Applications of BESS with Grid Forming Capability

Background of the Australian National Electricity Network

Australia is undertaking a major energy transformation by converting to renewable generation. Some states registered already 68 % of renewables penetration.
As a result, a number of network operating stability and security have been noticed ranging from state to state but in summary:

- Higher steady state voltage
- Poor ability to maintain a stable voltage waveform following system disturbances
- Low short circuit ratios across the network and started to limit the amount of renewable generation.
- Reduced system inertia
- Protection settings across the whole network had to be reviewed and altered in several locations.
- Network events would cause the loss of multiple generators and trigger overloading/tripping of the interconnectors resulting in high rates of change of frequency (RoCoF). The surviving generators and existing load shedding systems could no longer adequately respond.

To date in Australia 3700 MW of coal fired power stations have been de-commissioned. More coal and gas power stations are scheduled to be decommissioned between 2023 and 2035. Power stations - scheduled to be de-commissioned - are installing large scale BESS in the power station yards
According to AEMO:

- 30 GW of large-scale BESS to replace 63 % of coal fired generation by 2040
- 85 BESS applications are in the planning phase

These BESS have the role to improve the system security by improving the system inertia and the system strength and black start capability.

BESS will be installed in conjunction with the installation of synchronous condensers. The BESS sizing and services will be different from case to case and depending on the geographical location and the connection point.
Batteries provide energy, however network interface and power exchange is via power electronics (inverters):

- BESS can provide both active and reactive power (absorption and injection),
- Entirely dependent on batteries charge level
- BESS are much faster than the electro-mechanical systems
- Can provide system inertia. Inertia – programmed (i.e., not inherent) and generally lower than the one from the synchronous generators
- Can improve system strength

The key difference between various BESS solution is their ability to provide system strength by providing system inertia, and the ability to provide black start and system restart ancillary services (SRAS) support.
BESS are connected in substations as transmission network support or in solar and wind farm energy hubs and used as integrators for the intermittent generation.

Recently BESS have been successful integrated in solar farms using a DC-DC converter to connect the energy storage to the network via the solar farm inverters.

Currently there are two types of BESS installed in Australia:

1. Using Current Source Inverters
2. Voltage Source Inverters

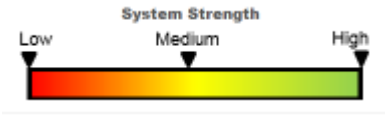
Typically, Current Source Inverters are used for Solar and Wind Farm applications as Grid Following Inverters.
Typically, Voltage Source Inverters are used as Grid Forming

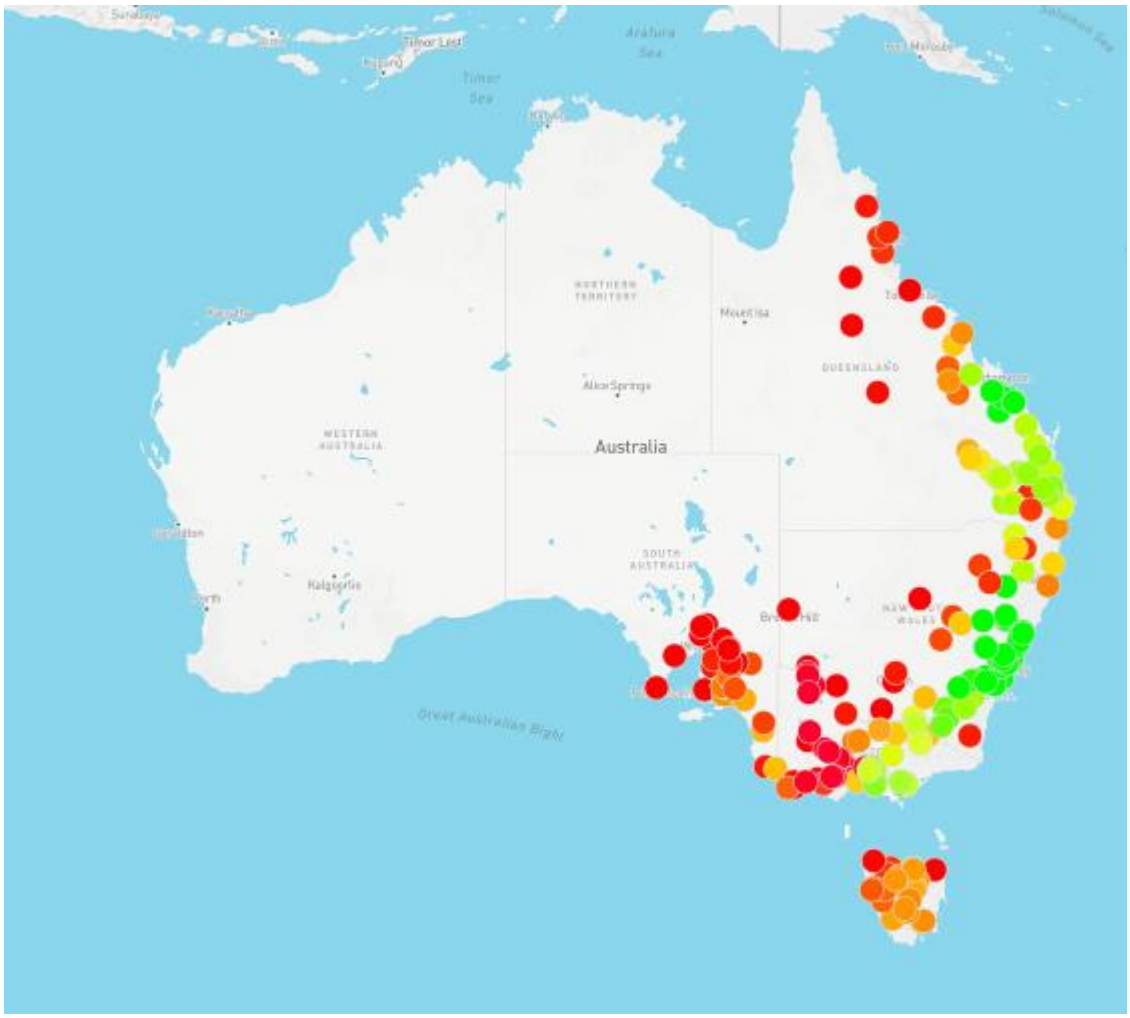
Only BESS using grid forming inverters can provide system inertia, black start and SRAS. Grid forming BESS can be modified to create a Virtual Synchronous Generator (VSG) by overlaying additional mathematical functions to the grid forming inverters mathematical model.

These additional logical blocks will essentially provide the power electronic inverters with synchronous machines like coefficients such as: virtual inertia, friction coefficient, field inductance, and mutual inductance.

Federal government has recently awarded $ 100 M sponsorship to encourage BESS suppliers demonstrate their equipment ability to provide grid forming inverters. This program aims to develop BESS solutions with grid forming capability, ability to conduct R & D and to share knowledge.

The placement of the BESS with grid forming capability will become critical to the Australian continuous energy transformation as more and more regions will become affected by low system strength, as shown in the AEMO map below.





To date there is only one operational large-scale BESS that has grid forming inverters and has proved islanding and black start capability.
In addition, a second large scale BESS has recently completed a two-year trial/development period to test its ability to provide synchronous inertia to the network. It has recently been given approval by AEMO to provide this functionality on an ongoing basis.

Conclusion

This presentation aims to present the current knowledge and experience with BESS using grid forming inverters that proved to address in Australia system strength issues. By 2040 68 % of coal-based power stations will be replaced by BESS. It is therefore expected that BESS solutions to become mature as more and more systems achieve commercial operation.

Submitted,

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