Flagship Report: System Strength Remediation

Darlington Point Energy Storage System

Project Name: Darlington Point Energy Storage System
Contract Number: 2020/ARP05
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Darlington Point Energy Storage System has received funding from the Australian Renewable Energy Agency (ARENA) as part of ARENA's Advancing Renewables Program and from the NSW Government, Emerging Energy Program.

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2 Executive Summary

Edify Energy Pty Ltd (Edify) developed the Darlington Point Energy Storage System (DPESS, the Project) which is a 25MW / 50MWh battery energy storage system (BESS) located adjacent to the 275MW Darlington Point Solar Farm in NSW (also developed by Edify). DPESS commenced construction in July 2022, completed construction in May 2023 and began commercial operations in September 2023.

DPESS was developed and constructed simultaneously with two other BESS projects – the Riverina Energy Storage System 1 (RESS1) and Riverina Energy Storage System 2 (RESS2). RESS1 is a 60MW / 120MWh BESS while RESS2 is a 65MW / 130MWh BESS, both of which are similar in technology type to DPESS.

The Project has tested the ability of large-scale battery storage with advanced grid forming inverters to provide a measurable improvement in system strength. The Project has demonstrated that grid forming batteries can be relied upon to provide certain system strength services which are required to enable the connection of additional renewable energy generators to the network and to eventually replace the services being provided by conventional synchronous generators (such as coal and gas-powered turbines).

The Project was successful in being the first project in the National Electricity Market (NEM) to navigate the connection process from the beginning using grid forming controls (as opposed to switching to a grid-forming connection after having previously been approved as a grid following connection). The Project has since been successfully tested and commissioned and has been operating commercially since September 2023.

A review of the capability of the plant and comparison to a grid following plant has shown that the plant meets the requirements for being considered 'grid forming; because it:

- Exhibits responses consistent with the behaviour of a voltage source; and
- Provides an inertial response.

The output of the total 150MW facility during different network disturbances has been compared to the output of a 150MVA synchronous condenser to assess the ability to replicate services of a synchronous condenser (syncon). Key findings of this assessment are as follows:

- During a frequency disturbance, the BESS and the syncon provided a similar amount of inertia, with the BESS providing the additional benefit of a frequency droop response due to the stored energy.
- During a simulated network fault, it was shown that the 150MW BESS was able to maintain stability of the network in a similar way to a 150MVA synchronous condenser when the BESS was operating at 0MW pre fault.
- When the BESS was simulated operating at full export prior to the same fault it was shown that it was not able to stabilise the network indicating equivalence to a much smaller synchronous condenser when operating at high export pre fault. This highlights one of the key considerations which must be taken into account when networks consider relying on BESSs for the provision of system strength. This was also largely to be expected due to the relatively low current limits of inverter-based plants in this scenario.

One important achievement of the Project has been to enter into a Network Support Agreement (NSA) with Transgrid for the BESS under which it provides network stability services. The ability to provide these services is due to the grid forming nature of the BESS but is only relying on the fast-acting voltage control of the plant and is therefore able to provide the services which are being relied upon while at any prior operating state.

The outcome of these network services is that the operating status of the facility is now used as an input to constraint equations in southwest NSW whereby it increases the transfer limit of the 330kV line 63, and in turn reduces the curtailment of renewable energy in NSW. This demonstrates the ability of grid forming BESS to provide critical services to the network.

3 Introduction

3.1 Darlington Point Project Summary

Edify developed the Darlington Point Energy Storage System (DPESS or the Project), a 25MW / 50MWh BESS located adjacent to the 275MW Darlington Point Solar Farm in NSW (also developed by Edify). DPESS commenced construction in July 2022, completed construction in May 2023 and began commercial operations in September 2023.

DPESS connects to Transgrid's 132kV network at Darlington Point Substation and has advanced inverters set to 'grid forming mode' (also known as 'virtual machine mode'), which can provide system strength services to the grid.

DPESS was developed and constructed concurrently with two other battery energy storage projects – the Riverina Energy Storage System 1 (RESS1) and Riverina Energy Storage System 2 (RESS2). RESS1 is a 60MW / 120MWh BESS while RESS2 is a 65MW / 130MWh BESS, both of which are similar in technology type to DPESS.

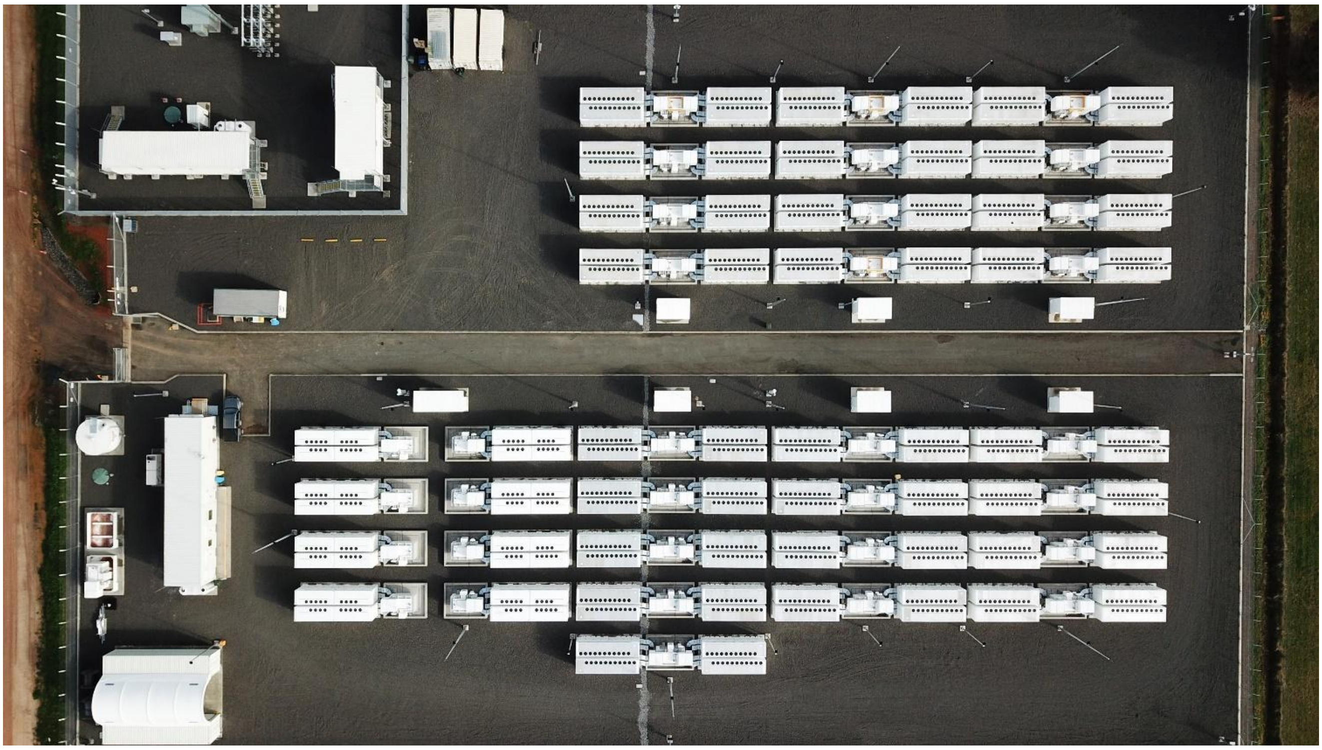


Figure 1 Aerial view of DPESS, RESS1 and RESS2

These three projects have been constructed as a single facility within the same compound and share common infrastructure such as the O&M building and maintenance facility. Each of the projects is a separately registered bi-directional unit (BDU) within the NEM and each has a separate connection point at 33kV within the Transgrid-owned Riverina BESS substation. To facilitate this connection arrangement, the Project had to establish a Designated Network Asset (DNA) between the 132kV Darlington Point Substation and the points of connection of the three projects.

Figure 2 DPESS, RESS1 and RESS2

3.2 Purpose of this Report

The Darlington Point Energy Storage System (DPESS or the Project) was awarded funding under the ARENA Advancing Renewables Program and the NSW Government under the Emerging Energy Program. The particular objective of DPESS under these programs was to demonstrate that a BESS with advanced inverters can reduce the cost of connecting variable renewable energy projects to weak grids by offsetting (fully or partially) the need for synchronous condensers or other system strength remediation schemes.

This flagship report is a knowledge deliverable under the ARENA Advancing Renewables Program and the NSW Government Emerging Energy Program to share knowledge about the Project with the broader industry. It represents one of the deliverables under the Knowledge Sharing Plan.

The report is intended to provide information in relation to the following topics about the Project:

- A description of the Project's system strength remediation capabilities;
- How the Project performed in a simulation environment during the network connection process;
- How the Project performed in a test environment during commissioning;
- Parameterisation of its system strength remediation effectiveness including how this performance compares to that of a synchronous condenser;
- Any relevant constraints in operation and / or design;
- The economic trade-offs when considering multi-purpose systems such as batteries for system strength remediation;
- A comprehensive description of the results and findings of any other elements of the Testing Plan;
- An overview of testing performed during a relevant operational period (as specified in the Testing Plan) including:

  – Aim of the test;
  – Methodology description; and

– Results and any key insights and learnings; and

- Broader implications for the NEM (e.g. role of batteries versus synchronous condensers).

3.2.1 Intended Audience

This intended audience of this report is as follows:

- Network service providers and AEMO;
- Original equipment manufacturers;
- Project developers;
- Persons involved in commissioning and testing generators;
- ARENA; and
- NSW Government.

3.3 Overview of Project Objectives

DPESS principally aims to demonstrate that a BESS with advanced inverters can reduce the cost of connecting variable renewable energy projects to weak grids by offsetting (fully or partially) the need for synchronous condensers (or other reactive plant) in future projects.

DPESS aligns with the objectives and desired outcomes of ARENA's Advancing Renewables Program (ARP)[1] as successful completion of DPESS will contribute to technical, regulatory and commercial outcomes that are of high priority for ARENA. DPESS will contribute to all five of the ARP objectives and outcomes, which are:

a) reduction in the cost of renewable energy;
b) increase in the value delivered by renewable energy;
c) improvement in technology readiness and commercial readiness of renewable energy technologies;
d) reduction in or removal of barriers to renewable energy uptake; and
e) increased skills, capacity and knowledge relevant to renewable energy technologies.

BESS projects using advanced grid forming inverters offer several key benefits to the electricity network, as follows:

a) **Provide system strength services and reduce the need for synchronous condensers**: BESS projects with advanced grid forming inverters provide system strength (i.e. frequency and voltage stabilisation, fast disturbance event response, etc.) with much faster response times than other energy storage or generation technologies. These services can allow nearby renewable energy projects to operate with fewer constraints or without constraints to their output, increasing the value of these projects and improving the utilisation of the network. By providing these services, BESS projects with advanced grid forming inverters can remove the need for synchronous condensers or other measures to be installed with renewable energy projects. Synchronous condensers are complex and expensive machines, with long procurement lead times. Therefore, removing the need for such machines significantly reduces the cost and risk profile associated with connecting renewable energy projects in weak grids.
b) **Multi-use technology**: BESS projects with grid forming inverters can also provide all the beneficial services that have been observed and well reported from other BESS projects (such as charging during periods of low demand / price, dispatching into high demand / volatile price periods and providing market ancillary services) making them a multi-use market and technical service technology, in contrast to single purpose technologies such as synchronous condensers.

[1] https://arena.gov.au/assets/2017/05/ARENA_ARP_Guidelines_FA_Single_Pages_LORES.pdf

These benefits combine to support the further commercialisation of BESS and advanced grid forming inverter technology, further development of renewable energy projects and increased economic, environmental and social benefits to Australian consumers.

4 Project Information

4.1 Technical Characteristics

DPESS is a 25MW / 50MWh (2 hour) lithium-ion battery facility based on the Tesla Megapack 2XL units.

Technical characteristic	Description
Nominal capacity	25MW / 50 MWh (2 hours)
Actual Connection Date	The Project achieved Commercial Operations on 29 September 2023
Generator Type	Battery Energy Storage (classified as a bi-directional unit (BDU) within the NEM
NMI	NTTTW0ZS50
Battery units	16 x Tesla Megapack 2XL, 2.40 MVA per unit
Inverters	Inverters are integral to the Tesla Megapack 2XL unit
Voltages	DC voltage: 480V High voltage: 33kV
Balance of plant	8 x 4.8MVA 33/0.48/0.48kV MV unit transformers ABB SafePlus GIS RMU Switchgear

4.1.1 Battery Cells

The battery cells employed in the Megapack 2XL are Lithium Iron Phosphate (LFP) type batteries which are a type of lithium-ion battery that uses iron phosphate as the cathode material. LFP batteries are used in the majority of stationary storage applications due to their low cost, consistent lifetime performance and higher resistance to thermal runway when compared to other lithium-ion battery chemistries. LFP batteries offer a good balance of safety, longevity, and cost-effectiveness. Several battery cells are connected together into battery modules.

4.1.2 Power Conversion Equipment

Tesla Megapacks vary from most other suppliers of stationary energy storage systems in that the inverters are of a much lower power level and are integrated into the battery modules (up to 24 per Megapack container). The inverters convert the battery-side DC energy to and from AC energy at 480V and each connect to a common AC bus within the Megapack providing a common 480V AC output.

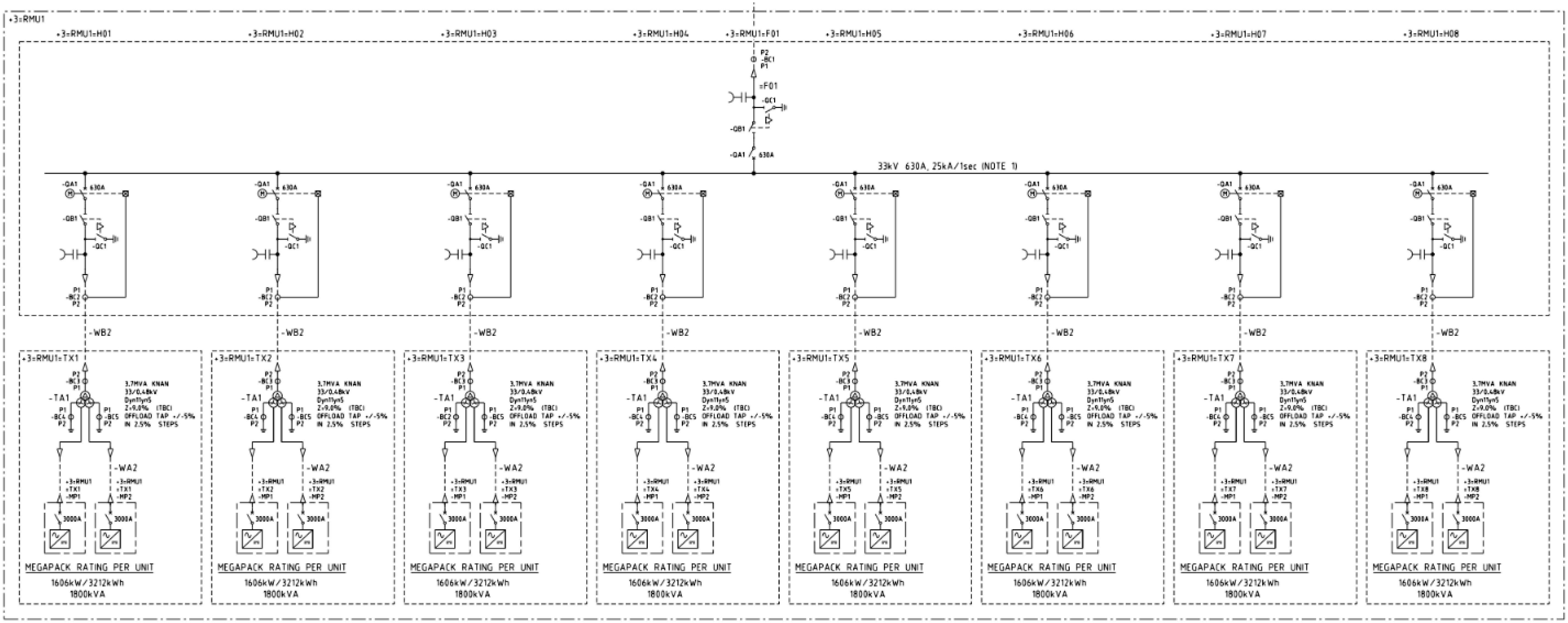
Most alternative battery systems connect an entire shipping container of batteries at DC level and use a large power converter to convert the output of one (or even several) battery shipping containers to AC power.

