ESCRI-SA Battery Energy Storage Project Operational Report #3

Third six months (14/12/2019 – 14/6/2020)

August 2020

In partnership with:

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This activity received funding from ARENA as part of their Advancing Renewables Program.

ARENA
Australian Government
Australian Renewable Energy Agency

Contents

Glossary of Terms

Term	Description
AEMO	Australian Energy Market Operator
ARENA	Australian Renewable Energy Agency
BESS	Battery Energy Storage System
BOA	Battery Operating Agreement
CPP	Consolidated Power Projects Australia Pty Ltd
EPC	Engineering, Procurement, and Construction
ESCOSA	Essential Services Commission of South Australia
ESCRI-SA	Energy Storage for Commercial Renewable Integration, South Australia
ESD	Energy Storage Device
FCAS	Frequency Control Ancillary Services
FFR	Fast Frequency Response
GPS	Generator Performance Standards
Hz	Hertz
Hz/s	Hertz per second
IDS	Island Detection Scheme
ITR	Inspection Test Report
kV	Kilovolts
MGC	Micro Grid Controller
MVP	Minimum Viable Product
MW	Megawatts
MWh	Megawatt hours
MWs	Megawatt seconds
NEM	National Electricity Market
NER	National Electricity Rules
PSSE	Power System Simulator for Engineering
RoCoF	Rate-of-change-of-frequency
SA	South Australia
SCADA	Supervisory Control And Data Acquisition
SIPS	System Integrity Protection Scheme
SOC	State of Charge
SRMTMP	Safety, Reliability, Maintenance and Technical Management Plan
WPWF	Wattle Point Wind Farm

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1. Document Purpose and Distribution

1.1 Purpose of Document

This document is a public report issued as part of the Knowledge Sharing commitments of Phase 3 of the Energy Storage for Commercial Renewables Integration, South Australia (ESCRI-SA Project), in accordance with the Funding Agreement between ElectraNet and the Australian Renewable Energy Agency (ARENA). ARENA has contributed funding support through its Advancing Renewables Programme.

ESCRI-SA involves the installation of a 30 MW, 8 MWh Battery Energy Storage System (BESS) at Dalrymple on the Yorke Peninsula of South Australia. Phase 1 of the Project, completed in 2015, involved preliminary business case work. Phase 2 was the actual procurement, installation, and commissioning and Stage 3 is the operation of the asset.

Two public reports on Phase 2 have been published:

- The “Project Summary Report – The Journey to Financial Close”, published in May 2018. This detailed the approach and resolution of issues required to commence the Project. It is referred to herein as the “Project Summary Report”
- The “ESCRI-SA Battery Energy Storage Project Commissioning Report – From Financial Close to Commissioning”, published in October 2018. This detailed the journey and lessons learnt in project delivery through to commissioning. It is referred to herein as the “Project Commissioning Report”

Two public reports on Phase 3 have been published:

- The “ESCRI-SA Battery Energy Storage Project Operational Report No. 1 – First six months (14/12/2018 – 14/6/2019), published in July 2019. This detailed the journey and lessons learnt from commissioning to full operation
- The “ESCRI-SA Battery Energy Storage Project Operational Report No. 2 – Second six months (14/6/2019 – 14/12/2019), published in February 2020. This detailed the key operational events and lessons learnt during the second six months of operation.

This Project Operational Report is the third of four six-monthly operational reports required under Phase 3 and focuses specifically on core components of the Project operation, and lessons learnt on the journey of full operation, including:

- Current operational status and key storage metrics for the reporting period
- Overview and analysis of key events for the reporting period
- Portal operation and usage
- Demonstration of key BESS regulated services, including analysis of unserved energy events, modelled reduction of interconnector Rate of Change of Frequency (RoCoF) constraint and test response rates for participation in the System Integration Protection Scheme (SIPS)
- Demonstration of key BESS market services, including revenue from energy arbitrage and Frequency Control Ancillary Services (FCAS), and
- Overview of system maintenance, remaining defects, faults and resolutions

Over the course of the Project a wide range of Knowledge Sharing work is being undertaken, including delivery of a range of reports, presentations, meetings and site visits.

Access to the full list of Knowledge Sharing resources as well as operational information and data is available at the Project Portal (the Portal), at http://escri-sa.com.au/, as described in Section 3.4.

1.2 Intended Distribution

This document is intended for the public domain and has no distribution restrictions.

2. Introduction

2.1 Background and Report Overview

The ESCRI-SA Project has been part funded by ARENA and began as a concept in 2013 to explore the role of energy storage in a future with more variable renewable energy-based generation within Australia's larger interconnected energy system.

This concept evolved into a consortium consisting of ElectraNet, AGL and Worley (the Consortium[1]), that jointly explored the business case for a non-hydro energy storage device (Phase 1). This was followed by the installation and commissioning of a BESS (Phase 2) and now operation of the BESS (Phase 3).

This Operational Report (Report) is a key requirement under Milestone 6 of the Funding Agreement between ElectraNet and ARENA. It covers the journey and lessons learnt for the third six months of the Project's commercial operation.

Section 1 describes the Report's purpose, the intended audience and any distribution restrictions. This section also includes a link to the on-line portal where all Project Knowledge Sharing information is located.

Section 2 provides context for the Project including a description of the system, configuration, operational priorities and key project objectives.

Section 3 provides a summary of the BESS operation over the reporting period including key storage metrics, key events and operation and usage of the portal.

Section 4 outlines the key BESS regulated services that have been demonstrated over the reporting period, covering un-served energy, any reduction of the interconnector RoCoF constraints and participation in the System Integration Protection Scheme.

Section 5 outlines the key BESS market services that have been demonstrated over the reporting period covering the revenue from energy arbitrage and FCAS services as well as consideration of future revenue streams.

Section 6 provides information on general operational issues including maintenance, safety incidents, stakeholder issues, any market non-compliance incidents, the status of the remaining Engineering, Procurement and Construction (EPC) contract and an update on the resolution of defects listed at commercial handover.

Section 7 contains observations about activities and engagements related to the BESS and also summarises new lessons learnt during the last six months of commercial operation.

[1] The parties and their roles are described in Section 8 along with contact details for Project enquiries

2.2 Overview of ESCRI-SA BESS System and Operation

The ESCRI-SA BESS system, a 30 MW, 8 MWh large-scale battery system, is connected to ElectraNet's Dalrymple substation, seven kilometres south-west of Stansbury on the lower Yorke Peninsula in South Australia, about 200 km from Adelaide.

Figure 2-1: Aerial photograph of Dalrymple BESS and the Dalrymple substation looking south

The Dalrymple substation is radially supplied via Hummocks and Ardrossan West substations. The BESS connection point is at a two 25 MVA 132/33 kV transformer substation.

In some ways Dalrymple's local electricity supply system can be considered a smaller version of the South Australian power system, as it includes significant local renewable energy generation at the nearby Wattle Point Wind Farm (90 MW) and has solar PV (about 3.4 MW total inverter capacity) installed on local customer roofs.

The local maximum demand at Dalrymple is about 8 MW, but the average demand is significantly lower at about 3 MW.

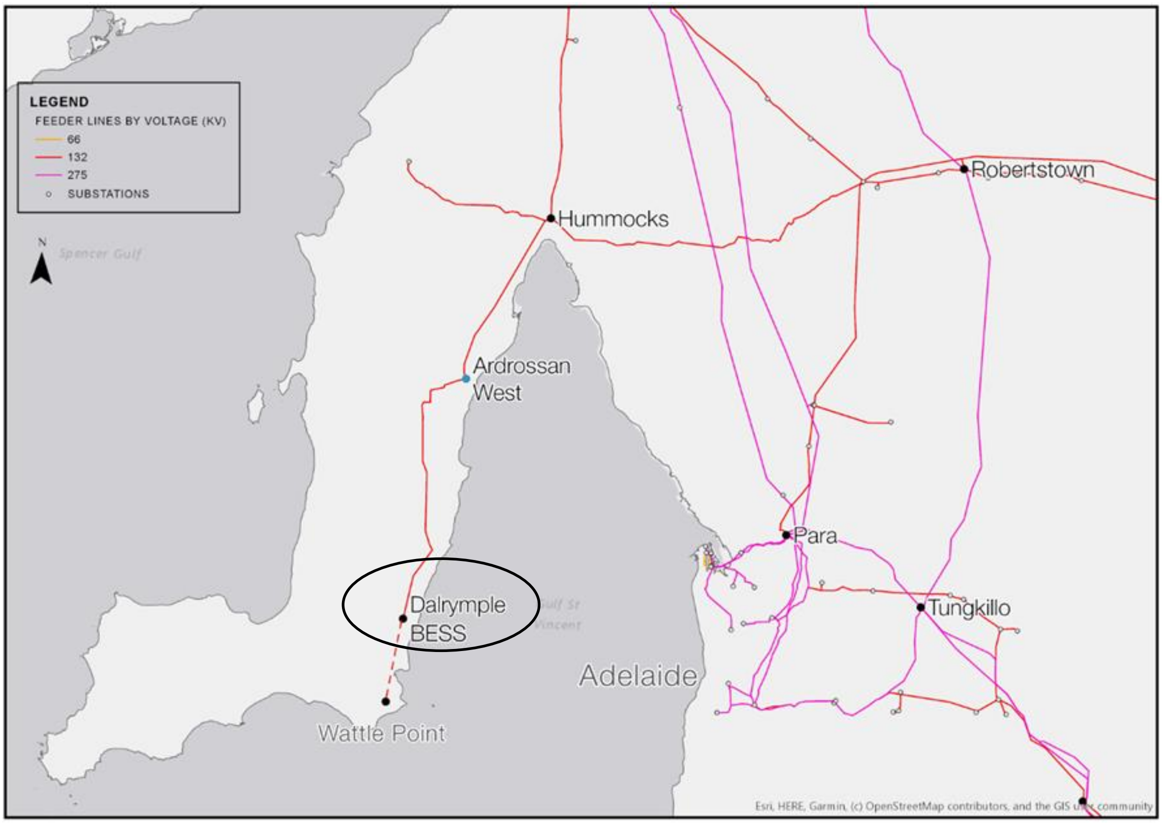

Figure 2-2: Dalrymple connection point relative to existing transmission assets

The Wattle Point Wind Farm, as is normal for wind farms, is only able to operate if a reference frequency is available from the power system. This means that if either the Hummocks to Ardrossan West 132 kV line or the Ardrossan West to Dalrymple 132 kV line are out of service, the local Dalrymple demand will be unsupplied, and the Wattle Point Wind Farm (WPWF) will also be out of service.

The installation of the BESS has provided the ability to supply the local Dalrymple demand in such situations and allow the WPWF to contribute – this means it can run in island mode with the wind farm as part of that island.

