Tesla Megapack: Grid forming and Augmentation

Askhat, Sarah, and Prashant
Jan 12, 2024

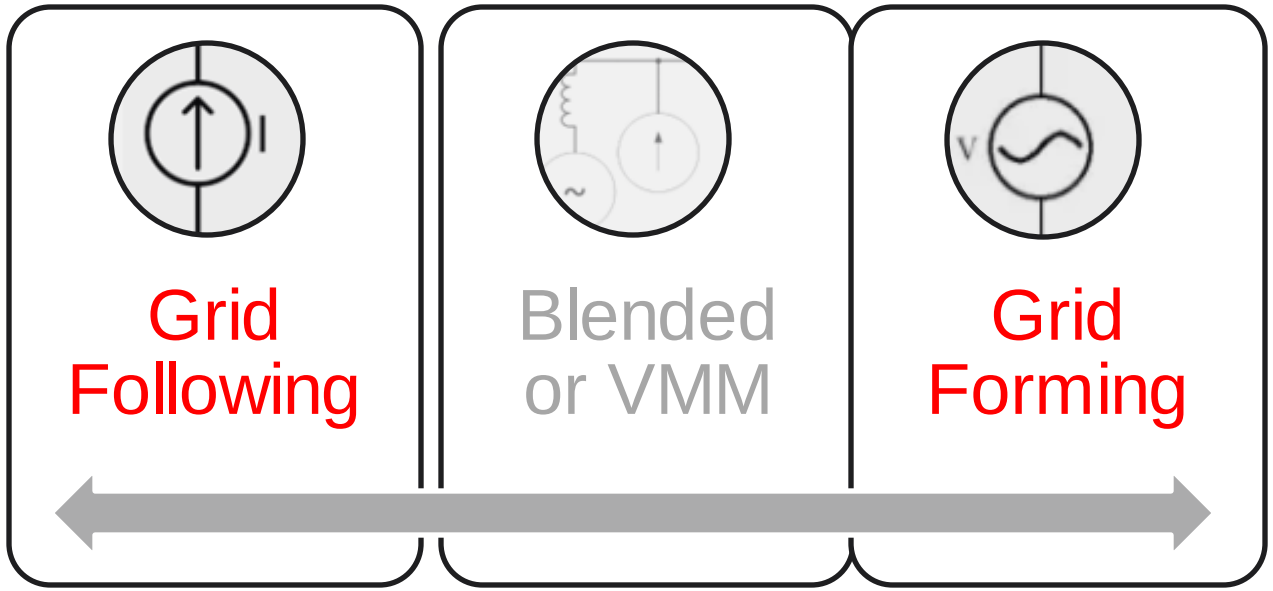
LAST EDITED
Jan 12, 2024

Agenda

- Grid forming overview
- Hornsdale grid forming experience
- Grid forming applications and modelling examples
- Synchronous condenser vs BESS
- Grid forming challenges
- Energy augmentation

BESS Overview

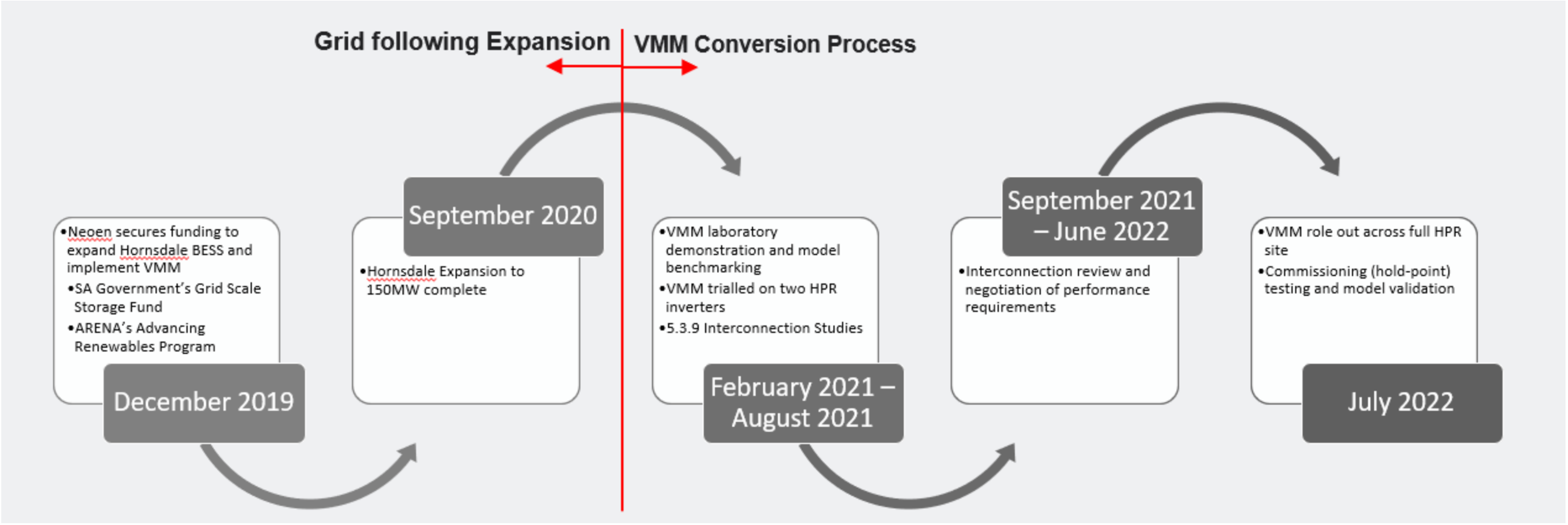
Controls stack that works across all grid applications



