GRID-SUPPORTING BATTERY ENERGY STORAGE SYSTEM MODELLING AND SIMULATION IN RTDS: AN AUSTRALIAN CASE STUDY

FELIPE ARRAÑO-VARGAS, GEORGIOS KONSTANTINOU

UNSW SYDNEY, AUSTRALIA

UNSW SYDNEY

Real-Time Simulations Laboratory

RTS@UNSW

USER SPOTLIGHT SERIES 2.0 BY RTDS Technologies

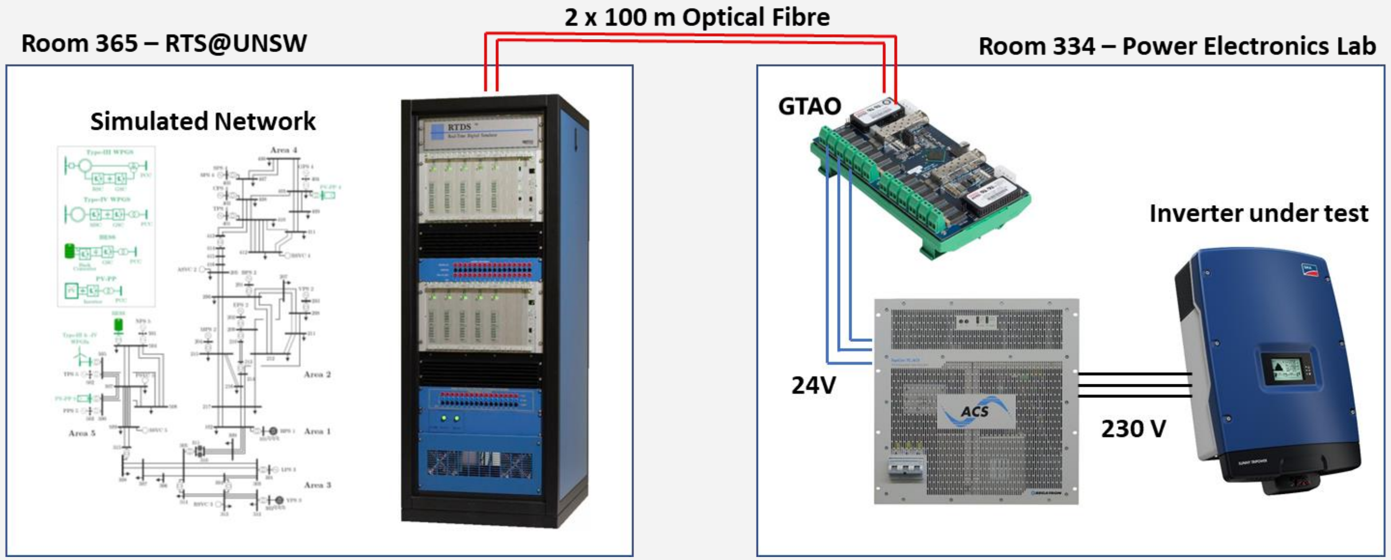
OUR FACILITIES

https://research.unsw.edu.au/projects/real-time-digital-simulation-rts-laboratory-unsw-sydney

OUR RESEARCH

- ➢ Power system modelling
- ➢ HVDC networks
- ➢ Multiterminal DC grids
- ➢ Renewable energy systems
- ➢ Smart grids
- ➢ Microgrids
- ➢ Power electronics
- ➢ CiL, HiL and PHiL testing

PHiL capabilities – Example



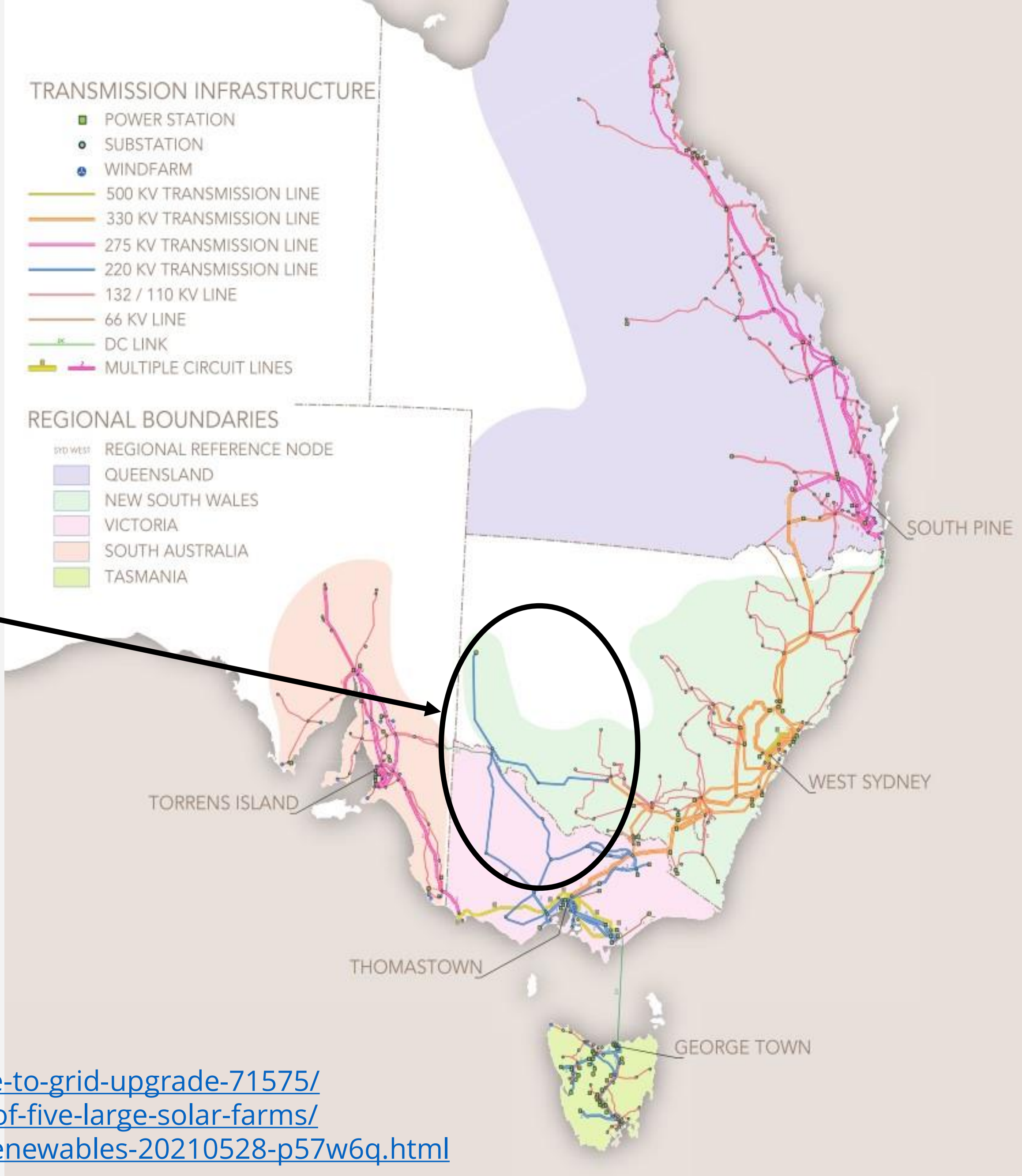
Addressing Barriers to Efficient Renewable Integration

- Understand PV inverter behaviour during grid disturbances
- Bench testing of commercial rooftop PV inverters
- Contribute to improve AS 4777.2: 2015 “Inverter requirements”

http://pvinverters.ee.unsw.edu.au

PROJECT OVERVIEW

“Replicate oscillations in the West Murray Zone and demonstrate the potential of a battery energy storage system (BESS), with grid-supporting capabilities, to improve system strength.”



https://www.energymagazine.com.au/aemo-outlines-west-murray-zone-challenges/
https://reneweconomy.com.au/wind-solar-farms-to-be-blacked-out-for-up-to-100-days-due-to-grid-upgrade-71575/
https://www.pv-magazine-australia.com/2019/09/16/jolted-aemo-radically-curtails-output-of-five-large-solar-farms/
https://www.theage.com.au/national/victoria/gridlock-on-the-grid-stalls-the-transition-to-renewables-20210528-p57w6q.html