Analysis of the Dalrymple connection point performance for the period 2006 to 2014 indicated there were 22 interruptions to supply, totalling 35.18 hours. This equates to an average yearly loss of supply of 3.52 hours and 9.46 MWh.

Our analysis indicated that 8 MWh of energy storage, if operated in conjunction with a small part of the WPWF, would enable the local Dalrymple demand to be supplied during 96-98% of unplanned outages of the relevant 132 kV lines.

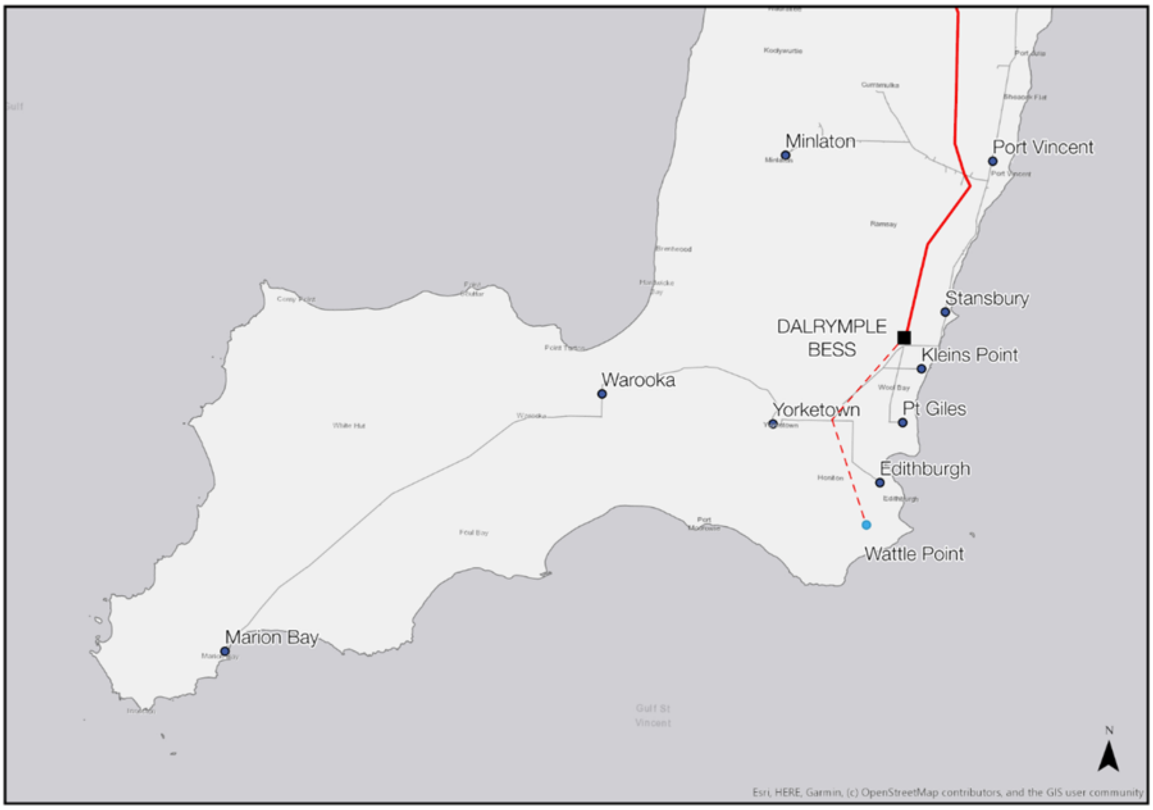

Figure 2-3: Region supported by the Dalrymple battery during an islanding event

During an islanding event, the Dalrymple battery supplies townships on the lower Yorke Peninsula region including Yorketown, Edithburgh and Stansbury. It also supplies communities, businesses and farms that are located south and southeast of Stansbury as shown in Figure 2-3.

The BESS has been designed and commissioned to provide the following services in the priority order listed below.

1. Islanded operation to enhance local reliability of supply
2. Fast Frequency Response (FFR)
3. Network support
4. Frequency Control Ancillary Services (FCAS), and
5. Energy arbitrage (previously referred to as Cap trading)

AGL operates the BESS and trades in the FCAS and energy markets. During a network event where the BESS is required to respond, the system has been configured to automatically switch to one of the higher priority services.

During commercial operation, AGL is required to operate the BESS between 10% and 90% of the installed battery capacity. This is to ensure that the BESS always has the capacity to respond to a network event.

2.3 Key Project Objectives

The key project outcomes, as defined in the Funding Agreement, include:

- Demonstrate the deployment and operation of a large-scale BESS to deliver a combination of network and market benefits
- Demonstrate a contracting and ownership model to maximise the value of a BESS
- Test the regulatory treatment for the ownership of large-scale BESS by regulated transmission network service providers
- Provide price discovery for the deployment of a large-scale grid-connected BESS, and
- Highlight and address technical and regulatory barriers in the deployment of large-scale batteries

Specific services and capability of the ESCRI-SA BESS, include:

- Supply of Fast Frequency Response (FFR) ancillary services into South Australia to reduce constraints on the Heywood interconnector, resulting in increased flows on the interconnector
- Reduction of expected unserved energy to Dalrymple following loss of supply, involving islanding of the BESS with the local load, the Wattle Point Wind Farm at reduced output, and local rooftop PV to supply local load until grid restoration
- Market trading of electricity within the South Australian National Electricity Market (NEM) region and provision of Frequency Control Ancillary Services (FCAS) services

Since commencement of the Project, the BESS has also been incorporated into the System Integration Protection Scheme (SIPS) to support the existing Heywood interconnector by injecting real power into the system following a system event that causes substantial loss of generation in South Australia.

3. Summary of ESCRI-SA Operation

3.1 Current Operational Status

The BESS has been in commercial operational since 14 December 2018 and continues to meet performance expectations within its design specification.

The BESS is designed to be operated as a power battery, providing various network support, FFR and FCAS services as well as energy trading.

Following up from the second Operational Report:

- ElectraNet's consultant has submitted the R2 model validation report. The validation report has identified some shortcomings in the model which are currently being investigated by CPP and ABB, and
- AGL submitted a WPWF non-compliance issue to AEMO in relation to WPWF wind turbine over-frequency protection settings. AEMO and ElectraNet approved the recommended solution provided by AGL to address the non-compliance, which resolved this issue.

3.2 Key Storage Metrics for Reporting Period

ElectraNet monitors the performance of the BESS, ensuring that operational data is captured and analysed to demonstrate its ability to operate as per its design specifications. Key performance metrics for the first 18 months of operation from 14 December 2018 to 14 June 2020 respectively, are shown in Table 3-1.

Table 3-1: Key Performance Metrics for First 18 Months of Operation

Key Performance Metric	Value for Reporting Period (14-12-2018 to 14-06-2019)	Value for reporting period (14-06-2019 to 14-12-2019)	Value for reporting period (14-12-2019 to 14-06-2020)
Average BESS Availability	98.01%	97.35%	98.93%
Total Energy Consumed	1,370 MWh	2,006 MWh	1499 MWh
Total Energy Exported	160 MWh	768 MWh	198 MWh
Average auxiliary load and losses (% of 30 MW rated capacity)	2.19%	2.25%	2.35%
Number of Charge and Discharge Cycles (per BOA definition)	2	4	1
BESS Charging Cost	$120,000	$101,000	$76,000
BESS Discharge Revenue	$116,000	$97,000	$102,000
FCAS Revenue	$1.33m	$3.73m	$15.6m

The average BESS availability for the period was 98.93%, which is greater than the 96% Guaranteed Annual Availability required under the Battery Operating Agreement. The slight increase in availability compared to the first 12 months is due to less planned outages in this reporting period.

The energy consumed by the BESS is significantly higher than the energy exported to the grid. The comparatively high energy use is because the BESS is designed as a power battery, rather than an energy battery, and therefore needs to be available all the time to be able to respond to system events at any point in time. This results in higher auxiliary load losses from transformers, inverters and the battery management system.

The number of charge and discharge cycles are contractually defined as the BESS state of charge (SOC) falling below 2.4 MWh. Limited cycles have been recorded during this reporting period which reflects how the BESS is being operated and how many significant unserved energy events have been avoided. Overall, for a power battery, the number of cycles is expected to be low.

The main source of revenue for this reporting period was FCAS, providing $15.6 million compared to $102,000 for energy discharge. This is consistent with the BESS operating as a power battery. The BESS market services are discussed in more detail in Section 5.

3.3 Overview of Key Events for Reporting Period

Since 14 December 2018 the BESS has been through 21 operational system events. The vast majority of these events were single-line trips with the remaining being either frequency events or led to the BESS supplying load to prevent or reduce the duration of an unserved energy event. High-speed data recordings from Power System Performance Monitor (PSPM) confirmed the BESS successfully rode through the fault or responded as required.

This section of the Report focuses on eight system events during the third six months of commercial operation.

3.3.1 Planned Outages

No planned outages relevant to the Dalrymple BESS occurred during the third reporting period.

3.3.2 Unplanned Outages

Over the past six months, from 14 December 2019 – 14 June 2020, the Dalrymple BESS responded to several unplanned outages due to various reasons. These unplanned outages are listed below:

- On 20 December 2019 at 13:52, the Ardrossan West – Dalrymple 132 kV line successfully reclosed following a single phase – ground fault resulting in the Dalrymple BESS supplying the local load for a short period of time
- On 31 January 2020 at 17:59, the Ardrossan West – Dalrymple 132 kV line successfully reclosed following a single phase – ground fault resulting in the Dalrymple BESS supplying the local load for a short period of time, and

- On 29 April 2020, inadvertent trips at Dalrymple due to tests at the Wattle Point Wind Farm resulted in the Dalrymple BESS supplying the local load for periods of time

3.3.2.1 Ardrossan West – Dalrymple 132 kV line trip (20 December 2019)

On 20 December 2019 at 13:52, the Ardrossan West - Dalrymple 132kV line tripped and successfully reclosed following a single phase to ground fault caused by lightning. The Dalrymple local supply remained connected and supplied by the Dalrymple BESS until re-synchronisation at 13:55. The Wattle Point Wind Farm was generating 15 MW when the fault occurred and remained connected. The BESS output for the unplanned outage event is illustrated in the graph below. Note negative numbers denotes generating power.

