Grid-forming takes charge

Grid-forming is an emerging technology that allows solar and inverter-based energy sources to power up the grid independently. We spoke with Blair Reynolds, product manager for energy storage with SMA America, about his perspective on the technology, case studies and how the future of the industry may change in response to grid-forming.

PES: It's lovely to chat with you Blair, welcome to PES. First of all, please could you introduce yourself to our readers, including your role with SMA and your experience with storage technology?

Blair Reynolds: As the large-scale energy storage product manager for SMA America, I'm in charge of SMA's energy storage solutions for North America. I'm also globally responsible for SMA's advanced DC-Coupled and grid-forming inverter capabilities. I've been active in the solar and energy storage industry since 2007 and consider myself a technology specialist with a focus on matching solar + storage systems and product design with market applications and needs.

PES: What emerging trends have you seen with large-scale storage?

BR: We are definitely seeing a shift towards longer duration storage of 4+ hours for energy shifting applications, addressing the classic 'Duck-Curve' problem, in markets with higher solar adoption.

We are also seeing grid-support storage systems really hit their stride nearly four years after the UL 1741-SA standard became mandated in high renewable penetration markets in the US, such as California and Hawaii. Driven in large part by more severe climate events in recent years, these systems are being put to the test by providing valuable ancillary services such as frequency regulation through active power reserve, voltage support via reactive power regulation and fault current support and fault-ride-through.

However, perhaps more interestingly, we are once again on the cusp of a transformative and rapid evolution from grid-support systems towards an exciting emerging trend for using synchronous grid-forming technologies to bolster the grid in areas where the network is weak or the retirement of fossil fuel generating assets has left gaps in the resiliency of the system.

PES: Are there specific storage applications that have recently emerged?

BR: Yes, synchronous grid-forming applications for inverter-based resources are a relatively new application that is seeing increasing demand. The fundamental principle involves operating the energy storage system in a voltage source such as grid-forming, rather than a current source, or grid-following mode.

Large scale grid-forming inverter technology has been used for several decades in islanded, or microgrid applications, but the unique element of the emerging applications is that this technology is now capable of operating in a synchronous manner with the electric grid. In doing so, the inverter-based resources can build strength and stability into the network through a variety of capabilities, including fast-frequency response and synthetic inertia. It can even aid in system restoration via black start capabilities.

PES: Are there new revenue streams being recognized by system owners as a result of new storage applications?

BR: Of course! This happens mostly in the realm of frequency support and stability. However, I fully expect to see synthetic inertia become mandatory for energy storage connected to the bulk power system in many parts of the world over the next five years. One major issue we see with deploying large-scale solar and wind projects is the amount of time and effort required to perform grid interconnection studies, which are used to ensure these assets won't cause further issues with network stability. In areas with the highest amounts of renewable penetration, every single project is highly scrutinized, and the modeling and design iterations can take years to fulfill the grid operators' fundamental concerns.

Blair Reynolds

However, if you can simply operate your inverter-based resources in such a way that they do not cause any harm, then I expect the bottlenecks and red tape to be lifted. In many cases, that will lead to fast-tracked interconnection approvals for large-scale solar and wind farms when coupled with synchronous grid-forming energy storage.

By closely adhering to the operational expectations on which our 20th Century electric grids were built, we can become a drop-in substitution of conventional generation assets.

In doing so, this drastically increases the addressable market for large-scale energy storage systems, because we can inject system strength in low short-circuit ratio

nodes and even increase network short-circuit ratios to serve as an alternative to traditional 20th Century assets such as synchronous condensers. So, we actually create further opportunities for more renewable assets to be interconnected, thus building a sustainable and healthy compounding market poised for growth.

PES: How are large-scale storage plants aiding with grid stability?

BR: Most inverter-based resources currently in service are grid-following assets, and that means they rely on fast synchronization with the external grid to tightly control their active and reactive current outputs. If these inverters cannot remain synchronized during grid events or under challenging network conditions, they are unable to maintain controlled, stable output.

The primary objective of grid-forming controls for inverter-based resources is to maintain an internal voltage phasor. When grid-forming controls are applied to the bulk power system connected inverter-based resources, the voltage phasor is held constant in the subtransient to transient time frame. This allows the inverter-based resource to immediately respond to changes in the external system and provide stability in the controls during challenging network conditions. This phasor is tightly controlled through proprietary software to maintain synchronism with other devices and control active and reactive currents to support the grid.