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PROJECT OVERVIEW

Stages

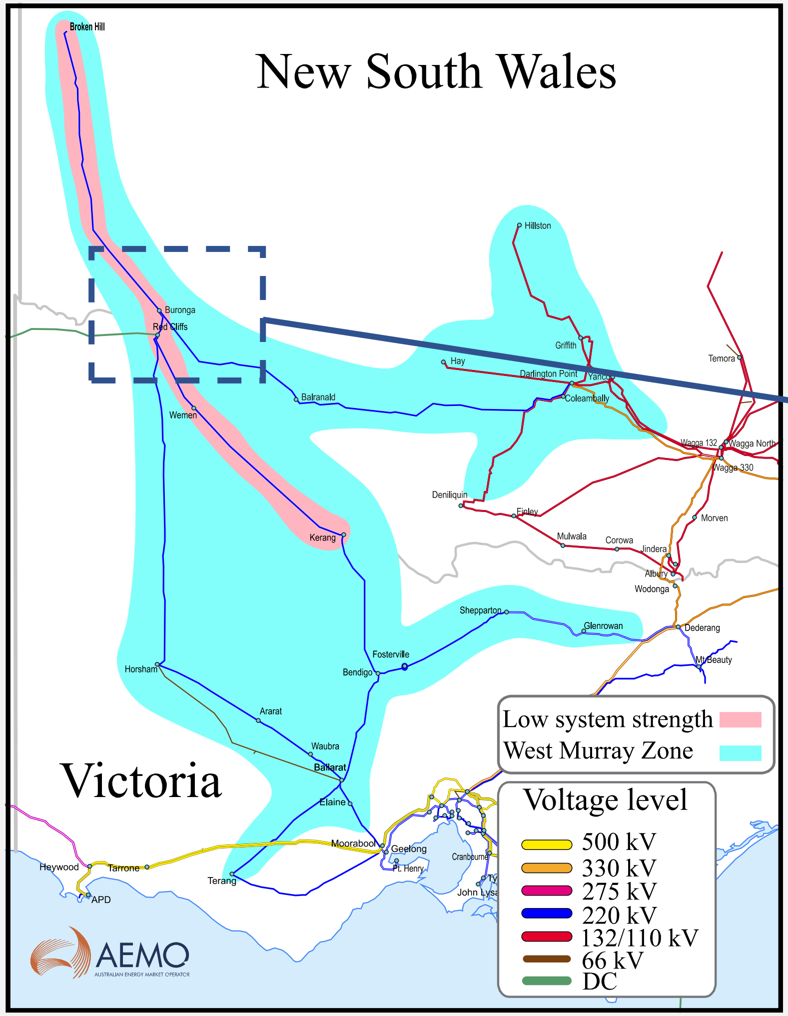
Market operator requirements

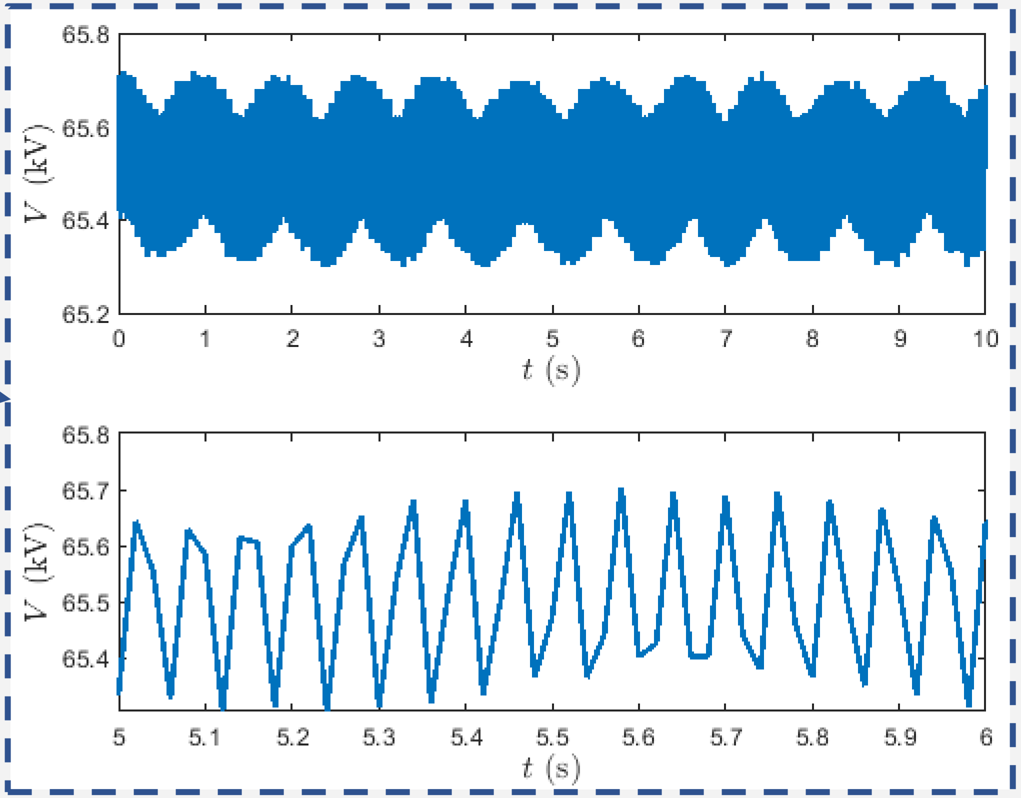
Stage 1
- Proof of concept based on generic modelling

Stage 2
- Implementation of OEM’s solution (control logic) in the battery energy storage model.

Stage 3
- Control hardware-in-the-loop testing

WEST MURRAY ZONE (WMZ)



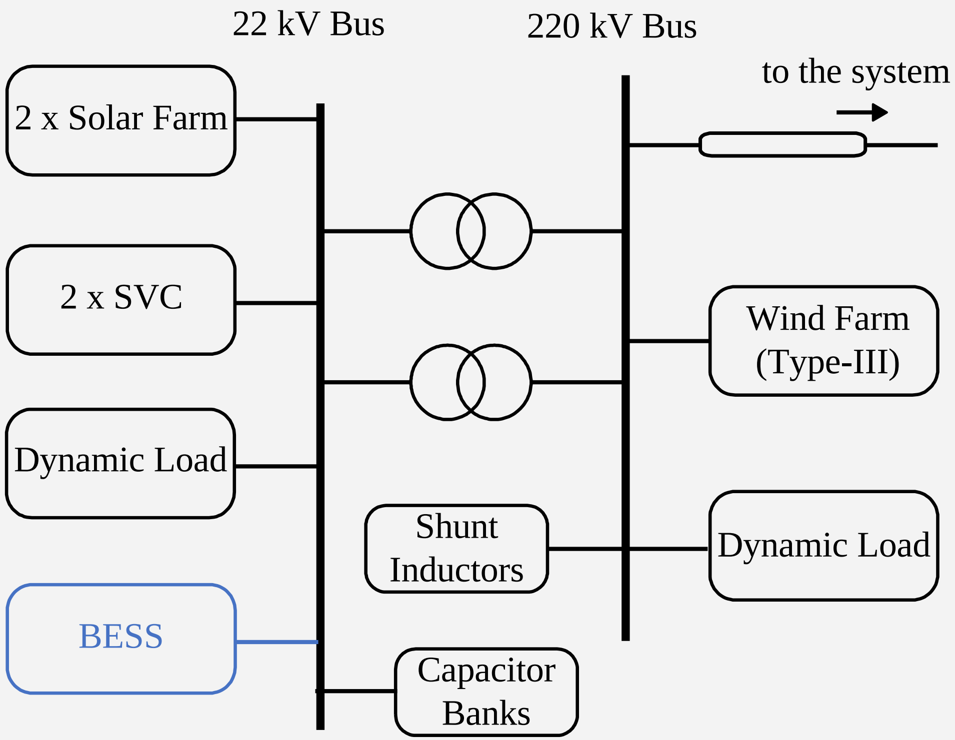


Voltage oscillation
(event captured at Red Cliffs)

https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/participate-in-the-market/network-connections/west-murray

WEAK AREA

- Oscillations are seen during normal operating conditions, planned outages, and disturbances
  - Oscillations may reach 5% peak-to-peak
  - Frequency varies from 7 to 19 Hz
- Very low system strength increases the potential of resonance and converter-driven instabilities
- New and existing variable renewable generation will be constrained
- Full system strength impact assessment will be required
- Significant delays in project assessments