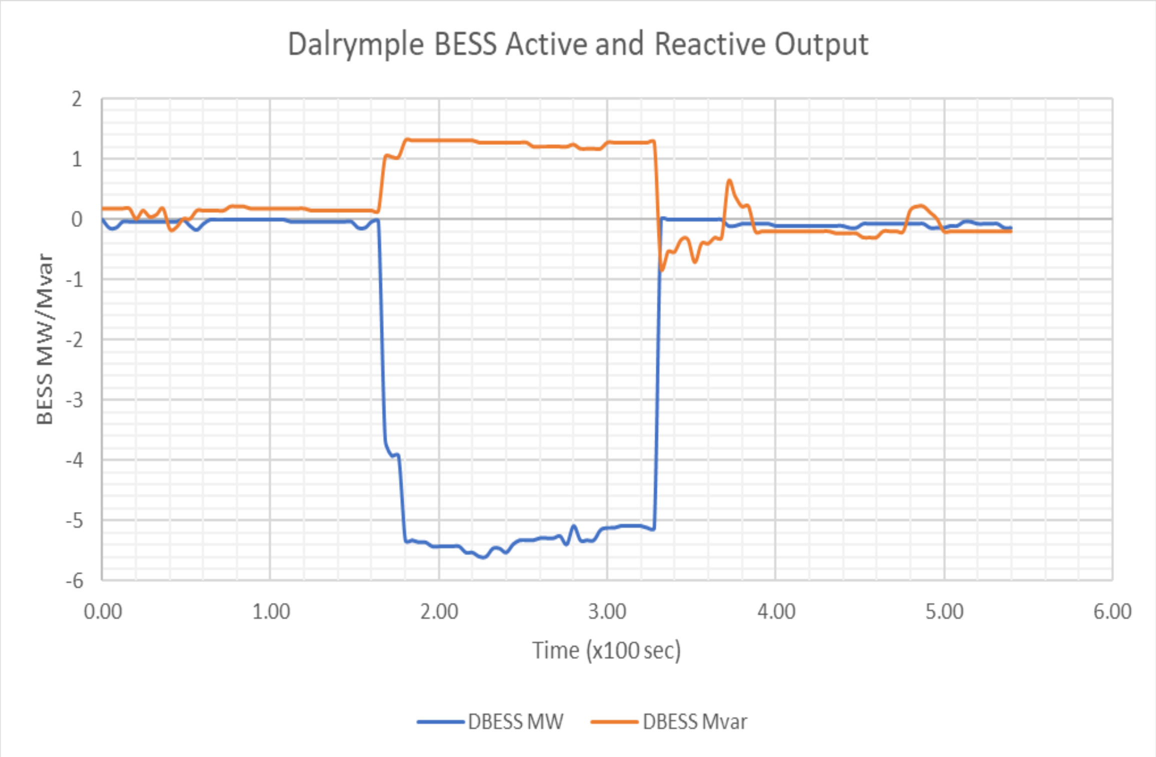

Figure 3-1: Dalrymple BESS active and reactive power output during the event

3.3.2.2 Ardrossan West – Dalrymple 132 kV line trip (31 January 2020)

On 31 January 2020 at 17:59, the Ardrossan West - Dalrymple 132kV line tripped and successfully reclosed due to lightning. The Dalrymple local supply and Wattle Point Wind Farm remained connected and supported by the Dalrymple BESS until it re-synchronised at 18:06. Wattle Point wind farm was generating 8 MW at the time of the event. The BESS output for the unplanned outage event is illustrated in the graph below. Note negative numbers denotes generating power.

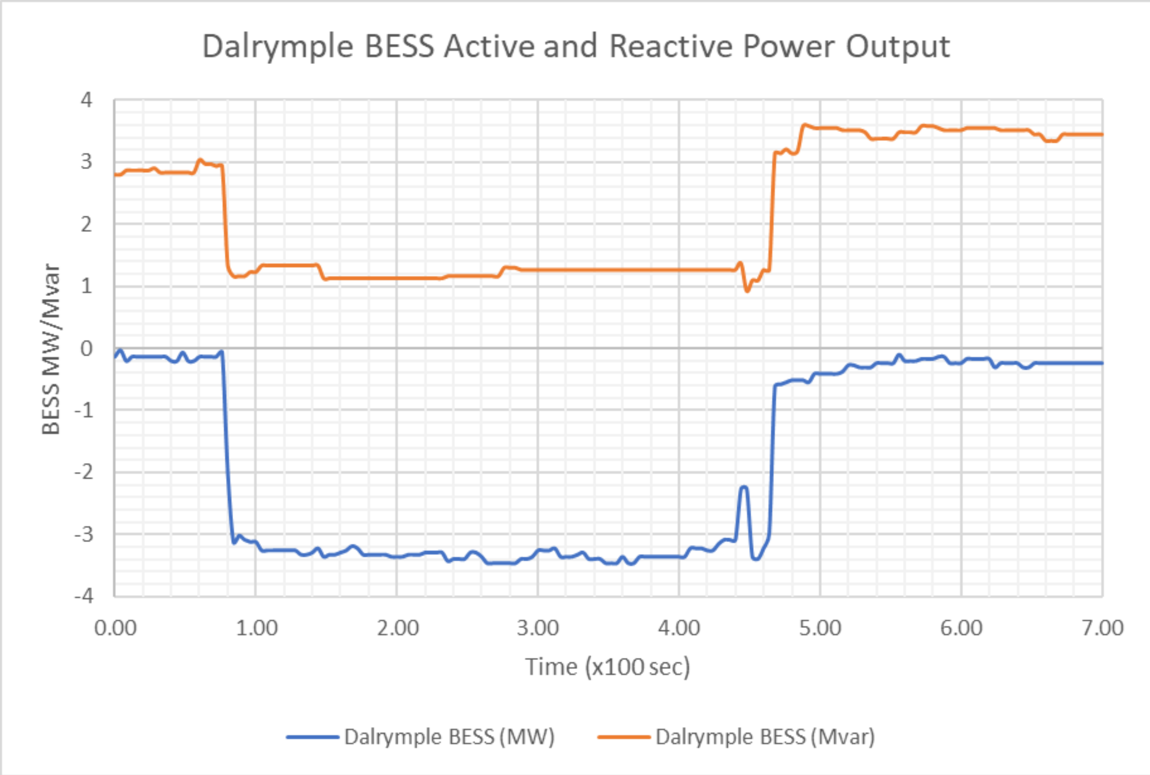

Figure 3-2: Dalrymple BESS active and reactive power output during the event

3.3.2.3 Inadvertent trips at Dalrymple due to tests at the Wattle Point Wind Farm

On Wednesday 29 April 2020 at 08:29, Dalrymple 132/33/11kV TF1 and TF2 inadvertently tripped due to tests at the Wattle Point Wind Farm. The Dalrymple load was successfully supplied from the BESS and operated in islanded mode for 14 minutes until attempting to re-synchronise at 08:43. The BESS tripped due to an unforeseen IDS logic issue (due to the intertrip from WPWF still being active at the time) and the 3.3 MW load was not supplied for about 2 minutes. Normal supply restoration commenced and Dalrymple TF1 was restored to load at 08:45 and TF2 was restored to load by 08:55. The BESS output for the unplanned outage event is illustrated in the graph below. Note negative numbers denotes generating power. The BESS was restored at 9:21.

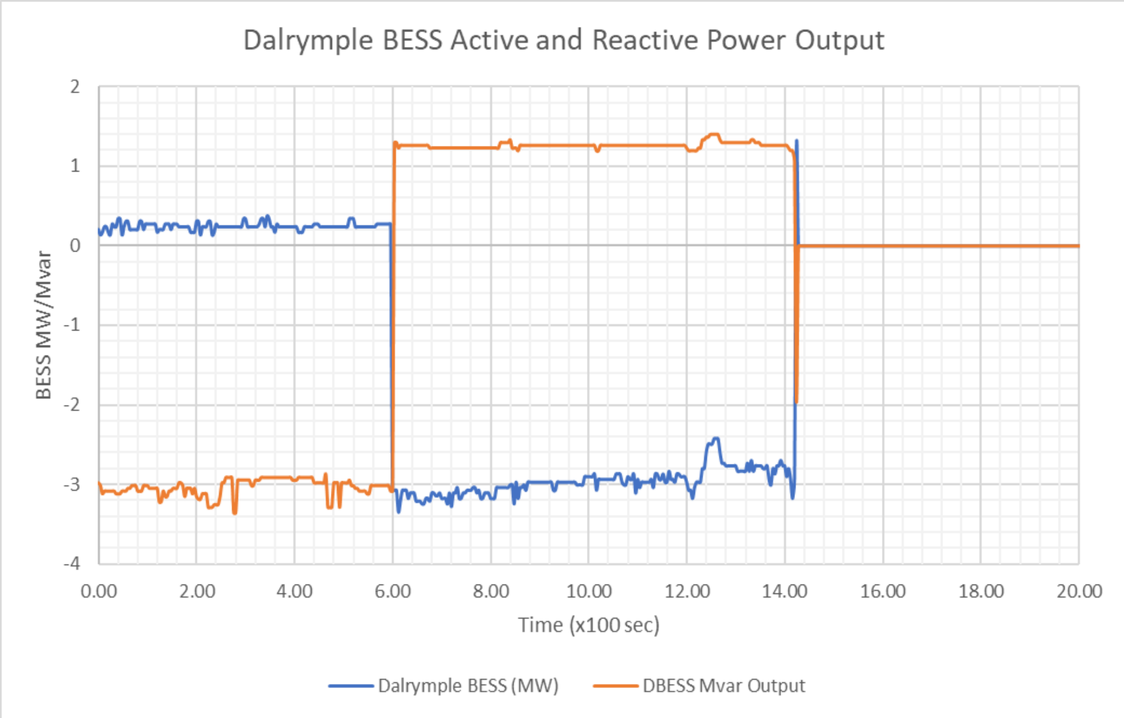

Figure 3-3: Dalrymple BESS active and reactive power output during the event

On 29 April 2020 at 10:57, Dalrymple 132/33/11kV TF1 and TF2 tripped due to loss of fibre optic communication between Dalrymple and the Wattle Point Wind Farm. No load was lost as the Dalrymple load was successfully supplied from the BESS for 2 hours and 22 minutes. The BESS output for the unplanned outage event is illustrated in the graph below.

