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New England BESS

Report to the Emerging Energy Program on connection of a grid-forming BESS

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Overview

This Report was prepared for the Emerging Energy Program on the grid connection process experienced with connecting the New England Battery Energy Storage System (NE BESS) to the grid. The New England BESS with its innovative inverter system is being built with the support of the NSW Government's Emerging Energy Program.

The Proponent is ACEN Australia.

Introduction

This report outlines the connection process for the New England Battery Energy Storage System (New England BESS), a 200 MW grid-forming battery system developed by ACEN Australia.

The connection is a grid-forming Virtual Synchronous Generator (VSG) Battery Energy Storage System at Uralla 330 kV Switching Station (NSW).

The facility features Siemens SINAMICS S120 voltage-source inverters operating in Virtual Synchronous Generator (VSG) mode, offering a 2 per unit (pu) current overload capacity and enabling support for system strength and advanced stability services.

The report provides an overview of the steps taken during stage R0 of the NEM's formal connection process for the initial 50 MW/1 hour BESS. It covers timelines, the development of performance standards, technical insights, and how regulatory rules influenced outcomes, especially before recent changes to VSG-based grid-forming technology assessments.

Additionally, the report briefly covers the 5.3.9 process for expanding the BESS to 200 MW/2 hour and discusses the subsequent registered performance standards under the R1 process. This discussion helps illustrate the progression of the NER and its evolving capability to accommodate grid-forming technology.

Background

Initially, the project was planned as a 50 MW, 1 hour BESS connected to the Uralla 330 kV switching station, located next to the 720 MW New England Solar Farm at Point of Connection 4 (POC4). This site is about 14 km south of Armidale and links into Transgrid's 330 kV Line 85 between Armidale and Tamworth.

The 50 MW project underwent the full connection application process under National Electricity Rules (NER) Version 168 and received a 5.3.4A/B letter on October 21, 2022. No system strength remediation was required or proposed. Figure 1 provides a connection overview of the system.

In 2023, a decision was made to increase the plant's capacity to a 200 MW, two-hour BESS, which would operate as two separate Dispatchable Units (DUIDs) of 100 MW each. This change necessitated an NER 5.3.9 process before procurement began. The process started in early 2024 and concluded with a 5.3.10 letter issued in November 2024.

Several GPS clauses were updated to reflect new rules (NER V211), including classification as an Integrated Resource Provider, system strength rule changes, and allowances for grid-forming inverter behaviour specified in S5.2.5.5.

After progressing through R1, the project was formally registered as an Integrated Resource Provider in February 2026.

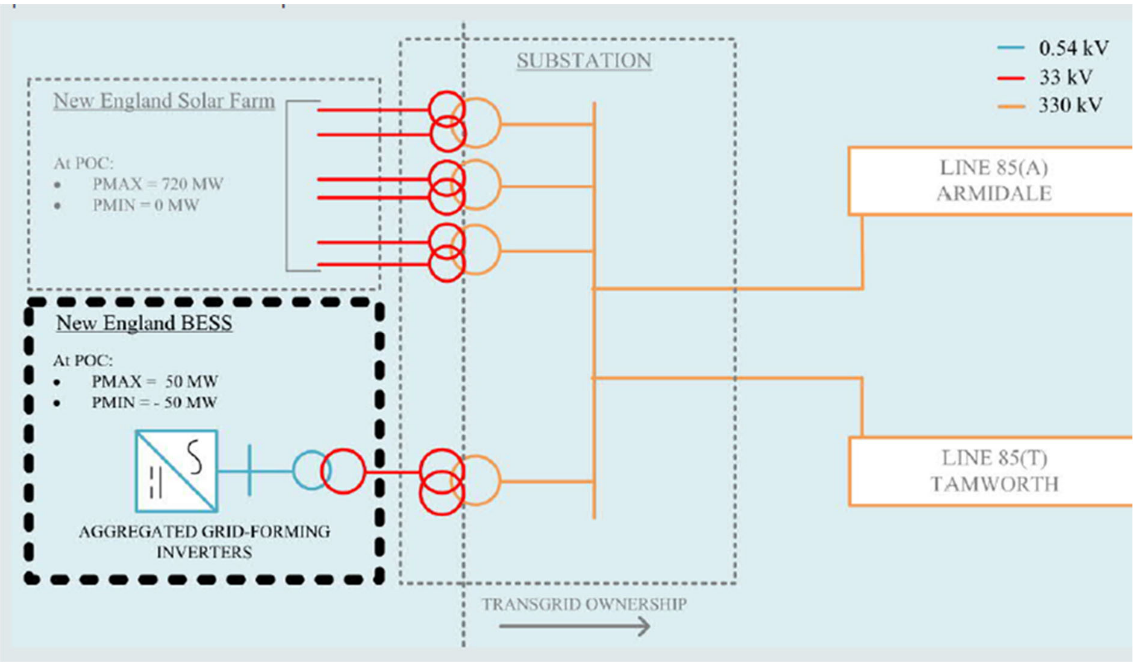


Figure 1 – NE BESS proposed connection arrangement for 50 MW (WSP 2022)

Grid-forming (GFM) vs Grid-following (GFL) Characteristics

The distinction between grid-forming and grid-following inverters is fundamental to understanding their operation within the power system. Grid-forming inverters possess the ability to generate their own voltage and frequency references, meaning they do not depend on the external grid to establish their waveform. This autonomy enables them to operate independently from the grid and, if appropriately designed, provide black start and islanding capability.

