POWER

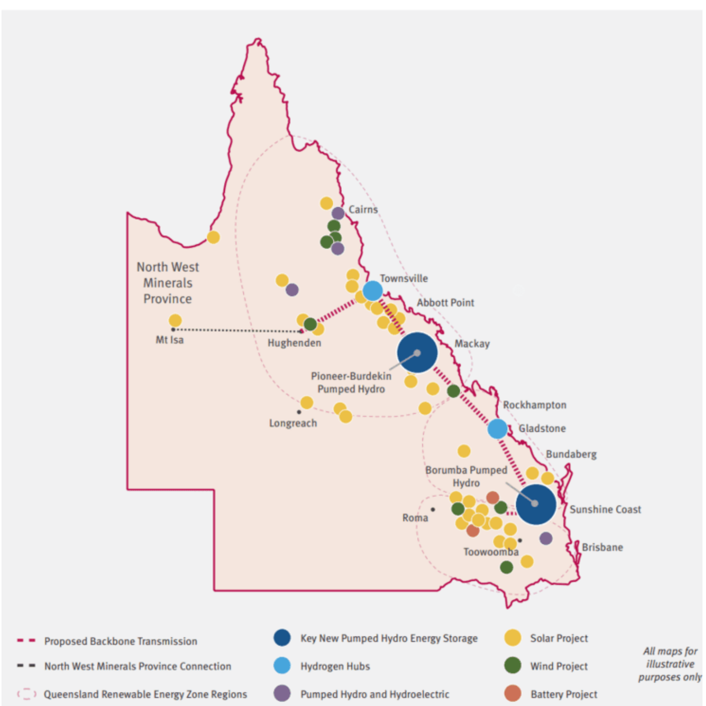
The Queensland SuperGrid Marries the Old and the New

By Drew Robb

The Australian state of Queensland is in the midst of a rapid changeover from coal to renewables. From 70% coal generation today, it is switching to 70% renewables by 2032. This means phasing out 8.1 GW of coal and some of its 3 GW of gas generation, while simultaneously building at least 25 GW of large-scale wind and solar, and 7 GW of rooftop solar, in less than a decade.

What is refreshing about this grand Queensland plan is that it is infused with a healthy dose of reality. As well as 3 GW of battery storage, regulators and grid planners are underpinning this vast renewable investment with plans for substantial build-out of transmission networks, as well as adding 6 GW of pumped-hydro storage (PHS) and 3 GW of gas generation. Government reports also stress the need to support wind and solar assets with large amounts of synchronous condensing to provide system strength, grid stability, and reactive power.

Siemens Energy are among those called in to help modernize existing power plants and bring them up to the latest standards for low-emission operation. Rotating assets are also being repurposed to operate as synchronous condensers. A gas turbine plant in the city of Townsville, for example, at the end of the transmission line in the north of the state is part of a complete grid overhaul known as the Queensland SuperGrid (Figure 1).



1. The proposed Queensland SuperGrid. Courtesy: Government of Queensland

“Australia needs strong grids to meet its 2030 decarbonization goals,” said Darren John Garwood, head of Field Sales Pacific Region, Gas Services, Siemens Energy. “RATCH-Australia Corp.’s Townsville Power Station [TPS, Figure 2] will contribute to grid stability by converting its gas turbine and generator to Hybrid Rotating Grid Stabilizer [RGS]. It can instantly switch from power generation to grid stabilization mode, preventing potential blackouts.”

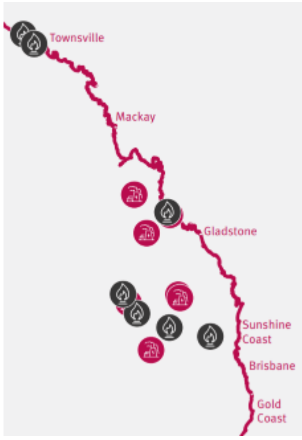
2. The Townsville Power Station in Queensland, Australia. Courtesy: Siemens Energy

Queensland SuperGrid

Phase One of the SuperGrid has already begun with work underway in all three Queensland Renewable Energy Zones (QREZs). This phase adds an initial 6 GW of renewable capacity. Funding is also in place for two PHS facilities of 2 GW, as well as four new high-voltage (up to 500 kV) backbone transmission projects to connect PHS assets and renewable resources to demand centers.

