

G-PST/CSIRO Australian Research Plan

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

Monash University

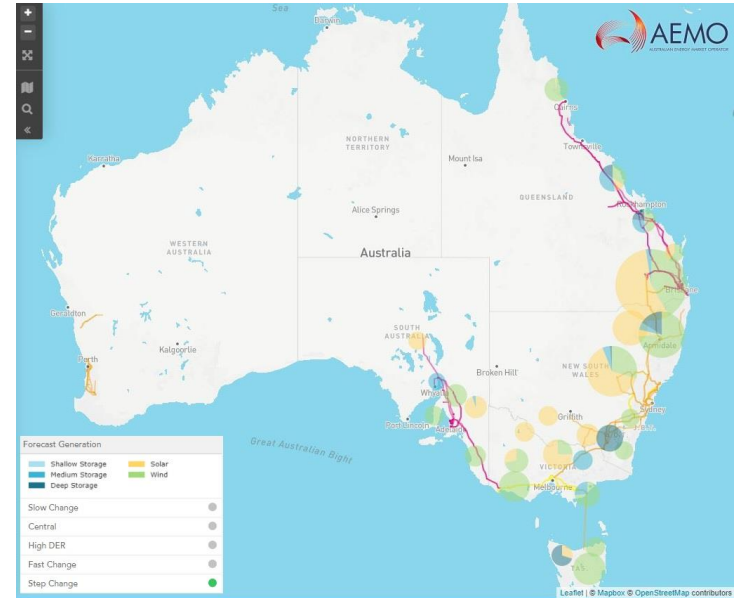
Dr Behrooz Bahrani, Director of Grid Innovation Hub

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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.



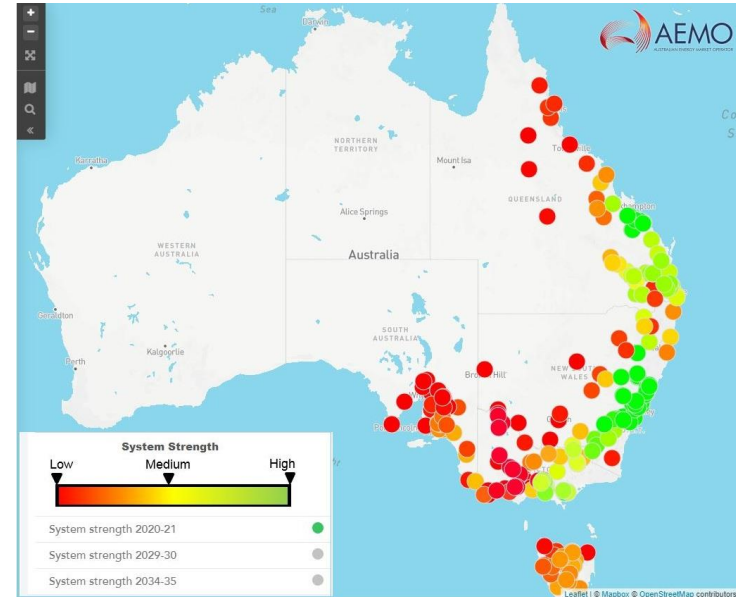
Forecast Generation (Step Change Scenario) for the Australian National Electricity Market (NEM)