One of the key advantages of grid-forming projects is their capacity to connect into weaker grids. By stabilising the voltage waveform, they offer what is known as system strength support, enhancing the resilience and reliability of the network.

In contrast, grid-following inverters rely on the external grid to function. They utilise a Phase-Locked Loop (PLL) to track the external waveform, making them dependent on grid conditions for operation.

Operationally, grid-forming inverters act as voltage sources, whereas grid-following inverters function as current sources. Up until recently, all inverters connecting to the National Electricity Market (NEM) were based on grid-following technology.

In May 2023, AEMO released a voluntary specification for grid-forming inverter standards – this was 6 months after the approval of the NE BESS's 50 MW stage. This specification clearly defined the requirements for grid-forming behaviour, including the ability to operate as a voltage source, regulate voltage without a PLL, and provide frequency support with an inertia-like response.

The NE BESS met these criteria, qualifying as a grid-forming inverter under AEMO's guidelines. The project also successfully completed the Stable Voltage Waveform assessment, demonstrating its system strengthening capabilities as a grid-forming plant.

It is important to note that not all grid-forming inverters share the same features as the Siemens SINAMICS S120. Nevertheless, as long as they exhibit the behaviour specified by AEMO, they are recognised as grid-forming inverters.

Project Overview

1. Project Name: New England BESS
2. Owner / Proponent: ACEN Australia Pty Ltd
3. Location: Uralla 330 kV Switching Station, NSW
4. Technology:
    a) 50 MW grid-forming BESS
    b) Siemens SINAMICS S120 VSG-mode inverters
    c) 2 pu overload capability
5. Network Service Provider (NSP): Transgrid
6. Connection Type: New generator connection under NER Chapter 5, V168.
7. Plant Overview: The NE BESS comprises of 7 SINAMICS Power Conversion Systems (PCS) each compromised of 8 inverter systems (fed by the Battery Energy Storage System). Each PCS has a capacity of ±7.3 MW and ±2.82 MVAr, which is based on 8 × 1219 Amp 540 Vac units. Configuration is shown in Figure 2.

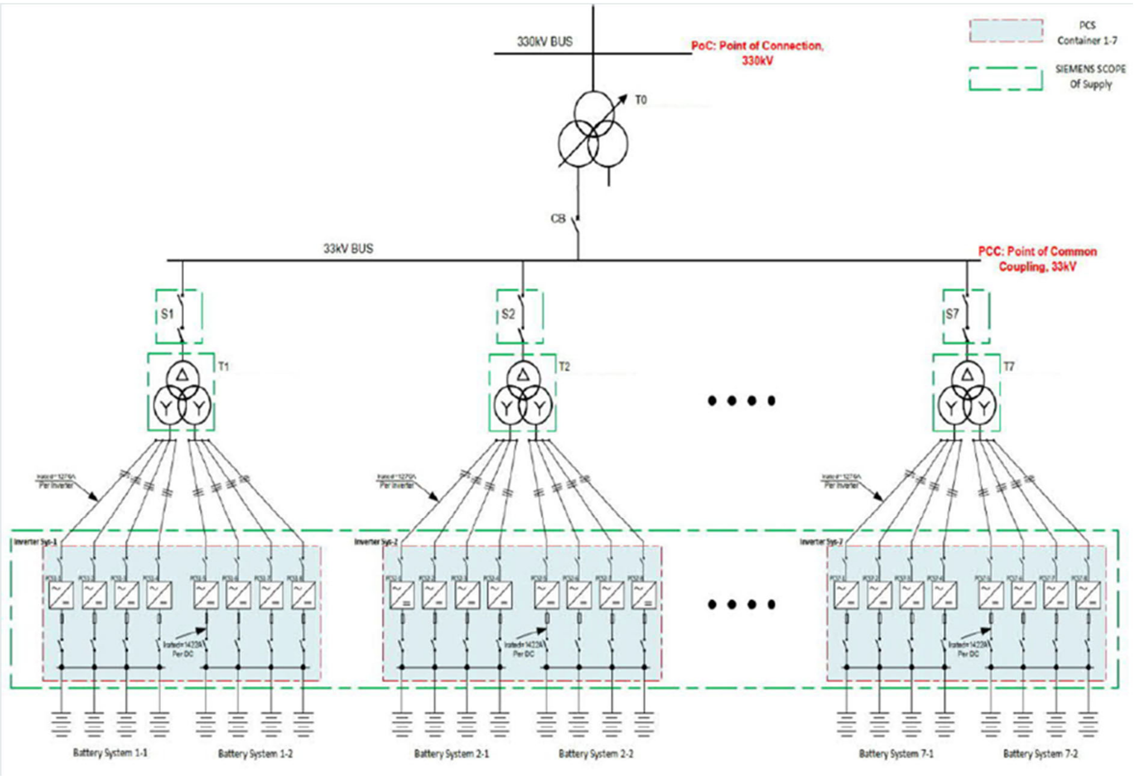


Figure 2 – NE BESS plant configuration 50 MW (WSP 2022)

Connection Process Summary

Table 1 below shows the inputs into the grid modelling for each of the phases that the NE BESS progressed through before commissioning.