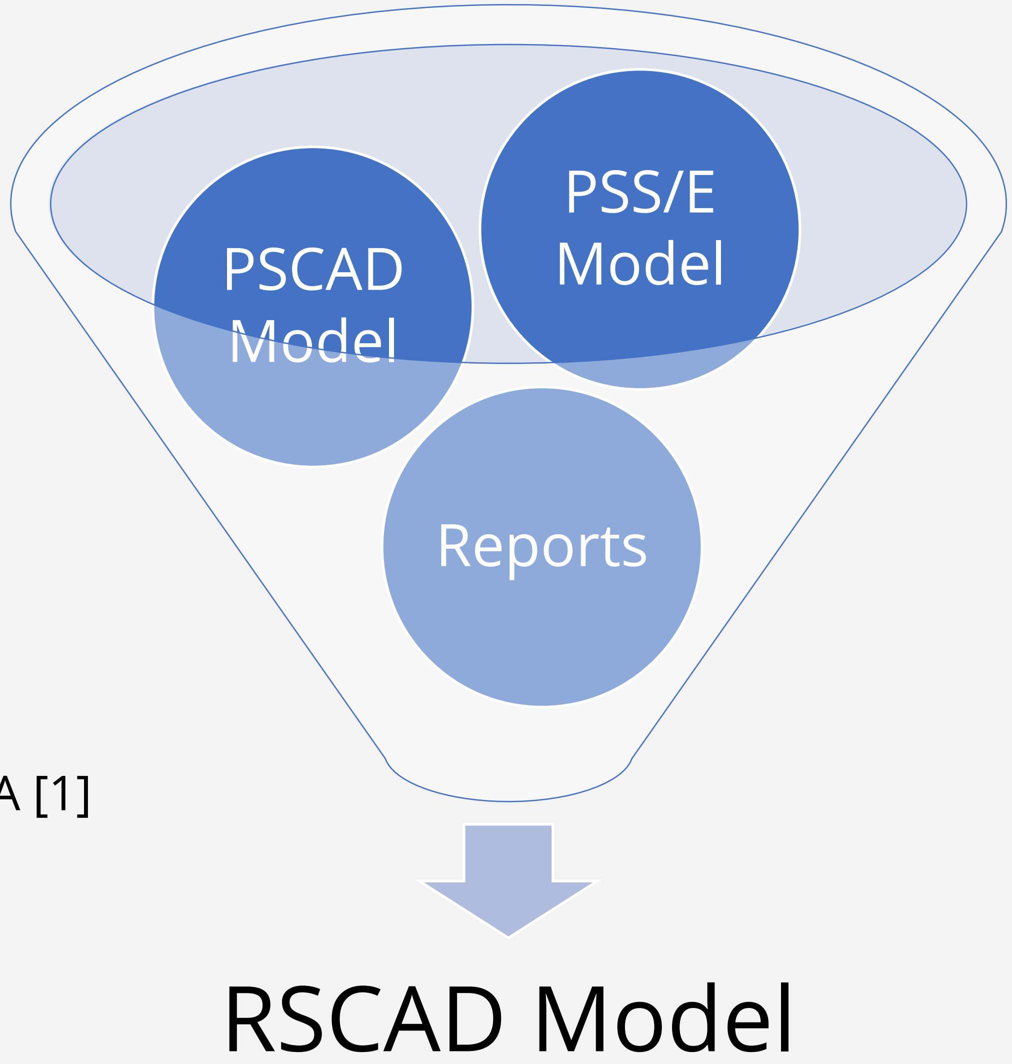


Proposed location for a battery energy storage system

NETWORK MODELLING

Inputs

- PSS/E model:
  - .raw, .dyw, .seq
- PSCAD model:
  - PSCAD / ETRAN from PSS/E
- Operating conditions:
  - Generation dispatch, loads, system voltage levels
  - Post-contingency fault level requirement of 1,000 MVA [1]



[1] AEMO 2020 System Strength and Inertia Report

NETWORK MODELLING

Inverter-based resources

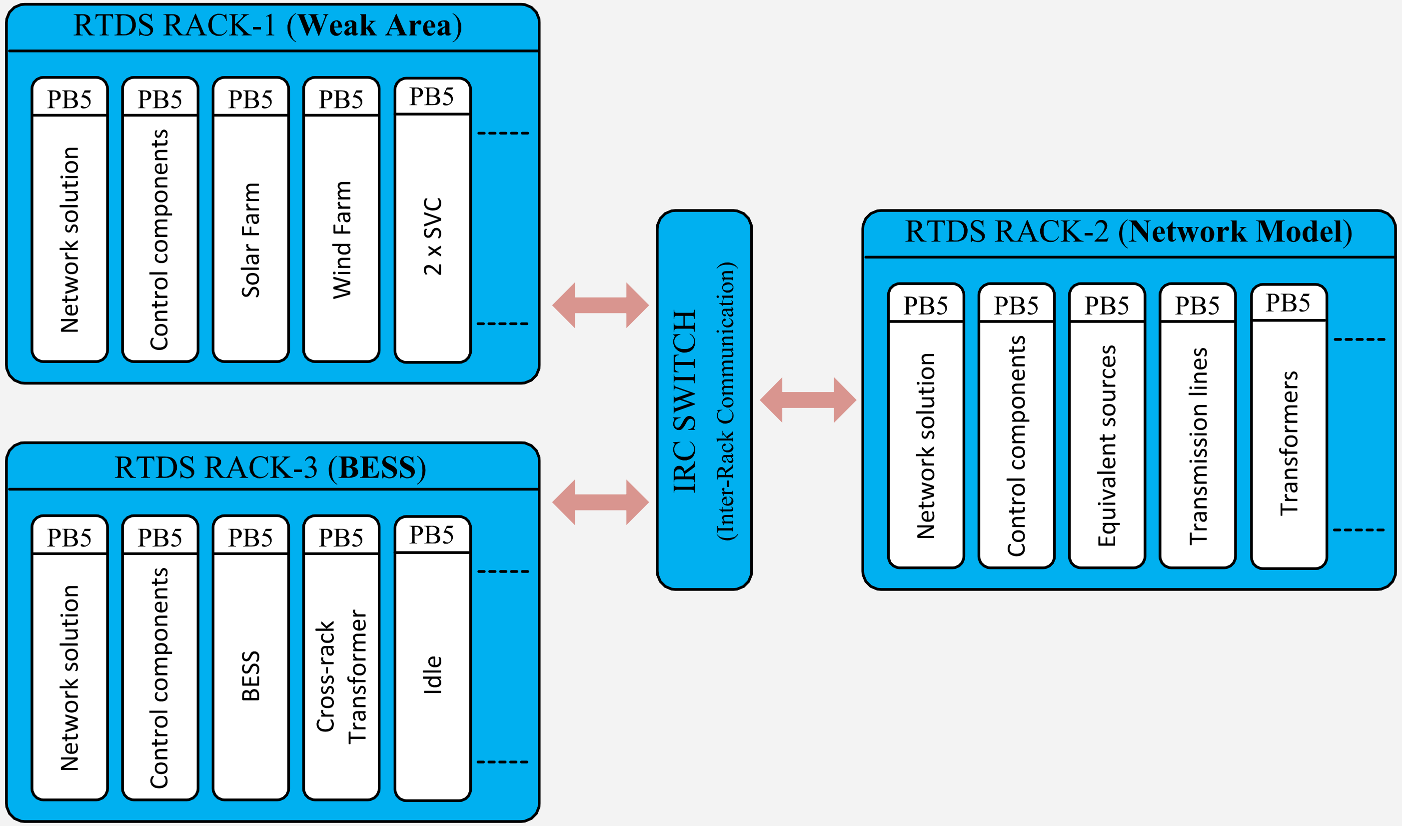
- Detailed switching model of a single unit (e.g., wind turbine, PV array, battery stack)
- Multiplication for current injection to show complete system response at the step-up transformer
- Grid-supporting BESS:
  - Virtual synchronous machine emulation
  - Reactive power control loop (voltage/reactive power control mode)
  - Frequency and voltage droop controllers

[1] F. Arraño-Vargas and G. Konstantinou, "Development of Real-Time Benchmark Models for Integration Studies of Advanced Energy Conversion Systems," in *IEEE Trans. Energy Convers.*, vol. 35, no.1, pp. 497-507, Mar. 2020.

