Australian experience with grid forming inverters

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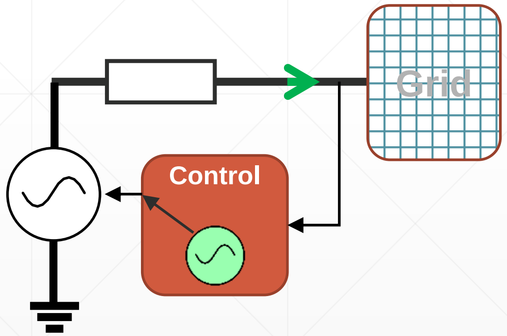
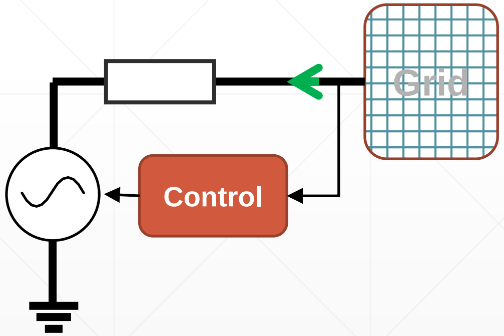
Types of generation technologies

Traditional inverters
- Require sufficient number of synchronous machines for their stable steady-state and transient operation.

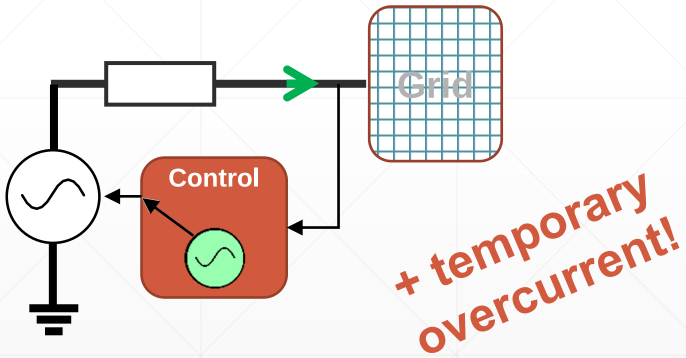
Grid-forming inverters
- Do not rely on synchronous generators for their stable operation.
- Require sufficient storage and fault current capability when used as a black starter in addition to default features of grid-forming inverters.