4.1.3 Single Line Diagram

A single line diagram for DPESS is shown on the following page. DPESS consist of 8 Megapack 2XL battery units. Each Megapack has a single 480V AC connection and is connected directly to an MV step-up transformer which steps the voltage up to 33kV. These transformers are each 3-winding transformers with 2 LV windings (each with a single Megapack connected) and a single HV winding.

DPESS consists of 8 MV transformers which are each connected to a single RMU via 33kV cables. There is a single outgoing feeder from the RMU which connects directly into a Transgrid owned 33kV switchroom which is the point of connection for the Project.

Figure 3 DPESS facility single-line diagram



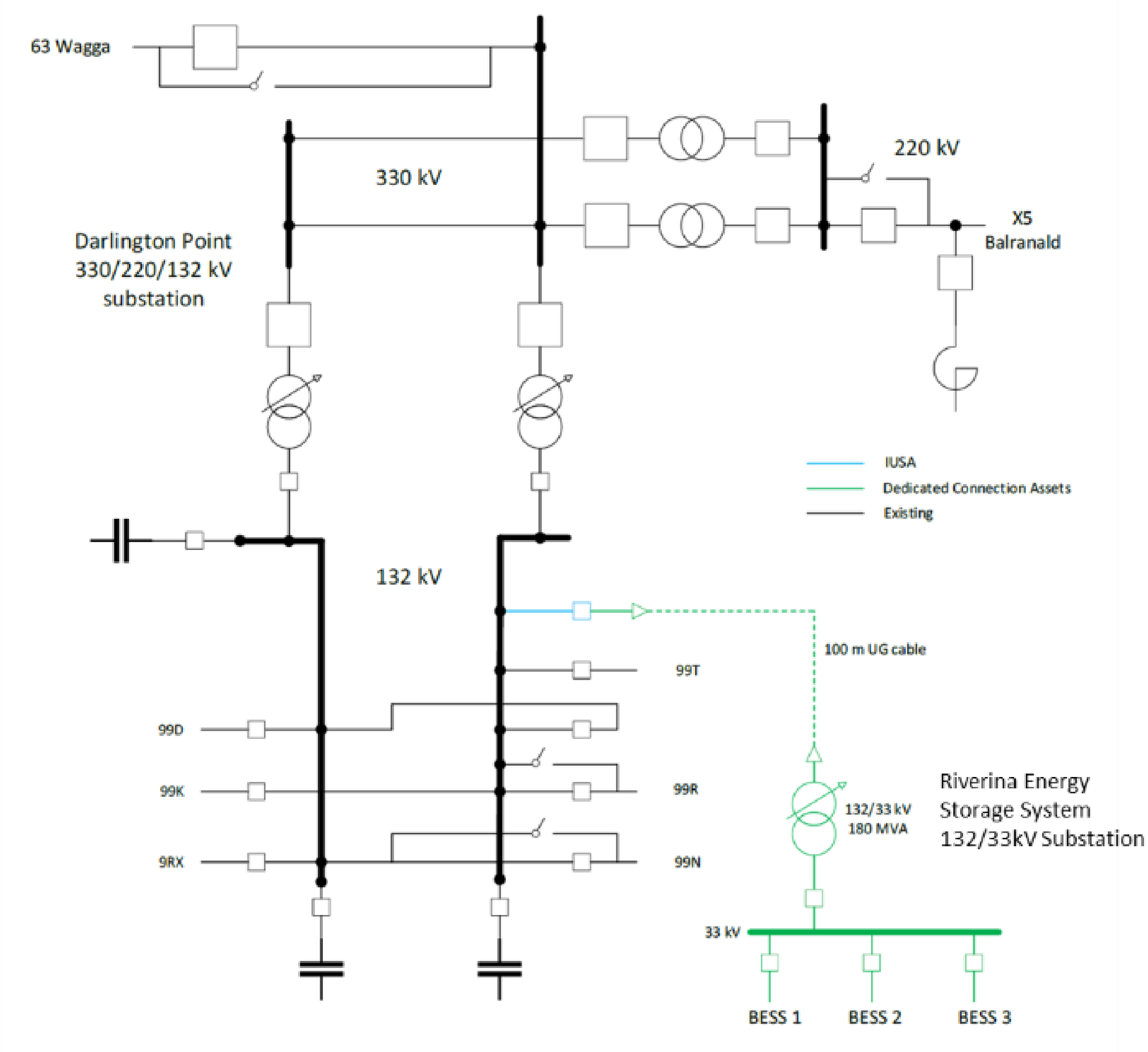
4.1.4 Connection to the Network

The arrangement of the connection to the network for the Project is unique on account of DPESS being built adjacent to the RESS1 and RESS2 battery systems. Due to having separate arrangements for parties who would be the Financially Responsible Market Participant (FRMP) for the battery projects, each of the three battery projects was required to have a separate point of connection to the transmission network.

To achieve this the Project engaged Transgrid to build own and operate a 132/33kV substation with a single transformer as a Designated Network Asset (DNA) which allowed for three connection points at 33kV and the effective sharing of a single transformer and substation connection. This is referred to as the Riverina Energy Storage System 132/33kV Substation.

DPESS therefore has meters at a 33kV point of connection which is the point of assessment for the performance and compliance of the Project.

As noted, each of DPESS, RESS1 and RESS2 are connected to a single 33kV bus. There is a single feeder off this bus to a 180MVA 132/33kV transformer. This is connected via a 132kV feeder into one of two 132kV buses at the Darlington Point 132/220/330kV Substation which the Project was built adjacent to. The diagram below shows an indicative representation of the overall connection arrangement.



4.1.5 Auxiliary Supply

The Megapacks internally supply all auxiliary power demands in the Megapack from the internal 480V AC bus. This means that no separate external auxiliary supply is required and allows Megapacks to self-supply auxiliary power where this is required. This differs from most other stationary storage suppliers where a separate auxiliary supply to the battery container is required.

The Project also has a separate 415VAC auxiliary supply from the Transgrid 132/33kV substation for the O&M building. This is backed up by a diesel generator.

4.1.6 Control Systems

The overall plant controls consist of three main control levels as follows:

1. **Gateway level control**
   The gateway level control is the highest level of control of the power plant. The plant consists of dual redundant gateways as they are critical to the control of the plant. The gateway controller performs the following key functions:
   - receives dispatch information form AEMO including Automatic Generator Control (AGC) setpoints and energy and FCAS enablement;
   - interprets the dispatch commands and converts these to setpoints actionable by the site controller;
   - communicates with the TNSP and AEMO for network controlled voltage control setpoints and modes;
   - provides relevant SCADA points to TNSP and AEMO; and
   - hosts the human-machine interface (HMI) for operator control of the Facility.
2. **Site Controller**
   Tesla standard site controller which performs the following functions:
   - receives setpoint and mode change information from the gateway controller as a result of remote signals from AEMO / TNSP or local commands from the HMI by the operators;
   - provides overall plant control of the facility;
   - monitors the actual output of the plant via the control meter; and
   - adjusts control signals sent to the Megapack level controllers for both active power and reactive power.
3. **Megapack Controllers**
   The Megapacks contain controllers which control the output of the Megapack and include the actual control of the inverters within the Megapack.

4.1.7 Site Level Voltage Control Strategy

The site level voltage control is performed by the Site Controller and consists of a standard droop type control strategy where the plant will inject or absorb reactive power based on the difference between the voltage setpoint and actual measured voltage. The standard operation mode for the plant is to be controlling the voltage at the 330kV bus within the Darlington Point Substation but controlling reactive power at the 33kV point of connection. The plant can also revert to a 132kV voltage control reference point on command from Transgrid. The setpoint is determined by Transgrid and AEMO, and changes based on the prevailing grid conditions.

This standard control function is typical of inverter connected plants and is not unique to grid forming inverters. In relative terms to grid forming controls, this control function operates in a slower timeframe as it relies on receiving a measurement update as to the actual voltage before the site level controller provides updated reactive power setpoints to each Megapack. The measurement for DPESS is only updated every 100ms and there is an estimated 40ms delay for each Megapack to receive the updated reactive power setpoint. These timeframes are typical for projects of this nature.

4.1.8 Site Level Frequency Control Strategy

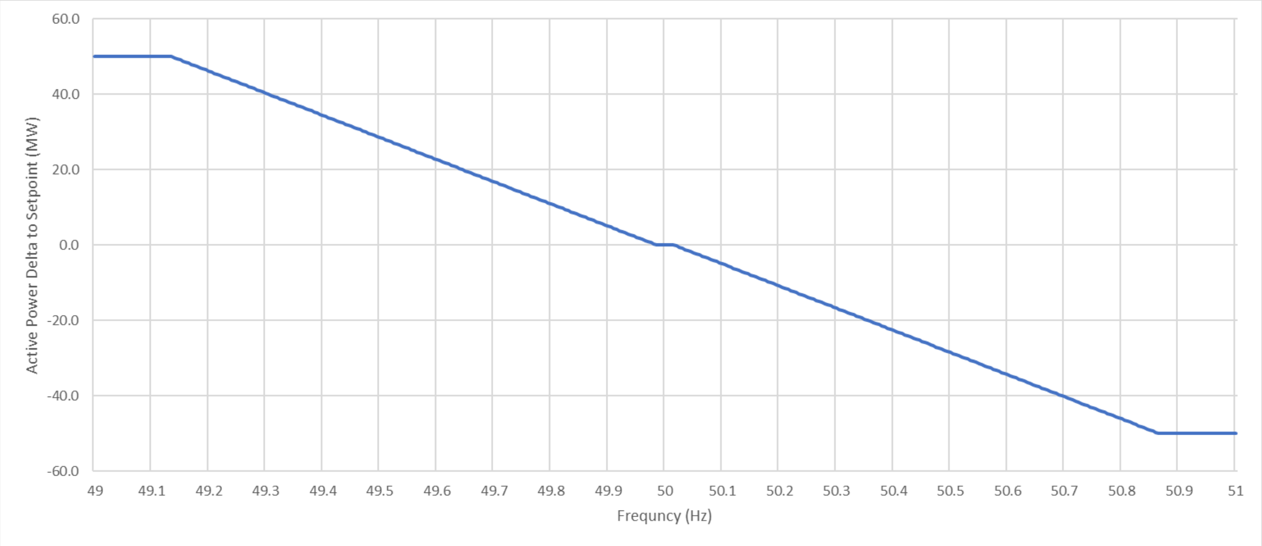
The site level frequency control is performed by the site controller and is a typical droop controller based on measured frequency.

The particular settings of DPESS are as follows:

Parameter	Unit	Value
Frequency Support	0 = Disable, 1 = Enable	Enabled
Frequency Support Freq Low	Hz	49.985
Frequency Support Freq High	Hz	50.015
Frequency Support Freq Low Delta	Hz	1.7
Frequency Support Freq High Delta	Hz	1.7
Frequency Support Delta Power at Low Frequency	MW	50
Frequency Support Delta Power at High Frequency	MW	-50
Frequency Support Hysteresis	Hz	0

The following diagram shows the droop curve for DPESS. The vertical axis shows the change to the active power setpoint as a result of the frequency.

Figure 4 DPESS droop curve



The site level frequency response occurs in a similar time frame to the site level voltage control as it relies on the site controller receiving a frequency measurement update from the site level meter followed by subsequent update to the active power setpoint of each Megapack. This type of control is not unique to grid forming inverters.

4.1.9 Inverter Level Controls

The inverters implement emulation of the following features of a synchronous machine which is performed based on the voltage at the inverter terminals rather than via feedback from the site level meter which enables fast acting control:

- Machine impedance;
- Excitation dynamics and control; and
- Mechanical dynamics (e.g. mechanical inertia and damping).

This means that in very short timescales following a disturbance, the response of the inverters consists of:

- Immediate (fast) voltage source-like behaviour to oppose the effect of a disturbance (there is no threshold for activation / deactivation of this control and the response is immediate);
- Slower mechanical (secondary) dynamics which act to maintain the controls in synchronisation with the grid; and
- Slower excitation control (secondary) dynamics which act to transition away from the immediate voltage source response.

Over long timescales following a disturbance, the inverter based responses decay to zero and the overall response reverts back to the control inputs from the site level controller. These controls act on both reactive and active power.

4.2 System Design and Limitations

4.2.1 System Limitations

The main limitations of the battery design are related to the ultimate current limits of the system.

The DPESS grid-forming plant will inject reactive current during low or high voltage disturbances due to the inherent nature of the grid forming control functions. Immediately after a disturbance (i.e. fault), the inverters behave like a constant voltage source behind an impedance (as long as current limits are not encountered). Hence the magnitude of additional reactive current injected is proportional to the voltage deviation at the inverter terminals and inversely proportional to the inverter source impedance.

For both balanced and unbalanced faults, the control function causes the inverters to behave like a balanced voltage source behind an impedance. This means that for unbalanced faults the inverter will inject negative sequence reactive current which reduces the level of system voltage unbalance caused by the fault.

Current limiting control is therefore implemented. The controls limit the converter output current such that it does not exceed the thermal capability of the equipment. The limiter controls operate on RMS current and consider thermal characteristics, and therefore they do not operate instantaneously. Reactive current is prioritised during current limitation.

The inverters at DPESS have a current overloading limit of 135% rated current for 1 second at the converter output. Beyond this overloading time limit, a thermal characteristic is applied and the current will be controlled down to within the thermal capability of the device. The device will not trip on over-current as a result of being limited to operating at its current limit.

This is an important consideration in the tuning of grid forming inverters. Unlike rotating machines, the magnitude of response to a certain event can be adjusted through control parameter changes and therefore it is important to consider the likelihood of the current limit applying during particular events and the impact this will have on the response and network outcome. There is a balance to be had between the response to smaller magnitude events and larger magnitude events.