[2] F. Arraño-Vargas and G. Konstantinou, "Real-Time Models of Advanced Energy Conversion Systems for Large-Scale Integration Studies." in *2019 IEEE 10th International Symposium on Power Electronics for Distributed Generation Systems (PEDG).* Xi'an, China, Jun. 2019, pp. 756-761.

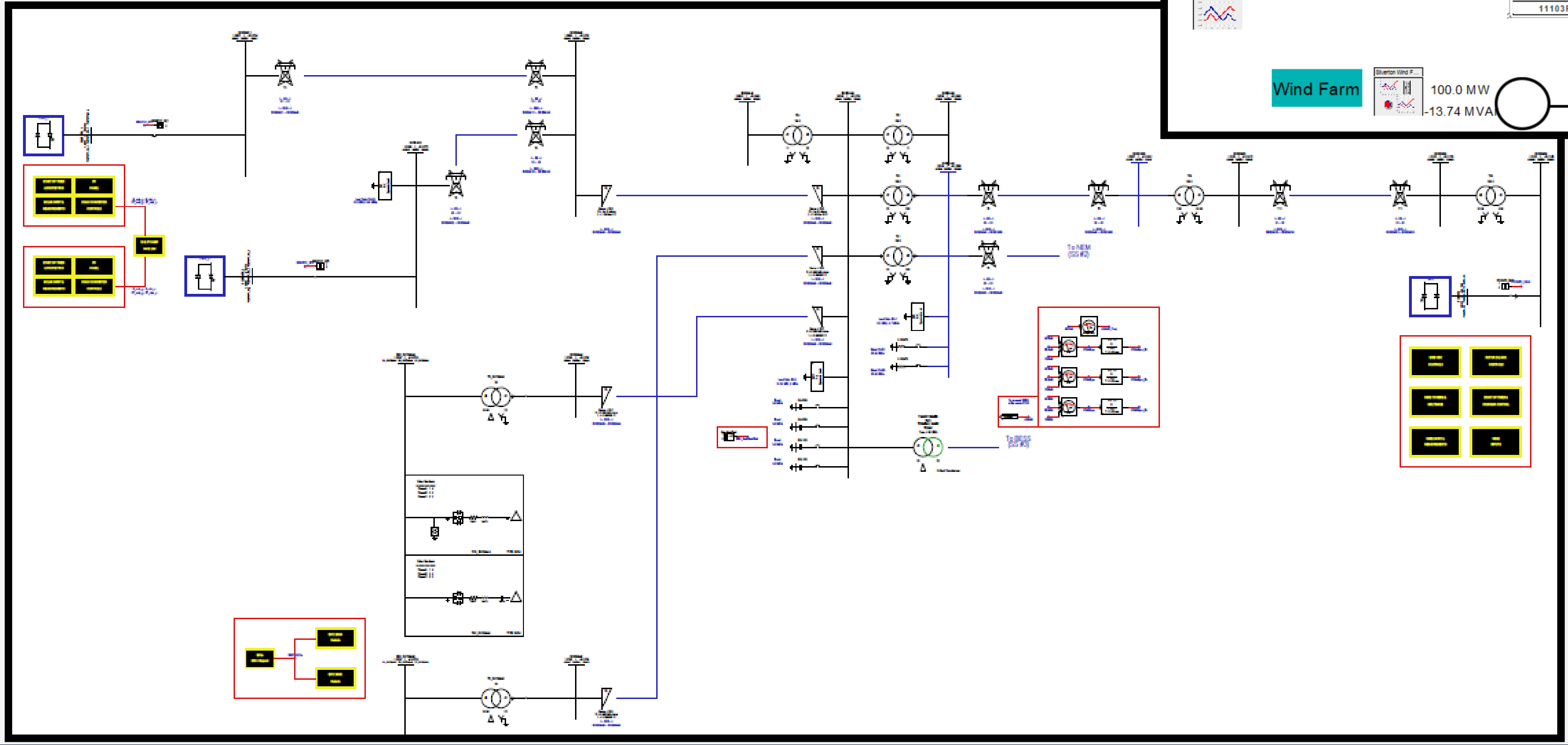
NETWORK MODELLING

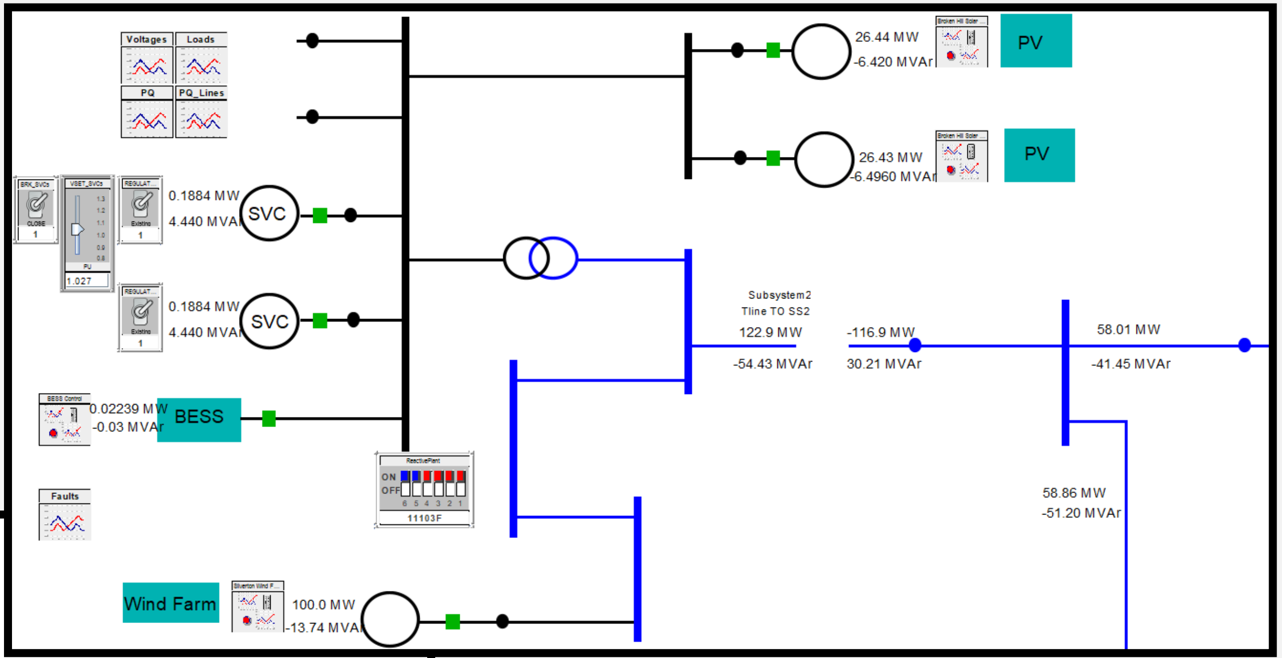
Scalability



RTDS MODEL

RSCAD: Subsystem #1 – Weak Area



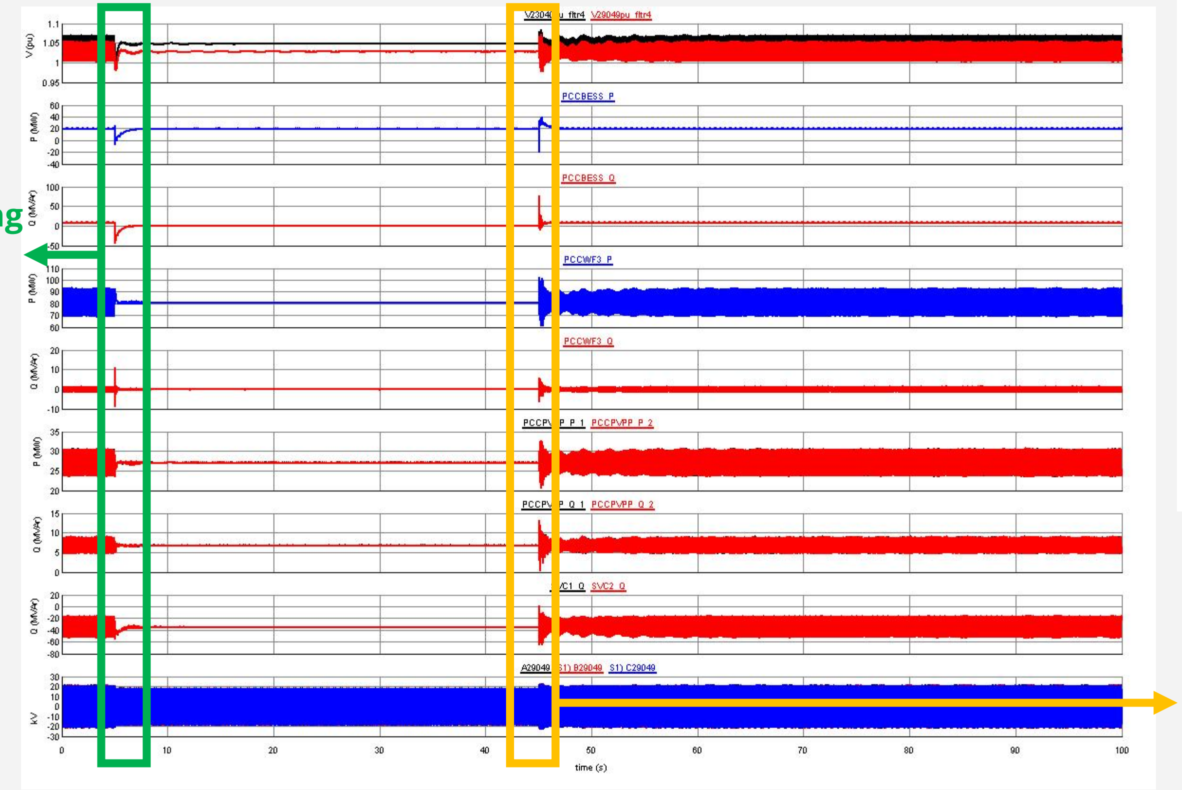


Runtime

RTDS SIMULATIONS

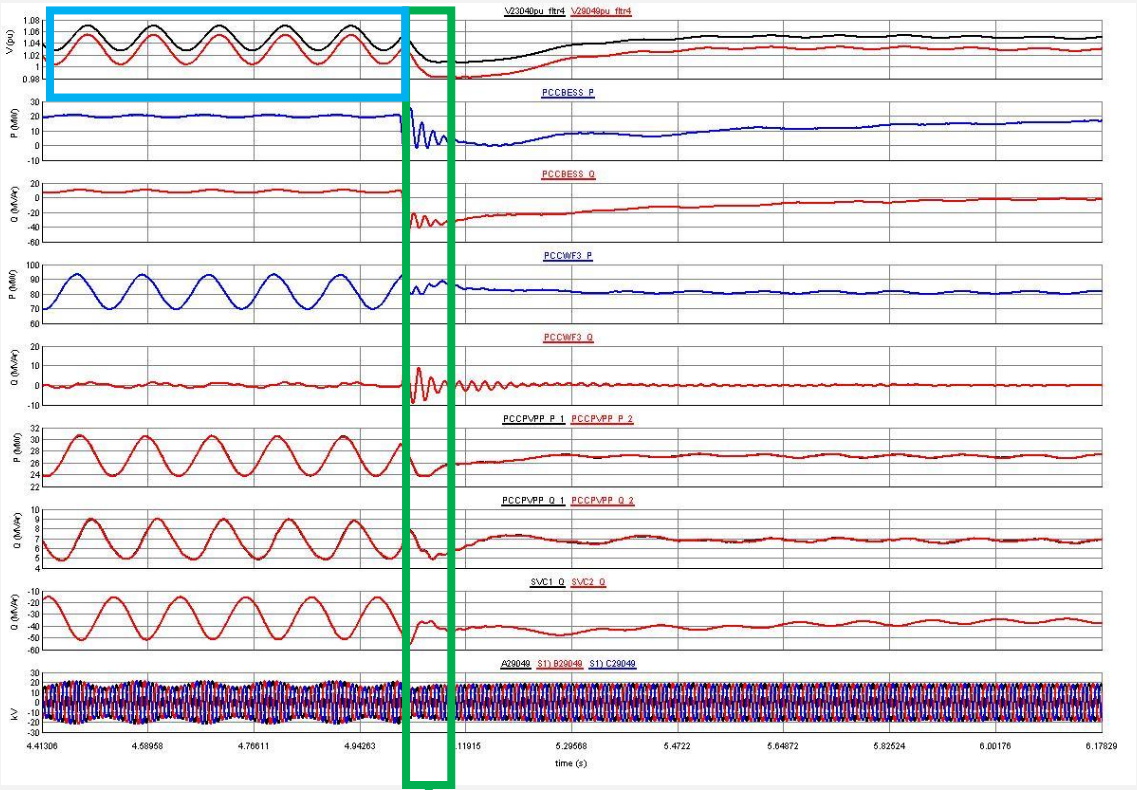
Stage 1: Generic modelling