VMM (Virtual Machine Mode): Dispatch ability of current source & instantaneous response of voltage source

Hornsdale grid forming experience

All studied in-house to prove the use case



Grid forming/Virtual Machine Mode (VMM) is already here!

Driven by market incentives in Australia

- Australia projects are mostly VMM now due to system strength charges
  - Pay system strength charges
  - Install synchronous condensers or **VMM mode for BESS**
- Hawaii has multiple VMM BESS online to provide grid stability

Source: https://www.pv-magazine.com/2022/07/27/tesla-big-battery-begins-providing-inertia-grid-services-at-scale-in-world-first-in-australia

Hornsdale big battery begins providing inertia grid services at scale in world first

South Australia's 150 MW / 193.5 Hornsdale Power Reserve, more commonly known as the Tesla Big Battery, will now provide inertia services to Australia's National Electricity Market after securing approval from AEMO. Neoen says it is the first big battery in the world to deliver the service at such a scale.

JULY 27, 2022 BELLA PEACOCK

ENERGY STORAGE | HIGHLIGHTS | TECHNOLOGY | TECHNOLOGY AND R&D | UTILITY SCALE STORAGE | AUSTRALIA | SOUTH AUSTRALIA

The Hornsdale Power Reserve is located approximately 16km north of Jamestown in South Australia.

Grid forming/Virtual Machine Mode (VMM) is already here!

Driven by market incentives in Australia

Wallgrove - 50MW

Synthetic inertia on show as Wallgrove big battery reaches full capacity

The first large-scale battery to be connected to the grid in New South Wales has officially reached full production, providing fast frequency response and synthetic inertia services to the transmission network as the state looks to fill the soon-to-be-revealed gap created by retiring coal-fired generators.

DECEMBER 19, 2022 DAVID CARROLL

ENERGY STORAGE | ENERGY STORAGE | UTILITY SCALE STORAGE | AUSTRALIA | NEW SOUTH WALES

The 50 MW/75 MWh Wallgrove Grid Battery is now fully operational.

https://www.pv-magazine-australia.com/2022/12/19/synthetic-inertia-on-show-as-wallgrove-big-battery-reaches-full-capacity/