Any response and limitation of the plant must also be considered in the context of the Project’s primary role which is to operate in the energy market. The impact of this is that in considering any limits, the plant should be assumed to be operating at any point between full import and full export prior to the occurrence of any fault. Depending on the fault this may impact the response of the plant and the application of the current limiters.

5 System Strength

5.1 What is System Strength?

In order to determine if the Project is contributing to system strength and to what extent, it is first necessary to establish what system strength is and how it is measured.

AEMO, in its whitepaper on Applications of Grid-Scale Inverters in the NEM, describes system strength as being the ability to generate, maintain and control the voltage waveform for the purpose of supporting network synchronism during steady state operation and following faults. System strength can be summarised as being the resilience of voltage waveform to disturbances on the network. Where system strength is low there is an increased likelihood of seeing larger deviations and undamped oscillations in this voltage waveform compared with areas of higher system strength.

Unfortunately, this is a holistic measure that is observed by the response of the network to various events rather than something that is directly quantifiable. The focus of this testing plan is therefore on the network outcomes that are influenced by system strength, being primarily voltage and frequency stability following faults and the magnitude and settling time of excursions in voltage and frequency.

5.2 Inertia and Frequency Response

Inertia is a related service to system strength primarily because the traditional means of provision of system strength is rotating machines which also have large amounts of inertia, being an inherent part of their response and also a beneficial aspect from a network perspective. Inertia is an instantaneous and inherent active power response to rapid changes in frequency. Grid forming batteries can and do provide inertia (synthetic inertia) as their control systems mimic rotating generator physical properties.

Grid following inverters can provide an active power response to frequency changes (commonly referred to as fast frequency response). Fast frequency response can be used to arrest the change in frequency in the same way inertia does; however, there is some delay in the provision of the response and therefore fast frequency response cannot match the performance of inertia.

While inertia is an important characteristic of both synchronous generators and grid-forming inverters, our observation is that the fast-acting voltage control provided by BESS with grid-forming inverters plays a more critical role in increasing the system's capacity to accommodate additional renewable generation in the NEM. Conversely, we have not observed instances where a high rate of change of frequency (RoCoF) has limited new renewable connections. Nonetheless, this may emerge as a future constraint and therefore warrants ongoing investigation.

5.3 Grid Forming Inverters

Grid-forming refers to the capability of inverters to establish and maintain stable voltage and frequency in a power system. When connected to a network, grid forming inverters operate by establishing an internal reference voltage source based on a machine model and will oppose disturbance to the voltage waveform while still maintaining synchronism to the grid. This differs from grid following inverters which maintain synchronism to the grid but do not oppose the changes.

Grid forming controls operate at the inverter level rather than at the site level so it is important to separate grid-forming controls from site level controls. As noted in sections 4.1.7 and 4.1.8, both grid forming and grid following plants can and typically do have site level controls which oppose voltage and frequency disturbances. However, it is the nature and speed of the response which are the key differentiators between these levels of control.

The main observed characteristics of the grid forming inverters used as part of the Project are as follows. Note these characteristics are generally observed similarly across grid-forming inverter technology.

- Under fault conditions:
  - Injects reactive current in inverse proportion to the virtual reactance and in proportion to the magnitude of the terminal voltage change up to its current limit.
  - Injects negative sequence reactive current in proportion to the negative sequence terminal voltage.
  - Can inject active current and slightly modify the injected reactive current as the emulated virtual machine.
  - For shallow faults the reactive current injection decays over time.
  - For bolted three phase faults (residual voltage less than 5%), a drift in the device terminal frequency is observed as long as the fault lasts.
- Immediately following fault clearance:
  - Exhibits damped active power oscillations due to its response to changes in voltage phase, again akin to a highly damped synchronous machine. Depending upon the internal virtual machine voltage phase angle prior to fault clearance and the system voltage phase angle, this effect can produce transient negative active power outputs. This behaviour acts in a manner to counter perceived phase angle changes.
  - When in the charging state, large post-fault oscillations and an undershoot are observed. These effects are also observed for phase angle steps which drive the system beyond its negative active power operating range.
  - Can reduce its reactive power to below pre-fault levels as part of its natural response to perceived voltage magnitude changes. This assists in inhibiting over-voltages from developing post-fault.
- For frequency disturbances:
  - Exhibits an inertial response from the virtual machine model and a primary frequency response from the Site Controller which regulates frequency and active power output.
  - Can exhibit some slightly oscillatory performance as the virtual machine attempts to maintain synchronism with the system with changing frequency.
- For voltage reference steps and disturbances exhibits overlapping responses from the virtual machine inherent response to voltage changes and the Site Controller which require coordination to achieve good performance.

The difference between grid forming and grid following is entirely within the control system, where the same hardware including the Megapack 2XL can be configured in either grid forming or grid following mode. The only consideration in regard to the hardware is the impact of current limits which will limit the tuning of the grid forming response to a greater extent than for grid following inverters. This is an interesting consideration as the relatively low short-circuit current limit of inverters is considered one of the key drawbacks when compared to rotating machine equivalents such as synchronous condensers. While this could be taken by manufacturers as a signal to increase their current limits, the value of this needs to be carefully considered noting that this will increase costs. However, given the emerging but strong preference for the addition of grid forming inverters to electrical networks in Australia and globally, this increased cost may represent a net benefit.

The fact that the Megapack 2XL has both grid forming and grid following controls is useful in this exercise in that it has enables us to compare the response of DPESS when operating in either control mode. In section 7, simulations have been presented showing the response of DPESS to a disturbance when operating in both grid forming and grid following modes.

5.4 Tuning of Grid Forming Inverters

In terms of tuning, the following considerations were observed to be required:

- The need to achieve good damping and avoid instability after fault clearance. This aspect of the performance was observed to worsen with a ‘lighter’ mechanical dynamic setting selection.
- The need to avoid oscillations and instability after the occurrence of a severe frequency disturbance. This aspect of the performance was observed to worsen with a ‘heavier’ mechanical dynamic setting selection.
- Target to maximise the stabilising capability of the system by limiting how quickly the inverter reactive power response to voltage disturbances decays.
- Target to achieve acceptable control responses without oscillations, minimal overshoot and without long settling times as a result of overly aggressive sliding mode control gains.
- Achieve fast control responses that at least meet the National Electricity Rules (NER) Minimum Access Standards for voltage disturbances and reference steps.

6 Connection Process

The grid connection process in the NEM involves several stages with AEMO and Network Service Providers (NSPs) playing key roles in each. The process is governed by the National Electricity Rules and aims to ensure a reliable and secure electricity supply.

Key elements of the connection process include:

- Detailed power system models (in PSS®E and PSCAD format) are required to be submitted to the TNSP and AEMO along with detailed connection studies to demonstrate that the plant is able to be connected to the network without any adverse impact on the network;
- The project must propose and negotiate Generator Performance Standards (GPS) and must demonstrate compliance via power system modelling;
- AEMO and the TNSP will undertake additional modelling assessments in their wide area network model to assess stability where there is insufficient system strength; and
- In parallel to the assessment of the project's impact on the network and negotiation of the GPS, it is required to negotiate with the TNSP to facilitate the physical connection to the network.

The connection process for DPESS was novel and delivered learnings outlined in the following sections.

6.1 First Connection Application for Grid Forming Inverter Generator

We understand that the Project represented the first connection application which Transgrid and AEMO assessed for grid forming inverters. While some earlier generators transitioned existing plants to grid forming, DPESS was the first to navigate the initial connection process as grid forming in NSW.

This did make the connection process more complicated due to there being a level of uncertainty and the need for engagement and consultation in the decision-making process in the negotiation.

Fundamentally the connection process for grid forming projects is identical to grid following projects and largely the same minimum standards for the GPS apply. The main point of discussion for the GPS was finding the ideal tuning of the generator while still meeting the negotiated standards of the GPS. We found that the reactive current rise and settling times were challenging due to the following reasons:

- For shallow network faults the reactive current settling times were found to be long and if these cases were used to assess GPS compliance, it was difficult to meet the automatic access standards unless the grid forming controls were materially restricted or tuned out. This was not the case for deep network faults where the settling times were generally within the automatic access standards.
- Tuning out the grid forming controls was overall detrimental to the network stability, while in the fault scenarios where the settling times were non-compliant there was an immaterial impact on the network, which Edify considered not to be the intention of GPS clauses.

Transgrid and AEMO are generally bound by the negotiating principles which mandate that where a plant can be tuned to meet automatic access standards, it should do so in preference to negotiating access standards. Ultimately, we were able to agree on a means for specifying and assessing the GPS which allowed for the grid forming controls to be applied in a best for network approach. However, there was concern that the decision-making process would delay and ultimately become a risk to the Project.

6.2 Benefit of Real World Projects

Our observation has been that the most significant benefits and knowledge sharing outcomes of the Project have come simply through moving a real project through the connection process. The Project provided the opportunity for power systems engineers from the consultant (DIgSILENT), Transgrid and AEMO to have a real-world project on which to learn about grid forming inverter tuning and performance. While it is possible that these learnings could be achieved via studies and simulated projects, a real life project drives schedule and forces decisions to be made. These learnings are highly valuable to the industry as these organisations all now have internal personnel with experience on these models and with grid forming inverters for future projects, which can establish a precedent for how similar projects proceed through the connection process.

Subsequent to the conclusion of the connection process we have observed that AEMO has now published a fact sheet for connection of grid forming BESS:

https://www.aemo.com.au/-/media/files/electricity/nem/network_connections/grid-forming-bess-connection-fact-sheet.pdf.

7 Comparison of Grid Following to Grid Forming

While the steady-state performance of a BESS with grid following (GFL) and grid forming (GFM) inverters is identical, the dynamic performance can be significantly different. To illustrate these differences, simulations were performed using the DPESS PSCAD model developed as part of the Project's GPS negotiations. This model is intended to reflect the real-world behaviour of the plant and was benchmarked as part of the commissioning process. Note that this model also includes the sister projects RESS1 and RESS2, together with DPESS collectively referred to in this section as 'RES'.

The inverters used at DPESS are capable of operating in either GFL or GFM mode, with the GFM controls effectively acting as a secondary control layer that can be turned off or on. While for DPESS these controls are on at all times, a comparison of the plant performance can be achieved by applying external disturbances to the model with and without the GFM controls enabled.

7.1 Voltage Angle Disturbance

The first example is for a voltage angle disturbance, where the phase of the 50Hz grid voltage shifts very quickly. This type of disturbance is extremely common and typically is caused by sudden changes in load or generation.

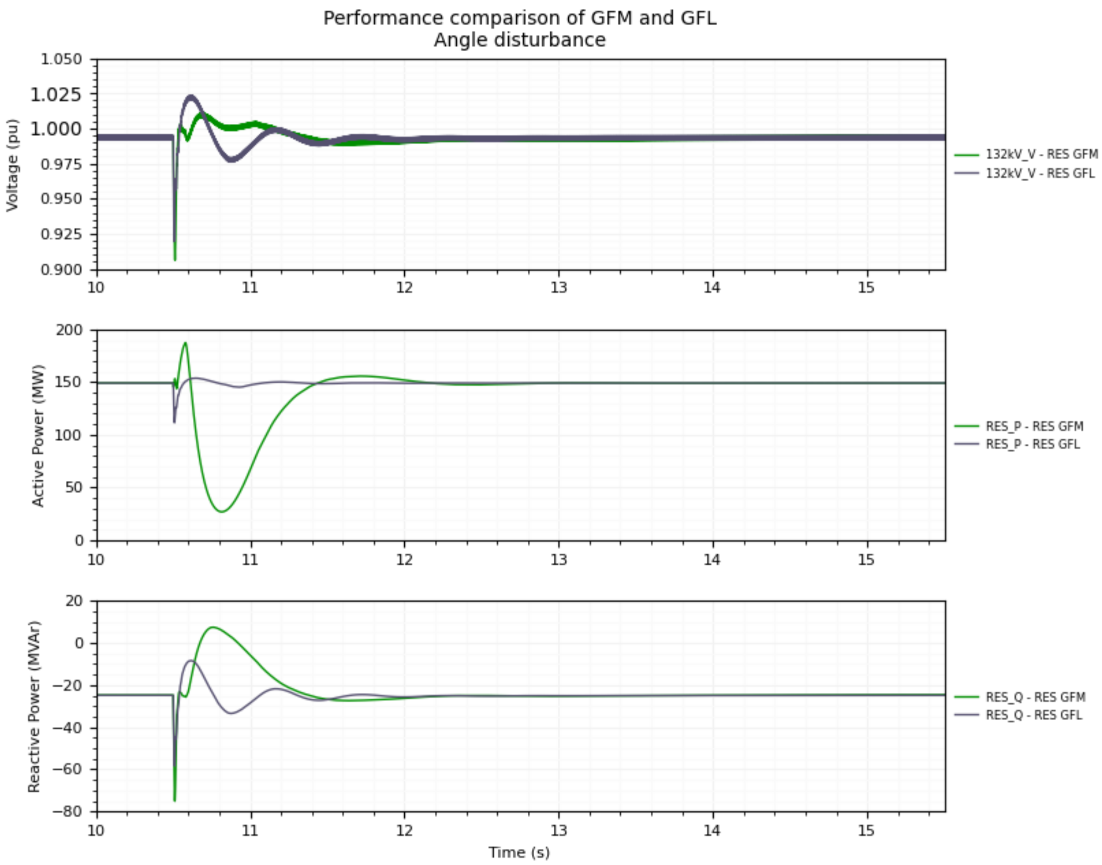


Figure 5: GFM vs GFL performance comparison for an angle disturbance

Under GFL controls the inverters inject power by measuring the angle of the grid voltage and manually commutating the voltage waveform at the appropriate angle to achieve the desired export (hence, 'following' the grid). In response to the sudden change in voltage angle, there is a brief error in this calculation that causes a minor transient in the plant output.

Under GFM controls the inverters maintain their own internal grid voltage angle that is not directly measured, but rather arises as a result of internal equations that calculate the behaviour of a virtual synchronous machine model and is not directly dependent on the grid voltage signal. Instead, when the grid voltage experiences this sudden disturbance, the inverters continue operating according to the calculated behaviour of this virtual machine. Most notably in this case this results in a sudden *increase* in power injected to the grid, which in a real machine would be a consequence of the mechanical inertia of the turbine-rotor.

7.2 Frequency Disturbance

Closely related to a voltage angle disturbance is a frequency change. Frequency and angle changes generally occur as part of the same disturbance. For example, if a generator trips, there will be a sudden angle change as well as a fast decrease in frequency. This type of disturbance is critically important to the stability of the grid and can result in a complete system black-out if there is insufficient inertia to arrest the drop in frequency.