Grid-supporting functionality enabled



Grid-supporting functionality disabled

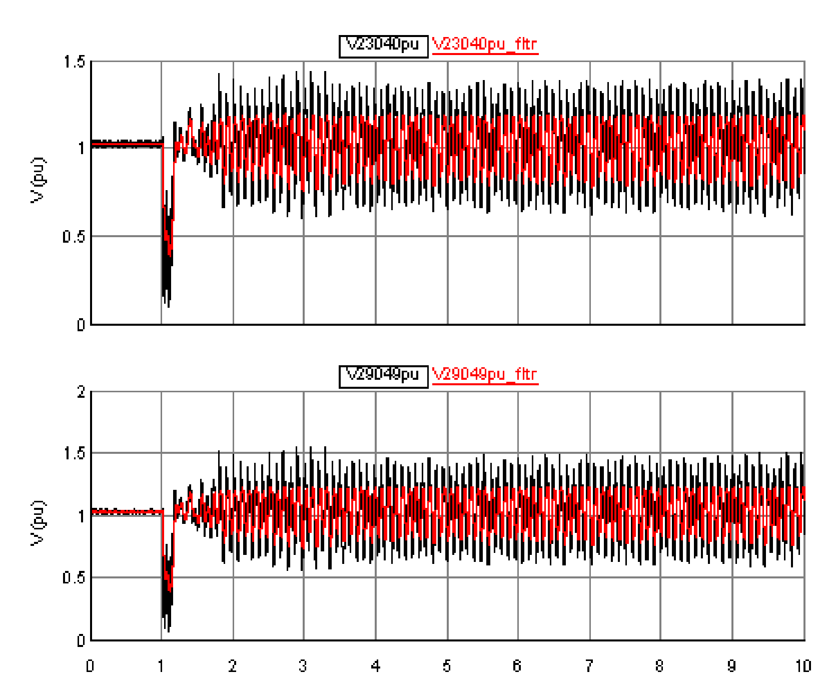
~9 Hz oscillation
5% amplitude



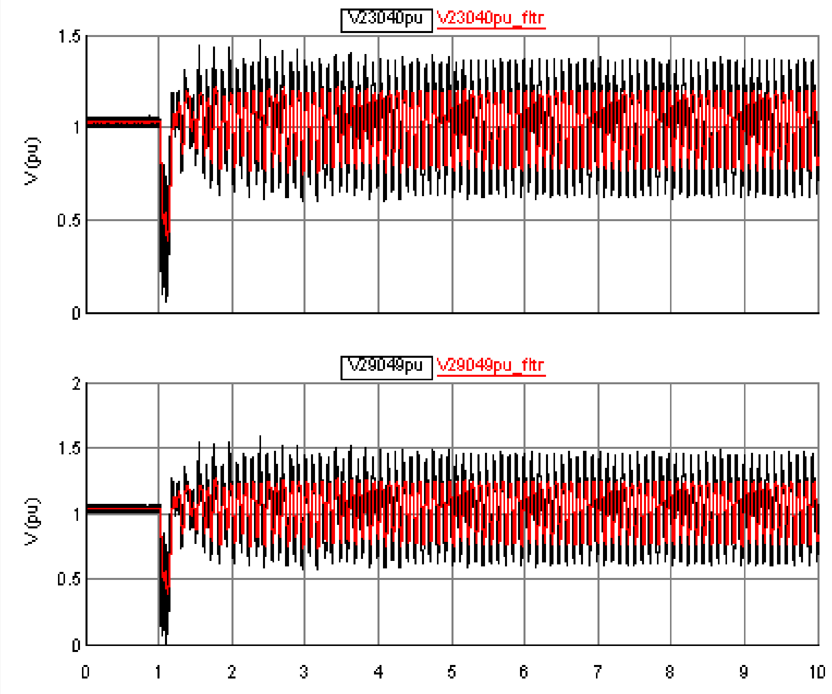
Grid-supporting functionality enabled

RTDS SIMULATIONS

Stage 2: OEM's implementation. Fault at Buronga – Red Cliffs line



No BESS



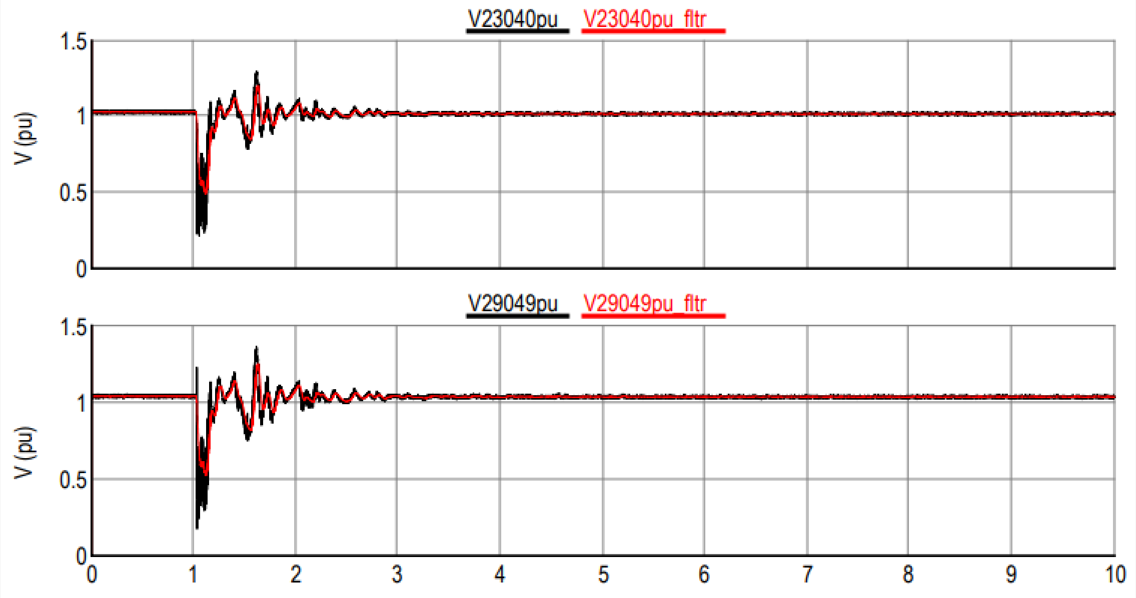
BESS in grid-feeding mode

Unstable operation

RTDS SIMULATIONS

Stage 2: OEM's implementation. Fault at Buronga – Red Cliffs line

Conditions	Resulting System
No BESS	Voltage Oscillations
BESS with $H = 5\,s$ / $D = 50$	Stable
