G-PST/CSIRO Australian Research Plan

Task 1 – Inverter Design – Development of capabilities, services, design methodologies and standards for Inverter-Based Resources (IBRs)

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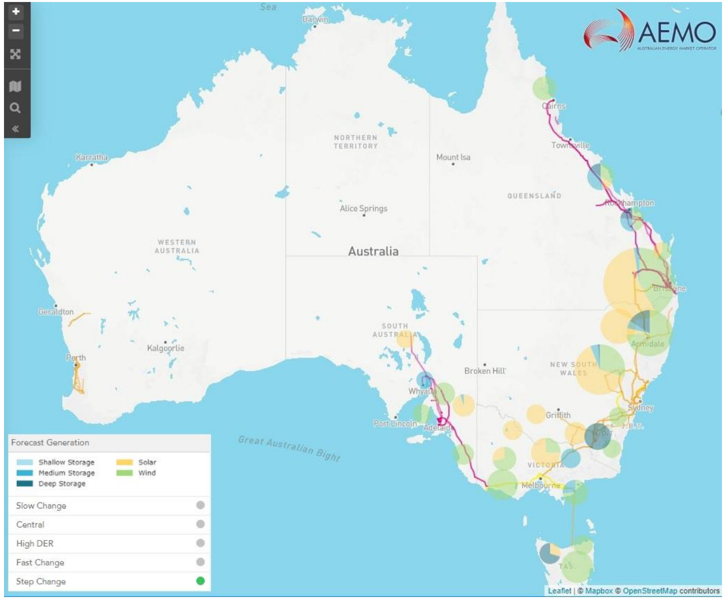
09/06/2022

Aims of Task 1 – Inverter Design

- Inverter-based resources (IBRs) are **increasingly the dominant** means to connect solar and wind energy to the Australian electricity grid.
- The **rate of new connections** to the grid and the time required to integrate these successfully is creating **operational issues and security constraints**.
- There are **many unanswered questions** about IBRs that must be solved as IBRs will be a mainstay in the future grid's generating fleet.

Aim: to contribute to the secure operation of the future IBR-dominant electricity grids, by solving unknowns about IBR design, development and operation.



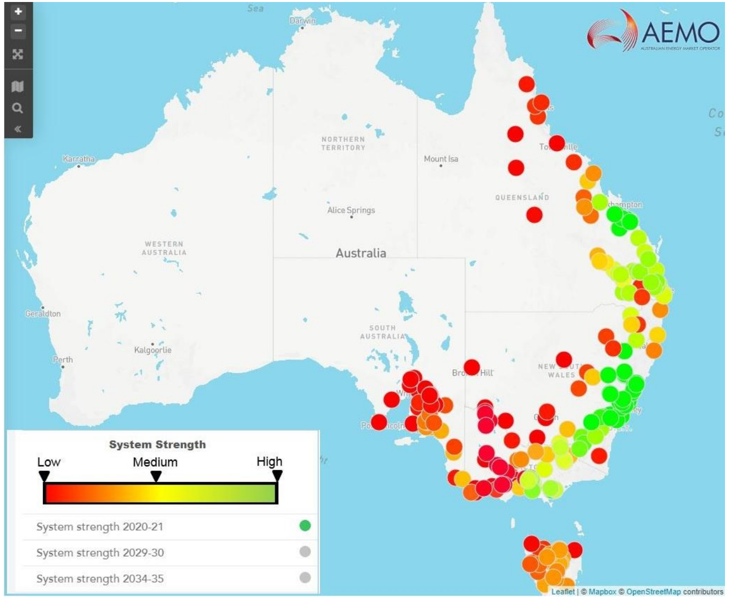
Forecast Generation (Step Change Scenario) for the Australian National Electricity Market (NEM)

https://www.aemo.com.au/aemo/apps/visualisations/map.html

Significance & Contributions to Australia

- This work would **support the bulk connection** of IBRs while ensuring that power system stability requirements are satisfied.
- As a result, this helps reduce or **alleviate some security constraints** being imposed to maintain energy security.
- Furthermore, this program will assist with:
  - **Secure operation** of future Australian electricity networks, benefiting all consumers.
  - **Improving investor and developer confidence** that projects will connect to the grid.
  - Ensuring new energy sources can connect as **old power sources** shut down.

This work is built for Australian needs using Australian developer, operator and investor experience and expertise.



