Practical Experiences and Lessons Learned from Connections and Planning Considerations of Grid Forming Inverters in Australia

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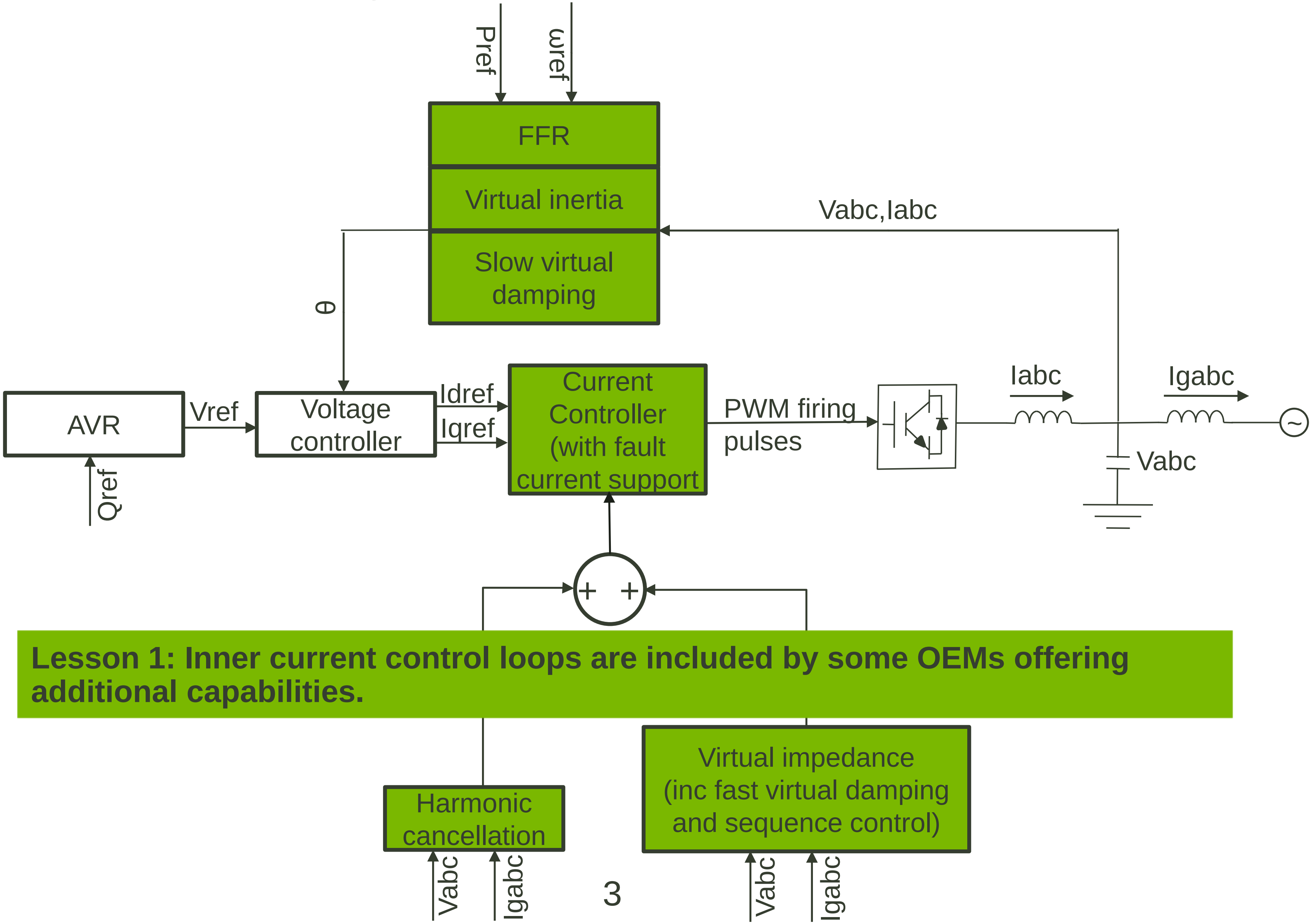
Outline

- Potential capabilities
- Practical performances
- Modelling
- Planning considerations
- Perceived risks

This presentation accounts for our learning from four grid-forming BESS projects.