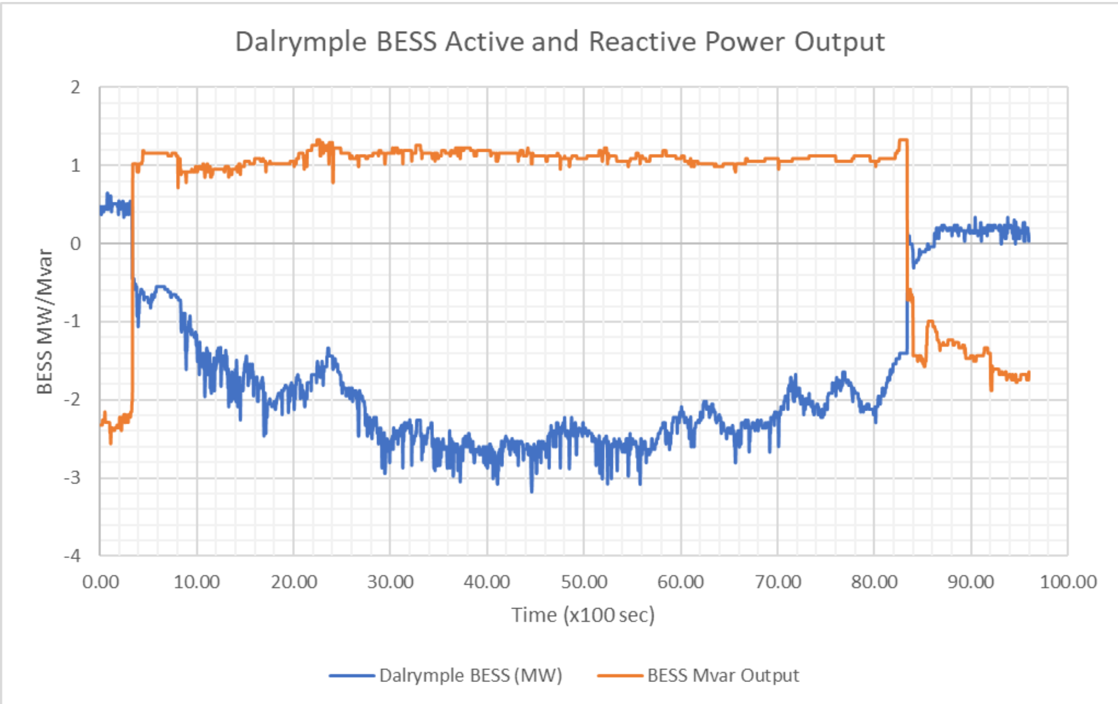

Figure 3-4: Dalrymple BESS active and reactive power output during the event

The data recorded for these unplanned outages indicate that the Dalrymple BESS successfully transited to islanding operating and supplied the local Dalrymple 33 kV load during the outages. Minimal load was lost as the result of these unplanned outage events.

3.3.3 Transmission Network Faults

Over the past six months, from 14 December 2019 – 14 June 2020, six transmission network fault events were relevant to the Dalrymple BESS, summarised below:

- On 20 December 2019 at 13:52, the Ardrossan West – Dalrymple 132 kV line successfully reclosed following a single phase – ground fault (refer Section 3.3.2)
- On 13 January 2020 at 2:19, a CT failure at the Waterloo substation resulted in tripping various element in the Mid-North region
- On 31 January 2020 at 13:54, the collapse of a number of steel transmission towers on the Moorabool – Mortlake and Moorabool – Haunted Gully 500 kV lines resulted in these lines tripping and remaining unavailable for service, effectively islanding South Australia from the NEM
- On 31 January 2020 at 17:59, the Ardrossan West – Dalrymple 132 kV line successfully reclosed following a single phase – ground fault (refer Section 3.3.2)
- On 7 February 2020 at 11:44, the Munno Para – Blyth West 275 kV line successfully reclosed following a single phase – ground fault
- On 7 February 2020 at 12:26, the Clare North - Brinkworth 132kV line tripped and locked out following a 3 phase – ground fault

High speed data recorded at the Dalrymple substation has been downloaded and plotted for the transmission network fault events. These are shown in Figure 3-5 to Figure 3-16. Unfortunately some of the event data from the high speed recording device could not be downloaded or was not useable.

The downloaded data demonstrates that the BESS successfully rode through the network fault events and its voltage, active power and reactive power response are in line with its design and technical performance expectations. The BESS responds almost instantly to the system voltage dip during the fault and injects a significant amount of active and reactive power into the network to support network voltage recovery.

3.3.3.1 Hummocks – Waterloo 132 kV line, CT failure at Waterloo

On the 13th January 2020 at 2:19:32, catastrophic failure of S phase CT 7022 at Waterloo resulted in operation of the Waterloo South Bus Zone protection and CB7022 CB Fail protection. This resulted in tripping of Waterloo TF5, Waterloo South Bus, Waterloo-Hummocks line and Hummocks TF1 (CB failed). Dalrymple BESS response due to this fault are shown below.

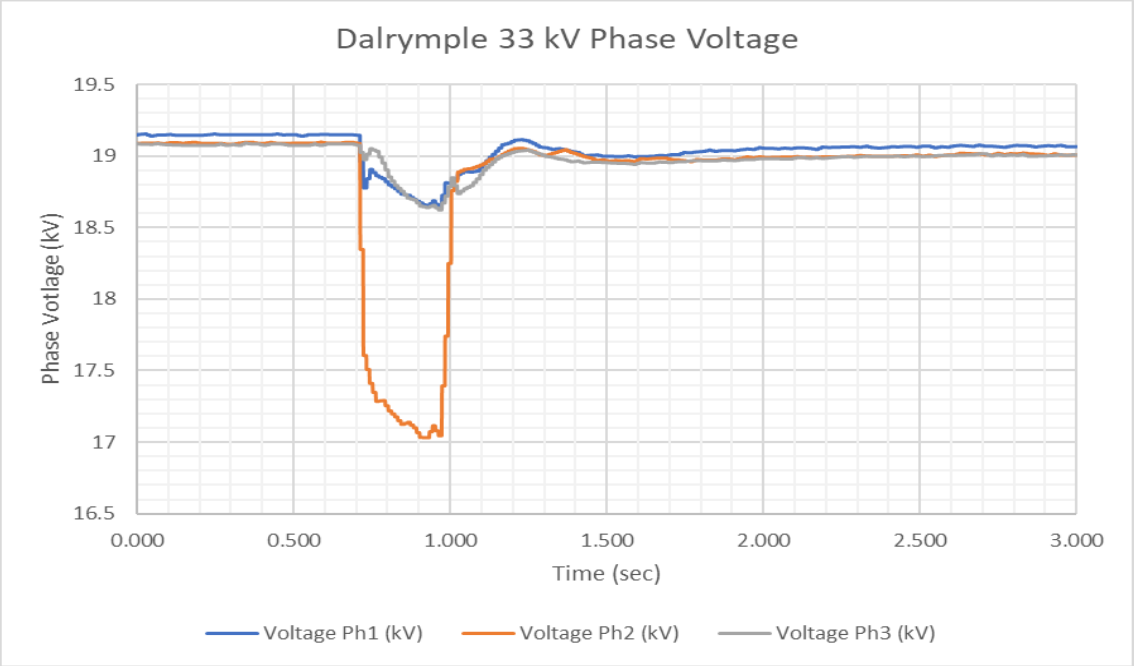

Figure 3-5: BESS voltage measured at the Dalrymple 33 kV substation

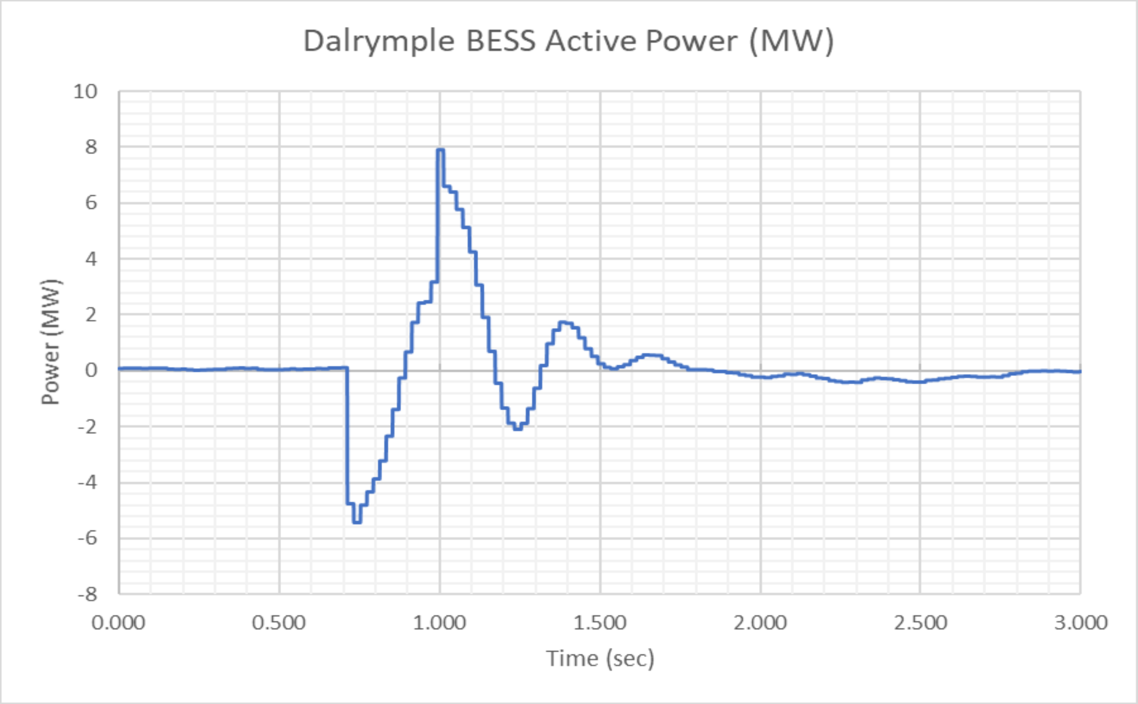

Figure 3-6: BESS active power output measured at the Dalrymple 33 kV substation

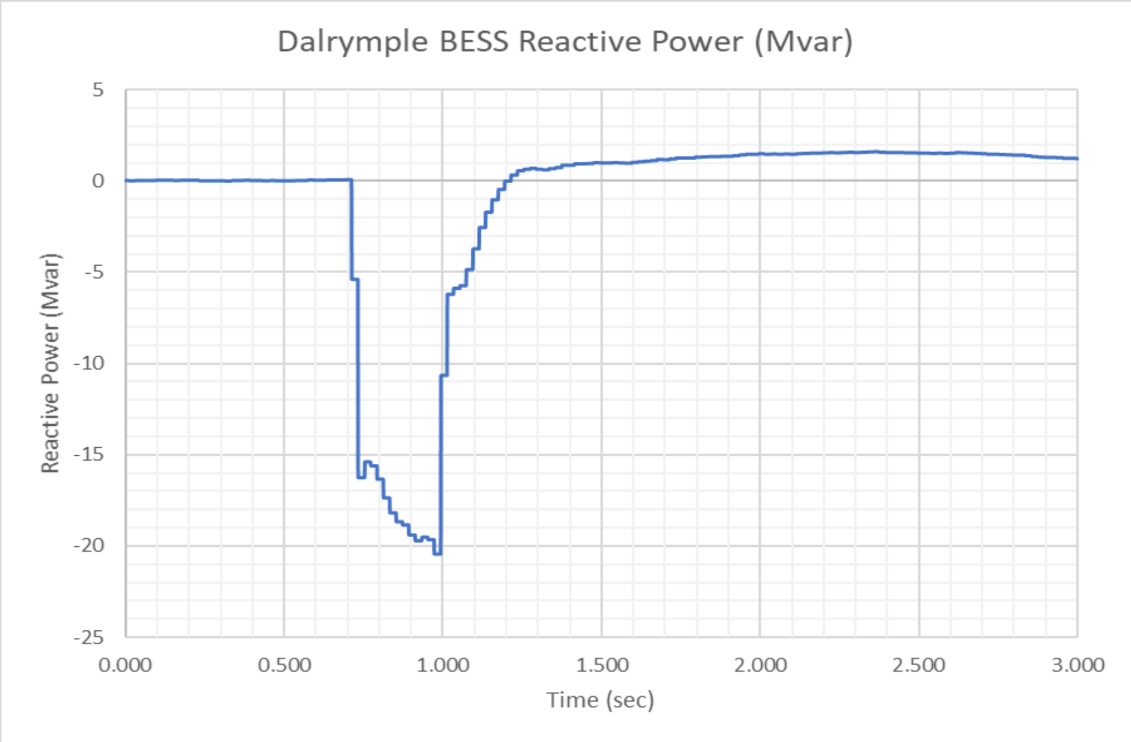

Figure 3-7: BESS reactive power output measured at the Dalrymple 33 kV substation