Riverina -150MW

The largest approved grid-forming battery in Australia

Rebecca Todesco

October 31, 2022

Batteries & Storage, Demand management, Features, Renewable Energy

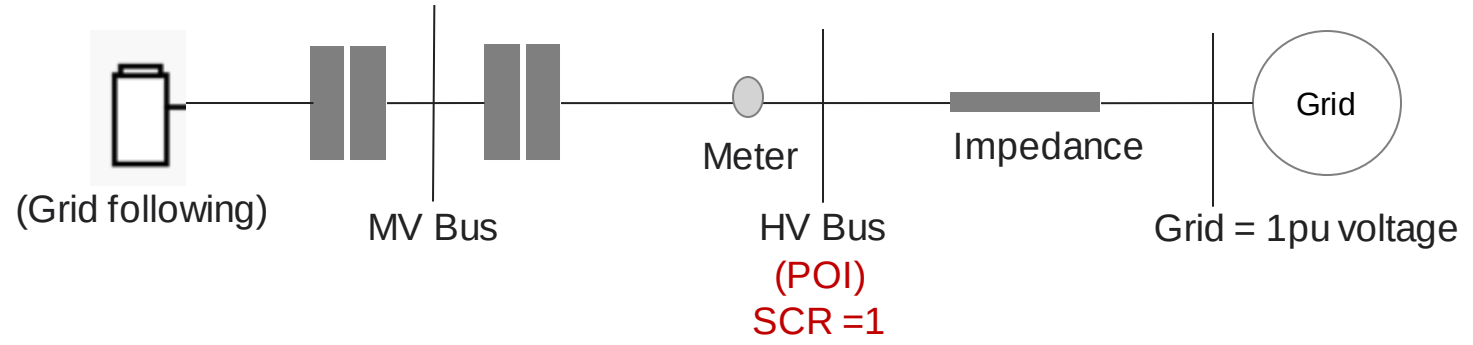
0

https://utilitymagazine.com.au/the-largest-approved-grid-forming-battery-in-australia/

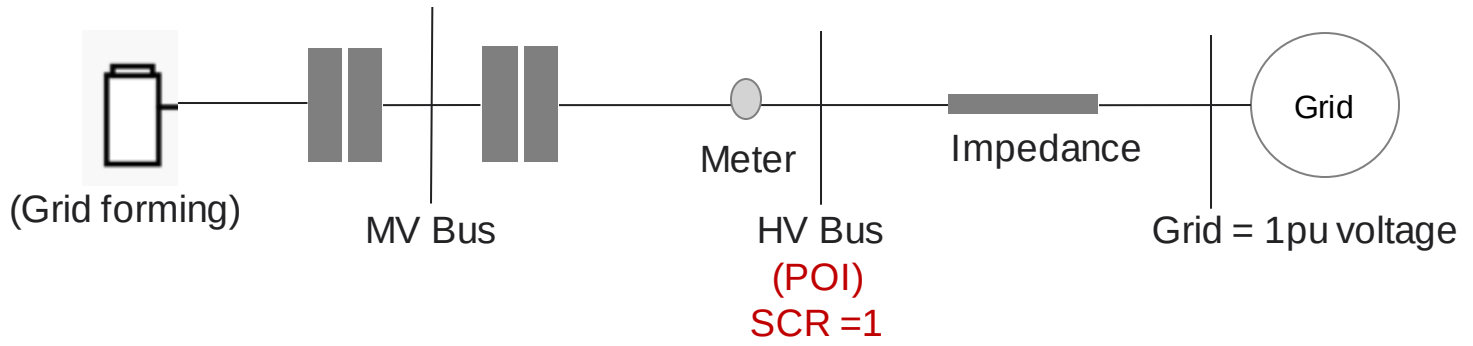
SCR – Modelling manifestation

Grid following will be unstable at very low SCR

- For SMIB models and very low SCR, power step test, fault and recovery etc. will be stable in grid forming mode