Table 1 – Grid modelling inputs and timelines per connection phase

NE BESS			
Process	R0	5.3.9	R1
Size	50 MW/1 hour	200 MW/2 hour	200 MW/2 hour
Technology	Grid forming	Grid forming	Grid forming
Inverter	Siemens SINAMICS S120	Siemens SINAMICS S120	Siemens SINAMICS S120
PPC	Siemens MCP	Siemens MCP x 2	Siemens MCP x 2
Connecting NSP	Transgrid	Transgrid	Transgrid
Connection point	Uralla 330 kV	Uralla 330 kV	Uralla 330 kV
DUID(s)	1	2	2
Voltage control point	330 kV	330 kV	330 kV
Primary voltage control point	Q(V) with droop	Q(V) with droop	Q(V) with droop
P control point	330 kV	33 kV bus	33 kV bus
Q control point	330 kV	33 kV bus	33 kV bus
Min Fault level	1772 MVA	1786 MVA	1786 MVA
Min X/R ratio	8.56	8.70	8.70
Min SCR	2.30	8.93	8.93
Max Fault level	5773 MVA	6374 MVA	6374 MVA
Max X/R ratio	9.25	9.90	9.90
Max SCR	60	31.86	31.86
FRT input	330 kV	330 kV	330 kV
Timelines			
Lodge application	24/08/2021	25/03/2024	01/04/2025
Approval	21/10/2022	13/11/2024	12/02/2026
Approval type	5.3.4a/b	5.3.10	Registration as IRP
Elapsed time (months)	14.1	7.8	10.6

The primary distinctions between the three connection phases in terms of technical assumptions were attributable to changes in Rules, guidelines, or plant configurations. The most significant differences are outlined below.

The timelines for each process reflect the industry's GFM technological expertise, supported by the AEMO voluntary standard for GFM inverters, Rule updates, and increased model maturity.

The 5.3.9 process was substantially expedited, taking eight months compared to fourteen months in the initial R0 phase, owing to these factors. Furthermore, the 5.3.9 package proceeded directly to FIA following the first review cycle.

SCR Calculations

During the initial R0 process, the entire capacity of Solar PV and BESS—770 MW—was included in the SCR calculations. This led to tuning based on 770 MW instead of 50 MW, resulting in an SCR range of 2.3 to 9.25 for this submission. The maximum SCR was determined with the solar farm offline or during nighttime conditions.

In the 5.3.9 process, the project size increased to 200 MW, but the methodology for calculating SCR changed. As a result, the overall SCR shifted to a range of 8.93 to 31.86 (Fault level/200 MW), and this approach remained unchanged for the R1 process.

Control points

The 5.3.9 modelling required adjustments to control topology because the plant was expected to operate as two dispatchable units—each assigned to a separate 33 kV transformer winding. As a result, both power and reactive power would be managed at the 33 kV level, while voltage droop control would remain at the 330 kV level. Each DUID needed its own PPC, and it was necessary to account for reactive power losses in the main transformer.

In the detailed design phase (R1), the PPCs were placed in the substation building alongside the other control systems, rather than in the usual location at the Transgrid 330 kV yard. This arrangement required transmitting the 330 kV voltage signals over fibre optic links between the yards to reach the PPCs, causing a 20 ms delay in signal receipt. To deal with this delay, the FRT detection point was shifted to the 33 kV bus to maintain rapid fault response. Despite this change, standards required proof of plant performance at the 330 kV level which were demonstrated.

Stage R0 – Connection application to approval

Timeline to R0 Completion

The total duration from the initial enquiry to final approval for the 50 MW plant was 25 months. Of this period, 14 months elapsed between the submission of the connection application and receipt of approval. The remaining time was allocated to plant design and model alignment to ensure compliance with performance standards. Table 2 provides a summary of the entire process timeline.

Table 2 – Timeline for R0 connection application

Milestone	Description	Date
Initial enquiry	ACEN Australia initiates connection discussion	20/09/2020
Preliminary design phase	Engage in plant design, inverter selection, modelling, connection package development	01/12/2020
R0 package submission	Full connection application submission to Transgrid and AEMO under NER V168	24/08/2021
AEMO/TransGrid feedback	Clarification of VSG modelling expectations	19/10/2021
Second package submission	Significant PSSE model updates and alterations to fit inverter standards	11/03/2022
FIA completion	Following review and response of package 2	12/07/2022
R0 completion	Issue of 5.3.4A/B letter	21/10/2022

Performance Standards – Initial Position (R0)

Submission of Original Performance Standards

The original performance standards were submitted in accordance with inverter-based rules for most clauses, with the exception of S5.2.5.5 – response to disturbances following contingency events. This particular clause was documented as a synchronous generator performance, reflecting the fact that the inverters were operating in Virtual Synchronous Generator (VSG) mode. Presenting S5.2.5.5 within inverter-based characteristics proved to be challenging.

Negotiations and Model Adjustments

Following the initial round of negotiations, AEMO determined that the project was required to comply with inverter-based standards, given that the hardware was ultimately an inverter. This decision led to the implementation of additional controls within the models to ensure that the inverter response characteristics were captured appropriately.