BESS with $H = 5\,s$ / $D = 75$	Stable
BESS with $H = 5\,s$ / $D = 100$	Stable
BESS with $H = 8\,s$ / $D = 50$	Stable
BESS with $H = 8\,s$ / $D = 75$	Stable
BESS with $H = 8\,s$ / $D = 100$	Stable



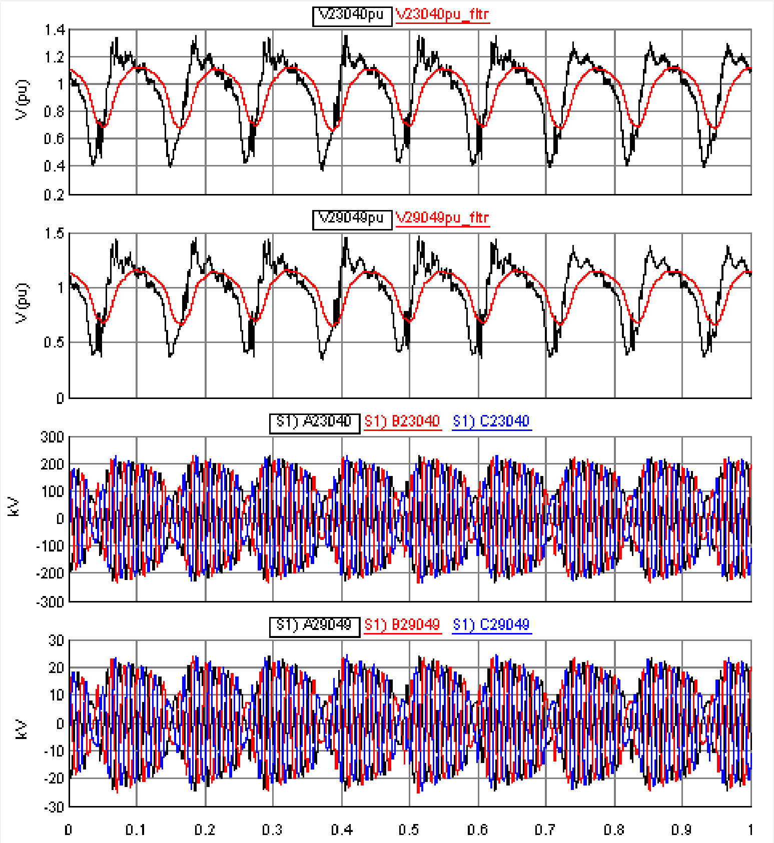
BESS in grid-supporting mode

Stable operation

RTDS SIMULATIONS

Stage 2: Maximum IBR generation

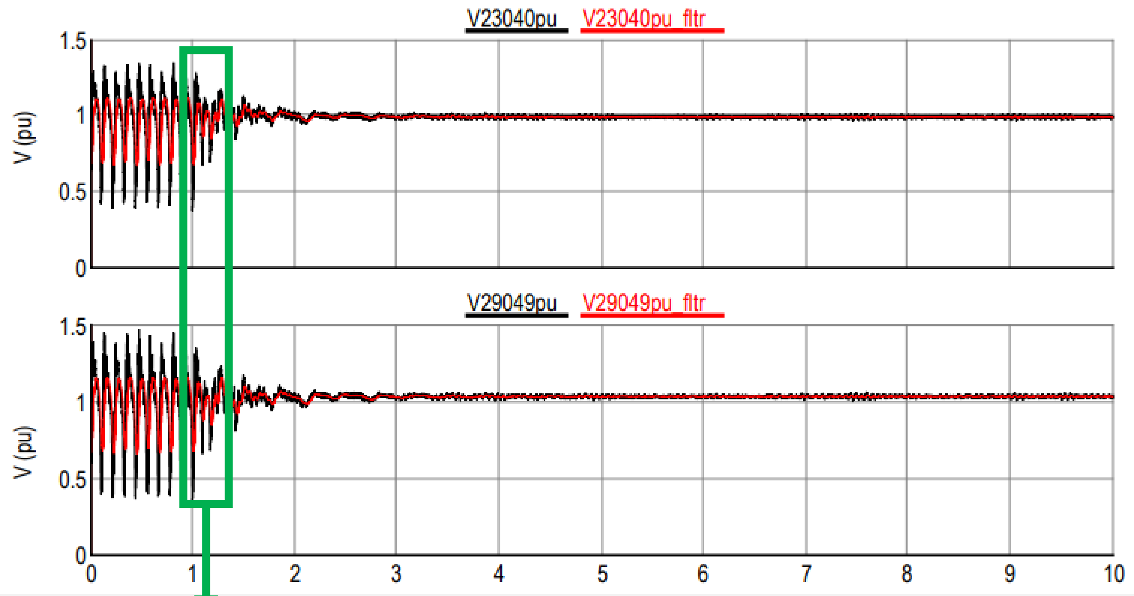
- BESS is not connected
- Voltage oscillations of 9 Hz and 0.9 p.u. amplitude
- Amplitude of the oscillations is characteristic of the model and the generic dynamic representation of IBRs and SVCs