Unstable

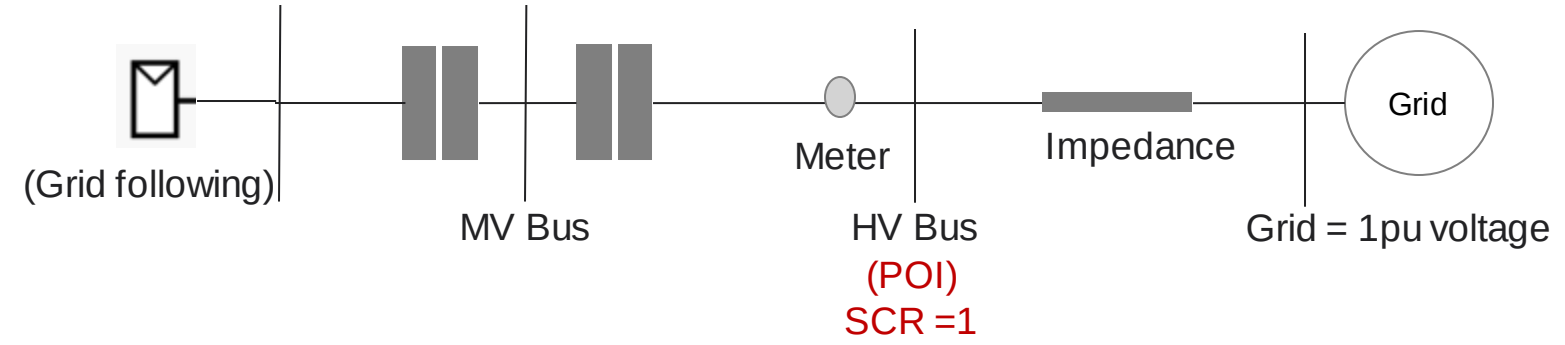


Stable

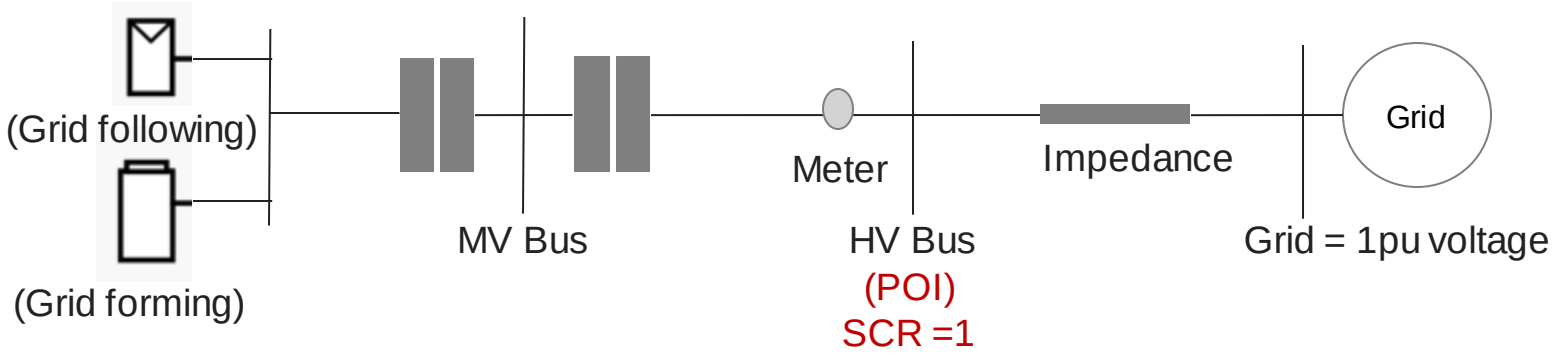
SCR – Modelling manifestation

Adding BESS to the existing Wind or PV

- Grid forming BESS can help stabilize existing PV or Wind



Unstable



Stable

Grid forming/Virtual Machine Mode (VMM) is already here!

Inertia market is coming in UK

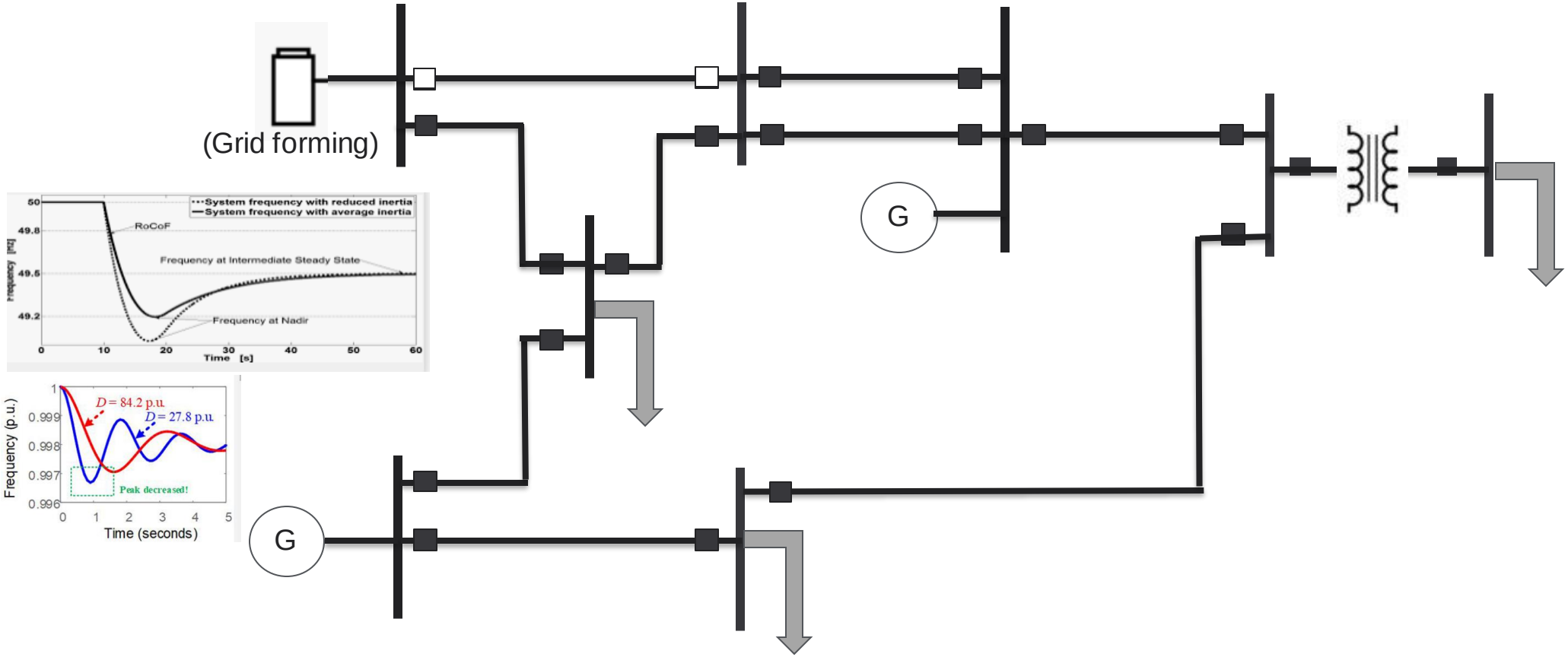
Thermal Retirement – Energy, Stability, and Blackstart