Final Accepted Standards and Specific wording

The performance standards that were accepted, as outlined in the 5.3.4A/B letter, necessitated specific wording under clause S5.2.5.5. This was done to accurately describe the operational behaviour of the grid-forming BESS.

Load Provisions and Bi-directional Assessment

As part of the performance standards, load provisions were included for all relevant clauses and were maintained throughout the R0 process. It is important to note that, at that time, there were no explicit S5.2.5.5 requirements for loads. Nevertheless, the NE BESS was evaluated for bi-directional operation.

Key Learnings

8. Modelling the VSG to align with grid-following inverter-based performance characteristics presented challenges under Rules Version 168; however, this was accomplished without compromising the core attributes of the grid-forming technology.

9. Accurately representing and modelling the inverter's overload (inertia) characteristics in the performance standards proved to be complex.

10. There was limited awareness within the NEM regarding the characteristics of voltage-source grid-forming BESS at the time.

11. As the Rules constitute a legal framework, it was necessary to develop a performance standard workaround that operated within these constraints.

Technical Evaluation

The NE BESS showed strong performance on the grid, as demonstrated by the Full Impact Assessment in July 2022. Reaching this point required several model revisions, educating stakeholders about the technology's advantages. These steps went beyond the usual requirements for a typical inverter-based application.

Table 3 below shows the plant, rules and performance standards agreed at each stage of the project. Greyed out sections indicate performance that weren't required under the Rules at the time.

Table 3 – Performance Standards Extract at each application stage

NE BESS			
Process	R0	5.3.9	R1
Size	50 MW/1 hour	200 MW/2 hour	200 MW/2 hour
Performance Standards			
Rule Version	168	211	211
Type	Generator/Load	IRP	IRP
Nameplate rating	63 MVA	252 MVA	252 MVA
Maximum capacity discharging	50 MW	200 MW	200 MW
Maximum capacity charging	50 MW	200 MW	200 MW
System strength remediation scheme	N/A	Self	Self
S5.2.5.1 Reactive power capability	A	N	N
S5.2.5.2 Quality of Electricity	A	A	A
S5.2.5.3 Response to frequency disturbances	A	A	A
S5.2.5.4 Response to voltage disturbances	A	A	A
S5.2.5.5 Response to disturbances following contingency events	N	N	N
iQ injection capacitive	3%	3.5%	3.5%
	below 85%	below 85%	below 85%
iQ injection inductive	3.5%	4.8%	4.5%
	above 131%	above 115%	above 115%
Reactive current rise time (no greater than)		40 ms	40 ms
Reactive current settling time (no greater than)		150 ms	240 ms
Reactive current commencement time		20 ms	20 ms
Active power recovery - discharging	200 ms	250 ms	250 ms
Active power recovery - charging	320 ms	350 ms	350 ms

The following section details issues that were found and needed further work as part of the R0 process due to the nature of the voltage-source, grid forming inverters.

Due Diligence

The connection application took three rounds of review before being approved. Significant time was taken between Round 1 and Round 2 submission due to the modelling updates and control upgrades required for the plant.

Overall, there were 273 issues raised as part of the R0 due diligence process. The breakdown of issues were balanced between modelling and performance. Not all of these were related to the grid-forming nature of the project, however many concepts such as provision of grid support at all times and not purely during faults, led to issues raised across both the model and performance components.

Inertia and overload capabilities were also the subject of many discussions.

Technical issues raised relating to grid-forming

Overload capabilities

The SINAMICS S120 has overload capabilities as part of the inbuilt inertia function. It is capable of 2 pu overload for up to 1 second, or 1.5 pu overload for up 60 seconds. This feature is deployed as part of the VSG functions such as inertia response to frequency deviations (ROCOF), and reactive current response to voltage changes. Note that the overload is up to 2 pu current which can be used for both power and reactive power responses – there is no Q priority setting in the inverter.

The overload capability was raised as an issue on various fronts, including:

1. Performance
2. Modelling
3. Protection
4. Performance standards

These are each discussed in the following sections.

Overload – Performance

During the studies, the inertia and overload capability presented as a conventional synchronous machine response, including exceeding maximum active power (Pmax) and maximum reactive power (Qmax) during contingency events. This is due to the control's architecture using phase angle and voltage differences to calculate the inverter's response.

As an example, Figure 3 shows a 1 Hz frequency decrease whilst the BESS is discharging at 35 MW. The BESS responds with an active power increase as the frequency is decreasing, with the POC active power reaching 65 MW. Once the frequency has stabilised, the BESS restores to Pmax of 50 MW. This is a typical response of a critically damped, synchronous generator but unusual for an asynchronous inverter without overload capabilities.

A conventional grid-following inverter would not respond to a frequency decrease when already at maximum power.

The reactive power has a similar response to the concurrent voltage change in this example but does not exceed the reactive power limit in this instance.