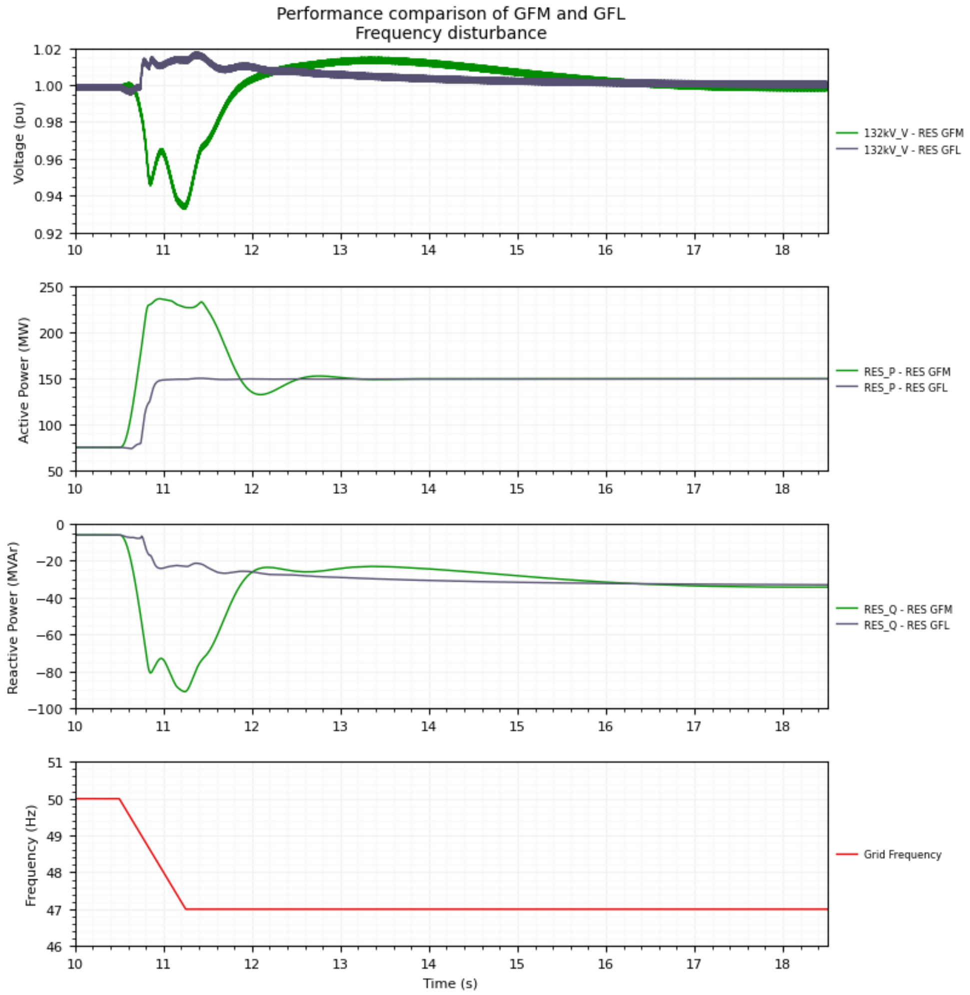


Figure 6: GFM vs GFL performance comparison for a frequency disturbance

Similarly to a voltage angle disturbance, with just GFL controls the inverters continue to export the same level of power by synchronising with the changed grid voltage. There is subsequently a delayed increase in active power driven by the plant's FCAS response. I n contrast, with GFM controls the inverters very quickly inject a significant amount of active power to oppose the drop in frequency before reducing to a lower steady-state response. This is equivalent to the inertial response of synchronous machine coupled with a slower governor response. A key benefit of GFM controls is that this inertial response is tuneable, offering significant flexibility compared to a machine response.

As an example, in the above simulation the voltage drops significantly in the GFM case as a consequence of the large inertial response. While in reality the fault level at Darlington Point is much higher than in this simulation and therefore would not experience the same drop in voltage, BESS projects are being connected at very weak locations in the grid. In this case while the large inertial response is beneficial to the stability of the overall grid, the impact on voltage may negatively affect the local network. This must therefore always be a consideration when determining the inertia settings for a GFM plant.

7.3 Network Fault

Under a network fault the goal of tuning is generally to provide as much fault current as possible (to support the grid voltage and ensure correct protection operation) and recover to a steady state as soon as possible. Both control schemes offer advantages and disadvantages here – a GFL plant can be tuned to provide a droop-based current response (providing more reactive current for a deeper fault) and recover to pre-disturbance levels very quickly, while a GFM plant will often provide greater fault current for a shallower fault but will generally provide a less stable response with a slower recovery.

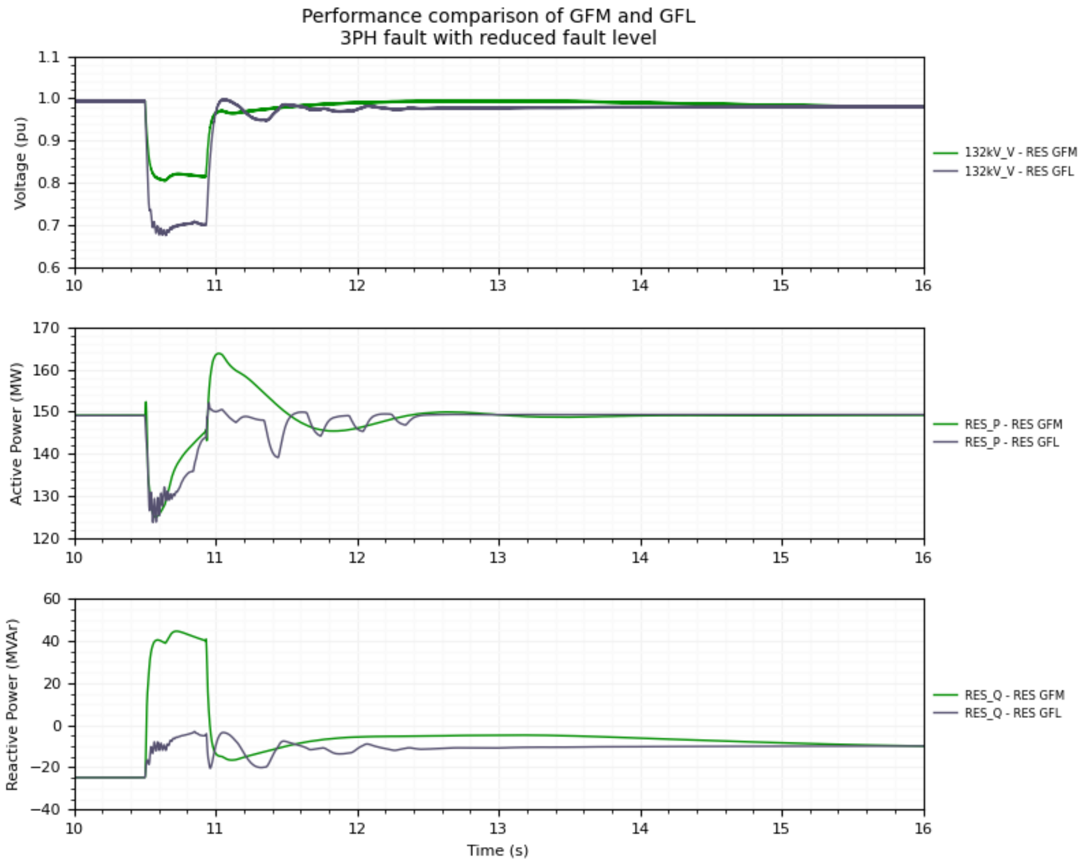


Figure 7: GFM vs GFL performance comparison for a shallow fault

Under this example the GFM controls are able to provide significantly more reactive current during the fault, which has a significant positive impact on the residual voltage. The post-fault recovery is, however, much closer to a typical synchronous machine response with an oscillation in output observed for up to 3s after the fault has cleared.

Due to the weak grid conditions in this test, the GFL controls demonstrate poor stability both during and after the fault, with poor current control during the disturbance and oscillatory behaviour after the disturbance. To achieve a stable response the GFL controls would likely have to be retuned to reduce the level of network support (by lessening the contribution and/or slowing the response).

7.4 Voltage Disturbance

Similarly to with shallow faults, GFM controls are also more generally able to support the grid to resist minor changes in voltage and therefore help stabilise the voltage waveform. In this study a simple 10% drop in grid voltage was applied to compare the two control modes.

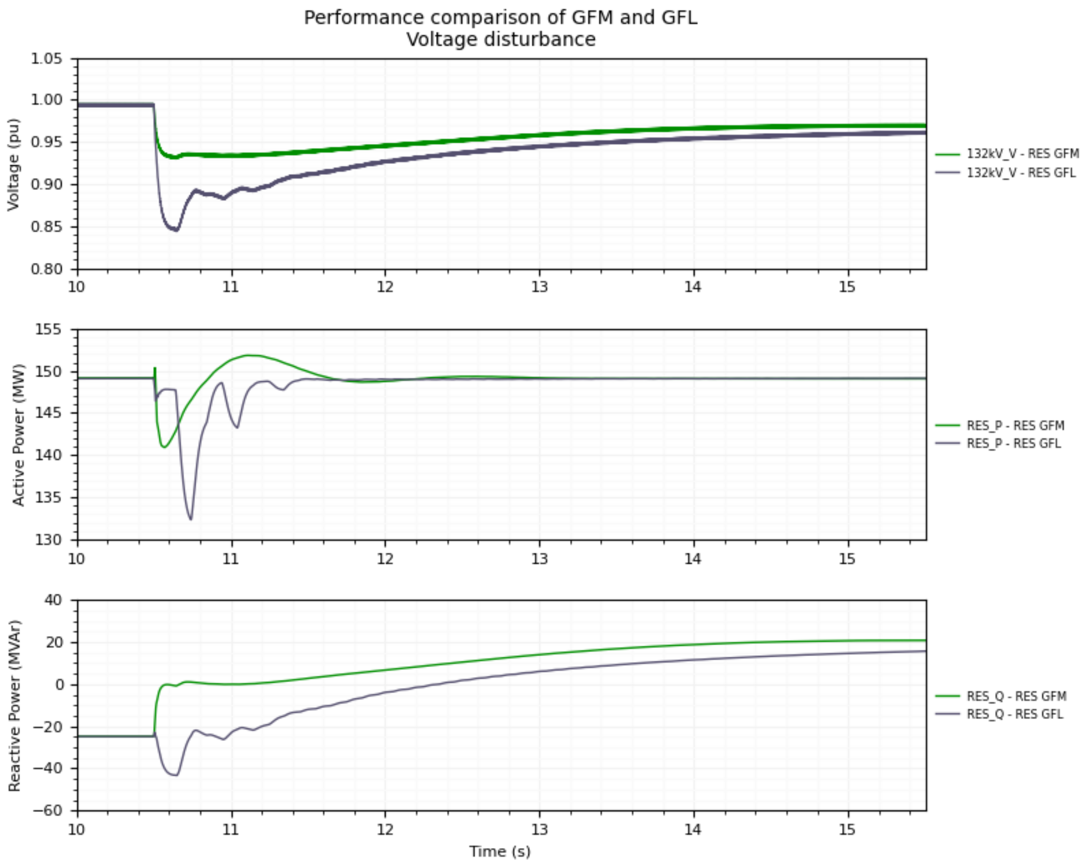


Figure 8: GFM vs GFL performance comparison for a voltage disturbance

Under the GFM control scheme the inverters provide an instantaneous injection of reactive power that sharply arrests the drop in voltage at the Darlington Point 132kV bus. By comparison, under GFL controls the inverters maintain their pre-disturbance reactive power at their terminals (with the increased losses within the balance of plant decreasing the overall reactive power delivered to the system), then increase their reactive power driven by the slower PPC voltage controls.

7.5 Voltage Oscillation

The advantages of the inverter-level voltage control offered by GFM are even clearer when considering a sustained oscillation in the grid voltage, as occurred in the West Murray Zone in 2020/21. In this modelling study a 5% oscillation was induced in the grid to demonstrate the damping capabilities of these controls.

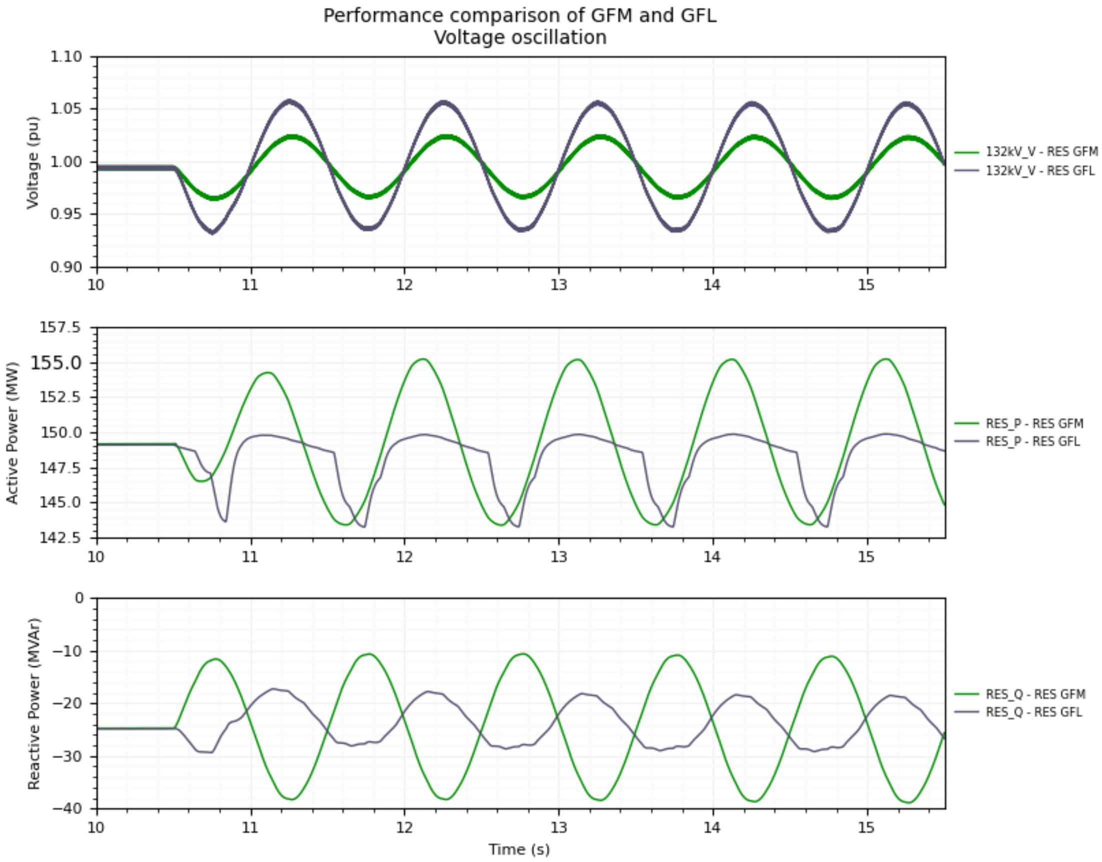


Figure 9: GFM vs GFL performance comparison for a voltage oscillation

The 'following' behaviour of the GFL controls extends to the sustained oscillation in this study, with the inverters continuing to inject power in-phase with the oscillating voltage. Despite the inverters not causing the oscillation, they inadvertently amplify its magnitude. By comparison, the voltage oscillation is roughly half the amplitude with GFM controls, as the inverters automatically oppose the oscillation.