Synchronous machines
Always has own internal reference



Traditional inverters
Reliant on grid reference

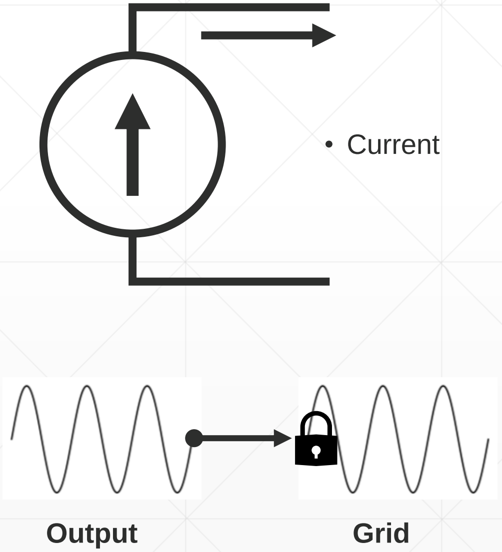


Grid-forming inverters
Has own internal reference plus grid reference

Evolution of grid-forming technology

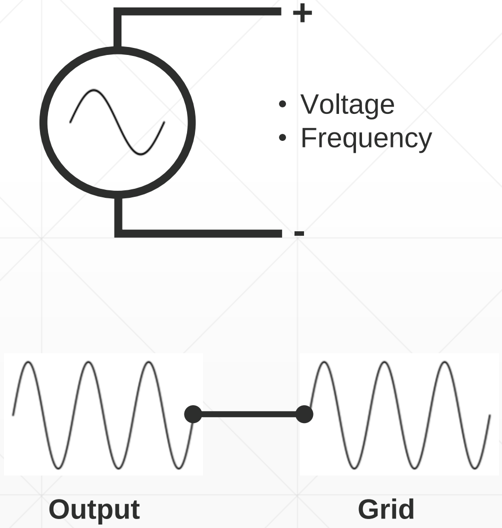
Grid Following

Current source converter



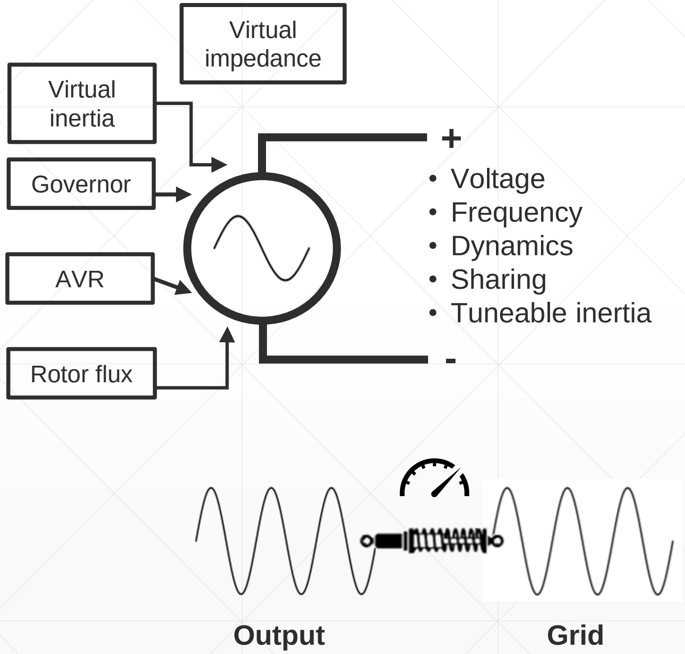
Grid Forming (early generation)

Voltage source converter



Grid forming (example of current generation)

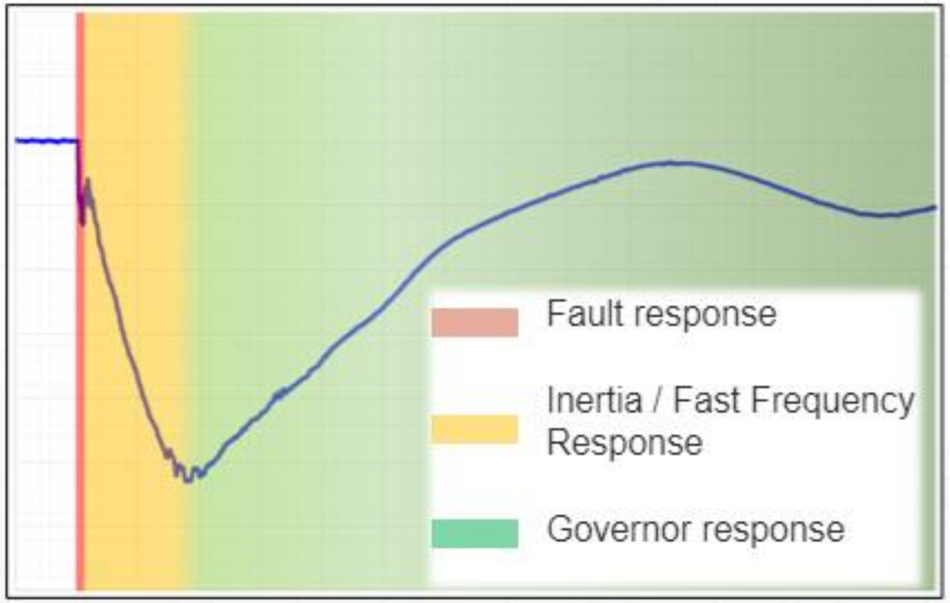
Grid forming inverter + Generator dynamics



- Almost all existing and proposed installations are based on the virtual synchronous machines design, however, other design types such as droop (as per NREL classification) have been recently proposed.