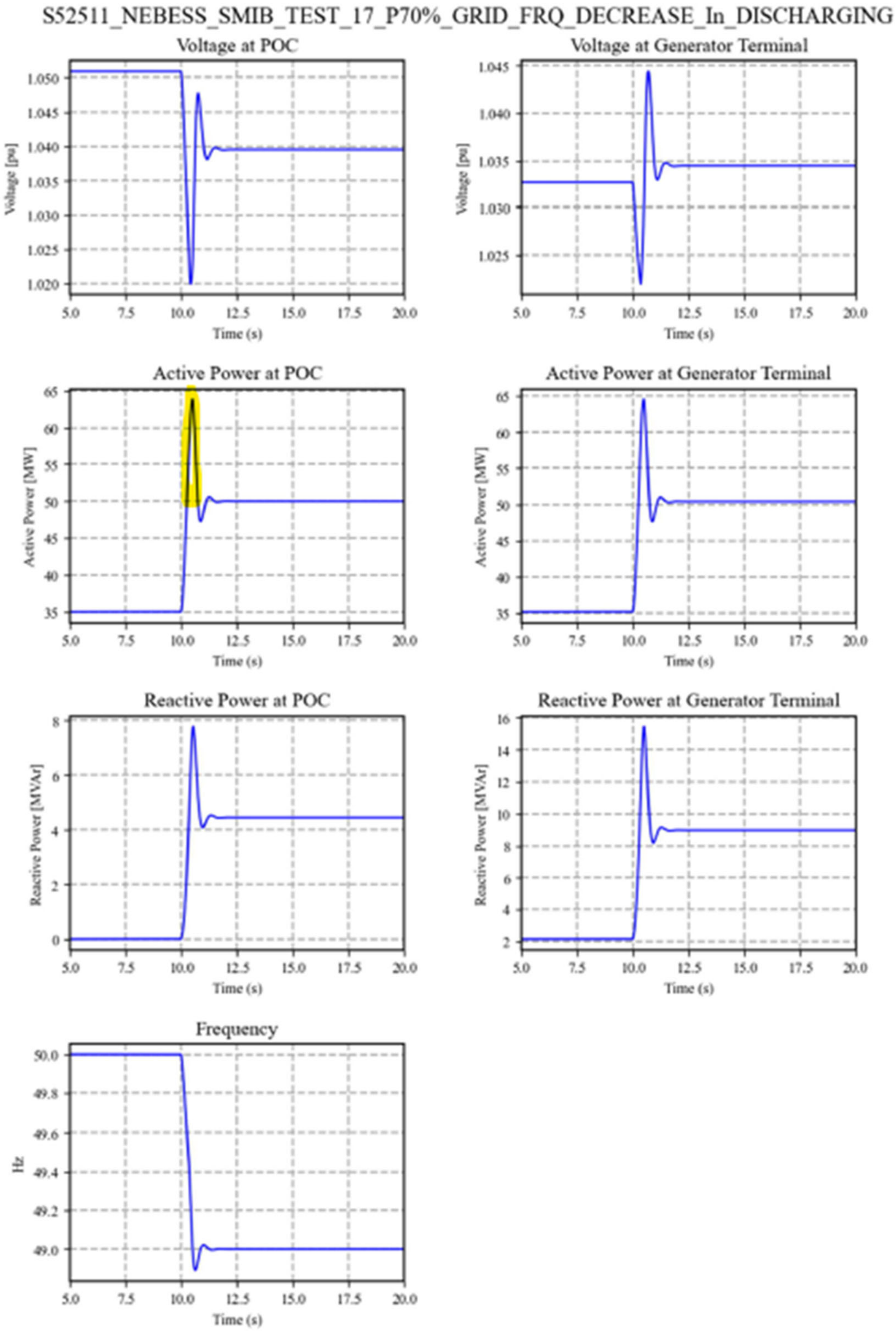


Figure 3 – NE BESS response to 1 Hz frequency decrease in NEM case (WSP 2022)

The same inertia characteristic occurs when in charging mode. The BESS's Pmin is exceeded to counteract an increase in frequency (Figure 4 – yellow highlight).