<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

- Categorized 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

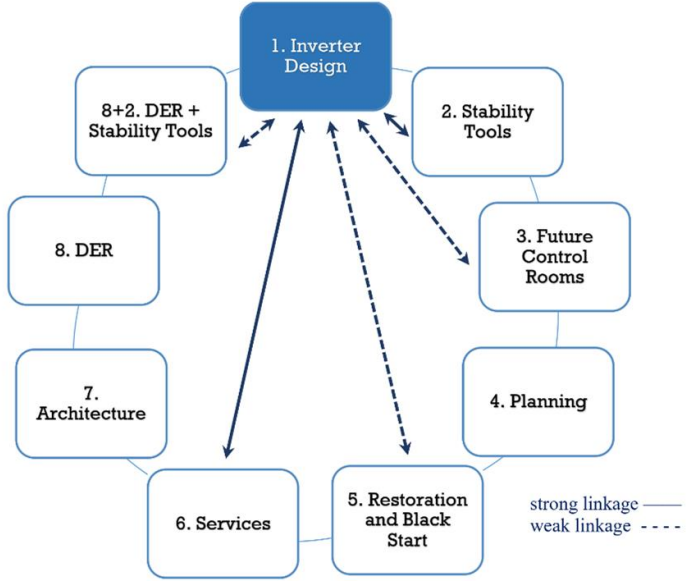
Stakeholder Engagement



Major Tasks & Links with Other Topics



Identified Major Tasks



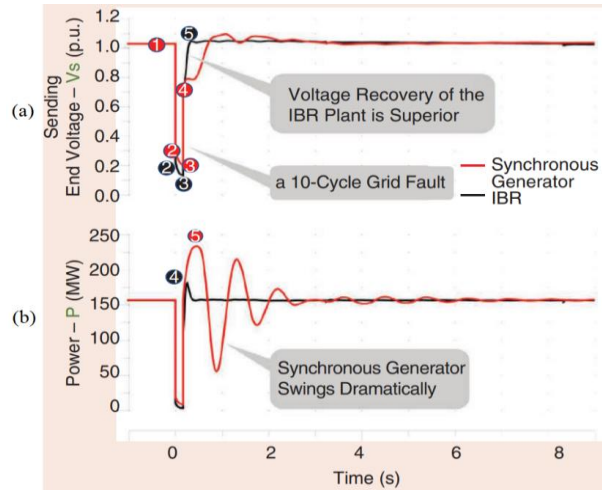
Links with Other Australian G-PST Research Topics

Major Tasks

Frequency Stability	define advanced IBRs and storage system frequency response requirements and capabilities for future grids	<ul style="list-style-type: none">• Defining the response of GFLIs and GFMIIs 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• 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
Voltage Stability	investigate the reactive capability and voltage control requirements of IBRs	<ul style="list-style-type: none">• Identifying the nature of oscillations in IBR-dominated grids• Standardising the models of IBRs• Modelling, analysis, control and coordination of IBRs for oscillation damping
Interaction Mitigation and Oscillation Damping	identify and resolve the source of adverse interaction among aggregated IBRs	<ul style="list-style-type: none">• 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
Protection and Reliability	determine and propose mitigation methods for the adverse impact of IBRs on power system control and protection systems	<ul style="list-style-type: none">• Developing alternative control methodologies for GFMIIs• Grid-forming capability for HVDC stations and wind and solar farms• AI in IBRs control
Trending Topics	develop advanced IBR control methods (grid-forming inverters) for future grid applications	

Example Defined Project: IBRs Transient Stability Studies

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

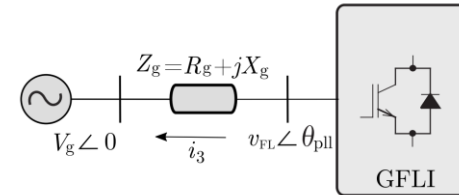


(a) Ending voltage (V_s [p.u.]), and (b) active power (P [MW]) when a 10-cycle grid fault occurs in the middle of a power line close to an IBR Farm Point of Connection

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



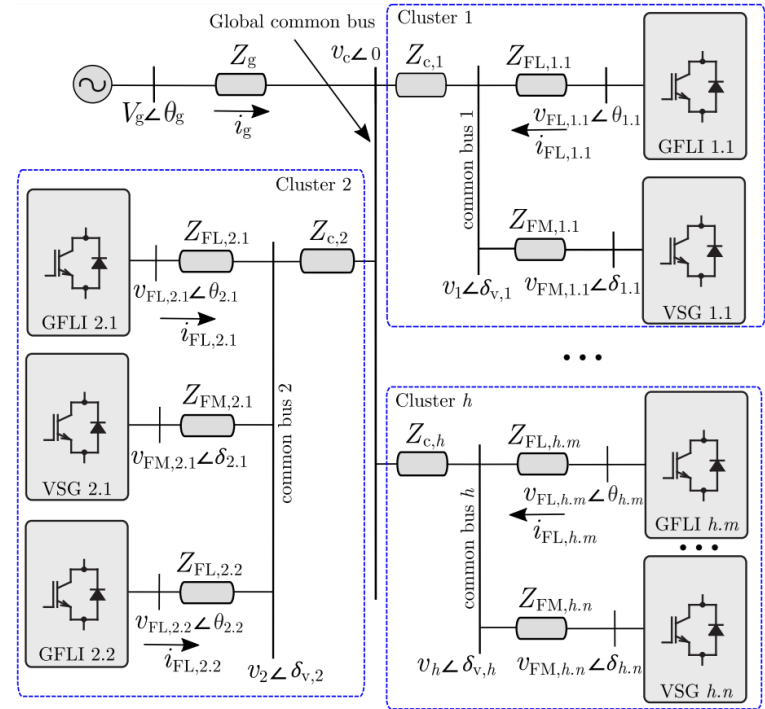
Single-line Diagram of a single grid-following inverter (GFLI) connected to an infinite bus

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 GFMs 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>

THANK YOU