inverter is simple to install and maintain. There is just one spare part, whereas a typical central inverter has more than 50 possible failure points. Thus, maintenance is simplified.

"The Huawei inverter also allows flexible system design with different panel brands and panel power. It is normal for system owners to replace panels as panel efficiencies increase. By using a string inverter, this process is made much simpler."

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