8 Comparison to Synchronous Condensers

Traditionally the various supportive grid functions offered by GFM inverters have been provided by synchronous machines. To support inverter-based resource generation many synchronous condensers (or 'syncons') have been installed across the NEM in recent years, however GFM inverters may be able to replace these installations.

To investigate the capacity of DPESS to support GFL inverters, a generic solar farm and syncon were added to the RES PSCAD model. Various disturbances were simulated with the solar farm in-service, and then with the solar farm in-service and either RES or the syncon in-service.

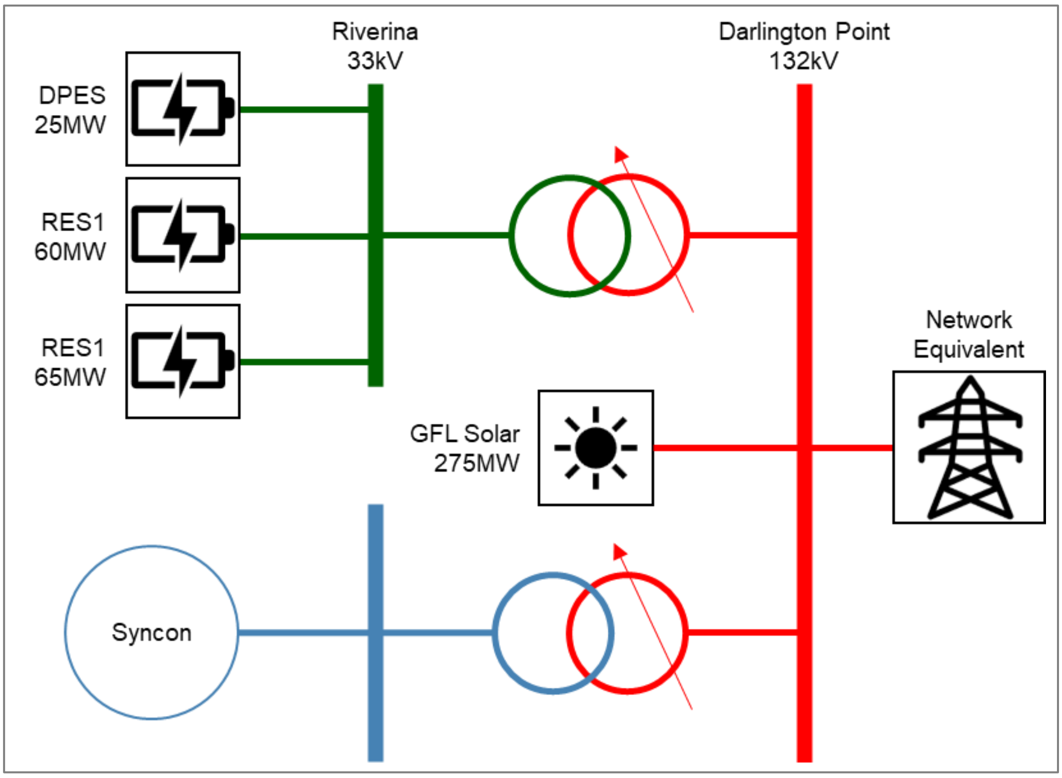


Figure 10: PSCAD model with solar farm and syncon

8.1 Frequency Disturbance

Under a frequency disturbance, the syncon and RES offer similar amounts of inertia, with the primary difference being that the syncon has no energy reserve beyond its mechanical inertia to support a sustained injection of active power. The syncon active power support therefore drops significantly after roughly 150ms as its rotational energy is expended, while RES continues to increase its injection of active power to a much higher sustained output level.

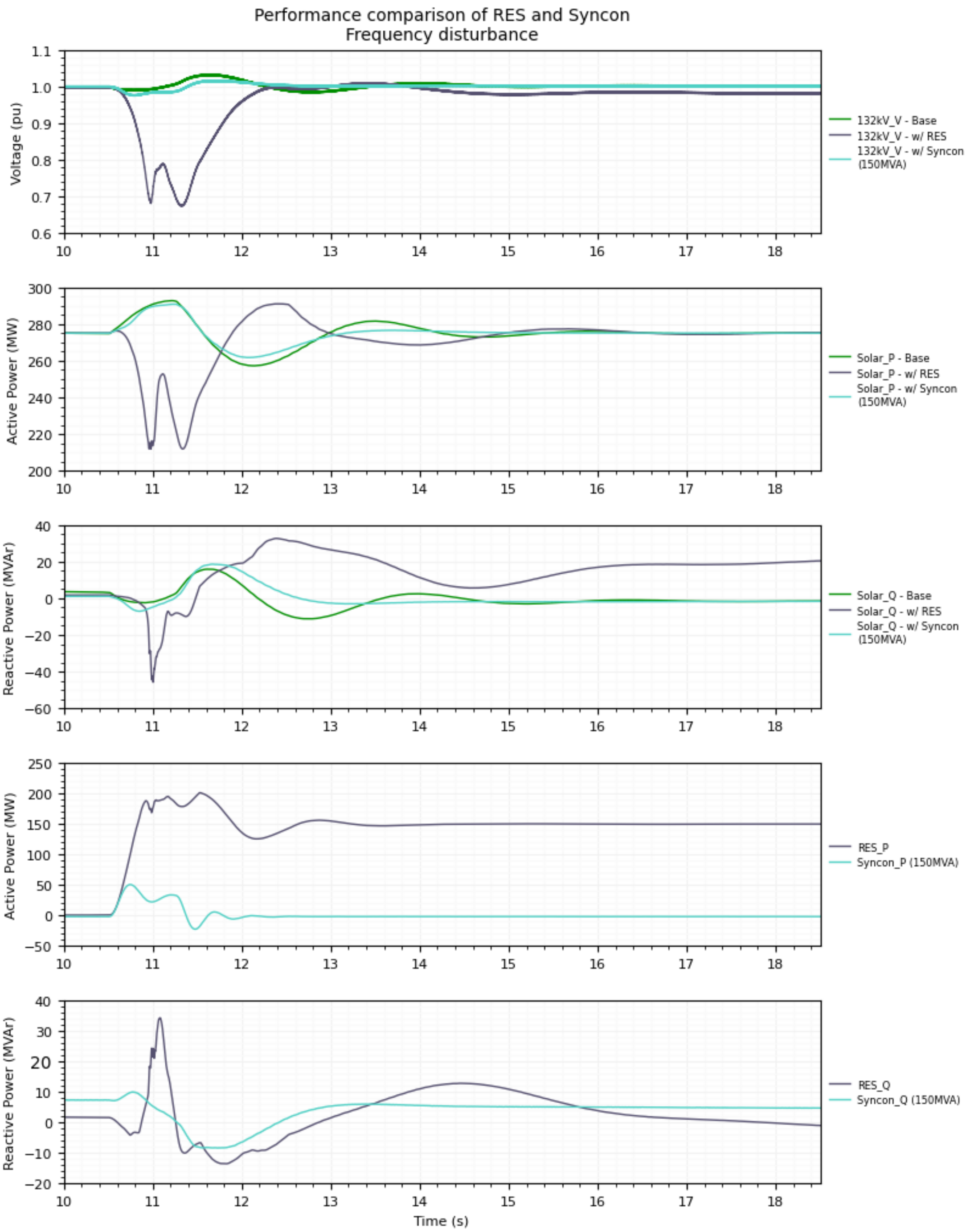


Figure 11: GFM vs syncon performance comparison for a frequency disturbance

8.2 Network Fault

Under a weak grid a network fault that further reduces system strength can be highly problematic for GFL plant. In this study the fault level was reduced on fault clearance to 350MVA, simulating the loss of a significant network element (such as the 330kV bus) giving the solar farm a short circuit ratio (SCR) of roughly 1.27. The resulting control responses are shown below in Figure 12.

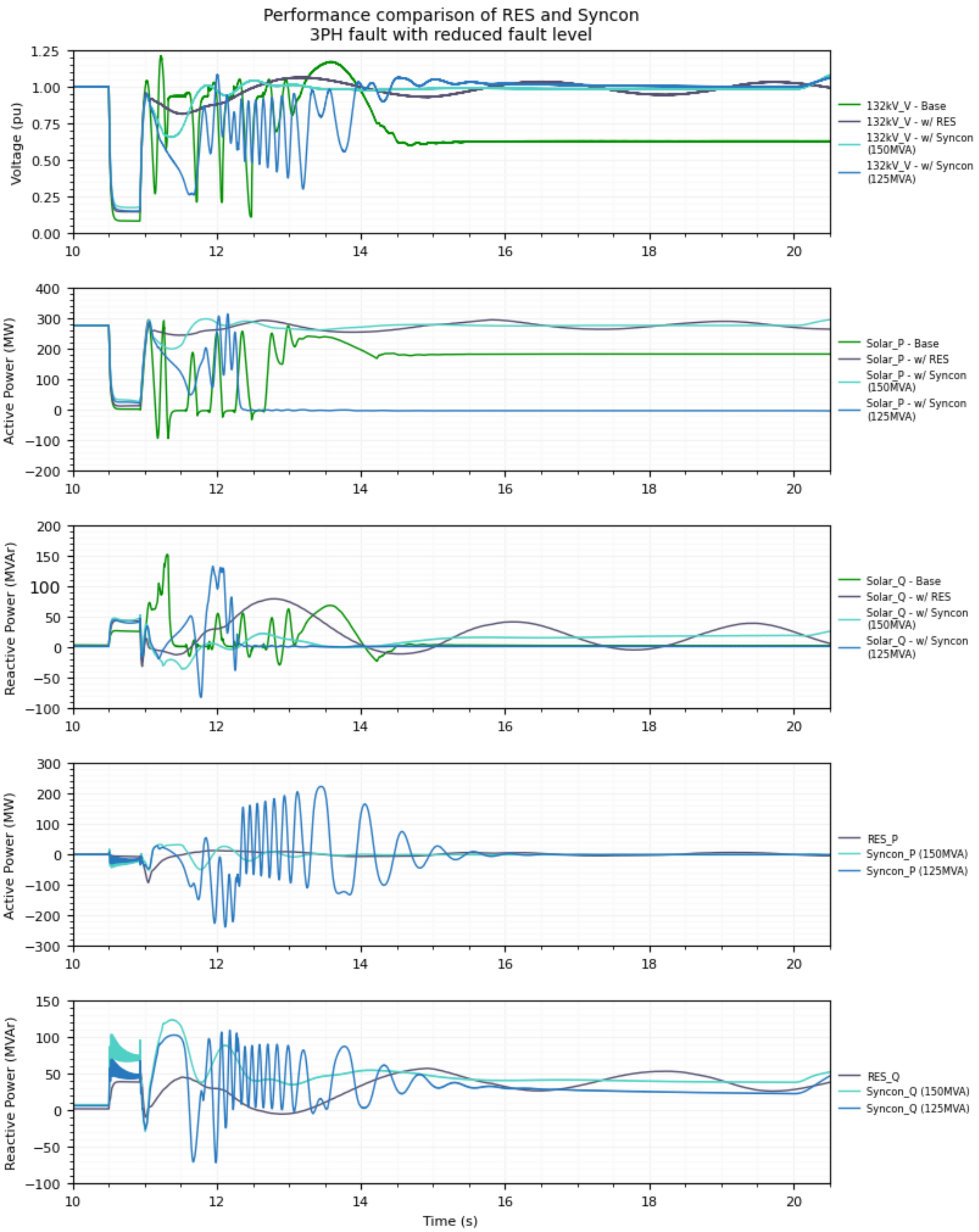


Figure 12: GFM vs syncon performance comparison for a network fault

Under the 'base' scenario (with only the solar farm in service) the solar farm successfully rides through the fault but experiences severe instability after the fault is cleared. It appears to eventually stabilise, however in reality this is because it has become 'stuck' in its fault ride-through mode (essentially freezing with the expectation that the current grid conditions will quickly resolve themselves). The most likely outcome of this disturbance in a real solar farm would be the operation of one or more protective functions to remove the plant (and likely the grid) from service.

By adding RES with GFM controls or a 150MVA syncon the solar farm is able to quickly stabilise after the fault and continues operating at full export despite the very low system strength provided by the grid. As a sensitivity, the same simulation was undertaken with a slightly smaller 125MVA syncon. At this reduced rating the syncon loses synchronism, and it would again be expected that the solar farm and potentially the grid would trip as a result.

It should be noted that this doesn't necessarily mean that RES provides the same level of system strength as a roughly 150MVA syncon. A key weakness of GFM inverters compared to synchronous machines is their very limited current overload capacity. The same study repeated with RES operating at full discharge power and therefore no capacity to increase its export (offset by a local load to mitigate the effects of increasing the power transfer across the network impedance) results in a very different outcome, shown below in Figure 13.

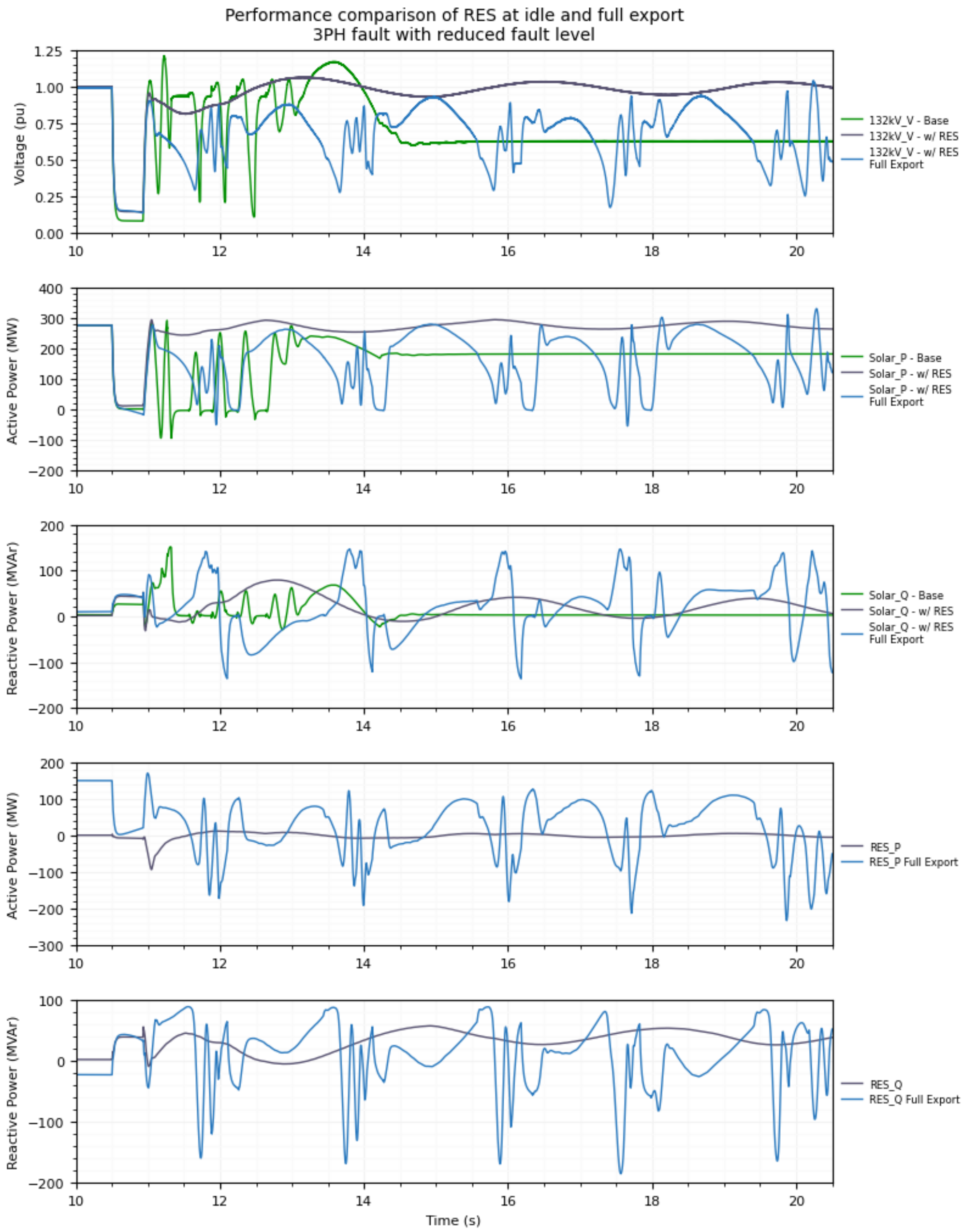


Figure 13: GFM performance for a network fault with reduced current capacity

With RES operating at full export prior to the fault, it effectively has a much lower current capacity for stabilising the grid. Similarly to the case with a lower syncon capacity, this reduction in current is enough to cause significant instability that would likely result in the tripping of the solar farm and potentially the local network.