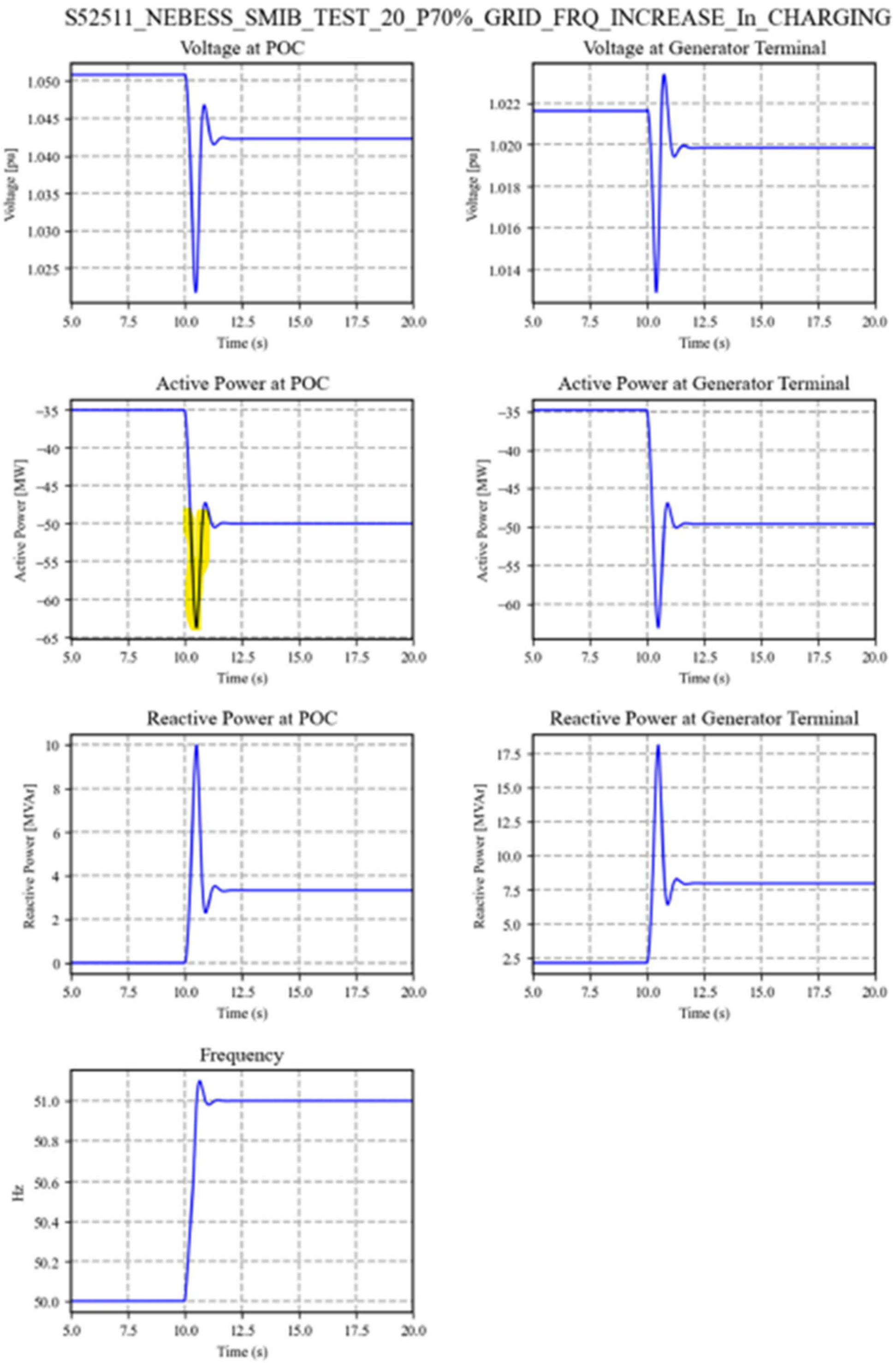
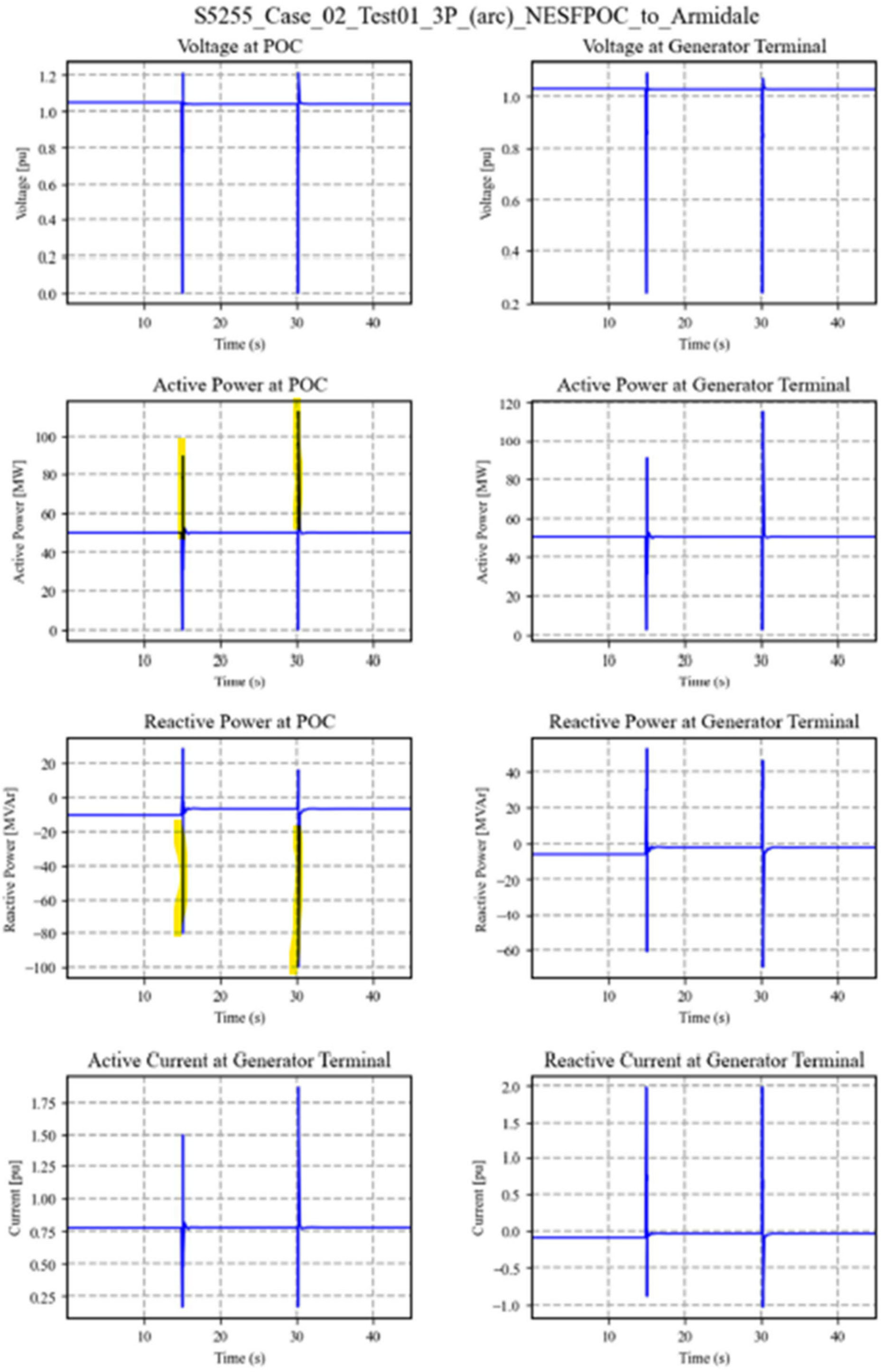