System Strength Map in the NEM 2020-21

https://www.aemo.com.au/aemo/apps/visualisations/map.html

Methodology

Stakeholder engagement

Primary round of interviews

- Interviewed 13 stakeholders
- From different backgrounds; SOs, NSPs, NOs, and OEMs.

Research questions

Identify the research questions

- Categorised the research questions into themes and subthemes
- 40+ questions

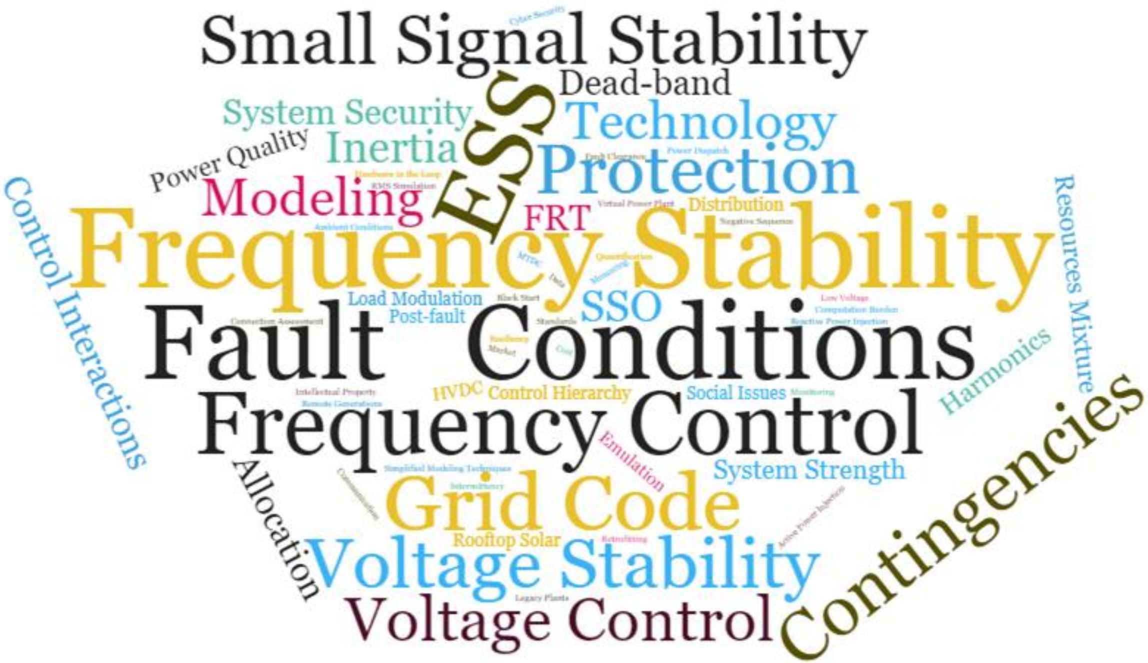
Task identification

Identify tasks to tackle the research questions

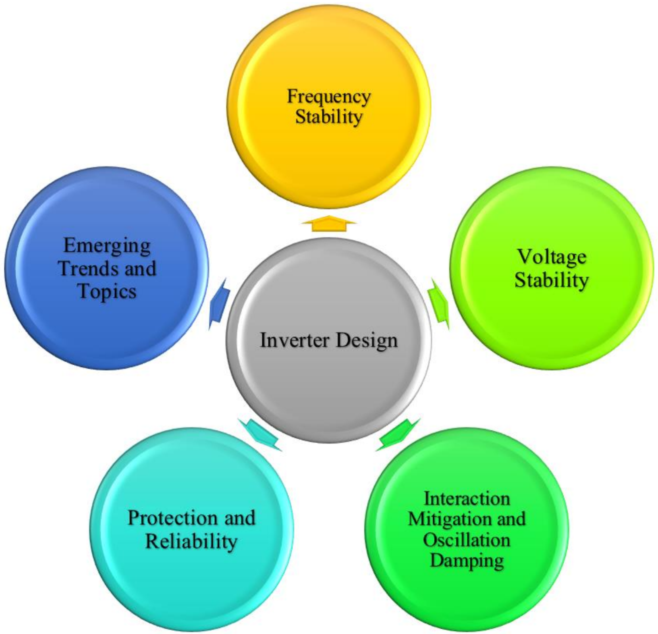
- Identified five Major Tasks and 14 subtasks
- Identified six Shared Tasks with other G-PST topics including five subtasks

