1,500V and beyond – where

Interview | Last year Sungrow became the first to market with both a string and central inverter at 1,500V. Geng Tian, director of product and engineering of Sungrow North America, tells Ben Willis how the evolution of inverter technology will help propel the next leap forward in PV plant design

Credit Sungrow

Sungrow's SG125HV was the first 1,500VDC string inverter on the market

When Chinese inverter specialist Sungrow launched the world's first 1,500V(DC)string inverter at Solar Power International in the US last September, the event underlined the extent to which the higher voltage power plant technology was well on its way to becoming industry standard. Previously restricted to central inverters and thus the larger projects for which these are generally used, 1,500V combined with the flexibility of the string inverter format opened up a whole new range of possibilities for the higher voltage architecture and the benefits it offers.

Sungrow North America's director of product and engineering, Geng Tian, was one of the team that developed the company's pioneering 125kW, 1,500V string inverter. He had also worked on the solar industry's very first 1,500V inverter, the LV5 central inverter produced by GE. This gave him a unique perspective on the 1,500V concept, both in terms of its potential possibilities but also its limitations.

One of the limitations, Geng says, is the fact that although 1,500V central inverters are well suited to large utility-scale projects, the reality is that opportunities for such projects are diminishing.

"The reason why we were thinking about a string inverter in the 1,500V range was because in the central inverter market, the power block size is changing from 1MW to 2MW to 3MW to 4MW; if you go outside the US – Mexico, Australia, India – they're looking at 5MW, 7MW and 10MW blocks," he explains. "But in reality the market has started moving away from the super power plants, like Desert Sunlight or Solar Star – those 500, 700MW plants. So a block size of 4MW or 3MW is becoming a limitation for relatively smaller projects.

"If you look at the commercial and industrial (C&I) and small utility market, predominantly over the past couple of years in that market most of the applications there is string inverters – three-

next for inverter technology?

phase, 1,000V string inverters at 20kW, 60kW. These are products targeted at the small commercial/industrial projects, from a couple of hundred kilowatts to 1-3MW. But there is a huge gap in the market, between around 1 and 20MW. And the sites for these are not like a square anymore; and the developers who are normally doing the big utility-scale projects, they have high overheads, they don't have enough justification to go after the 5, 10, 20MW projects anymore. But the smaller developers, who are normally doing the 1MW, 2MW projects, do not have the sophistication to deal with the complexity of utility-scale projects – the 10, 20MW projects. So it's like a hole in the market – there's the demand but no product."

The key attributes of the string inverter – ease of handling, installation and maintenance – made it the ideal product to fill this gap. But to produce it at the higher voltage threw up a number of technical challenges. Chief among these was how to squeeze the higher power into a unit that was still small enough to retain the characteristics of a string inverter.

"It's easy for us to produce a 200 or 300kW string inverter, but the issue is that always we want to make sure this is a string inverter and not a small central inverter, meaning that we can have two people easily carry and install it," Geng explains. "And at the same time we need to increase the power as much as we can, because the higher the power of each block, the less balance of plant components you're going to have to use. So 125kW is an ideal block – it's a trade-off between the higher power, the weight, the cost and other considerations such as manufacturability."

The technological leap that enabled Sungrow to achieve the necessary power density was a shift from the standard three-level topology normally found in inverters to five. What this essentially means is increasing by two the number of power conversion steps the inverter must make, but it had the advantage of enabling the use of smaller, more efficient components.

"We developed our own technology that allowed us to significantly shrink the size of the capacitors and the reactors and other components," Geng explains. "So that's the biggest technological achievement that allowed us to reduce the weight and increase the power density. Sungrow central inverters and older generation string inverters are all using three-level topology. But this 1,500V string inverter introduced a new five-level topology."

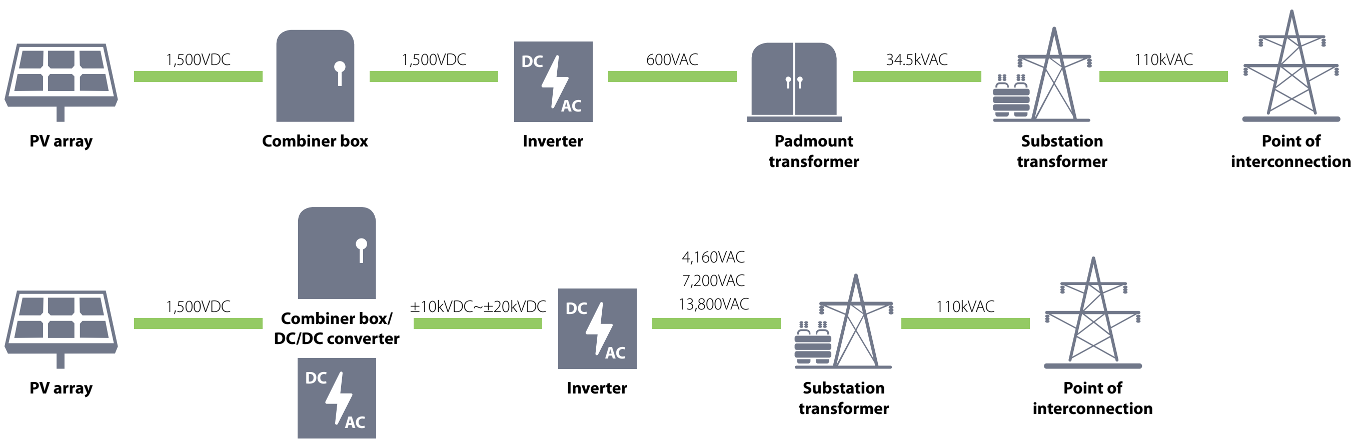
With the 1,500V string technology firmly under its belt, Sungrow is now pushing the concept of the 'virtual central inverter'. What this means is clustering a number of string inverters together in the field to emulate the balance-of-system benefits of a centralised architecture – reduced cabling, better control at the point of interconnection and so forth – but with the flexibility of a string inverter – ease of installation and ease of maintenance to name but two.