The northern town of Townsville lies at the heart of much of this work. Stronger transmission lines are being installed. A 750-kilometer (km), 500-kV line will connect it to a new PHS facility and other energy assets to the south. Another 370-km, 500-kV line will connect to the massive Hughenden wind and solar complex to the west. There are also tentative plans to extend that connection to the North West Minerals Province at Mount Isa. All of this will allow renewable energy to be stored and transported when and where it is needed around Queensland. This is a key factor in unlocking the renewable energy resources at Hughenden.

There is concern, however, about the speed of transition and the possibility of energy security risks. Planners realized that renewable energy generation must be complemented with storage and firming power to ensure that intermittent supply matches demand. They are operating on a best-case combined capacity factor of 33% for wind and solar, that is, it would take at least 24 GW of renewable generation to supply the equivalent energy of 8 GW of current coal-fired capacity (Figure 3).



3. Queensland's coal-fired and gas-fired generators have been predominately located near the resource basins (coal-fired generators are the red icons located near coal fields and gas-fired generators as grey icons located on gas fields). In Queensland, there is about 8.1 GW of coal-fired generation made up of 22 units at eight power stations. There is also about 3 GW of gas-fired generation. In 2021–2022, the grid-supplied maximum demand was 10.1 GW. Courtesy: Government of Queensland

System strength is another major concern. The Australian Renewable Energy Agency (ARENA) published a report highlighting requirements for system strength and inertia services to manage power system security, which said: "Retirement of fossil-fuel generation, particularly large coal-fired power stations, is projected to reduce both system strength and inertia. The international energy transition and adoption of more inverter-based renewable generation is driving international demand for large synchronous condensers (SCs). One possible solution is to convert existing fossil-fueled generators, which are synchronous machines, into SCs. At face value, this should provide a cost-effective way of providing the required security services."

This is the approach favored by ARENA for Australia. It said in its report, "Our analysis indicates that repurposing generators as SC can provide a viable solution for delivering the required security services. This approach can be used in combination with new SC investments to mitigate the risk of insufficient services."

The agency believes re-purposing generators as synchronous condensers will:

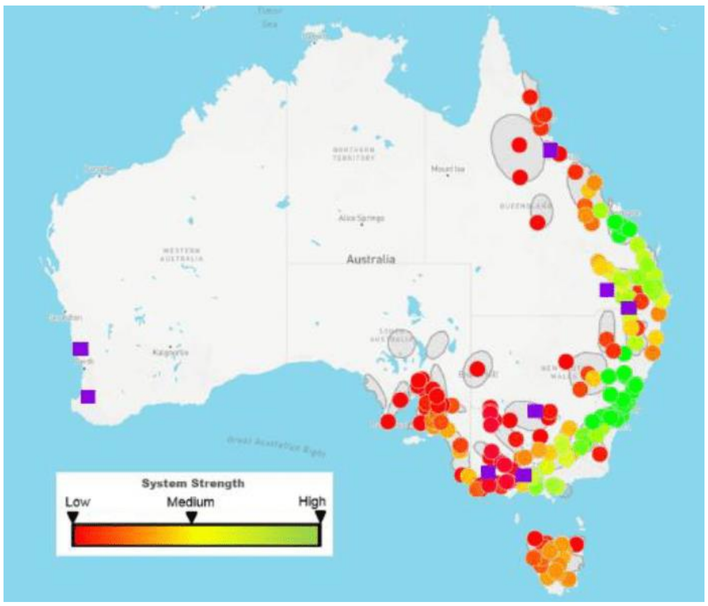
- Stabilize the voltage and thus provide system strength.
- Contribute inertia.
- Provide a source of reactive power for voltage control.
- Contribute positively to fault levels.
- Lower costs compared to purchasing new synchronous condensers.

This research, as well as detailed modeling by grid operator Powerlink and analysis from Ernst and Young, led to a conclusion in the SuperGrid Blueprint as follows: "[Gas-fueled generators] represent the lowest capital cost per megawatt way to provide backup and peaking generation to a renewables-based system," the report says. "Strategic use of low capital cost gas-fuelled plant (such as gas turbines or gas reciprocating engines using either gas or hydrogen blends in the short-term and/or 100 per cent renewable hydrogen in the longer term) may be an effective way to reduce the cost of meeting Queensland's total storage/peaking capacity requirements."