3.3.3.2 Moorabool – Mortlake and Moorabool – Haunted Gully 500 kV lines tripping and remaining unavailable for service, effectively islanding South Australia from the NEM

South Australia and parts of Victoria, including Mortlake Power Station and APD (Alcoa Portland), were islanded from the NEM at approximately 13:54 (SA time) on 31 January 2020 following the trip of the double 500 kV circuit transmission line between Moorabool – Haunted Gully and Moorabool – Mortlake in Victoria.

Prior to the time when the double circuit tripped, SA was exporting approximately 515 MW. SA system demand was approximately 2648 MW. There were 7 conventional generators online at the time in SA, with a total output of 1559 MW.

Power flow on the Heywood interconnector and frequency measured at South East substation are illustrated in the graphs below.

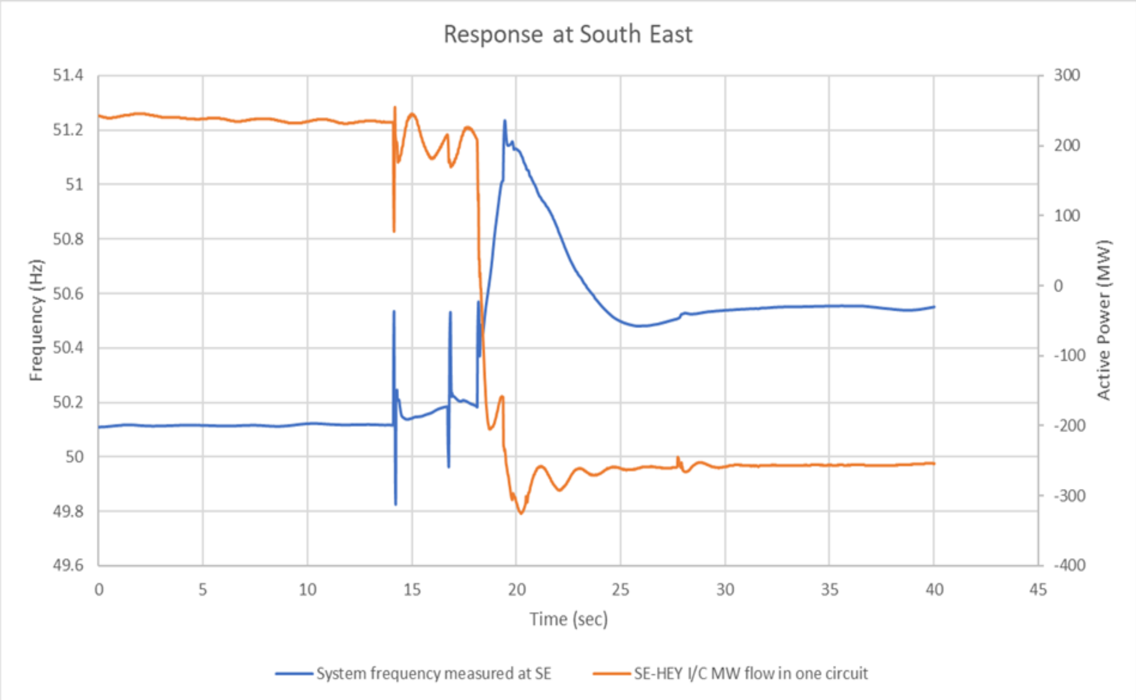

Figure 3-8: Power flow on the Heywood IC and Frequency measured at South East substation.

Dalrymple BESS response due to this over-frequency event is illustrated in the graphs below.

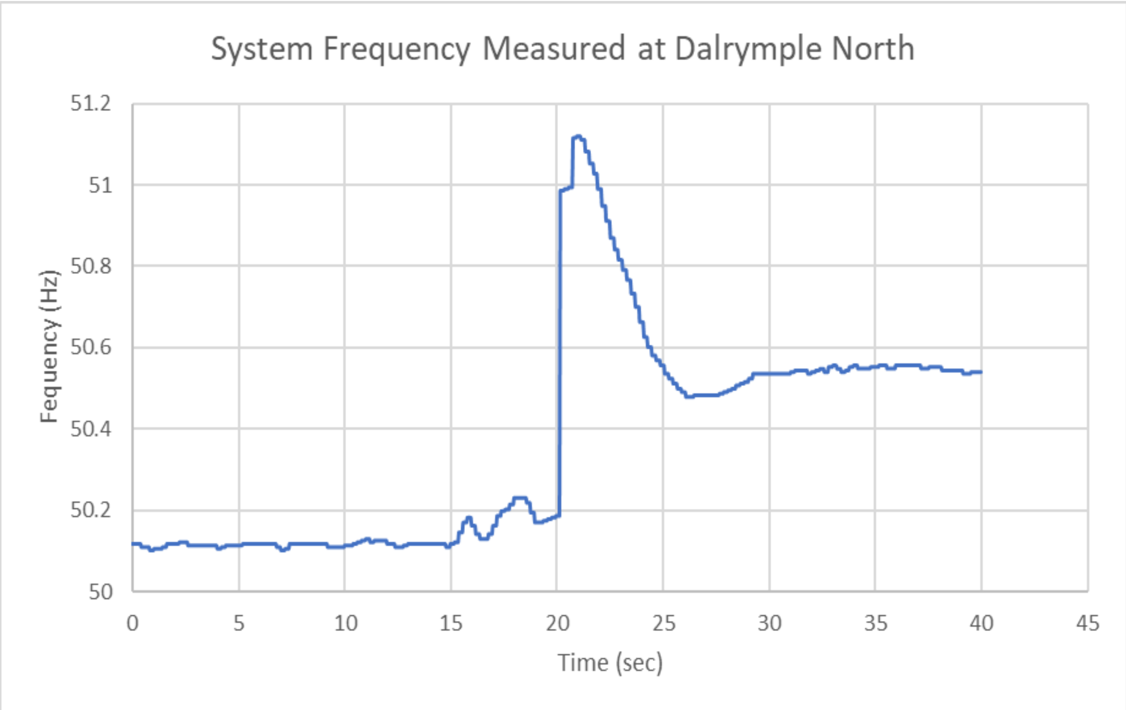

Figure 3-9: Frequency measured at the Dalrymple 33 kV substation

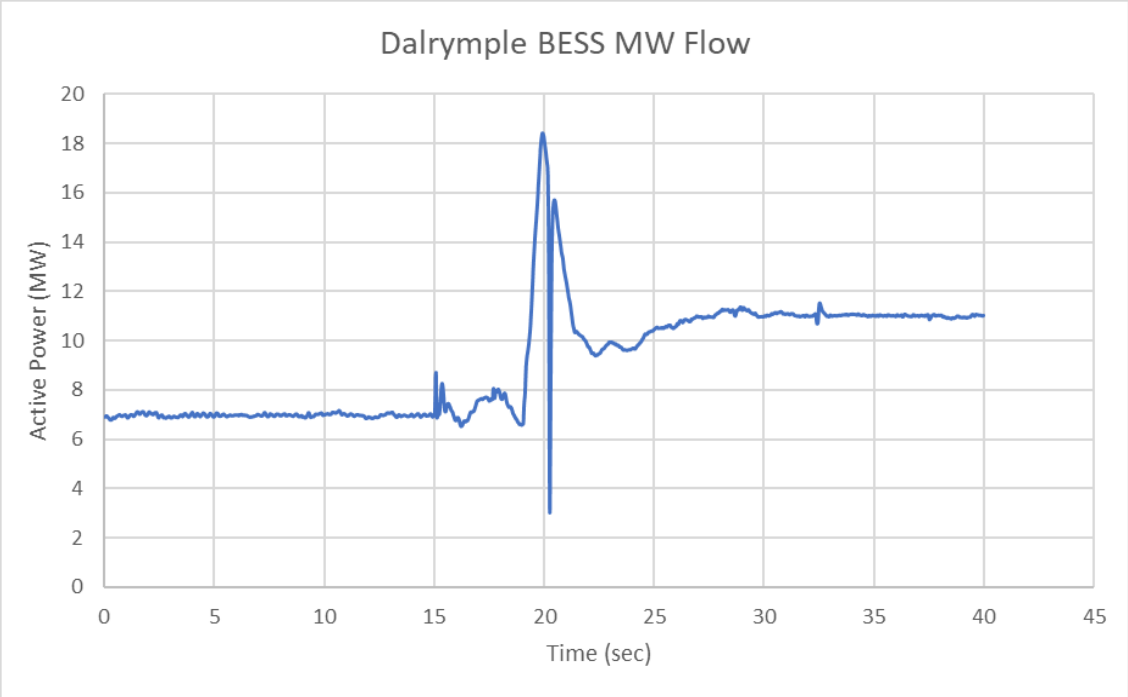

Figure 3-10: BESS active power response measured at the Dalrymple 33 kV substation

3.3.3.3 Munno Para – Blyth West 275 kV line, single phase to ground fault

On 7 February 2020 at 11:44, a single phase to ground fault occurred on the Munno Para – Blyth West 275 kV line due to a lightning strike. The fault was cleared, and the line successfully reclosed. High speed data recorded at the Dalrymple 33kV bus indicated the Dalrymple BESS successfully rode through the fault as shown below.