9 Commissioning and Testing

One of the key questions which was often raised during the execution of the DPESS project was how a grid forming inverter would be commissioned and tested. The reality is that the process for commissioning of a grid forming inverter-based BESS in the NEM is identical to commissioning of a grid following inverter-based BESS.

The Project commissioned in 2023 which was also the time at which AEMO published its Voluntary Specification for Grid-forming Inverters. However, it is noted that the AEMO document provides a list of qualities against which inverters can be assessed and does not provide guidance on the actual testing and commissioning process which follows a similar path as any type of inverter-based plant. Nevertheless, it was important to have projects demonstrate that this is indeed the case and that there are no unexpected delays during the commissioning.

9.1 Ability to test grid forming features

One aspect that the Project noted is that it is difficult to demonstrate the grid forming capabilities of a plant through a typical testing program due to the way in which a test program is run. The large majority of the standard hold point tests which are undertaken in the NEM for new plants are based on observing the response of the facility to changes in setpoints for voltage, reactive and active power to assess how the controller will respond to a delta between a setpoint and actual. These tests are intended to be a proxy for how the plant will respond to network disturbances which is of the greatest interest when considering the resilience of the network to faults. These setpoint changes occur at the PPC level during these tests. As explained previously, the grid forming controls however operate at the inverter level and respond to the actual voltage at the inverter terminals. As the tests are only changing the setpoints in the PPC and not the actual voltage at the inverter terminals the majority of the tests will not effectively test the grid forming capabilities.

However, it is not practical to otherwise simulate disturbances at the inverter terminals and so this is a necessary and accepted limitation of the testing. During the testing and commissioning program the only external disturbance test is testing the response to an external voltage disturbance. The most valuable testing of grid forming inverters is therefore undertaken by reviewing responses to actual network events. Some examples of the responses of the Project to actual grid disturbance events are provided in the following section.

Hardware-in-the-Loop (HIL) testing is particularly valuable for grid-forming inverters. HIL testing involves connecting the actual inverter controller and/or Power Plant Controller (PPC) to a grid simulator. This approach provides a more accurate assessment of how the controls will respond, avoiding the uncertainties inherent in software-based representations such as PSS®E or PSCAD.

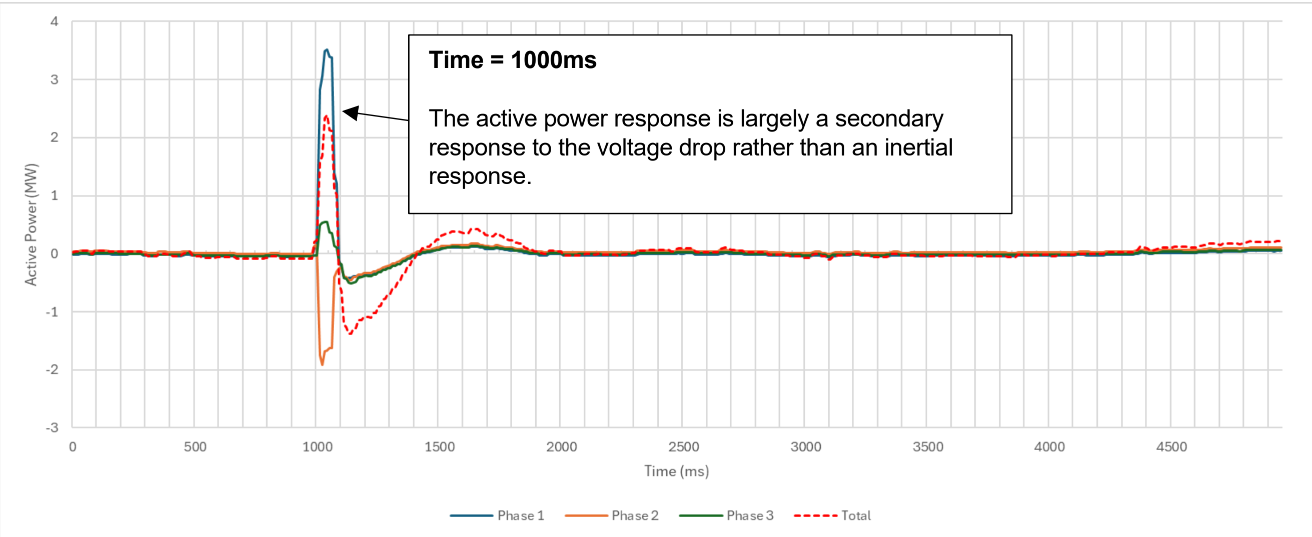
Many key grid-forming features cannot be fully simulated during on-grid testing. Therefore, we recommend using HIL testing to specifically validate these functionalities. While only limited HIL testing is currently required in the NEM commissioning process, we anticipate it will become increasingly important—especially in scenarios where networks depend on these capabilities for grid stability. For this reason, we suggest considering HIL testing for future projects.

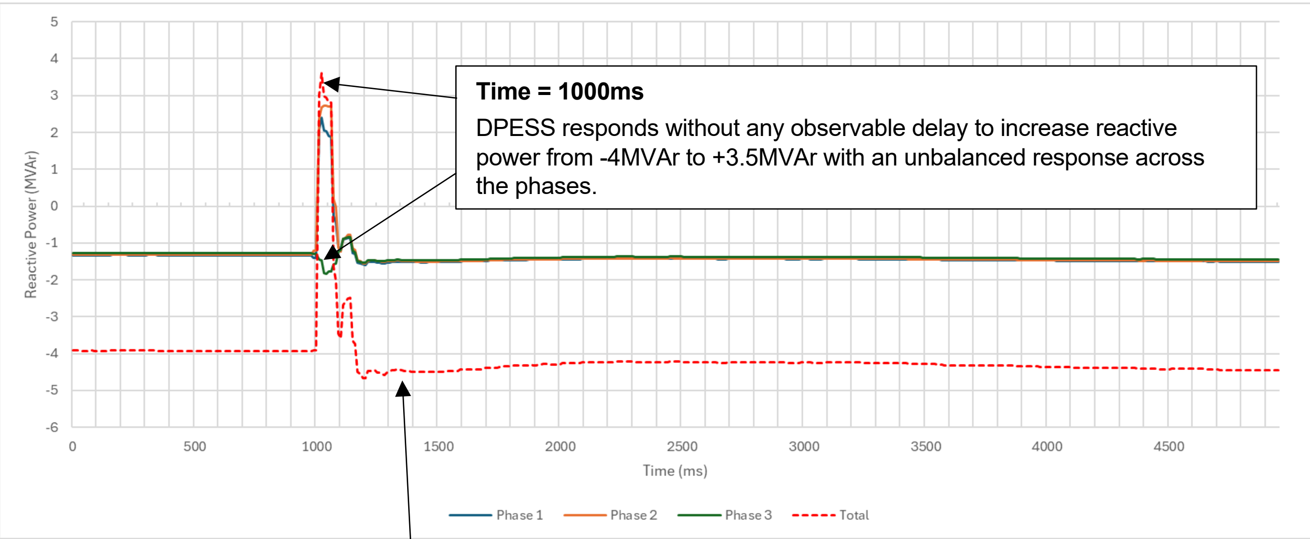
10 Review of Operations

This section includes a review of several network events which have occurred since the plant entered commercial operation.

10.1 Network Event 26 April 2025

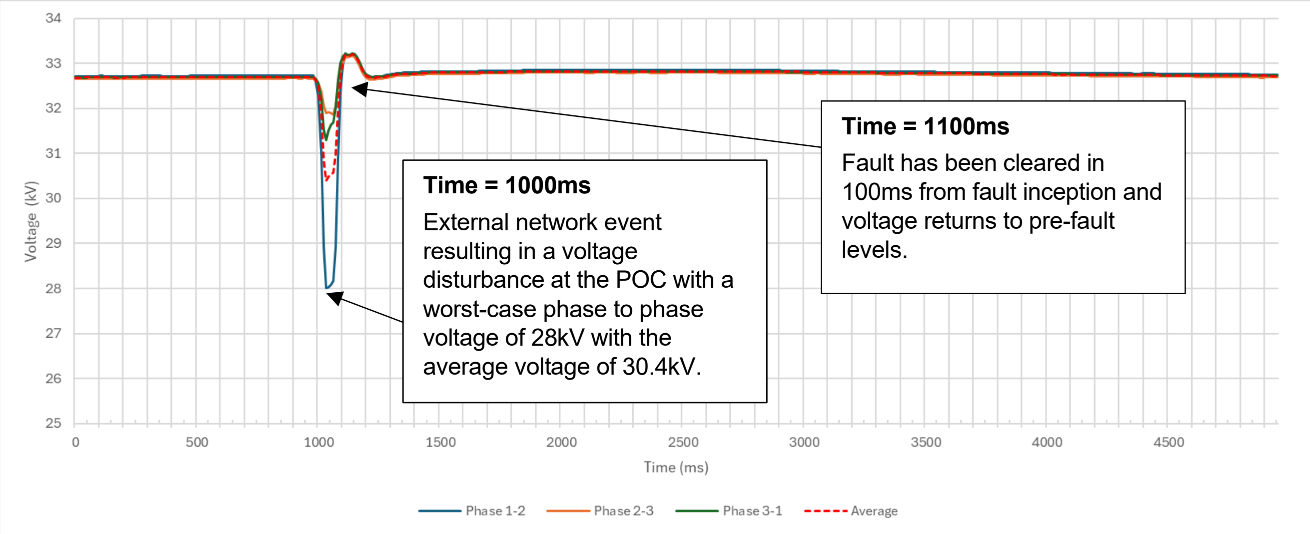
The following plots show the plant output at the point of connection of DPESS during a network fault which occurred at approximately 3:30 AM on 26 April 2025.

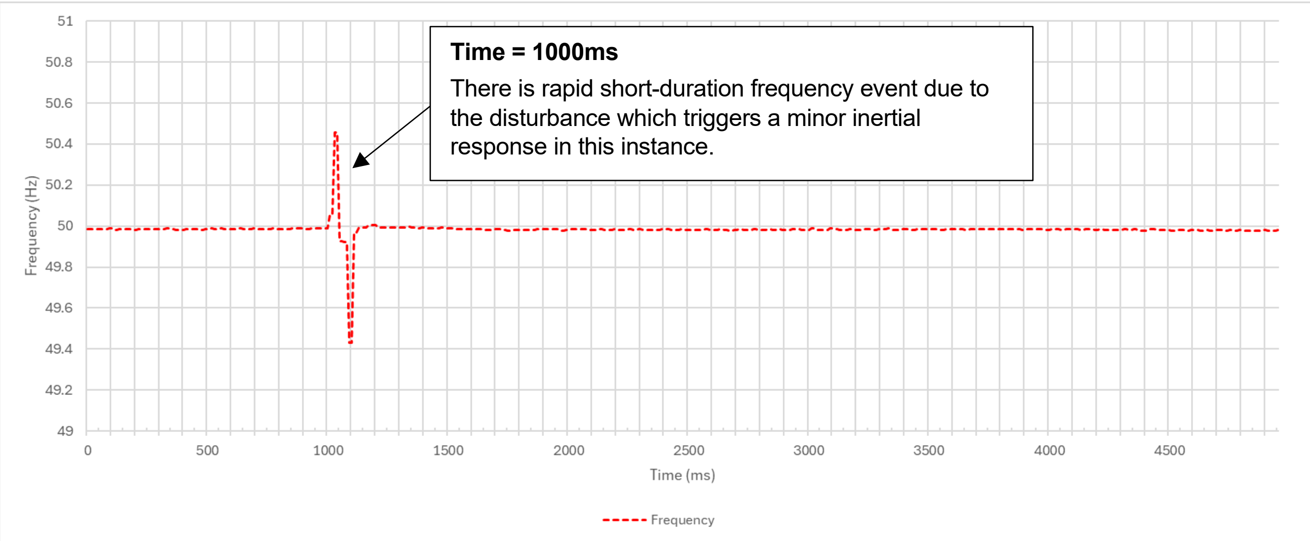




Time = 1100ms

DPESS returns to pre-disturbance levels following fault clearance.





It can be seen that an event has occurred on the network external to the plant which has caused a voltage disturbance. The largest phase to phase voltage dropped to 28kV with the average voltage dropping to 30.4kV or approximately 0.92 per unit of the nominal 33kV. There was no observed change in the network frequency. The period of the fault before clearance is of the order of 100ms.