Virtual inertia vs fast frequency response

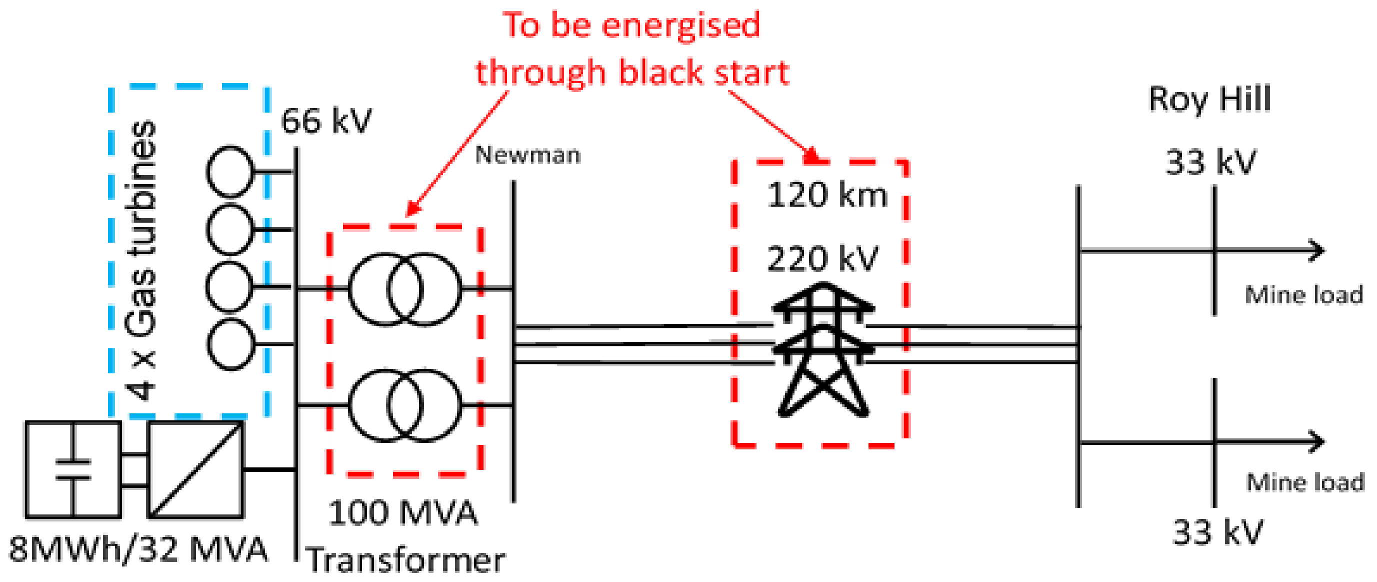
- Virtual inertia: grid forming inverters emulating the response of mechanical inertia provided by synchronous machines
- Fast frequency response (FFR): grid-following or grid-forming inverters providing a much faster governor like response to assist in frequency recovery.
- FFR is more universally needed than virtual inertia.
- Could there be any unintended consequences of prioritising virtual inertia against FFR?



Existing applications

- Black start in off-grid applications or embedded networks
- Connection at remote parts of the network without the need for ancillary equipment such as synchronous condensers
- Standalone islanding operation in the event of loss of normally connected main grid
- Seamless disconnection from the main grid and reconnection when required
- Additional fault current contribution for correct operation of protective relays
- Virtual inertia