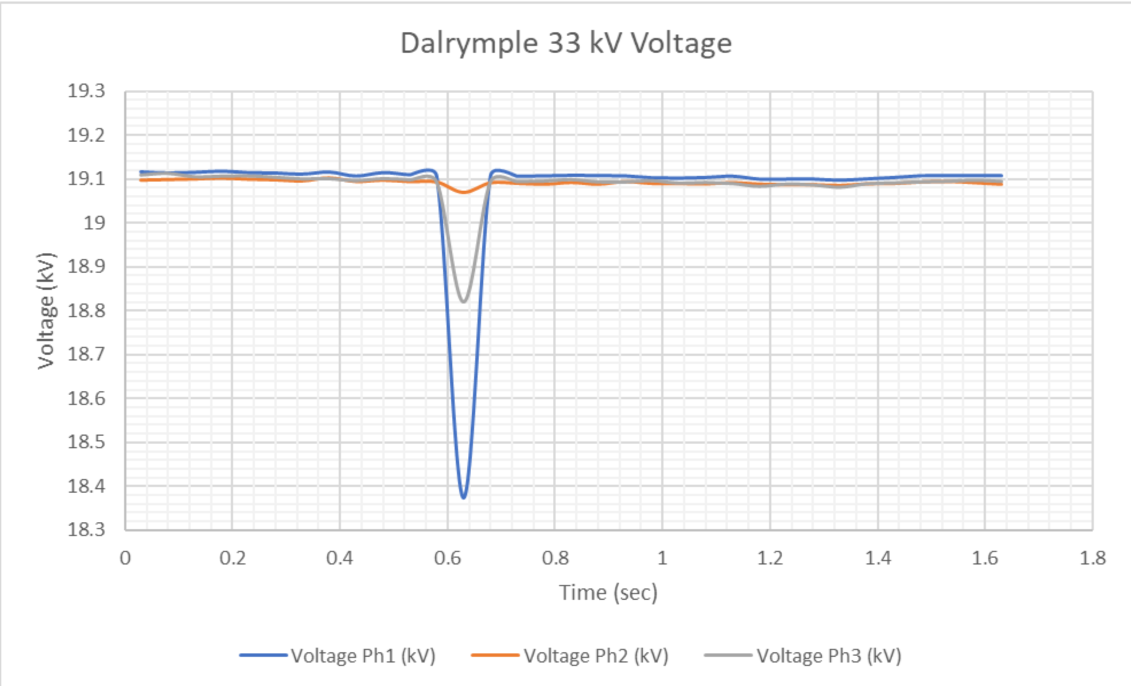

Figure 3-11: BESS voltage measured at the Dalrymple 33 kV substation

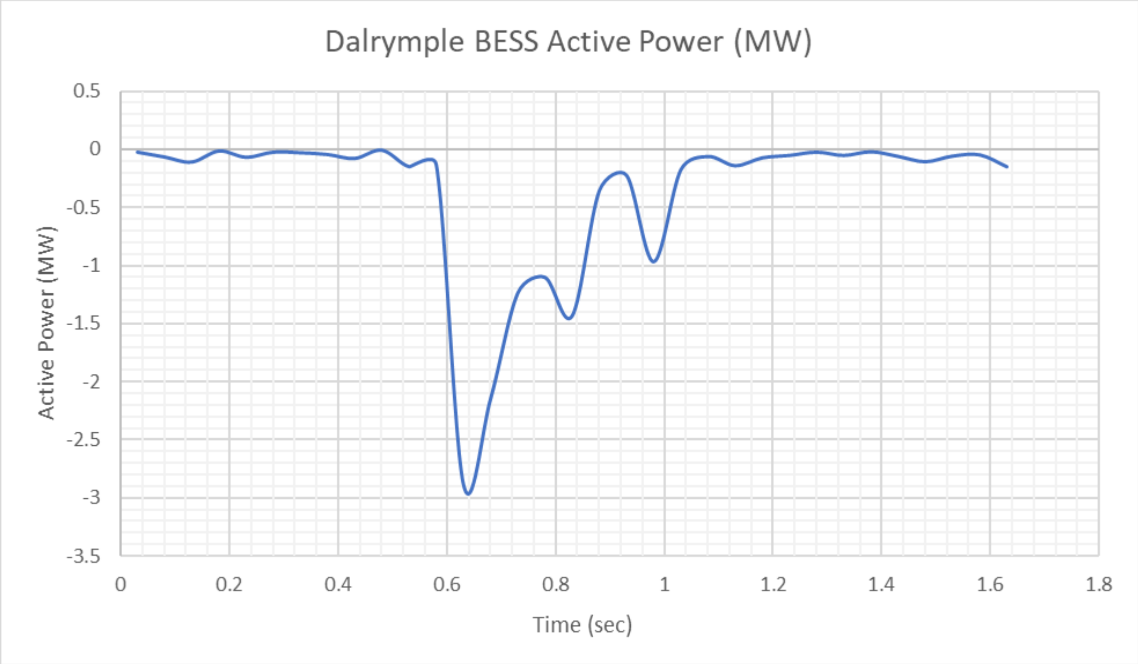

Figure 3-12: BESS active power output measured at the Dalrymple 33 kV substation

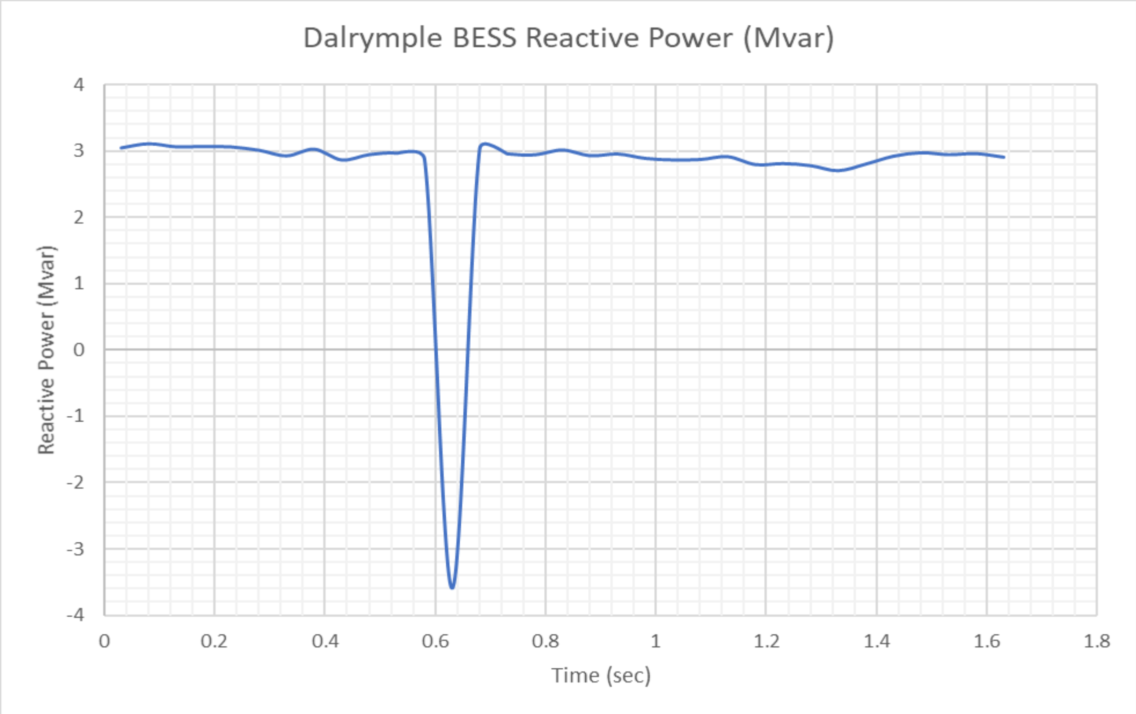

Figure 3-13: BESS reactive power output measured at the Dalrymple 33 kV substation

3.3.3.4 Clare North – Brinkworth 132 kV line, three phase to ground fault

On 7 February 2020 at 12:26, the Clare North - Brinkworth 132kV line tripped and locked out following a three phase to ground fault. The Dalrymple BESS successfully rode through the fault as shown in the graphs below.

