Future Security and Resilience: Common Quality Technical Group (FSR CQTG)

Meeting 12: 24 June 2025

ELECTRICITY AUTHORITY
TE MANA HIKO

AGENDA

Time	Item
1.30 pm	Presentation on *System strength literature review*
1.50 pm	Feedback/discussion/Next steps
2.35 pm	Minutes from meetings 9, 10 & 11
2.45 pm	Authority work programme for 2025/26
3.15 pm	AOB
3.30 pm	Meeting ends

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System strength Part I

Investigation of system strength challenges and opportunities

24 June 2025

Agenda

Literature review

- System Strength Concepts
- International Events exacerbated due to Low System Strength
- Jurisdictional Approaches to Assess and Mitigate System Strength

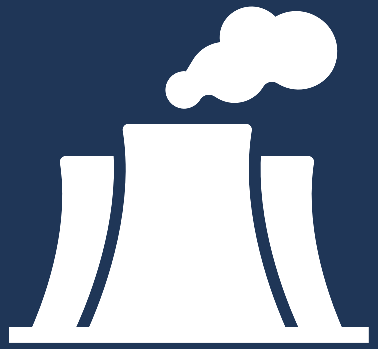
Application to the New Zealand Power System

Proposed Study Scope for Part II

Literature Review

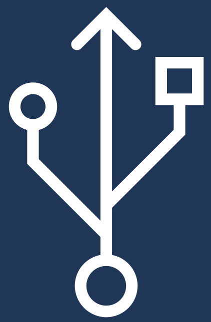
Motivation

Retirement of synchronous generating units



Limited fault current contribution by Inverter based resources

Oscillations introduced by inverter driven technologies



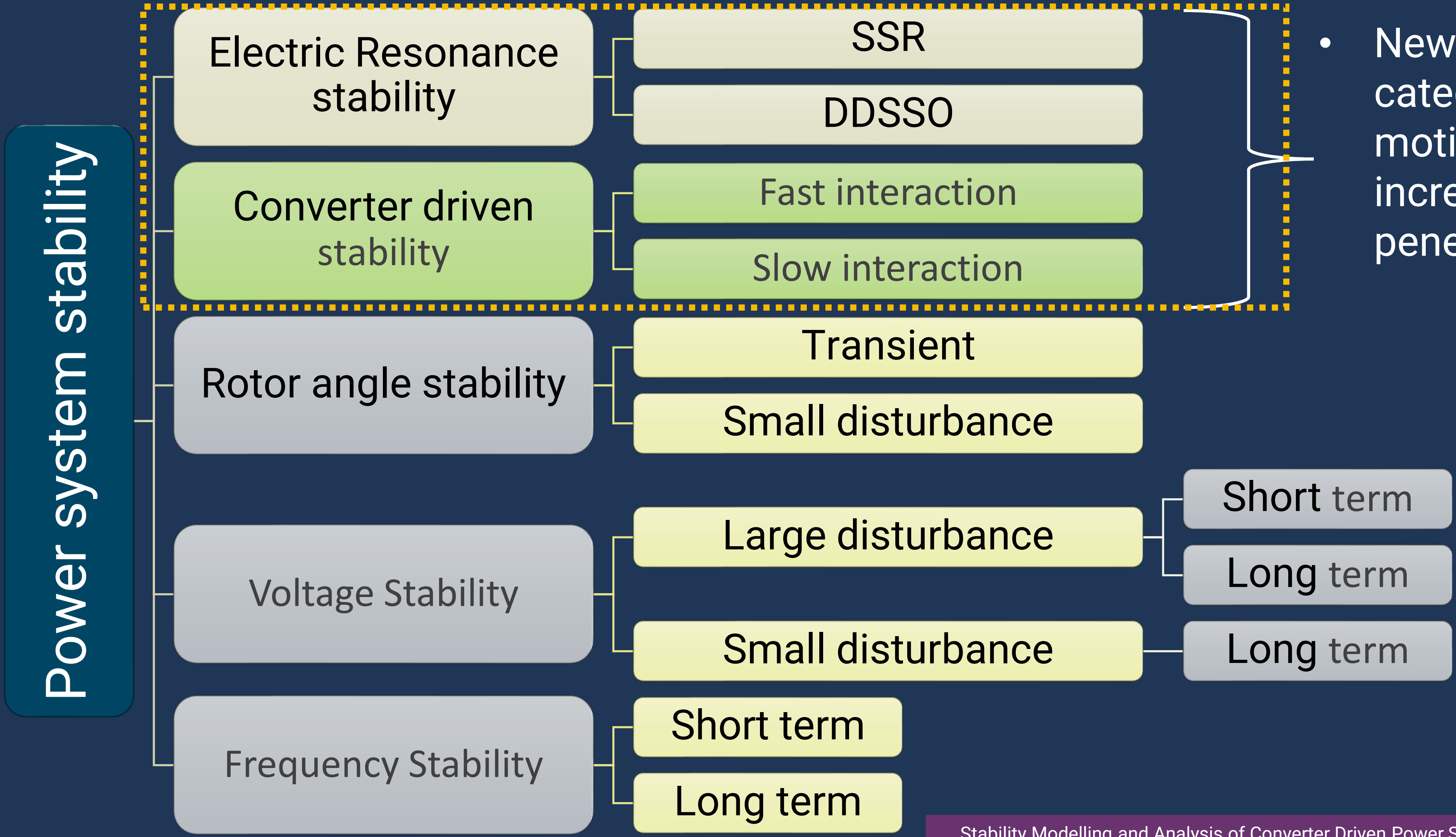
What then, is System Strength?