Existing gas generation assets are viewed as the best way to reduce the price tag for grid stability measures. The SuperGrid Blueprint outlines critical steps to maintain system strength and security such as introducing new standalone synchronous condenser machines, converting existing generators into synchronous condensers, and adding large-scale battery storage facilities. The Australian Energy Market Operator (AEMO) is investing in at least two greenfield synchronous condensers (estimated at $80 million each, according to the report). As well as high cost, the lead times for such equipment are lengthy.

Townsville Modernization

With the rising share of renewables within Australia's energy mix, in tandem with steady retirements among traditional power plants, grid stability from rotating equipment has decreased. This is particularly apparent in areas such as north Queensland (Figure 4).

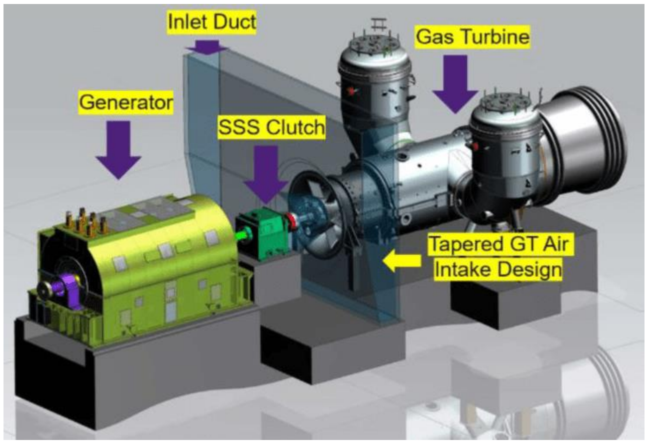


4. Low system strength has been identified in the north and central parts of Queensland. Courtesy: AEMO

Hence, AEMO requires grid operators like Powerlink to provide a minimum fault level, procure system strength, and add inertia as part of any transmission modernization efforts. System strength ensures the power system can maintain a stable voltage waveform, even after a disturbance. Inertia allows the power system to resist large changes in frequency arising from an imbalance in supply and demand after a disturbance.

Under the new framework, parties that submit an application to connect must choose to either remediate their system strength impact or pay for their use of system strength resources procured by Powerlink. This requirement led Powerlink to meet with TPS owner RATCH-Australia to discuss options. TPS is located in a suburb of Townsville. It includes a 160-MW Siemens Energy SGT5-2000E gas turbine and an 82-MW heat recovery steam generator (HRSG).

After reviewing eight possible solutions, Powerlink concluded that the least-cost option to address system strength services was the addition of a clutch from SSS Gears Ltd. to the shaft between the Siemens Energy gas turbine and the generator (Figure 5). Siemens Energy has been contracted to convert the existing Siemens Energy SGT5-2000E gas turbine to a hybrid RGS during a scheduled major outage in 2025.



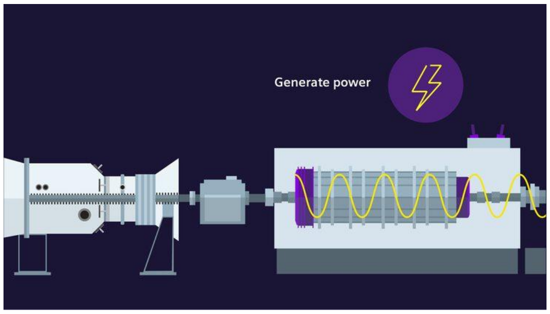
5. Conversion of the Siemens Energy SGT5-2000E gas turbine entails mainly the installation of a clutch between the gas turbine and its generator. Courtesy: Siemens Energy

"Replacing the intermediate shaft of the gas turbine with a Synchro-Self-Shifting (SSS) Clutch will provide an instantaneous switch from power generation to synchronous condenser mode," said Garwood.

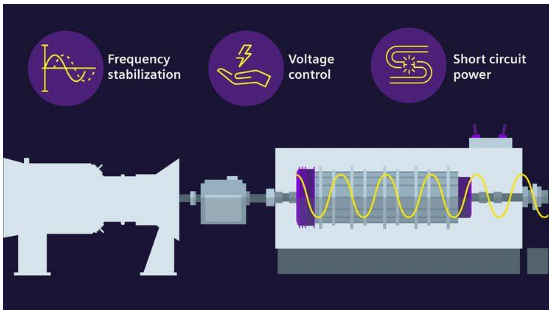
When in synchronous condenser mode, the hybrid RGS unit can provide rotating inertia and short-circuit power without the need to produce power and is calculated to provide a short-circuit contribution of approximately 350 MVA to 400 MVA. The electrical inertia while operating in the grid stabilization mode is calculated to be about 250 MW-seconds (MW-sec) and about 1,000 MW-sec while operating in power generation mode. Plant owner RATCH-Australia gains a new revenue stream from providing these additional grid services.