Stakeholder Engagement

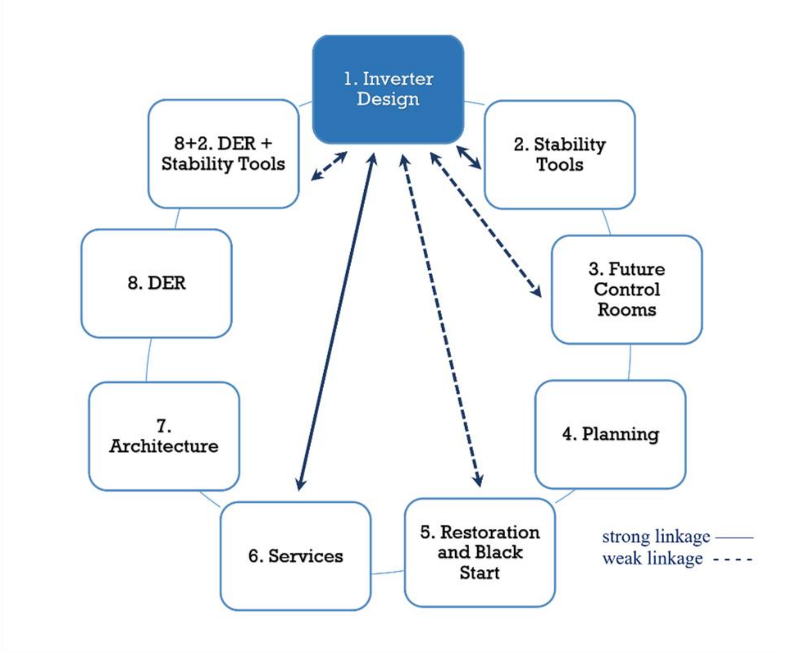
Themes of the Research Questions



Major Tasks & Links with Other Topics



Identified Major Tasks



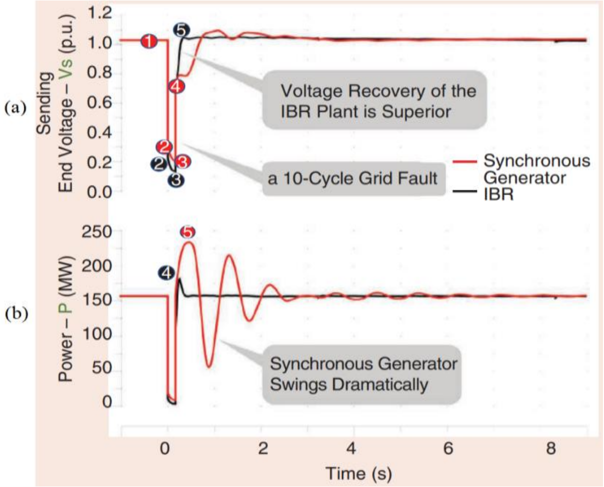
Links with Other Australian G-PST Research Topics

Major Tasks

Frequency Stability	define advanced IBRs and storage system frequency response requirements and capabilities for future grids	• Defining the response of GFLIs and GFMIs for a credible contingency • Control of ESS based on the capability of the energy source to provide various frequency services • Coordinated/distributed control of BESSs for frequency control
Voltage Stability	investigate the reactive capability and voltage control requirements of IBRs	• Investigation of IBR reactive power provision capabilities against the backdrop of losing synchronous machines • Interactions between synchronous machine AVR, GFMI AVR and GFLI in providing reactive power support
Interaction Mitigation and Oscillation Damping	identify and resolve the source of adverse interaction among aggregated IBRs	• Identifying the nature of oscillations in IBR-dominated grids • Standardising the models of IBRs • Modelling, analysis, control and coordination of IBRs for oscillation damping
Protection and Reliability	determine and propose mitigation methods for the adverse impact of IBRs on power system control and protection systems	• IBRs effect on existing protection systems • Enhancing IBR response during and subsequent to faults • Assessment and enhancement of IBRs reliability • Cyber-secure inverter design for grid-connected application
Trending Topics	develop advanced IBR control methods (grid-forming inverters) for future grid applications	• Developing alternative control methodologies for GFMIs • Grid-forming capability for HVDC stations and wind and solar farms • AI in IBRs control

Example Defined Project: IBRs Transient Stability Studies

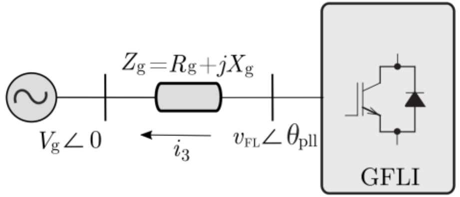
- During and after a fault, large transient behaviour of IBRs is inevitable.