- Refers to the:
  - ✓ *the measure of the power system's ability to maintain **stable voltage levels** during and after disturbances, such as faults or sudden changes in power flow." – EiRGrid*
  - ✓ *is a characteristic of an electrical power system that relates to the **size of the change in voltage** following a fault or disturbance on the power system. System strength is also a function of the severity of system events on the **stability of IBR** - AEMO*

- Traditionally used interchangeably with fault levels. i.e.. High fault levels indicate strong grid while low fault levels indicate a weak grid.

- Quantified by a proxy, Short Circuit Ratio (SCR). However, this has become inadequate with increased IBR penetration.

Recategorisation of Power System Stability



- New (in)stability categories motivated by increased IBR penetration

International events related to Low system strength

Event & Jurisdiction	Observation	Mitigating Actions
2019 UK (Great Britain)	9 Hz oscillations post-lightning strike triggered wind farm de-loading and UFLS	OEM re-tuned turbine controllers; detailed disaggregated modelling used
2015 Ontario (Hydro One)	20 Hz oscillations from capacitor switching affected 3 solar farms	Network tie reconfigured to reduce grid impedance
2020 Australia (West Murray Zone)	15–20 Hz SSOs in low-strength PV-rich region; underdamped inverter modes	OEM tuned PLLs and added fast reactive current loop; AEMO enhanced modelling tools
2017 Texas (ERCOT)	22–26 Hz SSOs during contingency left wind farms radially connected	Accurate PSCAD models obtained; damping controllers retuned
China (West Region)	30 Hz oscillations between wind farms and thermal plant torsional modes	Sub-synchronous damping control added; PLLs re-tuned

Australia (AEMO)

- **Rule change in 2021 introduced proactive system strength obligations.**
- **TNSPs must plan and provide system strength; IBRs can either pay for access or self-remediate.**
- **AEMO publishes impact assessment guidelines with clear thresholds, SCR-based metrics, and modelling methods.**

Great Britain (NESO)

- **"Strength to Connect" project (2022) explores alternatives to fault level (SCL).**
- **Developed Impedance Margin Ratio (IMR) and Type-Dependent SCR (TDSCR) for small- and large-signal strength.**
- **EMT modelling and future market services under development.**

Ireland & Northern Ireland (EirGrid & SONI)

- Moving beyond global constraints (SNSP, MUON) to **regional strength and inertia policies**.
- Working on **new system strength metrics**, **grid-forming strategies**, and enhanced **EMT modelling**.
- Draft policy expected mid-2025; strong focus on planning, operations, and model obligations.