Figure 4 – Increase in frequency response whilst charging (WSP 2022)

To show the full capabilities of the SINAMIC S120 a deep fault is required. Figure 5 is a 3-phase fault near the POC. Prior to the fault the NE BESS is at Pmax and near Q0. The fault at 30 seconds shows the response as 2 x Pmax at the same time as 5 x Qmin and the plant riding through the fault. The overall 2 pu current was not surpassed in this instance.



S5255_Case_02_Test01_3P_(arc)_NESFPOC_to_Armidale

Voltage at POC

Voltage at Generator Terminal

Active Power at POC

Active Power at Generator Terminal

Reactive Power at POC

Reactive Power at Generator Terminal

Active Current at Generator Terminal

Reactive Current at Generator Terminal

Figure 5 – NE BESS response to 3-phase fault near the POC

This far exceeds the steady state requirements of the BESS and was the point of much discussion during due diligence.

Overload – modelling

The models needed to correctly simulate the physical hardware. Some of the features of the inverter raised issues during the due diligence process.

Specifically, as the inverter approaches the 2pu current threshold, it utilises a hysteresis current limit controller to prevent tripping when an overload nears. The system maintains operation as close as possible to 2pu to maximise grid support for the necessary duration. Modelling this behaviour revealed a ripple effect in the inverter output, resulting from the controller alternately reducing and increasing current during faults that require elevated support levels.

This presented as on as a minor oscillation and required much discussion to resolve with stakeholders.

Overload – protection

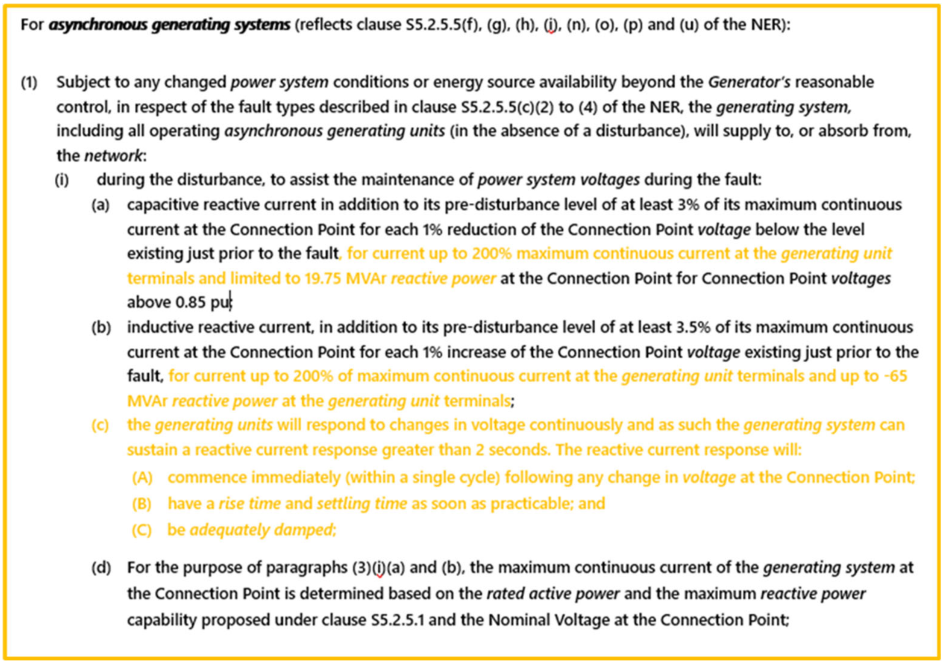
The modelling of the overload protection required significant work. As discussed earlier, the inverter can do 2 pu overload for 1 second, and 1.5 pu overload for up to 60 seconds. Whilst these protection features are inherent to the hardware and operate on a thermal basis with complex sensors and cooling systems, they proved difficult to model.

Various curves were trialled, with the final solution using the Inverse Time Over Current Relay component to simulate the I2T curve and thermal protection.