Example 1: black start provision



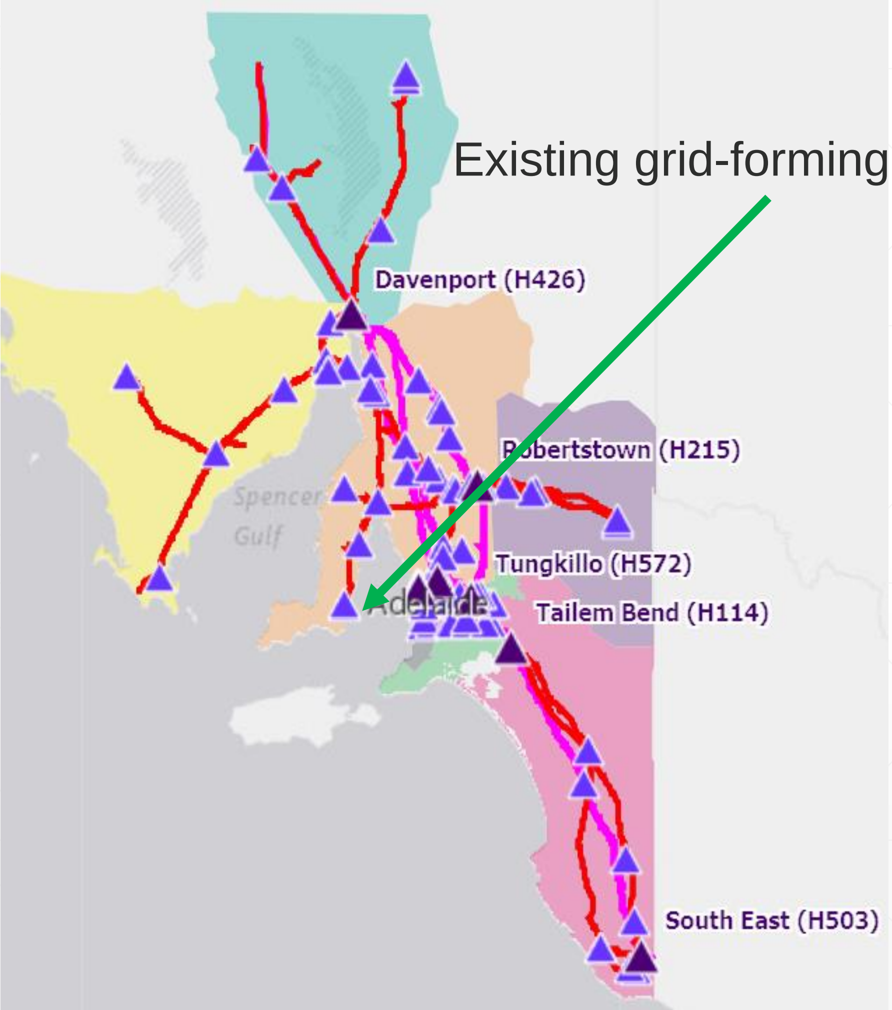
Source: Hitachi ABB Power Grids

- Grid-forming BESS is used as the black starter for larger synchronous generators at a mine.
- The same concept has been proposed for restarting larger thermal plants with several hundreds MVA, i.e. avoiding the need for a diesel unit or small gas turbine
- Only one proposal for grid-forming BESS to directly restart the transmission network.
  - High MWh requirement is a key consideration.