This approach is far less expensive than purchasing a standalone synchronous condenser as it takes advantage of existing equipment. Minor upgrades add a small amount to the cost, but the lead time is relatively quick and the upgrade can be accomplished during a scheduled gas turbine maintenance outage window. Further, RATCH-Australia can switch the unit from synchronous condensing mode back to power generation mode so the facility can provide peaking power whenever there is a need to make up for a lack of renewable energy.

"This modification is cheaper and faster than a greenfield dedicated synchronous condenser and provides our gas turbine customers with an additional revenue stream," said Garwood. "It allows one unit to fulfill two roles: To operate as a power generator as it always has [Figure 6, clutch closed]; or operate as a synchronous condenser when power generation is not required [Figure 7, clutch open and gas turbine not operating]."



6. Normal peaking operation with the clutch engaged and the gas turbine driving the generator to produce power for the grid. Courtesy: Siemens Energy



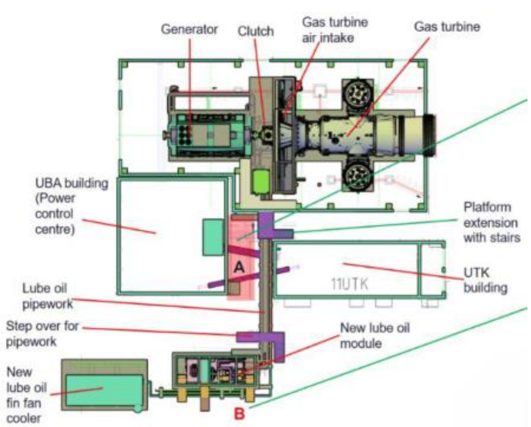
7. Synchronous condensing mode will disengage the SSS clutch, allowing the generator to rotate at 3,000 rpm without the gas turbine to provide stabilization services for the network (inertia, voltage control, and short circuit power). Courtesy: Siemens Energy

Gas Turbine Conversion Steps

Garwood noted that the choice of a converted SGT5-2000E was made by RATCH-Australia for several reasons, which include:

- Lead time versus alternative greenfield solutions, as stability services are needed by 2025.
- Cost competitiveness versus greenfield solutions.
- Location.
- Plant flexibility offering both generation and synchronous condensing capabilities.

To prepare TPS for this new role, a series of conversions and modifications are being made to the turbine-generator (Figure 8): An SSS Clutch is being installed between the turbine and generator; a new tapered air inlet design will facilitate optimum placement of the SSS Clutch; the foundation needs to be extended to the air intake module; and new lube oil tanks are being added (Figure 9). Given the additional capacity required for the clutch, a new fin fan cooler will need to be installed (Figure 10). In parallel, Siemens Energy is conducting a major inspection of the turbine including de-stack/re-stack.

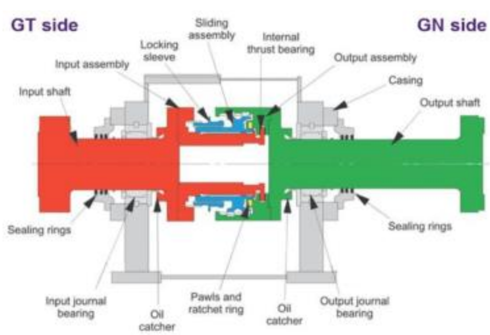


8. Layout of the modernization efforts being carried out at TPS. Courtesy: Siemens Energy

9. The existing lube oil tank is directly under the intermediate shaft. A new tank with enclosure needs to be installed outside the turbine hall. Courtesy: Siemens Energy

10. The existing lube oil fin fan cooler is undersized so a new one is needed. Courtesy: Siemens Energy

"The SSS Clutch [Figure 11] is being manufactured in the UK, shipped to the site, and installed on the intermediate shaft between the gas turbine and generator on new foundations," said Garwood. "Once installed, the capability exists for frequent changes in operating mode between gas turbine and synchronous condenser and back."



11. A diagram of a direct-acting encased SSS Clutch for the gas turbine at Townsville. Courtesy: SSS Clutch

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