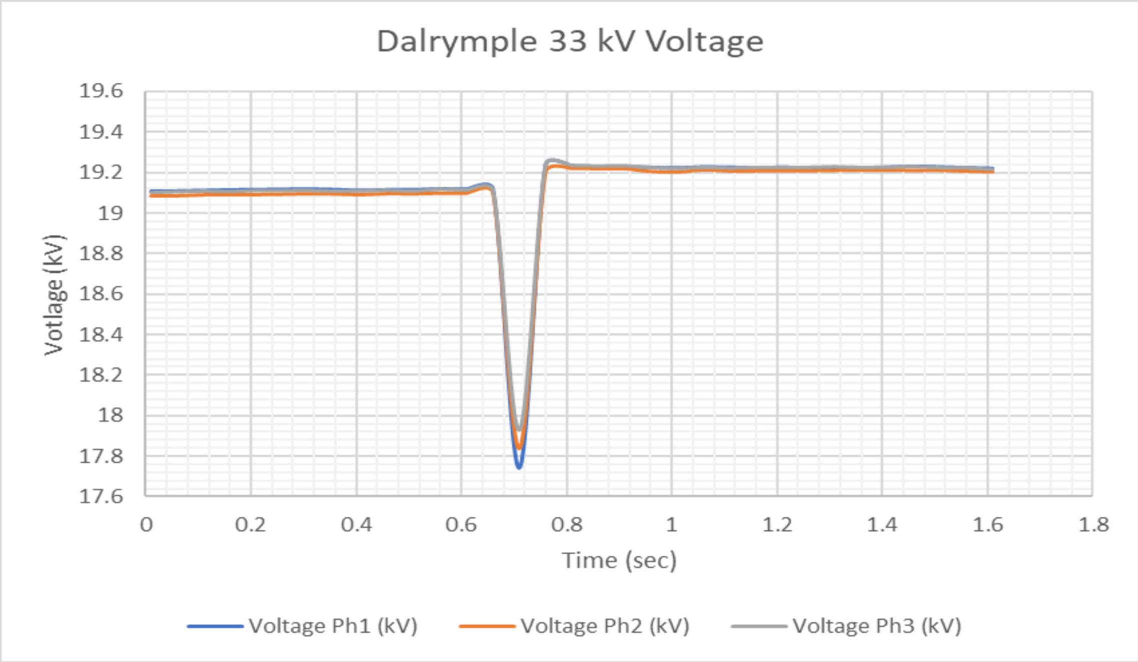

Figure 3-14: 33 kV Voltage measured at the Dalrymple 33 kV substation

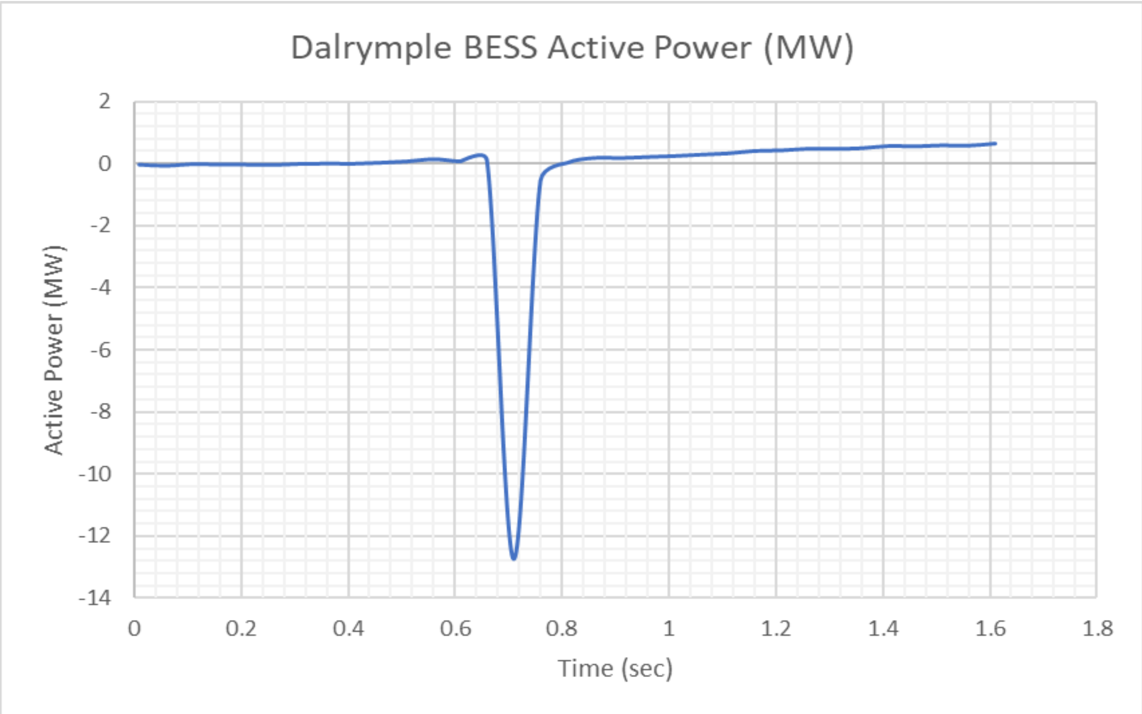

Figure 3-15: BESS active power measured at the Dalrymple 33 kV substation

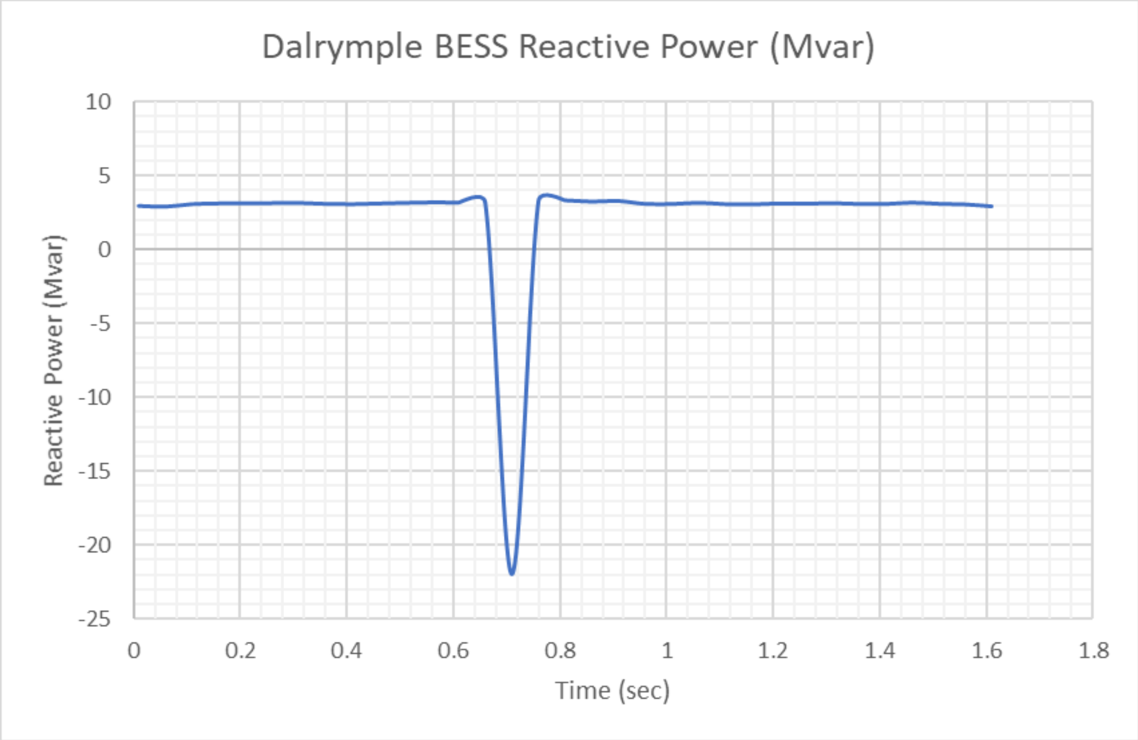

Figure 3-16: BESS reactive power measured at the Dalrymple 33 kV substation

3.4 Portal Operation and Usage

The ESCRI-SA web portal is one of the primary knowledge sharing tools for the Project and provides the public with access to key information, including a real-time dashboard that shows the performance of the battery, Wattle Point Wind Farm, Dalrymple substation, the incoming transmission line and the Lower Yorke Peninsula network.

Figure 3-17: ESCRI-SA Portal Dashboard

This data is available for download directly from the portal. The portal also contains copies of ElectraNet's industry presentations and public reports on the Project. Access to the web portal is available at http://escri-sa.com.au/.

Between 14 December 2018 and 14 June 2020, Google Analytics shows that the site has been visited 2723 times from interested parties from 32 countries, with the number of views peaking in January 2019, May 2019, October 2019 and May 2020. The majority of portal views were through direct access to the website, rather than LinkedIn, Empired, Google or other sources or channels. Further details are shown in Figure 3-18 to Figure 3-20 and Table 3-2.

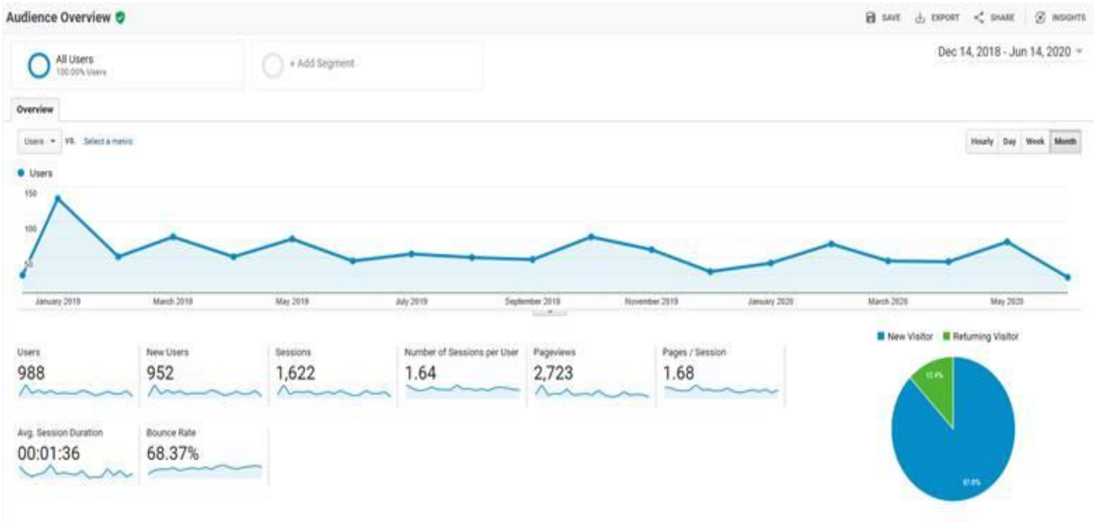

Figure 3-18: ESCRI-SA portal page views (18 months)

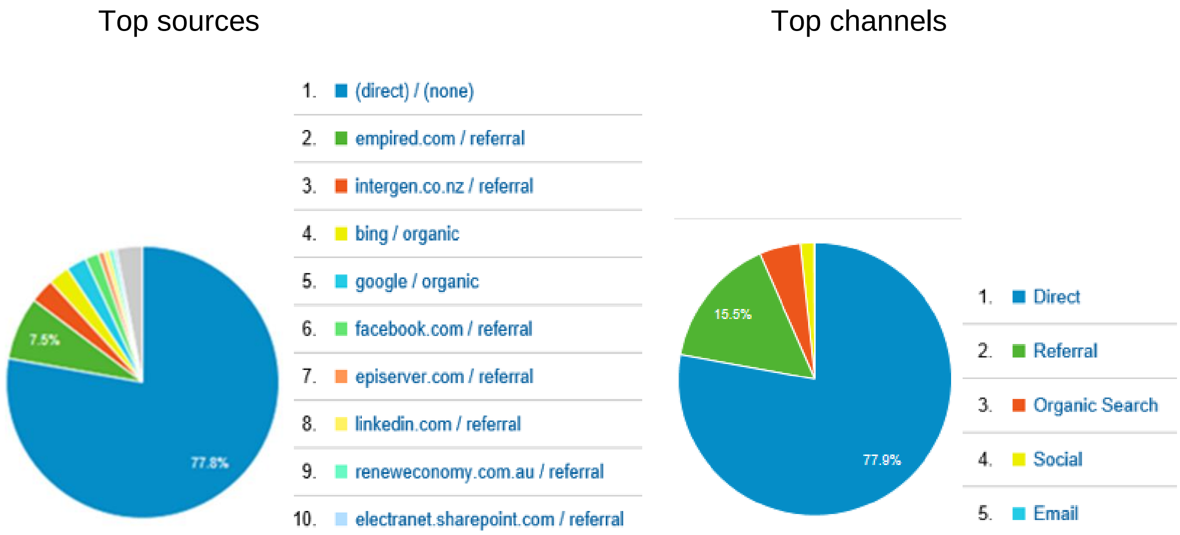

Figure 3-19: Top sources and channels used to locate ESCRI-SA portal (18 months)