KES || Hawaii || 185 MW

Inertia and damping – Modelling manifestation

BESS grid forming impact from network perspective

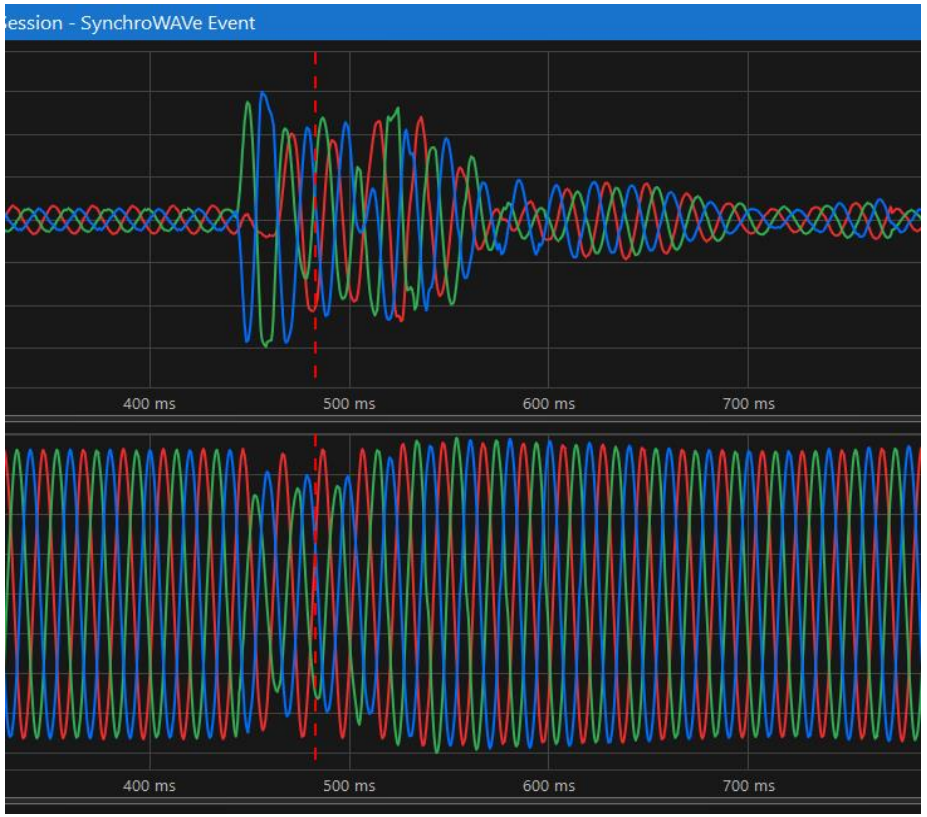
- Frequency nadir is improved – Could be a combination of fast PFR and Inertia
- Damping is improved