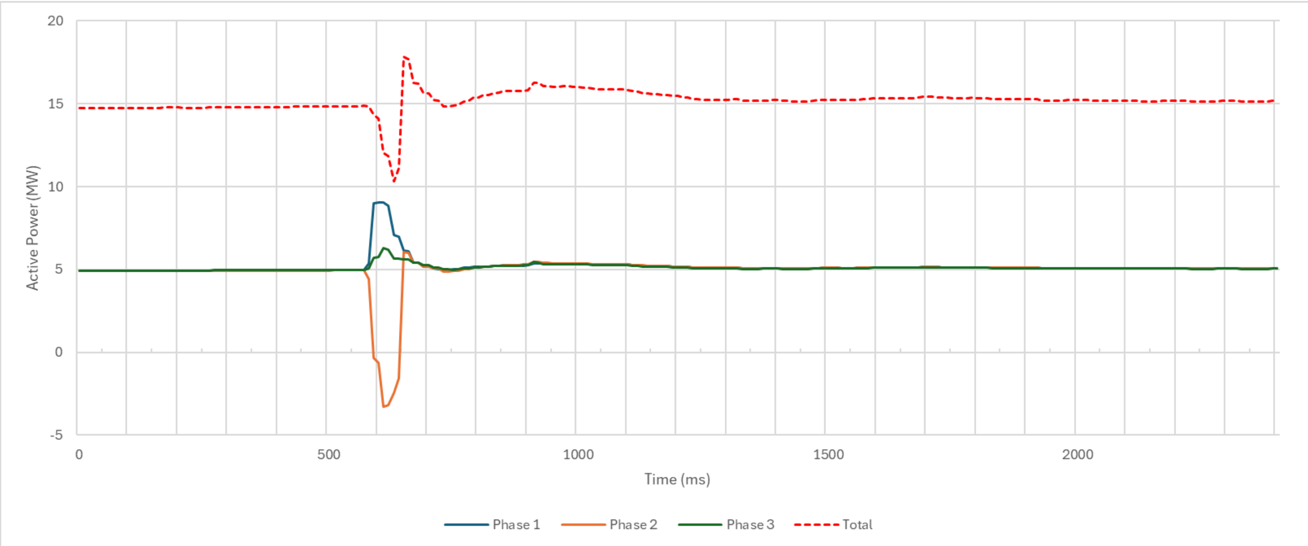
Prior to the event the plant is operating at 0MW but is actively connected to the network and is absorbing approximately 4MVAr. This demonstrates the ability of BESS to be providing network services even when idle provided they are operated such that they remain connected to the network as is the case for DPESS.

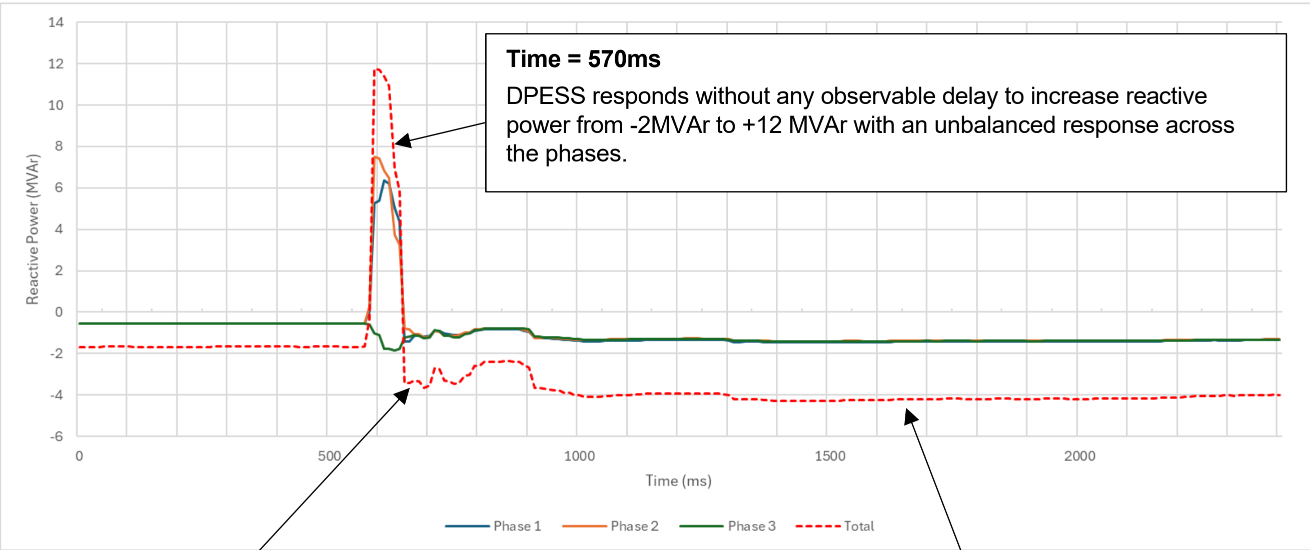
It can be seen that DPESS provides a reactive power response to the network voltage drop which is effectively instantaneous with there being no discernible difference between the commencement of the voltage drop and the reactive power response when reviewing 10ms data intervals. This response is in line with the Voluntary Specification for Grid-forming Inverters published by AEMO in May 2023 which requires near instantaneous response. The other observation made in regard to the reactive power response is that it occurs independently in each phase rather than on an average 3 phase basis. It is both the speed of response and independent phase response which differentiates the response most clearly from a grid following inverter response. This is consistent with the expected outcomes based on the modelling (refer to section 7.4)

There is also an associated active power response to the voltage drop and reactive power response which in this case is not a reaction to change in frequency.

10.2 Network Event 23 June 2025

The following plots show the plant output at the point of connection of DPESS during a network fault which occurred at approximately 5:20 PM on 23 June 2025.

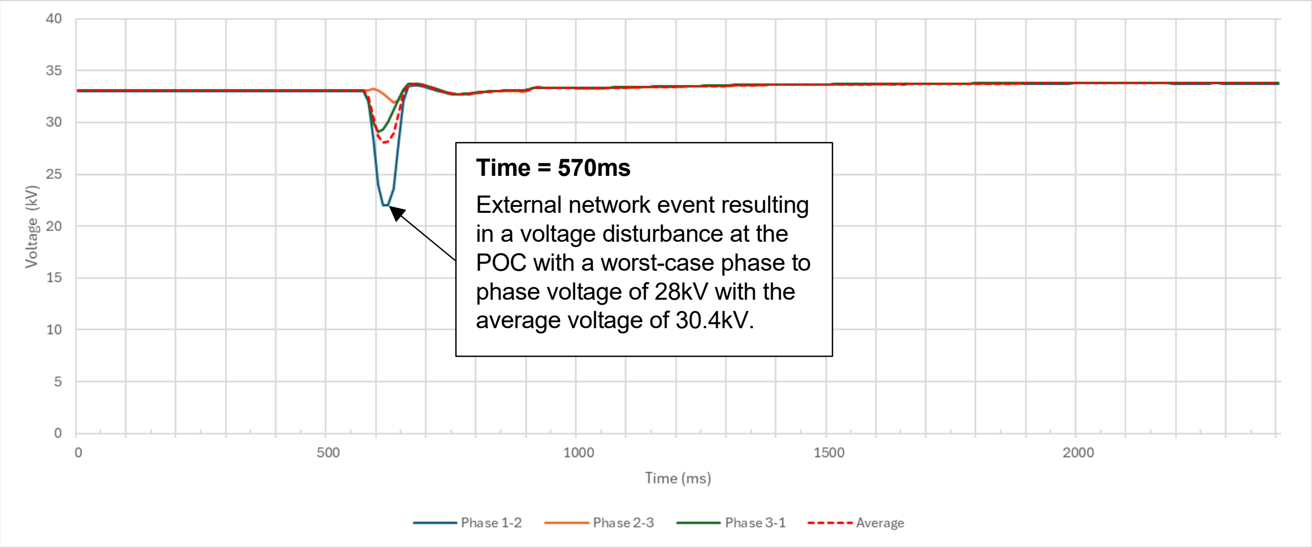


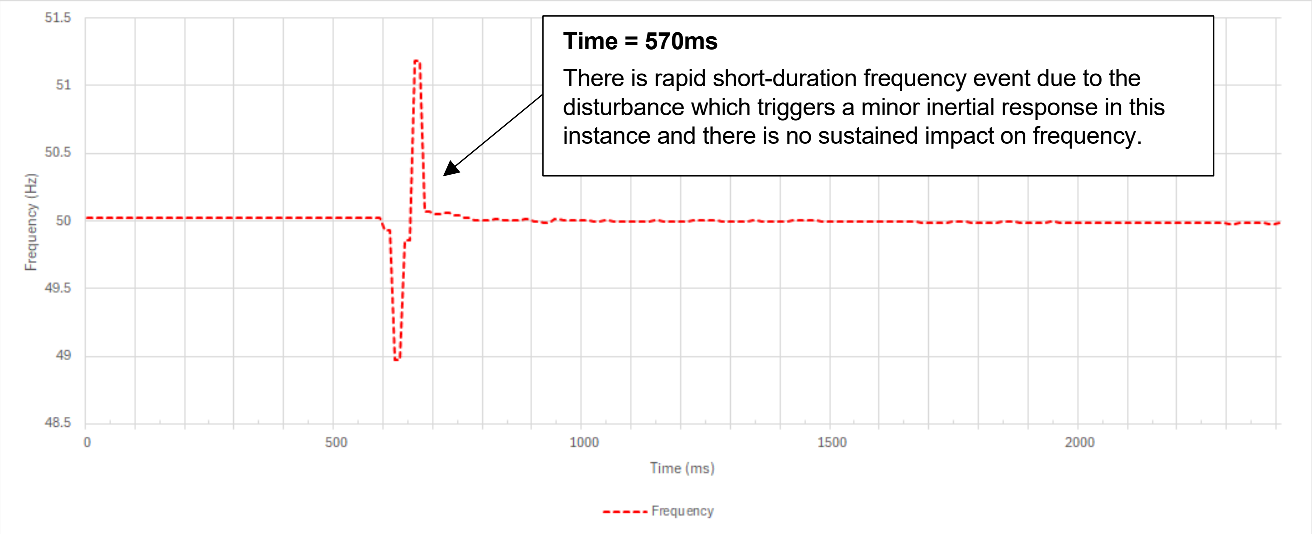


Time = 570ms
DPESS responds without any observable delay to increase reactive power from -2MVAr to +12 MVAr with an unbalanced response across the phases.

Time = 650ms
DPESS returns to pre-disturbance levels following fault clearance.

Time = +1000ms
Post fault reactive power settles at lower value due to change in voltage post clearance.





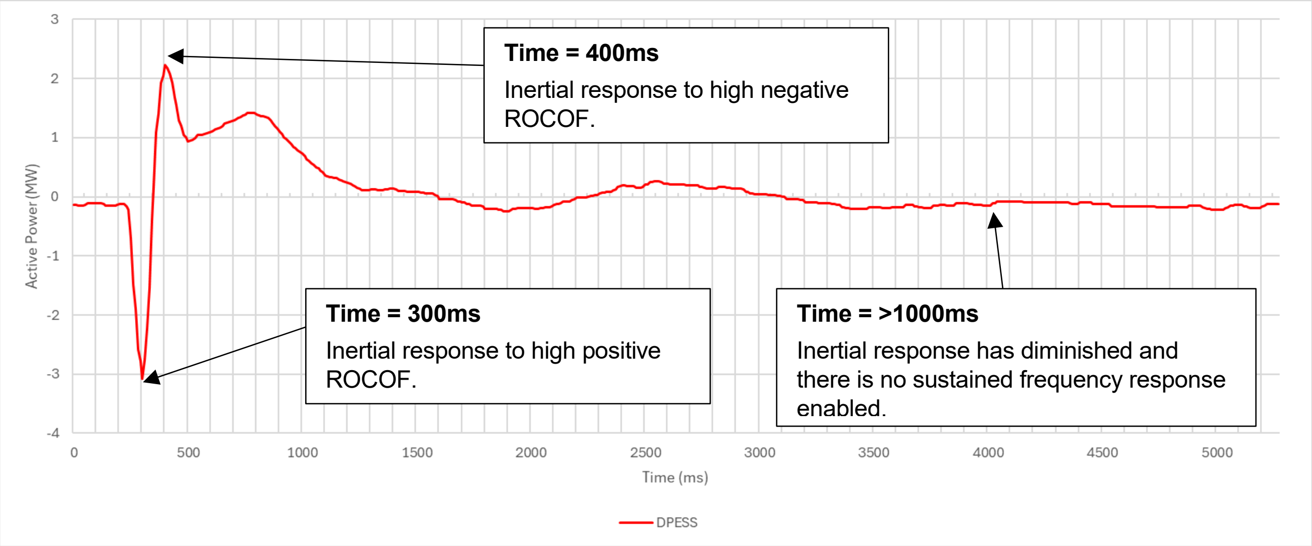
This event is notable in that it is understood to be caused by an unplanned outage of line 63 Darlington Point - Wagga. In this case the voltage drop is slightly more severe with a worst-case phase to phase voltage of approximately 22kV and average voltage drop of approximately 28kV (0.85pu).

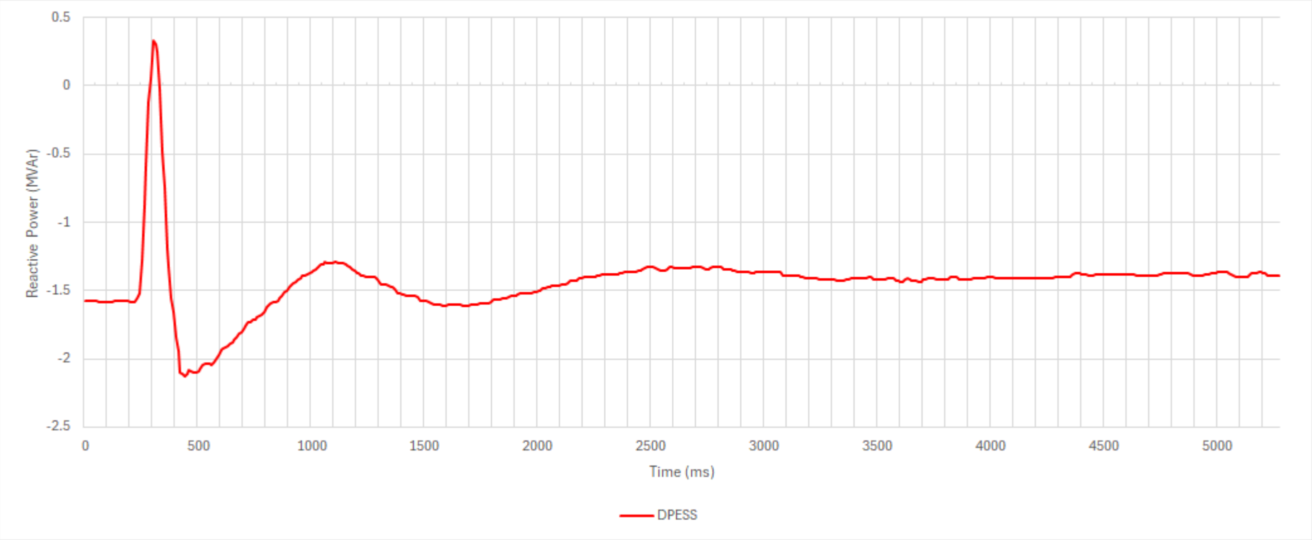
Prior to the event the BESS is operating at an export level of 15MW (60% rated power) and absorbing approximately 2MVAr.