Grid forming inverters



Lesson 1: Inner current control loops are included by some OEMs offering additional capabilities.

What is common between grid-following and grid-forming BESS?

- Frequency support inc. FFR
- Voltage control
- Damping of electromechanical oscillations
- Fault ride-through
- Harmonic cancellation

Lesson 2: An inverter does not have to be grid-forming to provide useful grid support capabilities.

Key performance observations

System strength support

Inertia

Harmonic cancellation

Most outstanding contribution to date: Slide 6

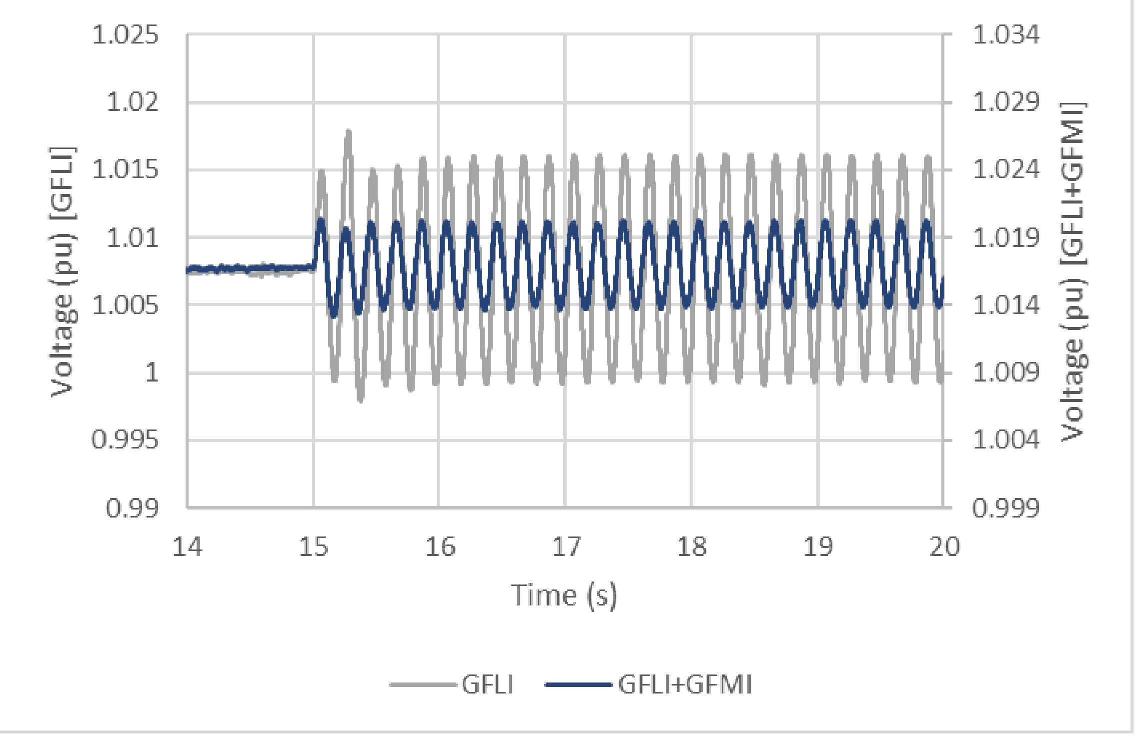
Conflict between FFR and inertia

Fault-ride through

Lesson 3: There are often trade-offs between various grid-support capabilities due to current limited nature of all inverters. Care is needed to avoid a secondary problem.

System strength support (1)

- Post-disturbance sub-synchronous oscillations are one of the key manifestation of low system strength conditions in Australia.
- Not only a grid-forming inverter does not have any susceptibilities, it will help reducing the oscillations on grid-following inverters.