Example 2: Microgrid applications

Existing grid-forming BESS

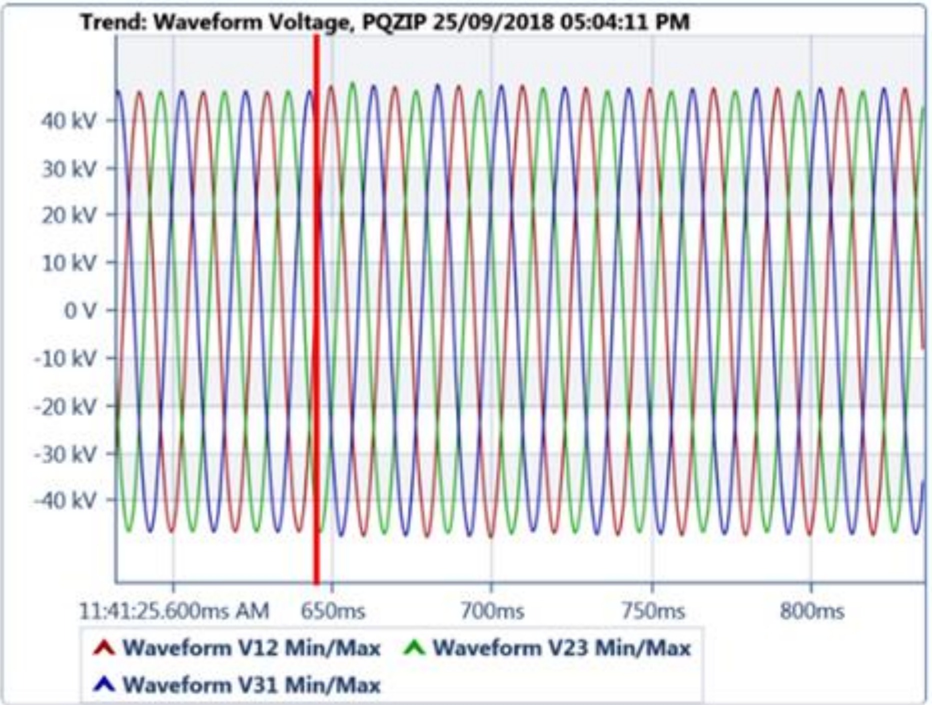
Proposed grid-forming BESS

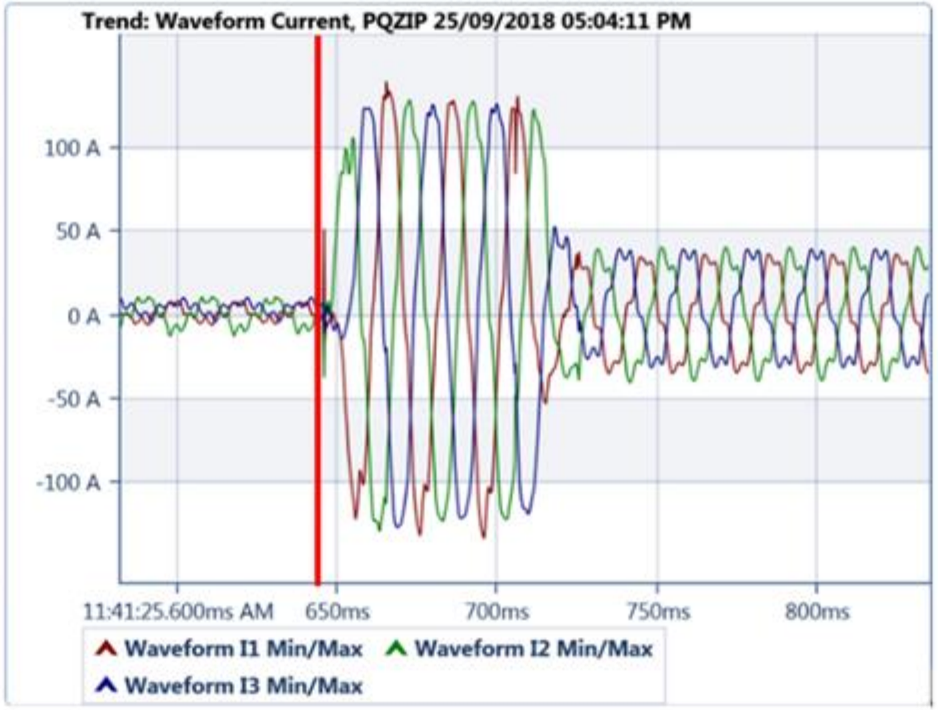


South Australia network map: Source ElectraNet

New South Wales network map: Source TransGrid

Example 2 (cont'd): Microgrid and high fault current capability





Source: Hitachi ABB Power Grids

- Seamless operation between grid-connected and islanded operation without synchronous generators.
- Allowing stable operation of a grid-following wind farm once islanded together.
- Provision of additional fault current (up to 3 pu) for successful operation of network protective relays.
- The first grid-connected grid-forming BESS in Australian power system.