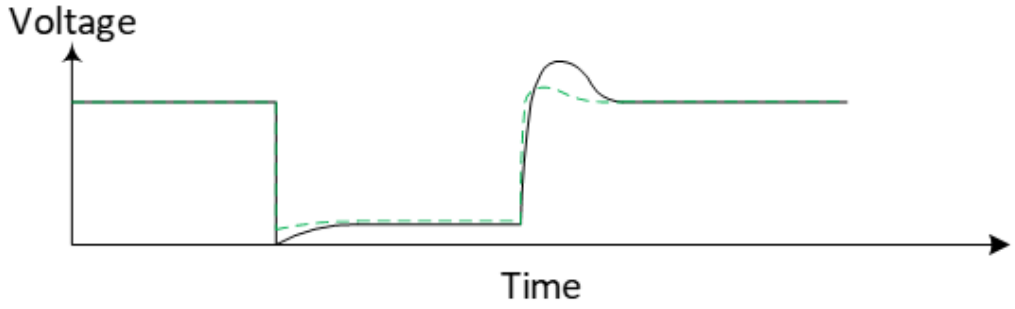


Voltage profile – Modelling manifestation

BESS grid forming impact from network perspective

- Voltage dip during the fault and post fault voltage recovery improvements due to instantaneous impact





Grid-forming batteries vs Synchronous Condenser?

- Software controlled parameters for BESS allows full control on tuning inertial (real power) and voltage support (reactive current) **behavior separately**

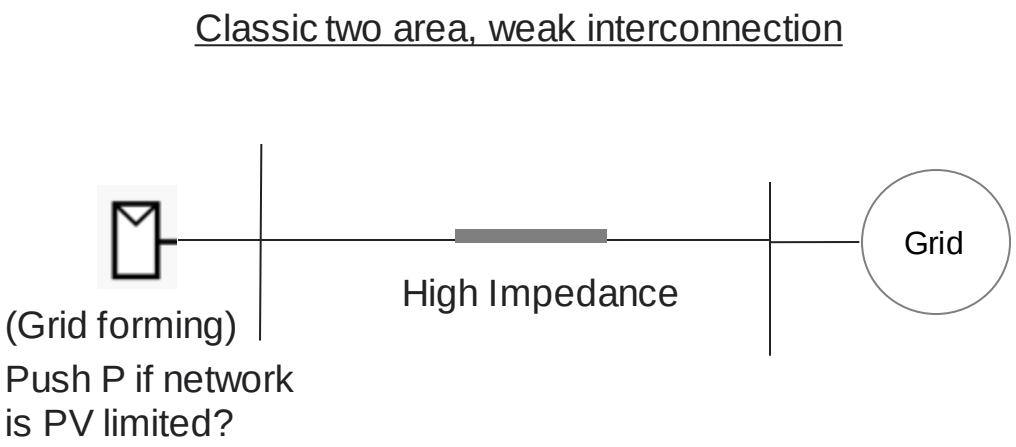
Asset / Service	Tesla Battery (with Virtual Machine Mode)	Synchronous Generator	Variable Renewable Generator	Static VAR Compensator (SVC)	Synchronous Condenser (Syncon)	Static Synchronous Compensator (STATCOM)
Inertia	✓	✓	✓*		✓	✓
Voltage stability	✓	✓	✓	✓	✓	✓
System strength	✓	✓			✓	
Harmonic dampening	✓					✓
Frequency Stability	✓	✓	✓			
Fast Frequency Response	✓					
Stand-alone/system re-re-start services	✓	✓				

✓ Some/minimal functionality – e.g. *some new wind farms with appropriate control systems
✓ Standard functionality
✓ with Tesla Virtual Machine Mode (grid-forming)

TESLA

Grid-forming batteries vs Synchronous Condenser?