System strength support (2)

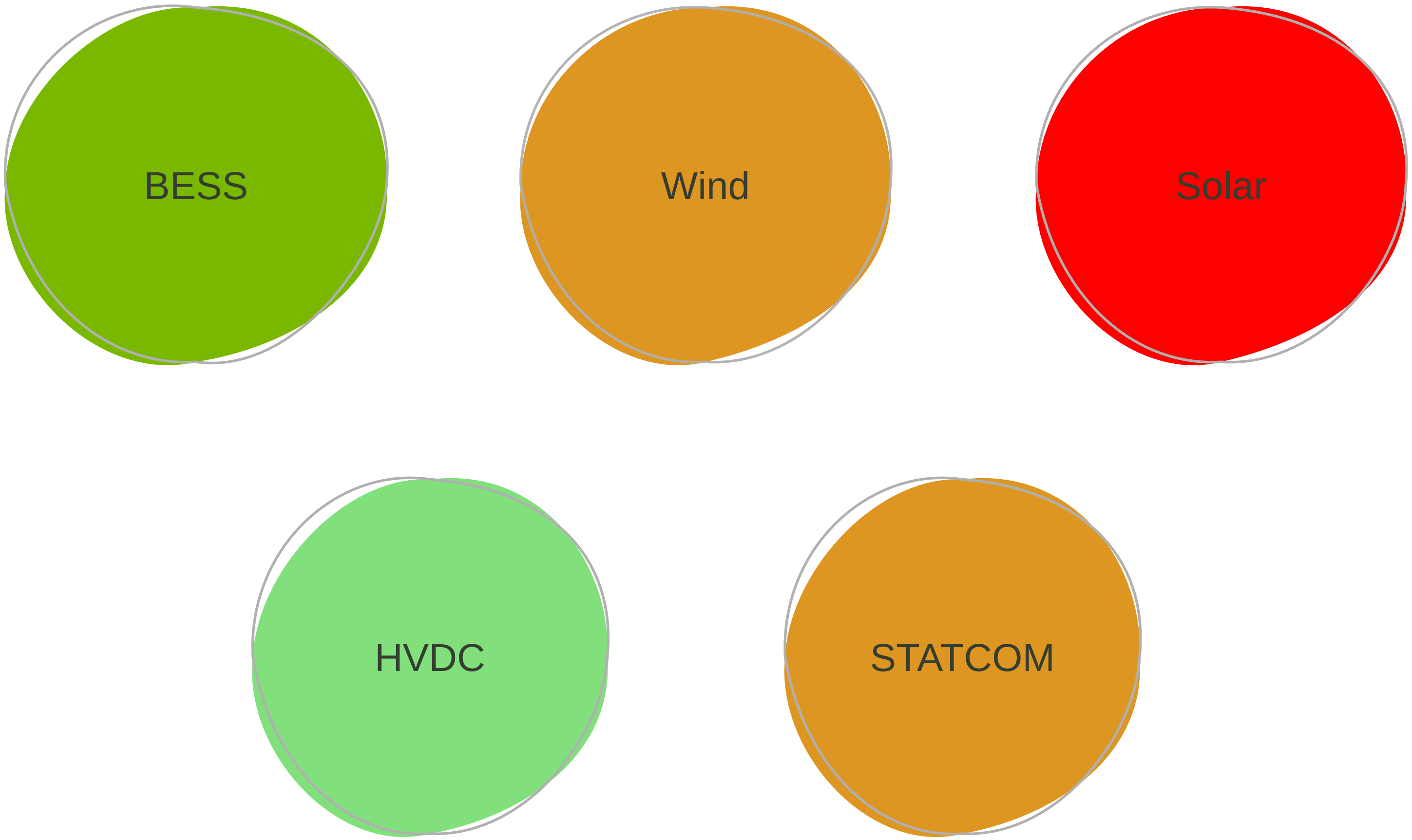
Grid-forming to synchronous condenser MVA effectiveness: 1.0-2.0 pu

Hosting capacity release of grid-following inverters: 2.0-4.0 pu

Lesson 4: System strength support provided by grid-forming inverters is comparable or sometimes better than that provided by synchronous condensers.