Texas (ERCOT)

- Adopted **Weighted SCR (WSCR)** in EMT-based screening, setting thresholds for IBR-rich areas. Installed **synchronous condensers** to improve strength and inertia; monitored for SSOs.
- New **dynamic model review** requirement (from May 2024) for all new/modified IBR connections.
- Developing **AGS-ESR test frameworks** aligned with **IEEE 2800-2022**.

Implications for New Zealand

Implications for New Zealand

- **Key Regulatory Gaps**
  - No defined system strength metric or threshold in the Code.
  - ESCR-based FRT provisions apply are assessed at connection stage but do not provide a comprehensive framework for ongoing system strength management.
  - No standard methodology to assess system strength for both system operator and asset owners modelling obligations for asset owners.

Clause 8.25(5)(b): amended, on 5 October 2017, by clause 92(3) of the Electricity Industry Participation Code Amendment (Code Review Programme) 2017.
Clause 8.25(5)(b): amended, on 1 November 2018, by clause 11 of the Electricity Industry Participation Code Amendment (Code Review Programme) 2018.

8.25A Fault ride through

(1) Each **generator** must ensure that each of its **assets**, when **electrically connected** to a **network**, is capable of remaining stable and **electrically connected** when the **grid**'s lowest **line-to-line** voltage is within the no-trip zone shaded and marked "No-trip zone" in Figure 8.1 (for an **asset** in the North Island) or Figure 8.2 (for an **asset** in the South Island) for the period of 6 seconds immediately following the commencement of a zero impedance three-phase short circuit fault, or an unbalanced short circuit fault, on any part of the **grid** at 110 kV or 220 kV in the **island** in which the **asset** is connected.

(2) Each **generator** must ensure that each of its **assets**, when **electrically connected** to a **network**, is capable of remaining stable and **electrically connected** when the highest **line-to-line** voltage at Haywards 220 kV bus (for an **asset** in the North Island) or Benmore 220 kV bus (for an **asset** in the South Island) is within the no-trip zone shaded and marked "No-trip zone" in Figure 8.3 for the period of 1 second immediately following the commencement of a trip of the **HVDC link**.

(3) Whether a **generator** is complying with subclause (2) must be determined using power system analysis that uses—
  (a) study cases provided by the relevant **grid owner**; and
  (b) relevant system assumptions provided by the **system operator**.

(4) A **generator** is not required to comply with subclause (1) in respect of an **asset** in the event of a fault of a type described in subclause (1) if the **asset** becomes isolated from the **grid** as a result of the fault.

(5) A **generating unit** need not comply with subclause (1) to the extent that it is complying with a **special protection scheme** approved by the **system operator**.

(6) The absolute **grid** voltage (per unit) shown on the Y axis of Figure 8.1 and Figure 8.2 is the ratio of **grid** lowest **line-to-line** voltage on a **line** to the nominal operating voltage of the **line** (that is, 110 kV or 220 kV).

Figure 8.1: North Island no-trip zone during 110 kV or 220 kV faults

Implications for New Zealand

- **Analysis Tools and modelling requirements**
  - PowerFactory: While eigenvalue analysis is available through the Power Quality/Harmonic module, a script is required to define input parameters. This is still in development.
  - SSAT: System operator has limited licences although work has started on using PSCAD impedance scan to integrate with SSAT analysis.
  - PSCAD: Studies are high fidelity but is compute-intensive so will be used to do; system operator has limited access to validated IBR models.

- **System strength studies require high-fidelity IBR models (GFL & GFM) across EMT & RMS tools due to the detailed study requirements.**

Implications for New Zealand

- **Capability gaps & Modelling requirements**
  - Building of knowledge base in stability theory, eigenvalue analysis, impedance scanning and relevant scripting (Python/MATLAB).

