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Dealing with the duck curve in Western Australia

How gas turbine based power plants have been modified to act as synchronous condensers, bringing increased stability and reliability to the Western Australian Grid

By Drew Robb

The Australian Grid has been heavily reliant on coal for decades. That is changing rapidly. An abundance of renewable resources are being introduced to the grid as coal plants are being steadily retired. According to Australian Energy Market Operator (AEMO), up to 90% of the National Electricity Market's (NEM) coal-fired power stations are projected to retire before 2035, and the entire fleet before 2040.

"As coal-fired power stations retire, renewable energy connected with transmission and distribution, firmed with storage, and backed up by gas-powered generation is the lowest-cost way to supply electricity to homes and businesses through Australia's transition to a net zero economy," said Daniel Westerman Chief Executive Officer, AEMO. 'New generation, storage and firming must be in place before coal power stations retire, and to meet Australia's growing demand for electricity."

Already this decade, 12.5 GW of new utility-scale generation and 1.3 GW/1.8 gigawatt hours (GWh) of storage has entered NEM and 490 km of transmission lines have been built. A further 20 GW of generation and storage and 2,090 km of transmission lines are progressing from planning to delivery. As more renewables are added, there is a need to support them with sufficient system stability and inertia. Hence, many regions of Australia are adding synchronous condensers to stabilize voltage levels and support the performance and reliability of the grid.

"In recent years, there has been an increased focus on the need for synchronous compensating functions worldwide," said Jean-Bernard Gross, Technical & Sales Area Manager for Australia at gearbox manufacturer Flender-Graffenstaden. "This is in line with the worldwide push for renewables integration and the need for increased system inertia and system strength."

The Southwest Integrated System of Western Australia has a network of over 7,800 km of transmission lines. Synchronous condensers are needed to add system strength in the face of coal plant retirements as well as to increase the efficiency of the transmission network. Courtesy of Synergy.

The Western Australian Picture

Western Australia (WA) covers about a third of the Australian landmass. Most of it is empty. Two million of the 2.6 million people in the state are located in the Perth metro region in the southwest.

WA's Southwest Integrated System (SWIS) includes Perth but reaches far to the north, south and east to take in a few distant population centers. Western Power owns and operates the transmission and distribution infrastructure within the SWIS. Synergy is a major generator and retailer of electricity in the SWIS, serving over one million residential, business and industrial customers. Western Power and Synergy are owned by the WA Government. Due to the enormous distances involved, the NEM grid in the eastern side of Australia is not connected to WA.

Electricity in SWIS is generated from a variety of sources. Coal plants, natural gas-fired generators, waste-to-energy plants (such as landfill gas), wind farms, and solar farms are all significant contributors. Installed rooftop solar is now the biggest single source of generation capacity during the middle of the day. More than 30% of homes in SWIS have rooftop photovoltaic (PV) systems. The rest of the time, the region relies largely on coal and gas, though wind power is steadily adding to its share of the total. As a result, SWIS now has a duck curve that is similar to the phenomenon first noted on the California grid.

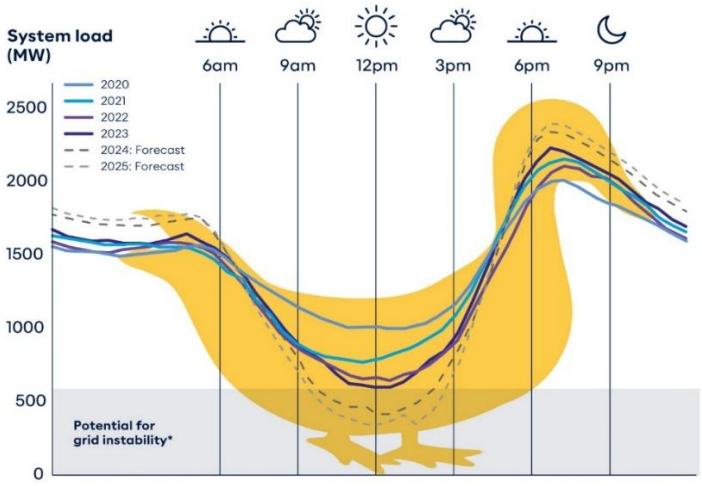
Decarbonizing Western Australia

The state government has established PoweringWA to coordinate the delivery of the new electricity infrastructure needed to decarbonize and strengthen the SWIS grid. As well as embracing renewable energy, the plan includes a more reliable transmission infrastructure that can bring wind and solar power to load centers. For example, the Merredin Solar Farm is being built about 260 km east of Perth. It comprises 360,000 solar panels and will generate 281GWh of electricity annually.

In addition, PoweringWA is adding more battery energy storage systems (BESS). Synergy has already deployed 100MW/200MWh of BESS in the Perth area, known as Kwinana Big Battery, enough to power 160,000 homes for two hours. This is all part of Synergy's goal to reduce carbon emissions by 80% by 2030, compared to 2020 levels and achieve net zero by 2050.

The latest forecast calls for 4,000km of new transmission lines and around 50GW of new renewable electricity and storage infrastructure to support increased demand over the next 20 years. Wind, solar and BESS, however, won't be enough to fulfil expected demand if coal is to be phased out simultaneously. Hence, investment in natural gas infrastructure continues. Current planning anticipates that additional gas generation will be required to provide firming to the energy system. Accordingly, existing gas plants will benefit from a 10-year exemption from new emission thresholds. Australian federal and state governments have shifted policy in recent years to make life less difficult for gas plants. This originated from the realization that they are required to maintain reliability. Thus, efforts are underway to entice gas plant owners to not prematurely exit the market for commercial reasons or due to regulatory pressure.