RTDS SIMULATIONS

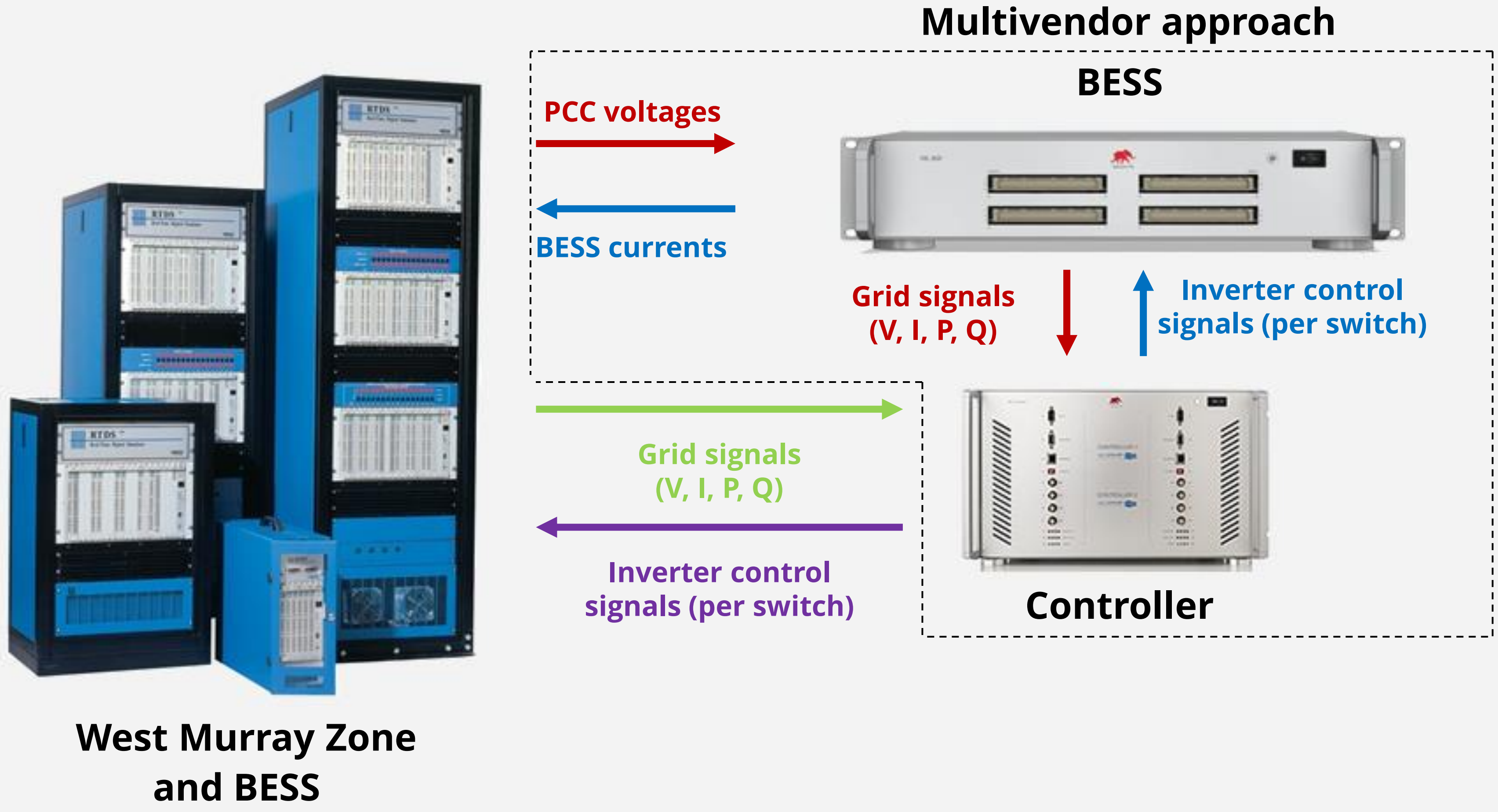
Stage 2: Maximum IBR generation

Conditions	Resulting System
No BESS	Voltage Oscillations
BESS with $H = 5\ s\ /\ D = 50$	Oscillations are damped
BESS with $H = 5\ s\ /\ D = 75$	Oscillations are damped
BESS with $H = 5\ s\ /\ D = 100$	Oscillations are damped
BESS with $H = 8\ s\ /\ D = 50$	Oscillations are damped
BESS with $H = 8\ s\ /\ D = 75$	Oscillations are damped
BESS with $H = 8\ s\ /\ D = 100$	Oscillations are damped



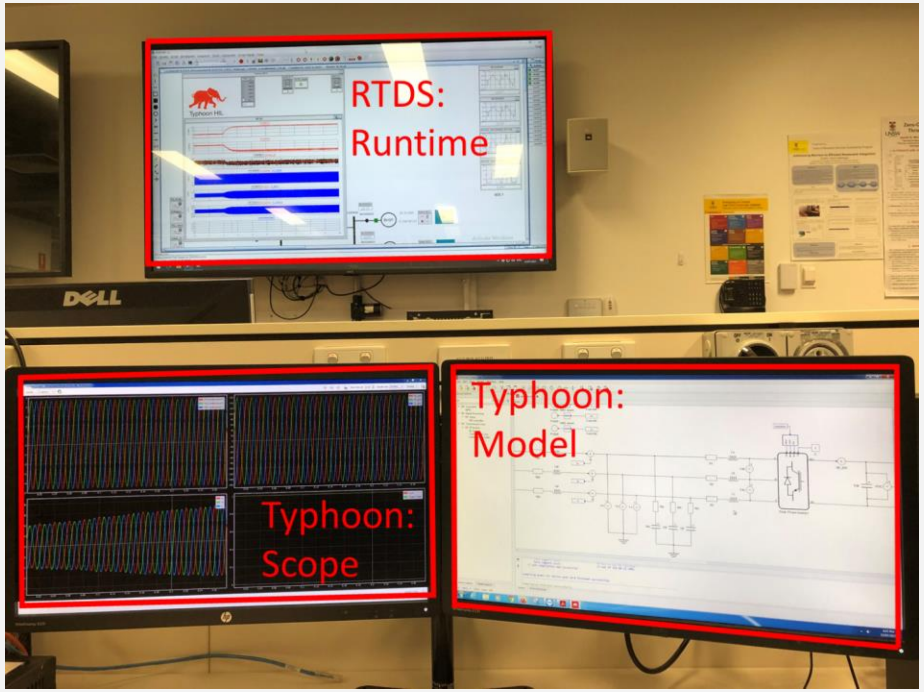
Grid-supporting functionality enabled

STAGE 3: CHIL


Multivendor approach
BESS
PCC voltages
BESS currents
Grid signals (V, I, P, Q)
Inverter control signals (per switch)
Grid signals (V, I, P, Q)
Inverter control signals (per switch)
Controller
West Murray Zone and BESS

STAGE 3: CHIL

- Multivendor interconnection between RTDS and Typhoon has been demonstrated through analogue/digital inputs/outputs:
  - West Murray Zone is running in RTDS.
  - Generic battery model is running in Typhoon.
- Time steps:
  - RTDS: 50μs for grid / <3μs for IBRs
  - Typhoon: 1μs



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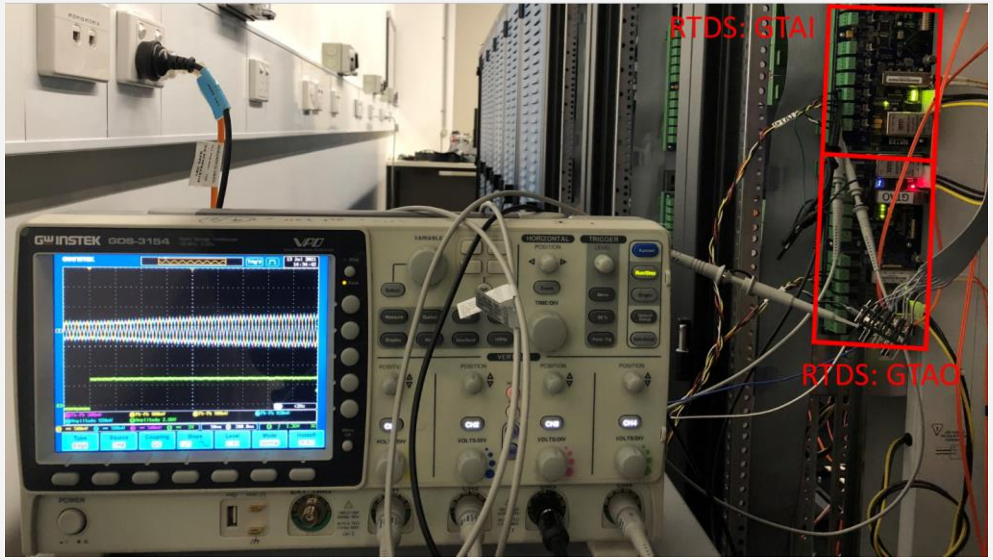