Overload – Performance Standards

As discussed above – the inverter-based performance standards (asynchronous) were not written to accommodate grid-forming inverter characteristics. This applies mostly to S5.2.5.5 section 3 which relates to asynchronous generating systems.

Whilst the BESS's performance exceeded minimum standard, capturing the overload capabilities required specific redrafting. The excerpt from this clause is shown below in Figure 6, with the yellow wording included to accommodate the GFM characteristics.



For ***asynchronous generating systems*** (reflects clause S5.2.5.5(f), (g), (h), (i), (n), (o), (p) and (u) of the NER):

(1) Subject to any changed *power system* conditions or energy source availability beyond the *Generator's* reasonable control, in respect of the fault types described in clause S5.2.5.5(c)(2) to (4) of the NER, the *generating system,* including all operating *asynchronous generating units* (in the absence of a disturbance), will supply to, or absorb from, the *network*:

- (i) during the disturbance, to assist the maintenance of *power system voltages* during the fault:
  - (a) capacitive reactive current in addition to its pre-disturbance level of at least 3% of its maximum continuous current at the Connection Point for each 1% reduction of the Connection Point *voltage* below the level existing just prior to the fault, for current up to 200% maximum continuous current at the *generating unit* terminals and limited to 19.75 MVAr *reactive power* at the Connection Point for Connection Point *voltages* above 0.85 pu
  - (b) inductive reactive current, in addition to its pre-disturbance level of at least 3.5% of its maximum continuous current at the Connection Point for each 1% increase of the Connection Point *voltage* existing just prior to the fault, for current up to 200% of maximum continuous current at the *generating unit* terminals and up to -65 MVAr *reactive power* at the *generating unit* terminals;
  - (c) the *generating units* will respond to changes in voltage continuously and as such the *generating system* can sustain a reactive current response greater than 2 seconds. The reactive current response will:
    - (A) commence immediately (within a single cycle) following any change in *voltage* at the Connection Point;
    - (B) have a *rise time* and *settling time* as soon as practicable; and
    - (C) be *adequately damped;*
  - (d) For the purpose of paragraphs (3)(i)(a) and (b), the maximum continuous current of the *generating system* at the Connection Point is determined based on the *rated active power* and the maximum *reactive power* capability proposed under clause S5.2.5.1 and the Nominal Voltage at the Connection Point;

Figure 6 – Excerpt from NE BESS S5.2.5.5 performance standard (R0)

Impact of Rule Changes on the New England BESS Connection

NER Rule change 197 (2023) incorporated a change in the S5.2.5.5 standard for inverter-based resources and how it is captured. This was the result of “Efficient reactive current access standards for inverter-based resources” rule change processed by the AEMC.

Whilst it was not specifically aimed at accommodating GFM technology, flexibility was included during the Rule change in order to make the capturing of the performance of GFMs less onerous. This included removal of the reactive current settling time, doubling of the rise time, addition of a commencement time, and the ability to elect the inverter terminals as a point of measurement. Maximum continuous current was also formally defined as a term. This provided a sufficient envelope to effectively capture the performance of the GFM technology.

This resulted in an update to clause S5.2.5.5 in the 5.3.9 process for the NE BESS that enabled the removal of the bespoke drafting. The values that were included in the normal wording of the clause are detailed in Table 3.

Conclusion

The NE BESS successfully completed its connection application as a grid-forming inverter before the Rules and Regulators were ready for this technology. This took additional resources and time; and required good cooperation and engineering judgement for all who worked towards this result.

The implementation of NER Rule change 197 (2023) streamlined the performance standard requirements for inverter-based resources. The experience from the New England BESS connection was included in discussions with the AEMC to help facilitate this result.

By introducing greater flexibility and removing some of the more restrictive criteria, the revised S5.2.5.5 standard now accommodates both GFM and GFL technologies more effectively without sacrificing grid reliability.

These changes have not only simplified the compliance process but also ensured that the performance envelope is robust enough to capture the operational characteristics of advanced battery storage systems. Overall, the updated standards provide a clearer and more practical framework for connection and ongoing operation, supporting the continued integration of innovative energy resources into the NEM.

Appendix A - Glossary of Terms & Abbreviations

Abbreviation	Definition
ACEN	ACEN Australia
AEMO	Australian Energy Market Operator
BESS	Battery Energy Storage System
DUID	Dispatchable Unit Identifier
FIA	Full Impact Assessment
FRT	Fault Ride Through
GFM	Grid Forming
GFL	Grid Following
GPS	Generator Performance Standards
IRP	Integrated Resource Provider
kV	Kilovolt
MW	Megawatt
MVAr	Megavolt ampere reactive
NE BESS	New England Battery Energy Storage System
NEM	National Electricity Market
NER	National Electricity Rules
PCS	Power Conversion System
POC	Point of Connection
PSSE	Power System Simulator for Engineering
pu	Per Unit
R0	Initial connection application stage under NER
R1	Registration stage
S5.2.5.5	NER clause: Response to Disturbances Following Contingency Events
S5.3.4A/B	Letters confirming negotiated performance standards
S5.3.9	NER clause: Alteration of a generating system
S5.3.10	NER clause: Outcome of 5.3.9 assessment
Transgrid	NSW Transmission Network Service Provider
Vac	Volts AC
VSG	Virtual Synchronous Generator