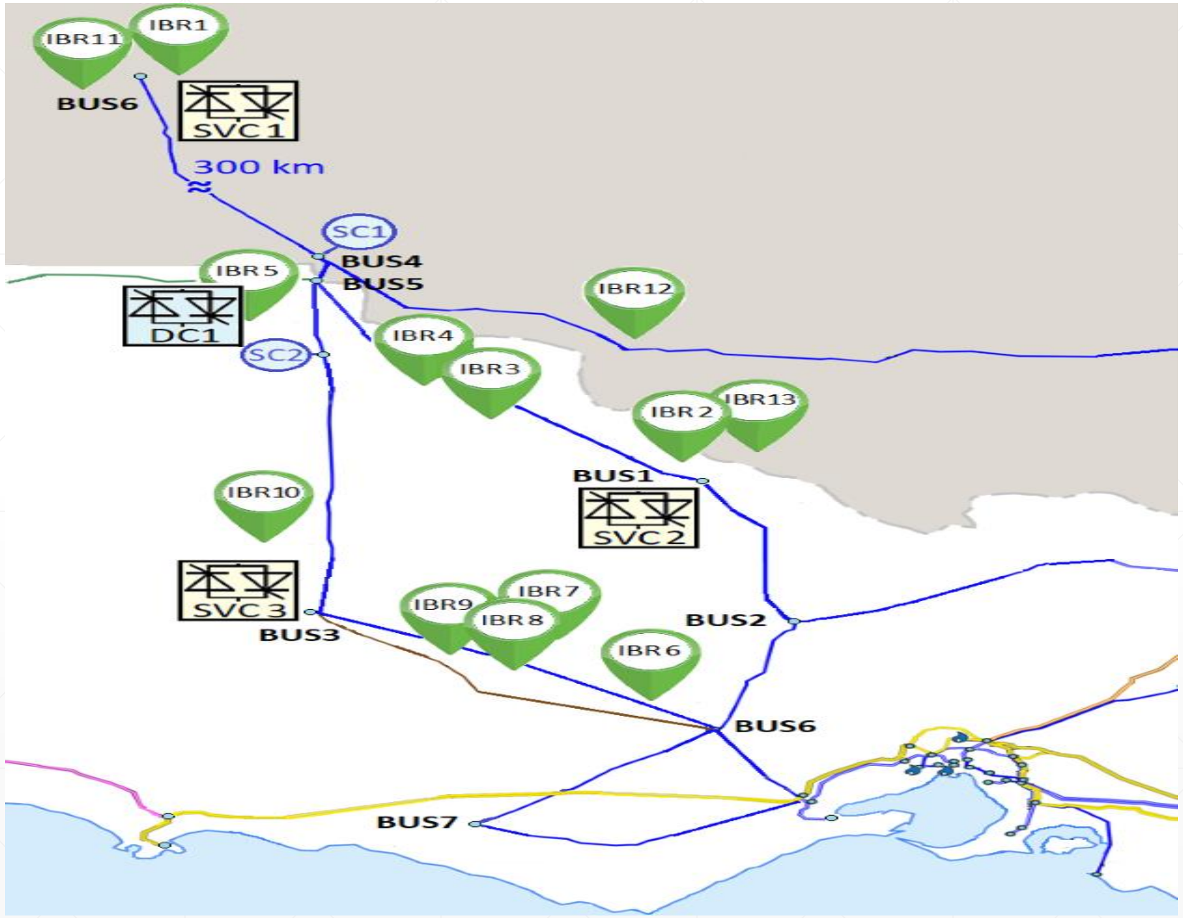
Example 3: Virtual inertia

Hornsdale Power Reserve

- Example 1: Existing grid-following BESS was enabled with updated grid-forming software to provide virtual inertia (150 MW/193.5 MWh)
- Example 2: 50 MW/75MWh currently under construction at Sydney metropolitan
- Example 3: Proposed 50 MW/100 MWh currently at a remote grid-connected site
- Locations vary from metropolitan areas to the most remote parts of the network

Emerging application: system strength enhancement

- System strength enhancement for nearby grid-following IBRs is one of the most desired characteristics in Australian power system
- Reducing the risk of gird-following IBR curtailment under low system strength conditions
- Early investigations demonstrate positive contribution of grid-forming IBRs to replace synchronous condensers



Example of an area where system strength enhancement is highly desired