Geng says it also gives developers "ultimate flexibility" with their site, overcoming the power block limitations of central inverters. "You can easily put eight or nine inverters per 1MW block; or you can put in 20 inverters for a 2.5MW block," he says. "And the entire balance of plant is essentially like a central inverter – you're running 1,500V cables, you're using the combiner boxes almost in exactly the same way as a central inverter…but still able to capture the benefits of the string inverter and its flexibility. For the people who are developing large-scale utility PV projects, their supply chain and design practices are really built around the central inverters. So this is like a natural transition for those developers – to replace one central inverter with multiple string inverters in the same location."

The next leap forward

The big question is where next for inverters and PV power plant design in general. There has been no shortage of debate about whether the next step is an even higher voltage – 2,000 or even 3,000VDC, which would bring into play medium voltage DC (MVDC) architecture. Such a transition would be a huge leap forward for the PV industry, but it seems a way off yet, as underlined recently when Greentech Media reported that US giant First Solar had indefinitely suspended previously announced plans to shift to MVDC due to what it said was ongoing competition in the inverter market.

Figure 1. The architecture of a typical 1,500VDC PV array (top) and (below) as envisaged by Geng Tian with the 600VAC power conversion stage eliminated



Geng's view is that this transition, if it happens at all, is a long way off yet. This is due not only to the massive implications it has in terms of component supply chains but also because moving to medium voltage on the DC side of a plant would require specially qualified medium-voltage technicians, significantly pushing up the cost of operations and maintenance.

Over the next two years Geng believes there will be no "fundamental change" in inverter technology, rather a steady lowering of costs and incremental improvements in performance and reliability. He predicts 1,500V will see ongoing geographic expansion beyond Europe and the US into pretty much all the world's growth solar markets – India, Australia, Mexico, MENA.

Beyond that, out to something like five years from now, Geng says it will be a "different story". "The PV inverter we're looking at right now is going to be a lot different in five years," he says.

One major development on the horizon will be the likely shift from silicon to silicon carbide componentry in inverters.

"The shift to five-level topology is using current semiconductor devices and putting a more sophisticated level of topology to improve the power and reduce the cost," Geng says. "But with silicon carbide, it will help simplify the topology because it can switch a lot faster, has much less switching losses. So silicon carbide will help to increase the efficiency as well as reduce the cost, providing that the price of silicon carbide devices will drop low enough."

A shift to high-power silicon carbide technology could also pave the way for innovation on the AC side of power plants, Geng believes. Currently, 1,500VDC inverters step down the output power to a low-voltage 600V (AC), before it is stepped back up by the transformer. Each of those stages result in voltage losses of several percent, so eliminating the low-voltage AC stage of the power conversion process Geng says would be a big breakthrough for the industry.

"You want to be able to break through the 600V (AC) limit so you can step up to 1,500V from the PV array directly to the medium voltage, so you break through the limit of the ideal block size," he says. "You don't need to worry about ok, is it going to be 4MW or 2.5MW, because you don't have to worry about running a 600V [AC] cable all over the place or a 1,500V cable all over the place; instead you can run a 10kV or 20kV DC cable across the field, rather than run a lot of AC cable across in the field. So there's a huge reduction in of cost in the cabling."

"Any breakthrough in any area could lead to a complete architectural change in solar plants"

Figure 1 (previous page) shows a schematic diagram of what such an innovation would look like.

Whether or not that happens depends on numerous factors, many on them based on the appetite at a policy and regulatory level for such a big change to the status quo. But on the technology side, the advent of high-voltage, low-cost silicon carbide could also be a key enabler in driving such an advance, Geng believes.

"Silicon carbide is an enabler for optimising and improving the entire balance of plant," he says. "There's a 10kV silicon carbide device coming into fruition; that single device will help to significantly simplify the topology required to go to a medium voltage type of architecture so you can easily use a 10kV device and traditional two-level topology to create the AC output at around 6.6kV or 7.2kV. If you use a three-level topology with a 10kV device you can easily convert that into a 13.8kV or something in that range. So you don't have to go through the low voltage stage anymore."

Such a progression of course remains within the realm of speculation for now. But as Geng points out, the evolution of PV power plant technology has already surpassed expectation, with many believing that even the previous jump from 600 to 1,000VDC was pushing the envelope, let alone the 1,000V to 1,500V that has since come around. It would be an unwise gambler, therefore, to bet against the next big leap forward being too far ahead.

"No one knows when there will be a unique development," Geng says. "It's not just the inverter manufacturers, it's the developers and EPCs and key component suppliers; it's the whole supply chain all the way from the top down. Any breakthrough in any area could lead to a complete architectural change in solar plants." ■

Credit Sungrow