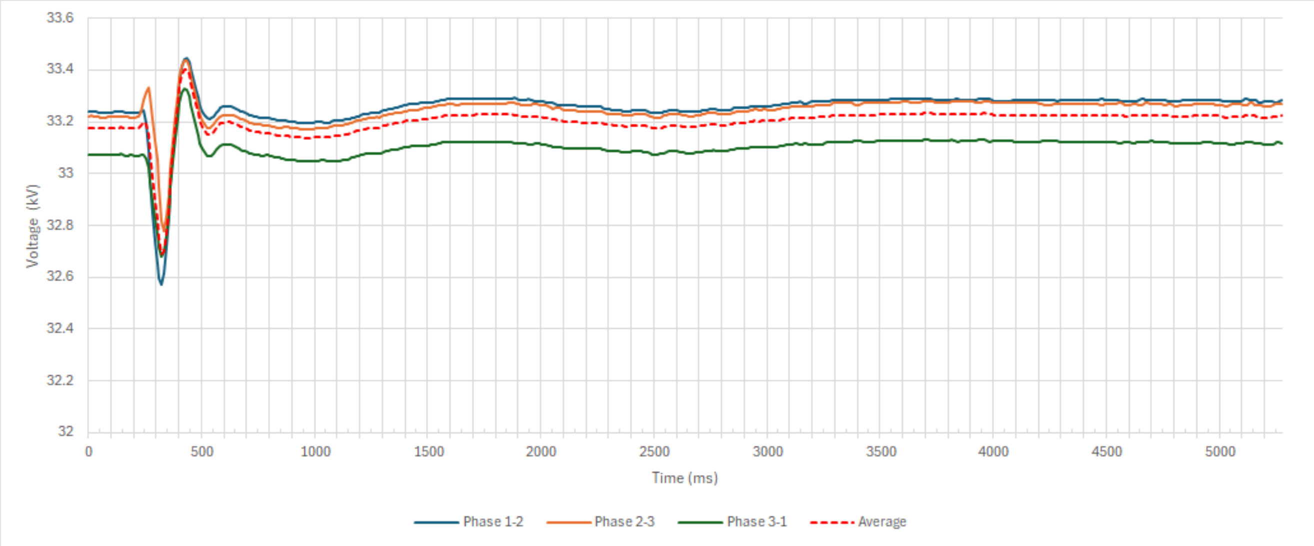
DPESS can be seen to provide a near instantaneous response to the voltage drop. The fault is cleared within 100ms and DPESS quickly returns to pre fault conditions although can be seen to be absorbing a higher amount of reactive power due to a slightly increased post-fault network voltage. Despite the small change in reactive power required in this case, it is this specific response that is highly beneficial to maintaining the stability of the local network. In this case the small change likely indicates the combination of network conditions that can lead to voltage collapse without DPESS in service were not in effect at the time. It is expected that if this outage had occurred earlier in the day when there was significant solar generation west of DPESS, the change in reactive power from DPESS would have been much more significant.

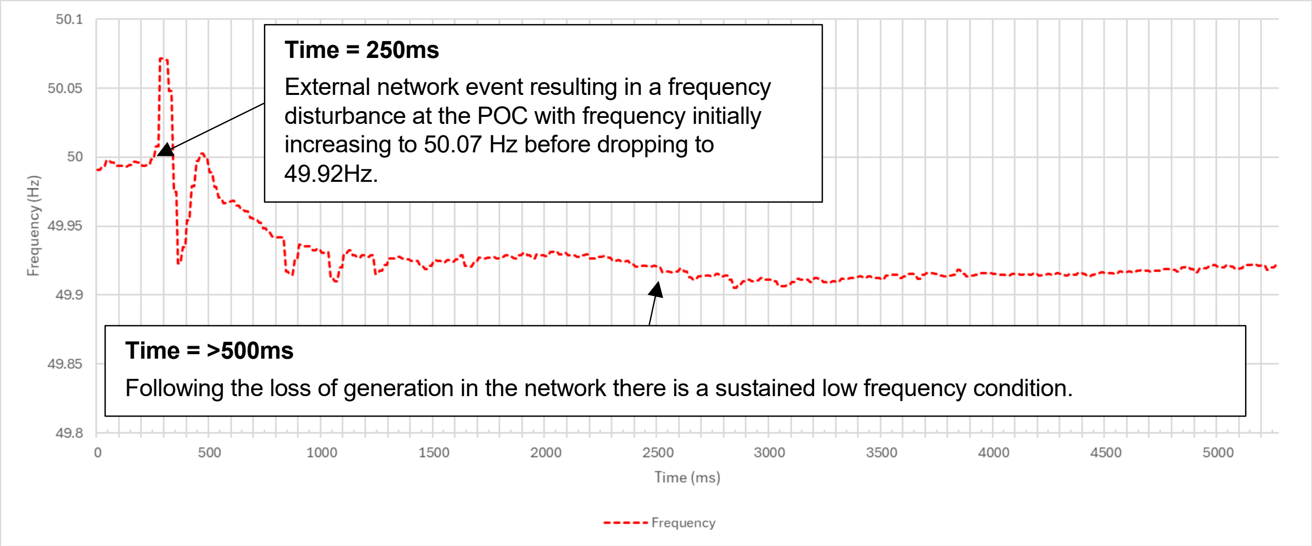
10.3 Network Event 11 April 2025

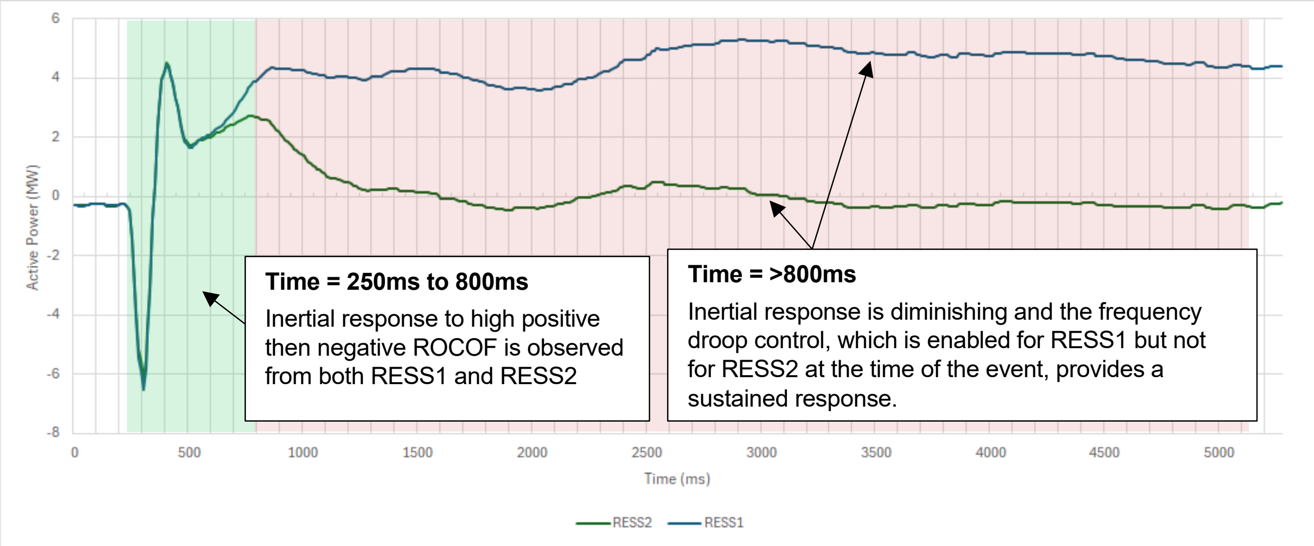
As reported in the most recent AEMO quarterly frequency review, the event with the highest rate of change of frequency (ROCOF) since the plant was operational occurred on 11 April 2025. This event was due to a trip of Wellington North Solar Farm which was operating at 281MW at the time of the disturbance. The maximum ROCOF recorded by AEMO was -0.23 Hz/s.






Voltage (kV)
Time (ms)
Phase 1-2
Phase 2-3
Phase 3-1
Average


Frequency (Hz)
Time (ms)
Frequency
Time = 250ms
External network event resulting in a frequency disturbance at the POC with frequency initially increasing to 50.07 Hz before dropping to 49.92Hz.
Time = >500ms
Following the loss of generation in the network there is a sustained low frequency condition.


Active Power (MW)
Time (ms)
RESS2
RESS1
Time = 250ms to 800ms
Inertial response to high positive then negative ROCOF is observed from both RESS1 and RESS2
Time = >800ms
Inertial response is diminishing and the frequency droop control, which is enabled for RESS1 but not for RESS2 at the time of the event, provides a sustained response.

As can be seen the event includes a small voltage disturbance followed by a decrease in frequency. DPESS can be seen to respond to the voltage event by providing reactive power and initially has a dip then recovery and overshoot in active power which would be expected during a voltage disturbance and is similar to the response to the network event on 23 June 2025.

What can be observed following is that the active power does not immediately return to the pre-disturbance level and has a second response between 500 and 800ms being an inertial response to the negative ROCOF which is peaking at around the 800ms timeframe corresponding with the secondary peak in active power. This is also to be expected as the grid forming inverters are expected to provide synthetic inertia.

The active power responses of the adjacent RESS1 and RESS2 projects are also shown in the final chart which provides an interesting comparison between an inertial response and a frequency droop response. At the time of the event RESS1 was enabled to provide contingency FCAS and so had the droop response enabled from a +-15mHz deadband but was otherwise not enabled in the energy market. RESS2 (and DPESS) was not enabled in any markets (wholesale energy or FCAS) and therefore was not required to provide primary frequency response (PFR) at the time and accordingly had the frequency droop control disabled. This provides a nice comparison between two similarly sized projects (both using the same technology and plant settings) showing the difference between the inertial response and that of the frequency droop. It can be seen that following the initial deviation due to the voltage disturbance both plants provided a similar secondary increase in response to the ROCOF (the inertial response). At the time marked 700ms, while both are still providing an inertial response, RESS1 begins to deviate in response on account of the frequency droop controller. As the inertial response drops away, RESS1 continues to provide an active power offset due to the sustained frequency being lower than the deadband and in the PFR response range. DPESS was similarly not enabled to provide frequency droop. All three plants responded as would be expected during the event and contributed to the quick recovery of the network following the event.

10.4 Sharing of Data

As the validation of grid forming inverters is difficult to achieve during testing, we believe one of the important contributions the Project can make in terms of knowledge sharing is the provision of these data recordings from actual network events with AEMO for analysis. The Project has shared high speed recordings for the first two network events reviewed in this section with AEMO for continued industry learnings and to provide further confidence in the technology.

10.5 Conclusions

Overall, the response to both events is in line with the expected response and demonstrates a number of key aspects for consideration when relying of grid forming inverters for network services:

- Speed of response is in line with model expectation of near instantaneous response. This is in clear contrast to typical grid following plant where there would be a delay in the response due to measurement delay.
- Acting in individual phases for voltage response.
- Ability of the BESS to provide network service while either idle or generating prior to a disturbance.

11 Broader implications for the NEM

The key goal of the Project was to demonstrate that a grid forming BESS could provide system strength. Ultimately the benefit of this will be that grid forming BESSs can deliver these critical services at a more efficient cost than solutions such as synchronous condenser and network upgrades.

11.1 Network Support Agreement

DPESS recently entered in a Network Support Agreement (NSA) with Transgrid under which it provides network stability services. The ability to provide these services is due to the grid forming nature of the BESS.

The origins of this agreement commenced with a Project Specification Consultation Report entitled *Improving stability in south-western NSW* which Transgrid published in July 2020 under the Regulatory Investment Test for Transmission (RIT-T) framework. In this they identified that the power system in south-western NSW had seen a significant growth in renewable connections as part of the wider energy market transition to renewables. This included approximately 560MW of renewable generation connected at the time and a further 800MW expected to connect in the near future. The report identified that the only way of managing the risk in the immediate term was to constrain generation in south-western NSW, such that AEMO implemented constraint equations which resulted in the main 330kV line between Darlington Point and Wagga Wagga (Line 63) being operated well below its thermal capacity due to stability concerns.

The underlying concern that system studies highlighted was that the 132kV system in south-western NSW would experience significant stability issues following the tripping of Line 63. Transgrid investigated a number of options to alleviate the constraint which initially included new transmission lines as well as a new static synchronous compensator (STATCOM) at Darlington Point. Transgrid initially discounted batteries as they noted they would need to be coupled with a STATCOM and so would always be more expensive than a STATCOM alone to provide the same benefit.

Edify proposed that Transgrid could contract the services of a non-network battery which could otherwise earn revenue from the energy market, meaning the cost of the network services could be as competitive as a STATCOM together with transmission upgrades.

While the battery was not able to fully alleviate the constraint up to the thermal limit of the transmission line, it was able to increase the permitted flow by over one third of the previous limit and was assessed to be the preferred solution in terms of cost-benefit to consumers.

DPESS executed the Network Support Agreement with Transgrid in July 2024 which requires the facility to regulate the voltage by automatically and continuously responding to disturbances. The services contracted under the NSA are all additional to the existing services contracted under the Project's energy market revenue contract with EnergyAustralia.

We believe that an agreement such as this is important as it shows that a network operator has recognised and accepted the ability of grid forming BESS to stabilise the network or to provide system strength.

11.2 Future of Grid Forming BESS in the NEM

BESS uptake in the NEM is forecast to grow significantly, driven by the transition to net-zero, coal plant retirements, and the increasing integration of renewable energy. The Australian Energy Market Operator (AEMO) forecasts show utility-scale BESS could grow to 18 GW by 2035, from 2.3 GW in 2024. This therefore represents a huge opportunity to utilise grid forming inverters at very large scale which will help to offset the significant loss of system strength due to coal plant retirements.

Due in part to the Project and others which have recently entered into operation, there is a growing recognition and acceptance of the role that grid forming BESSs can play in the NEM. It is noted in the recently published PACR titled 'Meeting system strength requirements in NSW' that Transgrid is now planning to factor grid forming BESSs into its future procurement of system strength in the NEM. This should provide an efficient provision of a portion of their system strength requirements due to the dual role that BESS can play compared to synchronous condensers.

Appendix A Glossary of Terms

Acronym	Meaning
AEMO	Australian Energy Market Operator
AGC	Automatic Generator Control
ARENA	Australian Renewable Energy Agency
ARP	Advancing Renewables Program
BESS	Battery Energy Storage System
BDU	Bidirectional Unit
BSSA	Battery Storage Services Agreement
DNA	Designated Network Asset
DPESS	Darlington Point Energy Storage System
Edify	Edify Energy Pty Ltd and its related entities
FCAS	Frequency Control Ancillary Services
FFR	Fast Frequency Response
FRMP	Financially Responsible Market Participant
GPS	Generator Performance Standards
GFL	Grid Following
GFM	Grid Forming
HIL	Hardware in the Loop
LFP	Lithium Iron Phosphate
NEM	National Electricity Market
NER	National Electricity Rules
NMI	National Metering Identifier
NSA	Network Support Agreement
NSP	Network Service Provider
O&M	Operations and Maintenance
PPC	Power Plant Controller
Project	DPESS
PSCAD	Power Systems Computer Aided Design

PSSE	Power System Simulator for Engineering
RES	Collectively, RESS1, RESS2 and DPESS
RESS1	Riverina Energy Storage System 1
RESS2	Riverina Energy Storage System 2
PFR	Primary Frequency Response
RIT-T	Regulatory Investment Test for Transmission
ROCOF	Rate of Change of Frequency
RRP	Regional Reference Price
RTE	Round-Trip Efficiency
SCADA	Supervisory Control and Data Acquisition
SOC	State-of-Charge
STATCOM	Static Synchronous Compensator
Syncon	Synchronous Condenser
TNSP	Transmission Network Service Provider

Edify™