(a) Ending voltage (Vs [p.u.]), and (b) active power (P [MW]) when a 10-cycle grid fault occurs in the middle of a power line close to an IBR Farm Point of Connection

J. Matevosyan et al., "A Future With Inverter-Based Resources: Finding Strength From Traditional Weakness," in IEEE Power and Energy Mag., vol. 19, no. 6, pp. 18-28, Nov.-Dec. 2021, doi: 10.1109/MPE.2021.3104075

- Transient stability analysis is employed to investigate the system response when dealing with a fault or severe voltage sag.
- In a single-machine infinite-bus (SMIB) system, these transients can be analysed by the conventional methods like:
    - Equal Area Criterion (EAC) method
    - Phase-portrait method
    - Lyapunov's method



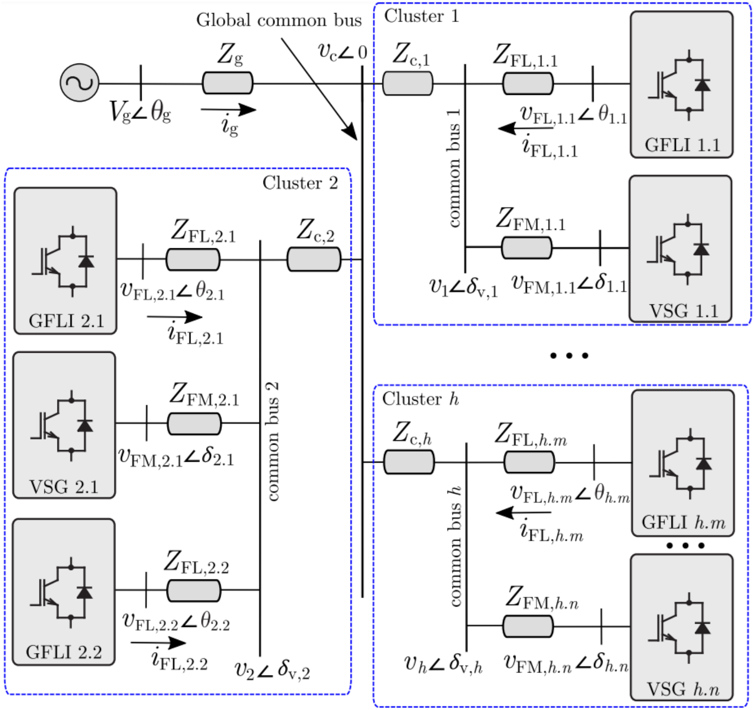
Single-line Diagram of a single grid-following inverter (GFLI) connected to an infinite bus

Example Defined Project: IBRs Transient Stability Studies

- In a more complex system, consisting of multiple IBRs, IBR responses are not only governed by their controllers but also by the interactions with other assets

⇨ The over-simplified SMIB model are no longer accurate enough

- This project aims to develop a transient stability analysis and enhancement method that can be applied to a multi-IBR system:
  - A GFLI-based solar PV farm equipped with a lumped GFM-BESS
  - A multi-clustered wind farm equipped with a distributed GFM-BESS
  - An IBR-dominated region in the presence of other assets such as SynCons and loads



Single-line Diagram of a system consisting of multiple GFMIs and GFLIs

Monash/ARENA Project on Grid Integration of IBRs in Weak Grids

At Monash, we are currently running a research project funded by the Australian Renewable Energy Agency (ARENA) to investigate the integration of IBRs in weak grids.

- We have investigated GFLI control and proposed several methods to enhance their stability in weak grids
- We have proposed a few GFMI control to enhance their performance.
- We are currently looking into a specific part of the NEM and studying the performance of the controllers we have developed in that region.

For more info: https://www.monash.edu/energy-institute/grid-innovation-hub/home/stability-enhancing-project

Single-line Diagram of a system consisting of multiple GFMIs and GFLIs

THANK YOU