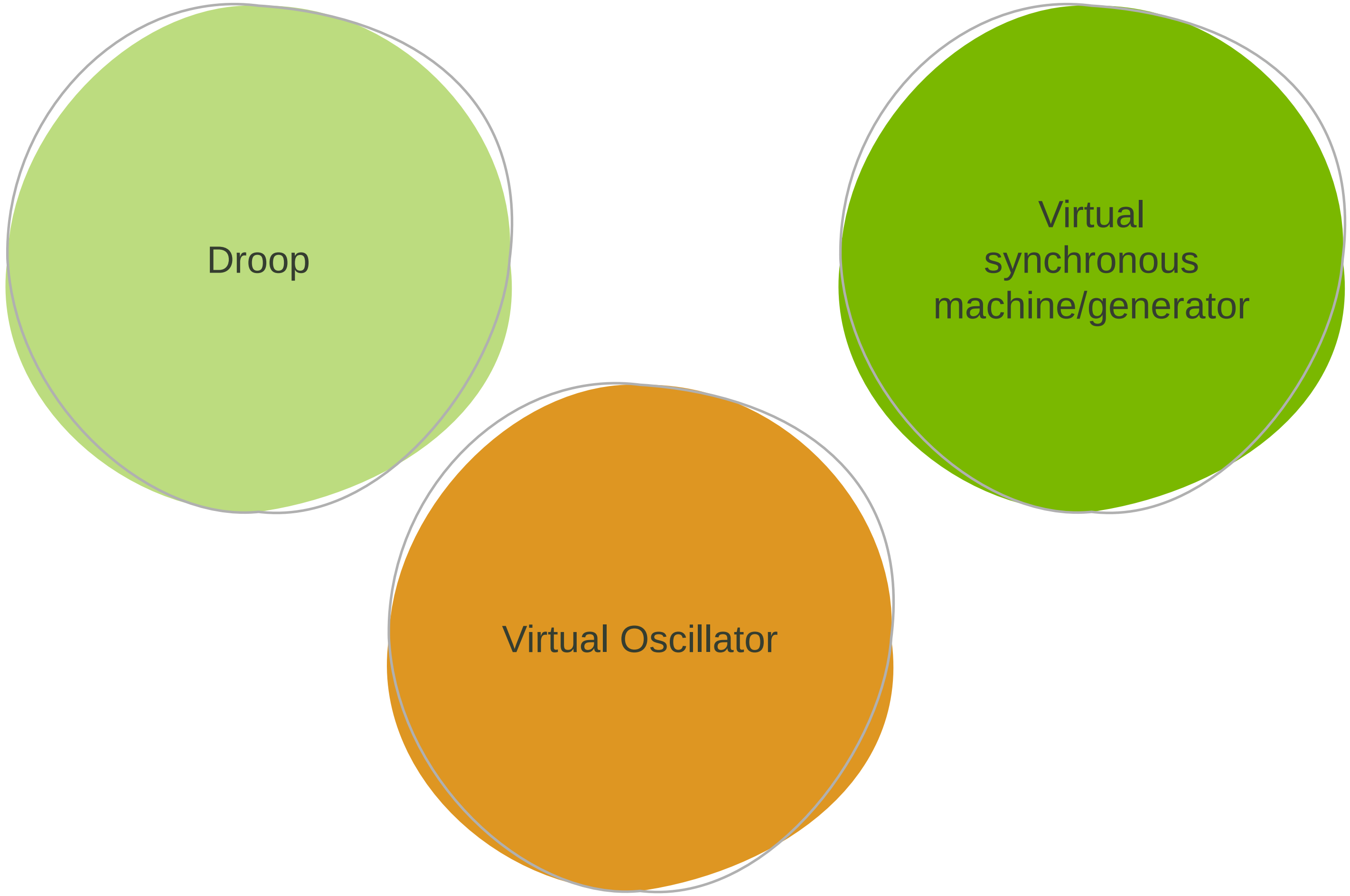
Lesson 5: Provision of additional fault current has not been always identified as a key factor from a system strength support perspective.