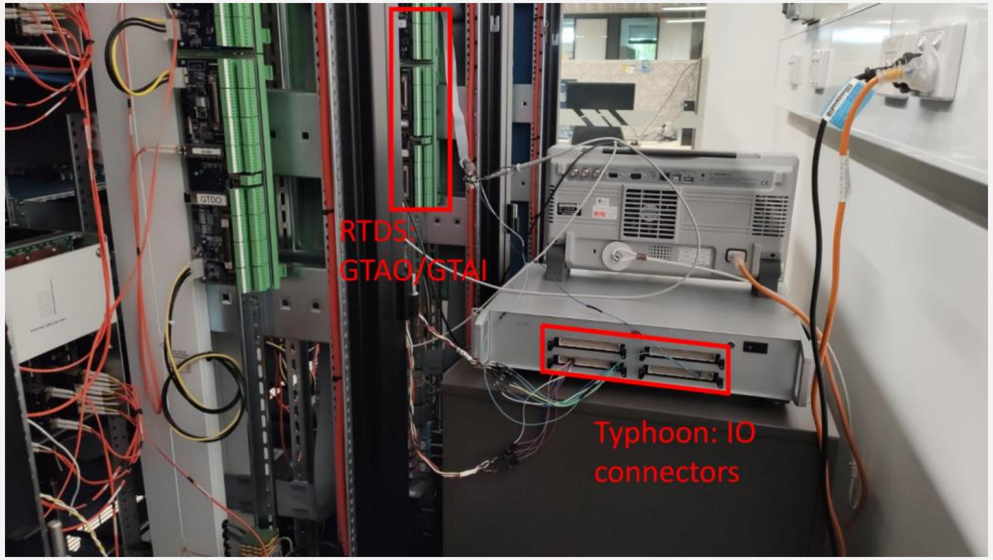

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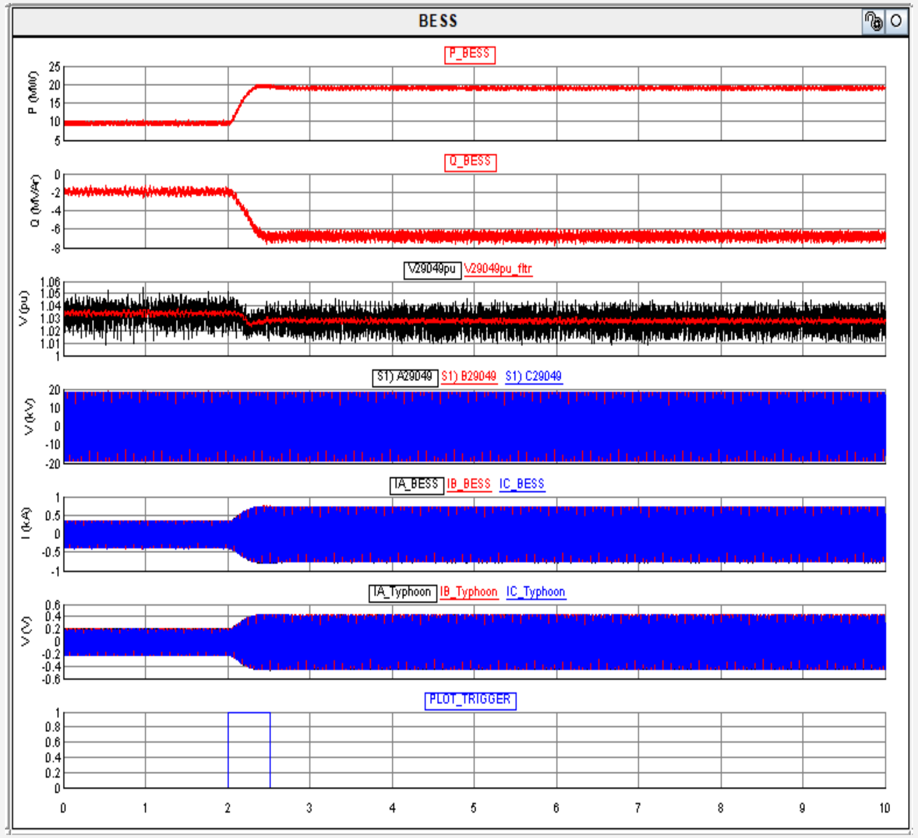
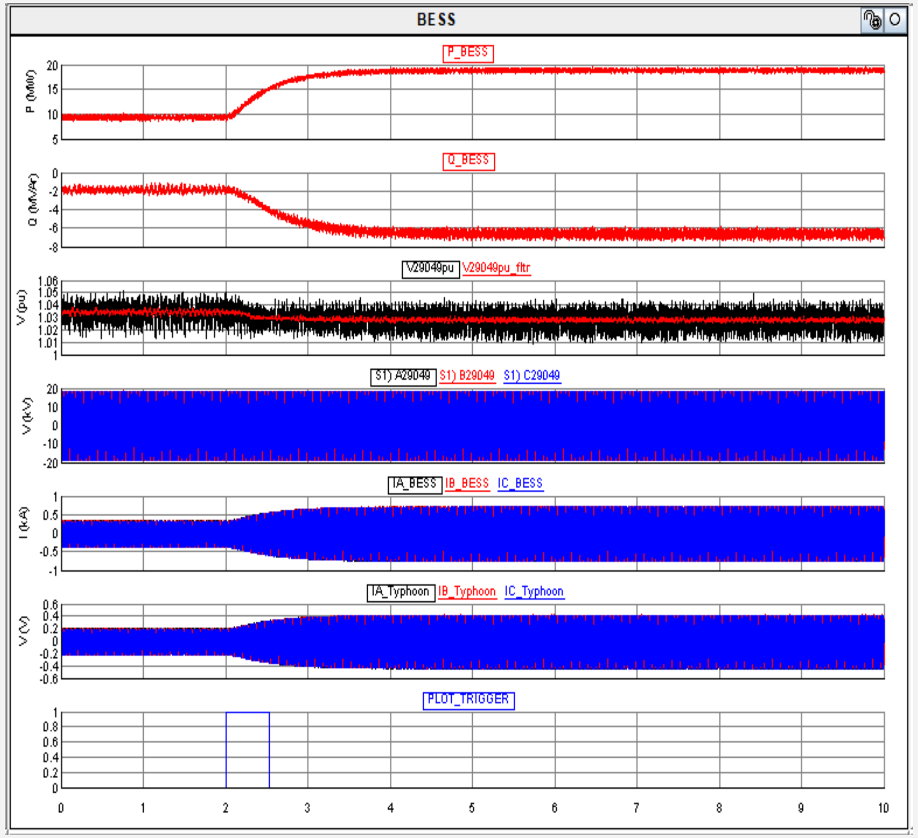


Step change (10 to 20 MW)
VSM H=2 s / D=25



Step change (10 to 20 MW)
VSM H=8 s / D=100

SUMMARY

- Targeted actions together with suitable investments in infrastructure are required to address existing challenges in weak areas of the Australian National Electricity Market (NEM).
- HiL testing is becoming more necessary for analysing and testing modern power systems with high penetration of IBRs.
- Real-time EMT simulations validates the proposed approach for the grid-supporting BESS at a multi-infeed weak area of the Australian NEM.
- The inclusion of a grid-supporting BESS damps voltage oscillations caused by faults and control interactions during periods of high generation of IBRs.
- Multi-vendor co-simulation through analogue/digital I/Os facilitates the black-box modelling and testing of control and protection devices.