"Risks to the transition are emerging and must be carefully managed," said Westerman.



Abundant solar during the day means the bulk of the electricity in the Perth region is provided by PV. However, the mornings and late afternoons see a switch to conventional power sources.

Low Load Challenges

With the Perth metro area being dominated by rooftop solar, low load periods have become a real issue. Demand for grid electricity drops dramatically as the sun moves higher in the sky. With so many peaks and troughs in grid demand, maintaining a stable and reliable electricity supply and avoiding blackouts is a concern.

As in other duck curve regions like California, peak usage periods occur in the early morning and late afternoon/evening when solar isn't available in sufficient quantity. The WA power system needs its existing coal- and gas-fired generators to be available at these times to provide a steady and reliable flow of electricity.

Synergy and other utilities are campaigning for people to shift as much energy consumption to the middle of the day to use up available solar energy and lower demand during peak periods. Synergy is also operating virtual power plants (VPPs) which can better adjust and respond to the needs of the electricity system. As part of this, rooftop solar and other distributed energy resources (DERs) are being incorporated into the power system in various ways.

The Emergency Solar Management (ESM) is one example. It seeks to add stability when there is a high amount of solar energy being generated from rooftop solar systems, and not enough grid demand. At such times, remote management of household solar is needed to prevent potential outages. For a few hours, a Synergy customer's solar can be remotely turned off, and then on again when the emergency is over.

These measures certainly help. But they are not enough to keep the grid stable. What has been realized is the critical role played by rotating assets such as steam turbines and gas turbines in adding inertia, stability, and support to the grid.

Pinjar Power Station

The policy position in WA is to continue to add renewable resources at a high pace, accelerate transmission network improvements, and phase out coal while encouraging investment in improvements to existing natural gas facilities as the best way to manage the energy transition.

The Pinjar Power Station near Perth is one example. It provides peaking power when needed as well as grid stability. Located approximately 50 km north of Perth, it consists of nine GE Vernova gas turbines – six Frame 6s and three Frame 9s. They are mainly called upon during hot summer days, in emergencies, and at times in response to the morning/late afternoon duck curve pattern. The plant has a capacity of 576 MW. It is operated by Synergy. The turbines can be online and available to the grid within 15 minutes when requested.

In addition to peaking power, several of the units are installed with synchronous self-shifting clutches from SSS Gears Ltd. of Sunbury, UK to provide system stability and grid support. These clutches are designed so that when the turbine is moving faster than generator, the clutch automatically is engaged, and the turbine drives the generator. Once the generator is synchronized to the grid, the turbine slows down and the clutch automatically disconnects from the generator, turning it into a synchronous condenser. These SSS clutches are incorporated into the load gears made by Flender-Graffenstaden of Strasbourg, France. This synchronous condensing upgrade provides a number of benefits to the grid.

Reactive power provided by a synchronous condenser offers voltage stability. While real power accomplishes useful work form voltage and current, reactive power (measured in volts amperes, reactive or VARs) provides much needed voltage support. In addition to inhibiting the possibility of a catastrophic voltage collapse, reactive power increases transmission efficiency and boosts the amount of real power that can be transmitted over a line.

Due to the large distances involved in WA, plenty of reactive power support is needed. With coal plants retirements moving forward, the need for system stability is only going to increase. Synergy owns two coal power stations, both of which are scheduled for closure. The 854 MW Muja plant and the 340 MW Collie plant are both in the SWIS region about 200km south of Perth. Collie will be closed by 2027 while Muja will be shuttered in 2029.

With so much system inertia coming offline in the region, the work of the generators at Pinjar becomes more critical. Hence, Synergy has placed an order for a critical spare load gear and SSS Clutch to ensure that unexpected faults, failures, or routine maintenance do not diminish the ability of the system to supply real and reactive power.

“There has been an increasing requirement from the grid operator to validate the availability of the synchronizing condenser function and hence the requirement for the purchase of the critical spare,” said Gross of Flender-Graffenstaden. “We received an order for a replacement gearbox at Pinjar with an SSS clutch to act as a critical spare gear box for the fleet in Pinjar with synchronizing condenser functions.”

Several generators at the Pinjar Power Station were retrofitted with size 194T SSS Clutches that were incorporated into the Flender-Graffenstaden load gears to provide reactive power and system support.

The addition of clutches improves the value of the gas turbines. Instead of them sitting idle most of the time, the clutch enables them to provide ancillary services to the grid. Depending on the region, these services are incentivized by the grid operator. Gross reports that Flender-Graffenstaden has received an order for 16 more turbomachinery gear boxes recently, all with the SSS Clutch installed.

According to Nicholas Bellamy, Applications Manager at SSS Gears Limited, all six gas turbine generators at Pinjar include SSS Clutches within their main load gearboxes. Clutches were originally added only to enable synchronous condensing revenue by providing reactive power when the gas turbines are shut down.

“Local grids have now realized the importance of electrical inertia, which is generally reducing as more rotating generation is becoming replaced by solar PV and other renewable technologies,” said Bellamy. “The added flexibility courtesy of the SSS Clutch qualifies the asset for any electrical inertia payments which local grids may authorize in due course, in addition to the reactive power payments, without the requirement to operate the gas turbine.”