This technology can, of course, also provide voltage support through reactive power injection and can fundamentally replace the need for rotating generators and synchronous condensers by providing the same sort of spinning reserve inertia. This limits the Rate of Change Frequency (RoCoF) of the network by providing the same sort of inertial response.

And finally, the ability to isolate a portion of the grid in the event of a natural disaster allows communities at risk to continue to receive a reliable power supply through a series of microgrids, which can operate independently as needed.

PES: Do you envisage the growth of the large-scale storage market to continue as rapidly as we've seen in recent years?

BR: There is no doubt in my mind that the growth will continue. The fundamental technology at play here, in particular the synchronous grid-forming technology, is the lowest cost, lowest risk pathway toward replacing traditional fossil fuel generation with renewable generation. If you believe that fossil fuel reserves are finite and that nuclear fusion is still many decades away from being commercially viable, then we really have no better technical solution to enable more than 25 per cent renewable penetration on our world's 20th Century electrical grids without suffering from massive reliability shortcomings. SMA is leveraging its decades of experience engineering reliable grid-forming systems to help make that a reality.

PES: SMA worked on a power plant project in Bordesholm Germany that featured grid-forming technology. Can you explain why this technology was the right fit in that situation?

BR: Bordesholm is a municipality located in the northern German state of Schleswig-Holstein. Here, a 15 megawatt-hour SMA energy storage system with grid-forming technology is ensuring the electricity supply for the entire Bordesholm region in the event of grid failure.

It's a tightly coordinated system solution featuring seven Sunny Central Storage

battery inverters and an SMA Hybrid Controller XL. In grid-tied operation, the public utility company is able to supply the European utility grid with critical balancing energy. In fact, the battery storage system is considered one of the most state-of-the-art balancing energy power plants in the world. If there are sensitive frequency fluctuations in the utility grid, the SMA system provides frequency containment reserve from the battery storage system within a fraction of a second.

Therefore, the electric utility company helps to ensure a stable utility frequency of exactly 50 Hertz – and participation in the primary frequency control energy market opens up lucrative business opportunities.

However, the grid-forming SMA energy storage system is capable of much more. In the event of a power outage, it forms a stand-alone grid within fractions of a second. In doing so, it supplies the connected loads with fully renewable energy from PV systems and biomass and CHP plants without any interruptions.

In an intentional islanding demonstration conducted at the end of 2019, the public utility company simulated a large-scale power outage. They disconnected the village of Bordesholm from the European utility grid for one hour via the synchronous tie breaker. Best of all, the 8,000 residents of Bordesholm did not even notice it.

All households, businesses and institutions were still supplied with electricity without any interruptions. However, the power no longer came from the European utility grid but instead from the stand-alone grid, supplied by 100 percent renewable energy.

PES: Are there any other projects SMA has powered that are relevant to this technology?

BR: At the turn of the century, SMA demonstrated a new way to power remote communities with a fully autonomous power supply system on the Greek island of Kythos. The system is an interconnected network consisting of a 100 kW PV array, 665 kW of wind turbines, 500 kW battery energy storage system and a diesel genset – thus harboring a new era of Sunny Island microgrids.

Almost a decade later, SMA surpassed yet another milestone when it powered up Tokelau, the first country in the world with 100% solar power. SMA replaced the constant hum of diesel gensets on the South Pacific atoll with the silent, clean and practically limitless fuel source, virtually eliminating the need for the small island nation to import diesel fuel. This saves its citizens more than $1 million a year.

The same engineering principles and fundamental grid-forming technology that powered the islands of Kythos and Tokelau can be scaled to achieve even more ambitious goals. For example, in 2017 on the Caribbean Island of St. Eustatius, SMA switched off the island's central diesel generators. This ushered in a new era for the local electric utility company with the complete commissioning of a 4.15 MW PV plant coupled with a 5.9 MWh battery energy storage system.

We have made substantial progress in just the last two decades. There are no technical barriers that prevent us from continuing to scale up this grid-forming technology, and very soon the cost curves will justify large-scale investment and deployment in more mainland networks. When this happens, the transition away from 20th Century fossil fuel powered base load generators and towards a completely renewable energy grid will be swift.

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