Prospect in different IBR types



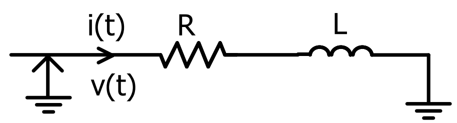
Lesson 6: Almost all active and prospective grid-forming projects are based on BESS.

Practical grid-forming control philosophies



Lesson 7: Virtual synchronous machine/generator is the most widely used control but not the only possible way of control.

Phasor domain and EMT models



$$v(t) = R.i(t) + L\frac{d}{dt}i(t)$$

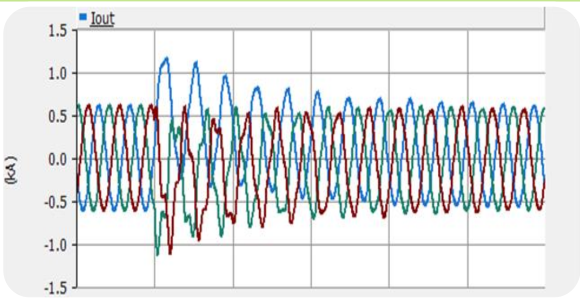
$$V(\omega) = R.I(\omega) + j(L\,\omega).I(\omega)$$

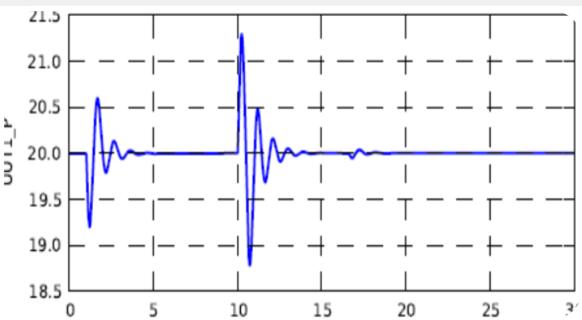
Electromagnetic transient (EMT)

- Real source code integration makes modelling more straightforward
- All OEMs have a model available
- Capable of modelling both inner and outer loops

Phasor-domain transient (PDT)

- Manual implementation and differences with each of the synchronous machines and grid-following IBRs makes modelling non-trivial
- Not all OEMs have a model ready
- Capable of modelling outer loops





Lesson 8: Availability of accurate and reliable PDT models can be a key project risk.

Modelling: SMIB vs wide-area EMT modelling

Overly optimistic or pessimistic SMIB results

Restrictions on the access and use of wide-area models

Grid-forming inverters can provide many grid support functions but not all at the same time

Wide-area models allow for a detailed whole system assessment and solution optimisation

Lesson 9: Increasing need for wide-area EMT modelling by all parties to accurately account for the response of grid-forming inverters.

SCR calculations for planning applications

- Grid-forming inverters shall be treated the same as synchronous machines for short-circuit ratio (SCR) calculations.
- This is noting that the two provide similar level of system strength support regardless of how much each will provide real fault current contribution.
- Fault current contribution of a grid-forming inverter should be up-scaled to be the same (or higher as further studies become available) as that of a synchronous machine.

Lesson 10: Using the actual fault current contribution of a grid-forming inverter for SCR calculations will significantly under-estimate its system strength contribution.

What is slowing down the pace of grid-forming IBR connections?

Availability of tailored performance requirements

Readiness of simulation models

Concerns on longer connection timeframes

Lack of field experiences in bulk power system applications

Revenue streams are not adequately identified

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