Power grids regain missing inertia with synchronous condensers

Power grids are evolving to become more decentralised while the penetration of renewable resources is increasing. These two factors are causing a steady decrease in the level of inertia essential to maintain stable operation. ABB's **Kristina Carlquist** explains how synchronous condensers can restore inertia in applications as diverse as urban networks and remote islands.

Spinning inertia, otherwise known as kinetic reserve, is vital for power grids. It helps to resist sudden changes, such as when a generator trips offline, so that the grid frequency remains within tightly controlled limits. Its role can be compared to the way a car's shock absorbers smooth out a sudden bump in the road to keep it safely on course.

Historically, power grids have relied on the inertia inherent in large, centralised generation plant to keep them in balance. However, as large fossil-fuel plants are decommissioned in favour of renewable energy, usually wind and solar power, there is an ongoing, dramatic reduction in the amount of spinning inertia available within the grid.

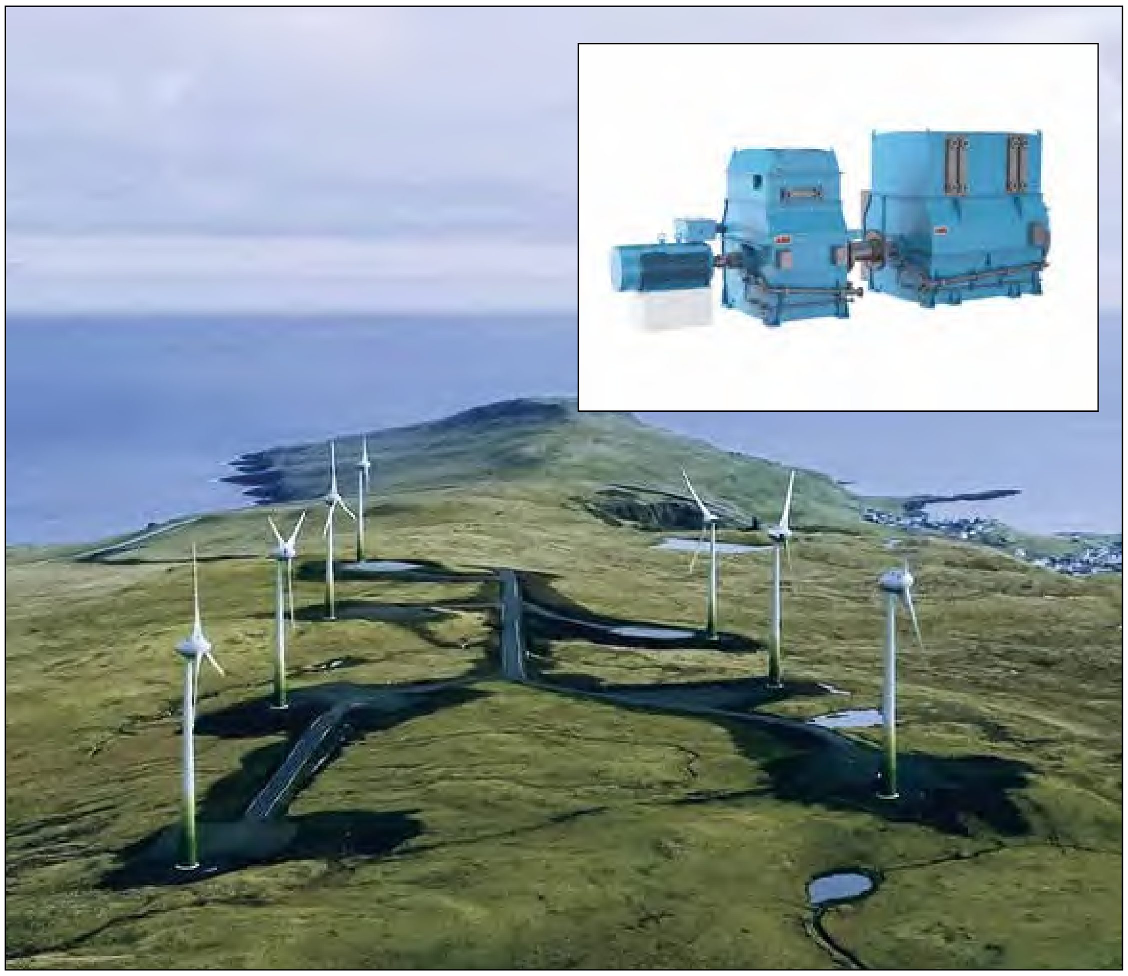
The loss of inertia presents a challenge for many types of public utility and private grids, including large networks serving urban areas, island networks and microgrids that power remote mining facilities. That is prompting operators to seek ways to restore their reserves of inertia. Many are finding the answer in the well-proven technology of synchronous condensers (SCs). These are large rotating machines that can restore physical inertia to grids to deliver instantaneous support. This ensures that stable operation can be maintained, irrespective of the upstream network voltage or frequency.

SCs appear similar to large motor and generators in design. The difference is that they are not motors since they do not drive anything. Equally they are not generators as they have no prime movers. The historic application for SCs was to produce reactive power to balance out highly inductive loads on the grid, like electric motors.