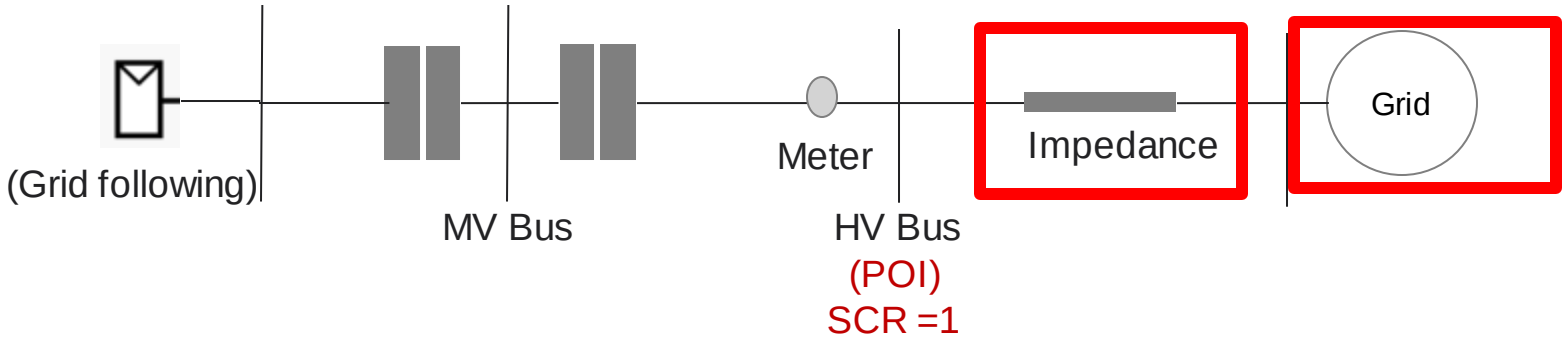
- Software controlled parameters for BESS allows full control on tuning inertial (real power) and voltage support (reactive current) **behavior separately**
- There can be network limitations like PV/QV curve where post contingency you would might want lower real power response (due to PV curve limitation) and mostly reactive power response to support voltage.



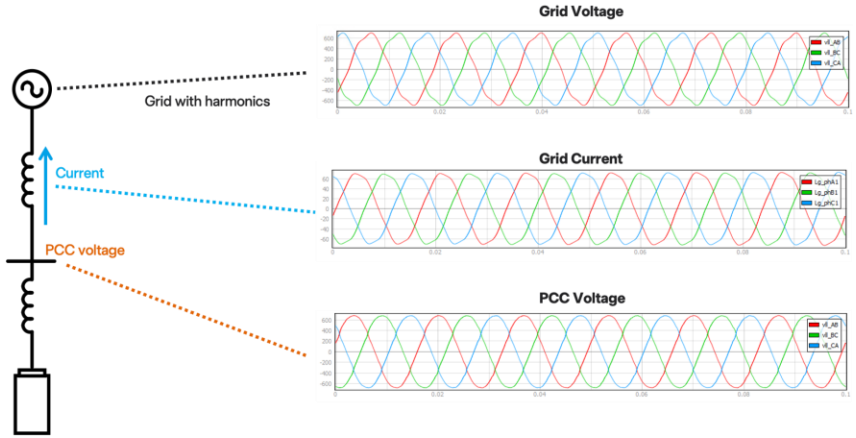
Grid forming open questions

Modelling practices, objective, and standards will need to evolve

- SCR – Impedance or current limited source?



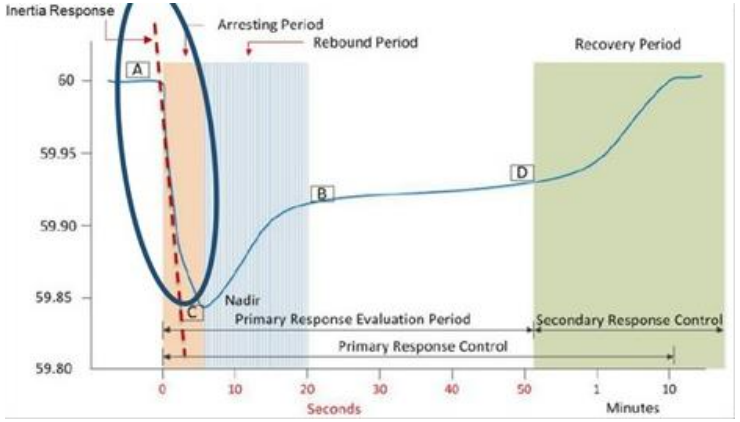
- Harmonics – Grid forming BESS will try to negate the harmonics if grid has background harmonics
  - Rules in IEEE 2800 need to be clear that the harmonics testing should assuming no background harmonics



Grid forming open questions

Standards like IEEE 2800 or studies practice will need to evolve

- Inertia vs fast PFR
  - Do we need same amount of system inertia if primary frequency response is less than 200ms
  - The goals should be to **replace** but **not replicate** the existing system



- Grid forming BESS vs Synchronous condenser
  - Do we care about the amount of fault current injection?
  - Is this purely a function of protection or network as well?