- **Next Steps**
  - Upgrade existing tool licences, build engineering expertise and improve access to detailed inverter models.
  - System strength PART II

Part II Scope

Overall goal

Conduct detailed power system studies to evaluate candidate system strength metrics and conduct studies that will inform future technical frameworks.

Out of scope

- Protection implications
- System inertia considerations

Key Objectives

1. **Develop an assessment matrix** for evaluating system strength using key performance indicators.
2. **Define operational boundaries** for various IBR technology types, aligned with best practice.
3. **Specify technical requirements** for robust IBR performance.

1 Is SCR the best metric for NZPS to use? Is a threshold of 3 still adequate?

Study Approach

- Review and compare **2–3 candidate metrics**
  - Define calculation methods and instability thresholds
  - Assess pros/cons and NZPS applicability
- Conduct **EMT studies** using SMIB or regional network models
  - Simulate various fault levels at PCC

Expected Outcomes

- A validated **assessment matrix** to evaluate IBR connection impacts
- A recommended **threshold** for screening system strength at connection points

2

What are the Power System Operational Boundaries required to ensure inverter stability?

Study Approach

- Consider **GFL vs GFM** inverter control methods
- Assess **GFL + GFM interactions** at/near same PCC
- Varying:
  - IBR penetration levels
  - Fault levels at PCC
  - MW output
  - Fault types (Balanced and unbalanced faults)

2 What are the Power System Operational Boundaries required to ensure inverter stability?

- **Detailed site-specific IBR models** from OEMs (GFL & GFM)
- Start with **SMIB model**; expand to **regional network** (incl. transformers, compensation, GXP lumped loads)

Analysis Methods

Study 1: Eigenvalue Analysis

- Assess system stability by evaluating the IBR's state matrix.
- **Mode Identification** – determine oscillation frequencies and how they shift with grid changes.
- **Participation Factor Analysis** – identify key components influencing each mode.
- **Assess Grid Condition Sensitivity** – evaluate stability impacts from impedance changes, voltage steps, and phase jumps.

2 What are the Power System Operational Boundaries required to ensure inverter stability?

Study type 2: Impedance Scan

- **Sub-harmonic Resonance Analysis** - especially when the system oscillates at frequencies that are fractions of the fundamental frequency, leading to electrical instability.
- **Frequency-Domain Impedance Scan** - Identify resonance points by scanning IBR impedance across frequency range.
- **Impedance vs Power Output** - Assess how impedance profile changes with varying generation levels to reveal dynamic instability risks.

Study type 3: EMT simulation

- **EMT Simulation for Final Verification** - Confirm findings from impedance scans or eigenvalue analysis by using detailed network models.

3 Specify technical requirements for robust IBR performance

FRT Performance

- Evaluate IBR **ride-through capability**
- Identify fault types and conditions that cause inverter tripping
- Contingencies to apply can include **balanced & unbalanced faults** and **including removing transmission circuit without a fault**

Thank you

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Activities planned for 2025-26

Review of Common Quality requirements in Part 8 of the Code

- Finalising decisions for Code amendment proposals (Issues 1 to 4, 6 & 7) and gazetting Code amendments
- AOPOs for BESS and hybrid plants
- Operating with low system strength - investigate system strength challenges and opportunities

Future system operation

- Consider submissions to inform a decision on a DSO model in the first half of 2026.

Activities planned for 2025-26

Issue	Description	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
2,3,4	System strength- Stage 2: Investigating system strength including GFM inverters -Options paper												[C]
2,3,4	Option 2- managing reactive power across GXPs												
6	Option 1			SO [C]			[D]						
2,3,4	-AOPO's for BESSs in 'idle' mode and hybrid plant -Definition of ESS -Frequency: Droop and ramp rate -Definition of generating unit -Definition of 'Hybrid'												[C]
5	Harmonics: -Governance (EA) -Management (SO)										[C]		
6	Options 2 & 3												
1-7	CAP (combined issues): -Cl 8.21(1): Definition of excluded generation -Cl 8.23: Point of compliance -Part 1 of the Code: Clarity for FIR -Definition of generating system (considered in the CACTIS)										[C]		
4	FRT curves												

AOB