Fifty years or more ago, SCs would have been found in almost every power grid. But since then, their reactive power role has been replaced by power electronics equipment. There is now new interest in the capability of SCs to mimic the operation of large generating plant by providing an alternative source of spinning inertia.

SCs are able to both supply and absorb reactive power, delivering voltage support and dynamic regulation. This makes them a very cost-effective and reliable way to maintain power quality. A critical added advantage is that they also provide the fault current essential for the strengthening of a weak grid. This makes SCs a key enabler for the introduction of more renewables within a grid.

Normally, SCs are based on small or medium sized modules that can be strategically sited for optimal results. SC systems are tailored for specific locations, according to network studies. This enables the creation of pre-designed SC packages that are easy to transport, install, commission and integrate for a decentralised solution to increase grid strength and stability.



The Faroe Islands in the North Atlantic will rely on SCs to reach an ambitious 100 per cent renewable energy target by 2030 (inset: ABB synchronous condensers)

A typical size for the new generation of SCs is in ratings up to 80 MVAr of reactive power and 3-15 kV system voltage. When higher outputs are required then several modules can be linked together. This approach offers better redundancy and availability compared to deploying one large unit.

Some operators ask if it is possible to convert an old, unused generator they have into an SC? Technically, this is entirely possible and there are a number of these projects operating successfully. However, this may not always be the optimal solution. The reason is that the existing equipment will, by definition, be old technology and its actual condition unknown. Before starting a project, it is advisable to have the condition of the generator assessed thoroughly, such as by ABB's Lifetime Expectancy Analysis Program (LEAP) service. In any case, modern SCs are smaller and simpler, enabling them to be installed in any location. They also come with the benefits of modern control and communication technology.

The Faroe Islands in the North Atlantic will rely on SCs to reach an ambitious 100 per cent renewable energy target by 2030. They want to become the world's greenest group of islands and power utility, SEV, intends to use green electricity from hydropower, solar, wind, and potentially tidal streams. The initiative also holds economic benefits for the Faroes since they will no longer be dependent on expensive fossil-fuel imports.

A significant challenge for SEV is that switching off its current diesel-fuelled generating plant could impact the stability of the grid. Any grid instability could affect the fish processing and aquaculture industries that are a major contributor to the Faroese GDP. Furthermore, there are no power cables connecting the Faroe Islands to neighbouring countries, so external grid support is not available.

ABB is working with SEV to deliver SCs to keep the grid in balance. The first installation is at the 6 MW Porkeri Wind Farm on Suðuroy, the southernmost, electrically isolated island of the archipelago. This unit is currently undergoing trial operations and is scheduled to be fully up and running in 2022. Together with battery energy storage, the SC could enable 100 per cent of the island's demand to be met with wind energy at times with good wind conditions.

SEV has placed an order for a similar unit at Sund, close to Tórshavn, the Faroese capital on the island of Streymoy. The unit is scheduled to be online in 2023.

ABB is currently delivering a contract for Europe's largest renewable energy producer, Statkraft, to design, manufacture and install two high-inertia SC systems for the Lister Drive Greener Grid project in Liverpool, England. The innovative project will play a key role in stabilising the local grid to handle more wind and solar power. This will help National Grid meet its target of operating a zero-carbon electricity system by 2025.

This project is ABB's first anywhere in the world to feature a high-inertia SC configuration. This couples a 67 MVAr SC with a 40-tonne flywheel that increases the instantaneously available inertia by 3.5 times. The advantage of combining a mid-size SC with a flywheel is that it multiplies the inertia several times, while the losses will be much lower compared to installing the whole inertia as SC. This is also a cost-effective way of using up to two mid-sized SCs coupled together with the benefits of a high level of redundancy, increased inertia and greater controllability.

Decentralised solutions will be vital to help the networks of the future maintain grid stability and resilience. SCs are a well-proven solution that can be deployed to strengthen weak networks in remote areas. They offer a number of advantages such as inertia support for frequency stability, fault level contribution and voltage regulation. These are all functions that can be demanding to provide using power electronic systems on their own.

The need for SCs is set to grow significantly as grid operators seek new approaches to address their network quality issues and ensure reliability and continuity of supply. It is possible that over the next decade several hundreds of SCs might be deployed worldwide, either as stand-alone solutions or in combination with static power electronic devices.

To gauge the potential for SCs, the two Statkraft units in Liverpool will provide a total of more than 900 MWs (megawatt-seconds) inertia. For comparison, the UK has a current total of around 220 GWs (gigawatt-seconds). That means Lister Drive will provide about 0.5 per cent of the UK's total inertia. That contribution might seem relatively small. But it is certain that the traditional source of inertia from large generating plant will diminish, and SCs will be needed to fill the gap.

It is anticipated that the same pattern will be repeated globally. This is because existing SC installations are already playing a vital role in reinforcing networks in Australia, Canada and Scotland, where they support a wide variety of applications from solar power farms to remote mining operations.

The worldwide drive for decarbonisation will continue to gather momentum. That means synchronous condensers will become an increasingly important technology for maintaining grid stability.

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