Tesla Augmentation - Overview

Augmentation Goal: Mitigate BESS degradation to maintain clean firm energy capacity

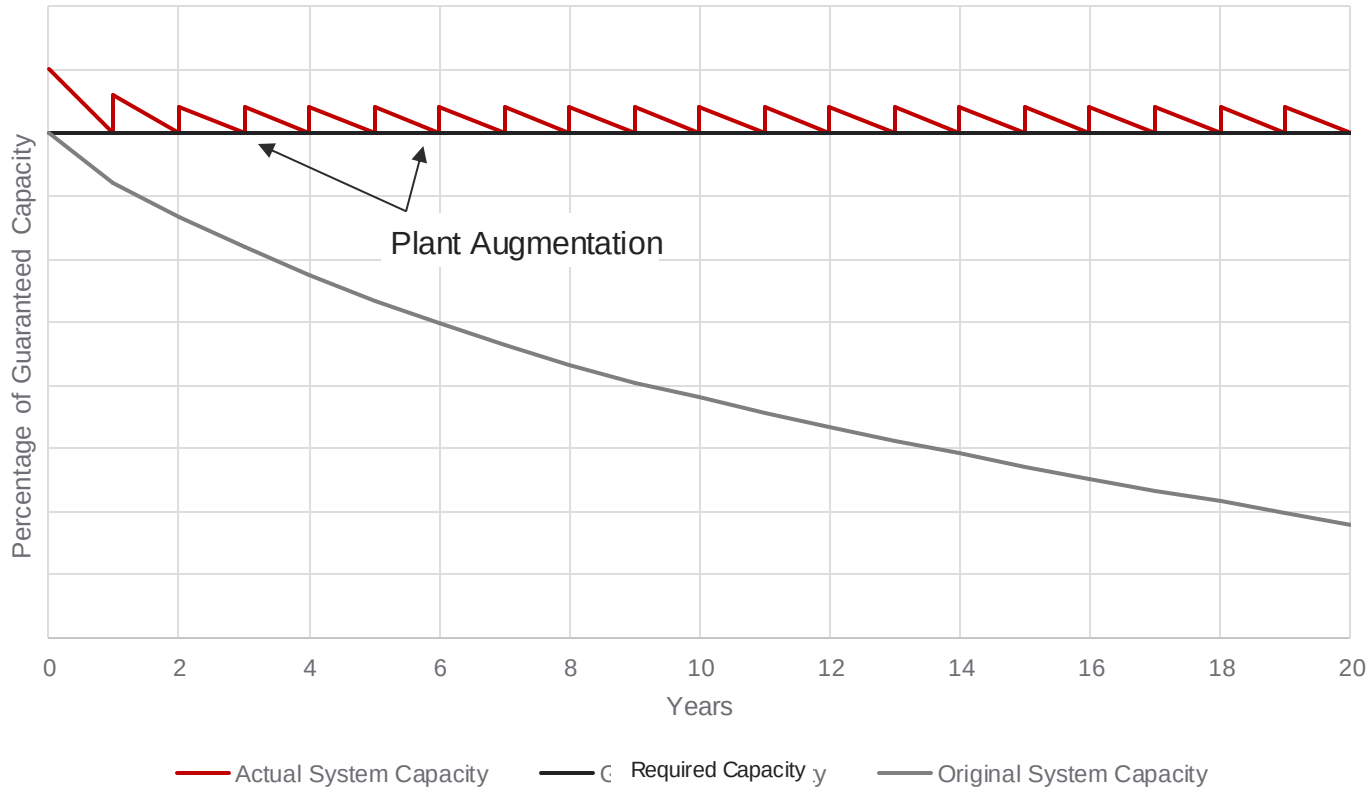
Deployment Options

- Augment at LV or MV with AC integrated BESS unit
- Yearly augmentations can minimize LCOS

Tesla's Power Capability Strategy

- **Plant performance** must not change throughout the augmentation process – possible via software capability management
- Derate existing inverter capability as AC capability is added via augmentation

Generic Capacity Maintenance Concept – Not Product Specific



Maintain Plant Performance throughout Augmentation - Validation Proposal

Recommending language within P2800.2 SG5 to verify augmentation performance

Motivation to enable *efficient* augmentation

- Most BESS plants will require augmentation to mitigate degradation to provide the grid with firm & clean capacity
- Language within P2800.2 SG5 will enable efficient deployment while ensuring plant performance is maintained

Results required within P2800.2 SG5 to verify augmentation performance – by providing unit test performance overlays

- The following unit type test overlays with pre- & post-augmentation equipment should be identical *(reference upcoming 2800.2 benchmarking guidelines to define identical)*:
  - System MVA
  - Short-circuit rating
  - Dynamic performance
- Harmonic performance of the inverters should be maintained within the standard defined limits at the point of interconnection (POI)