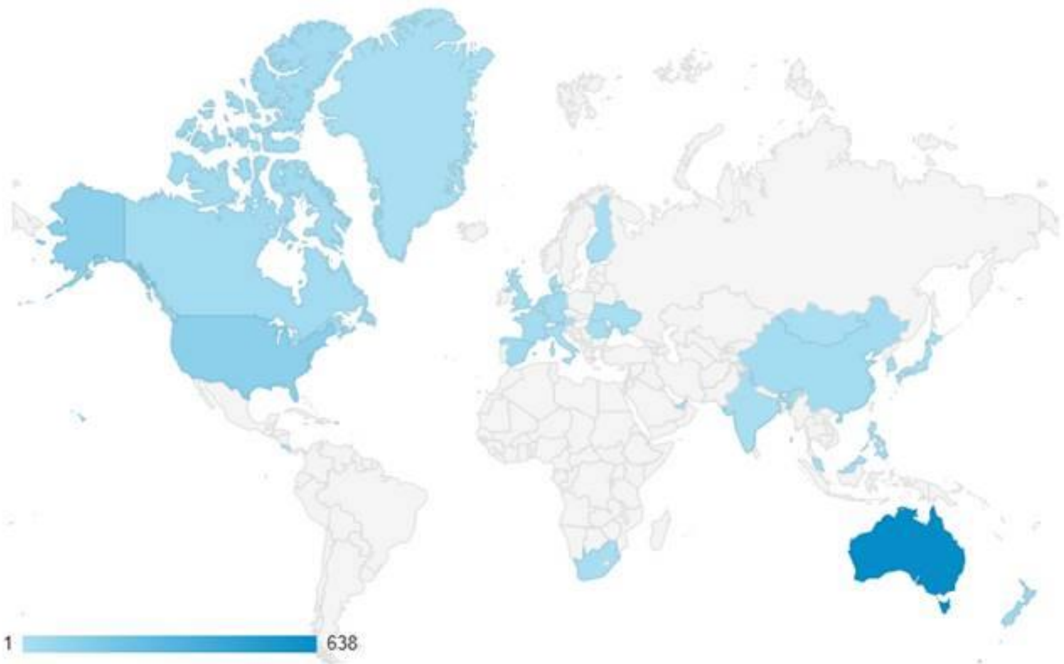

Figure 3-20: Geolocation of ESCRI-SA portal users (18 months)

	14/12/2018 to 14/06/2019	14/06/2019 to 14/12/2019	14/06/2019 to 14/12/2019	Total 14/12/2018 to 14/06/2020
Page views	1241	799	683	2723
Unique page views	984	666	592	2242
Average time on page	1:54	2:14	3:04	2:13
Number of report/presentation downloads	76	47	46	169
Number of data downloads	230	103	57	390

Table 3-2: Six-monthly metrics of Portal operation

4. Demonstration of Key BESS Regulated Services

4.1 Reducing Expected Unserved Energy/Islanding

From 2006 to 2014 there was an average yearly loss of supply of 3.52 hours and 9.46 MWh for the Dalrymple connection point.

The benefits of being able to continue to supply the local load from the BESS island network during an outage are significant and go beyond reducing the duration of a loss of supply. For example, planned outages can be scheduled during normal hours rather than overnight and live line techniques need not be used, resulting in higher levels of safety for work crews.

From 14 December 2019 to 14 June 2020, there have been no planned outages requiring the Dalrymple BESS to supply the local load as an islanded network. However, there were three unplanned outages as discussed in Section 3.3.2. The Dalrymple BESS has prevented or reduced the duration of the unserved energy events. In combination, these events reduced the loss of supply from abound 2 hours 48 minutes to approximately 2 minutes.

4.2 Fast Frequency Response (FFR) to reduce constraints on the Heywood Interconnector

Currently a 3 Hz/s RoCoF constraint is applied to the Heywood Interconnector. The constraint defines the maximum import/export limit allowed based on the amount of synchronous system inertia online in South Australia at any point in time.

To achieve 650 MW transfer across the Heywood Interconnector based on the 3 Hz/s RoCoF, approximately 5,400 MWs of inertia is required to be available in South Australia.

4.2.1 BESS Reduction of Synchronous System Inertia Required

Detailed power system analysis and test results have demonstrated that the FFR from the ESCRI-SA BESS results in an increase in the Heywood Interconnector transfer capability which is equal to a total 200 MWs of equivalent inertia contribution from the BESS.

This 200 MWs ‘offset’ has been implemented in the RoCoF constraint equation. As a result, when the BESS is in service the total inertia requirement in SA for a 3 Hz/s RoCoF is reduced from 5,417 MWs to 5,217 MWs.

Since the BESS has been in commercial operation there has been two system frequency events due the loss of the South East – Heywood Interconnector on 16 November 2019 and also on 31 January 2020, to confirm the actual operation of the FFR function of the BESS.

During the third six months of operation the RoCoF constraint has bound for 4 hours and 10 minutes for SA import direction and it has not bound for SA export direction with ESCRI BESS in service. Without the BESS in service, it is estimated that the RoCoF constraint would have bound for 18 hours and 35 minutes in the SA import direction and not binding for the SA export direction.

For the system separation event on 31 January 2020, the system frequency increased to approximately 51.11 Hz following the loss in the South East – Heywood Interconnector, while SA was exporting about 515 MW. The plots presented below indicate that the Dalrymple BESS responded to this frequency rise event by increasing its charge level from 7 MW to 18 MW following the contingency event.

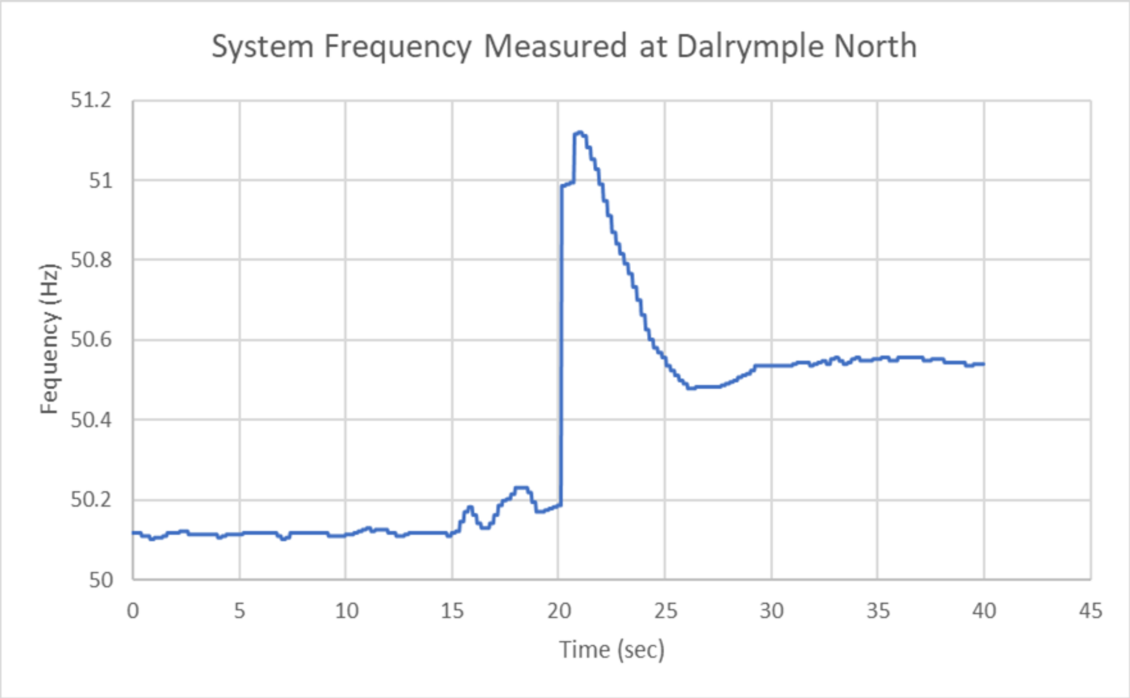

Figure 4-1: System frequency rise measured at the Dalrymple 33 kV substation

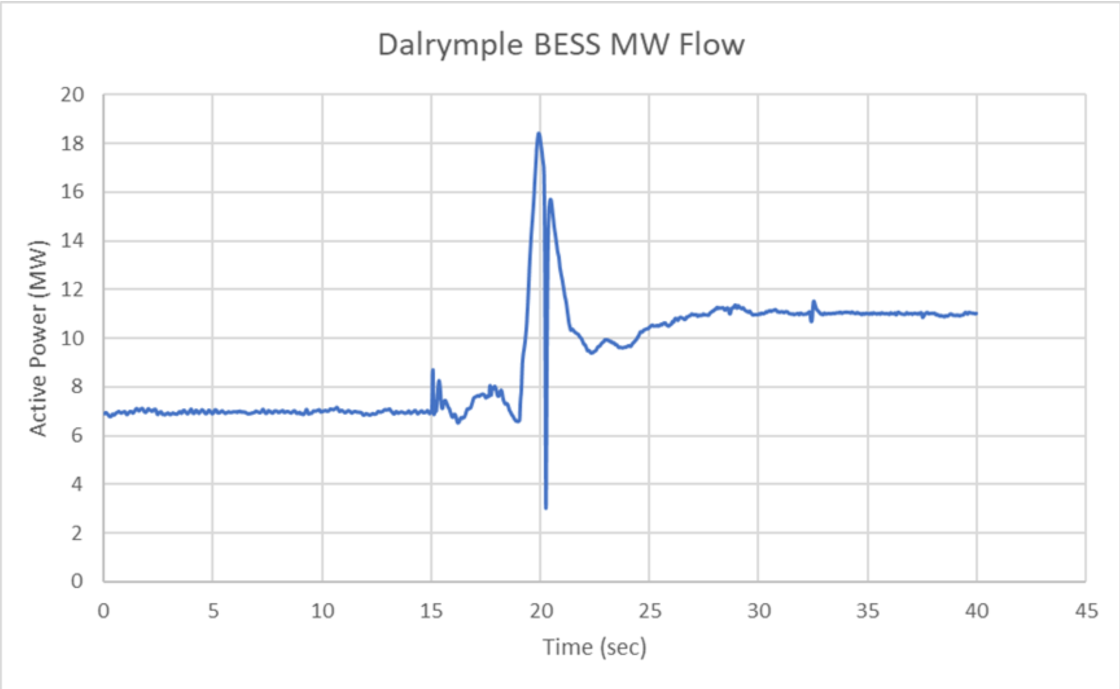

Figure 4-2: BESS active power (charging) response due to system frequency rise event

The above event data confirms the Dalrymple BESS' response to a system frequency event, as required by its NER technical requirements. It also demonstrated the functional design and implementation of the control system.

4.3 System Integrity Protection Scheme

Following the SA power system black event in September 2016, maintaining the connection of the Heywood Interconnector during a system event that results in significant generation loss in South Australia has been identified as a high priority.

The System Integration Protection Scheme (SIPS) was introduced to address this risk and is designed to rapidly identify conditions that could otherwise result in a loss of synchronism between South Australia and Victoria. The SIPS is designed to correct these conditions by rapidly injecting power from batteries or shedding sufficient load to assist in re-balancing supply and demand in South Australia and prevent a loss of the Heywood Interconnector.

The BESS has been incorporated into the SIPS and is able to provide rapid response on receipt of a SIPS command. The SIPS function of the BESS has been tested and operated correctly.

Since the BESS has been in operation, there has been no system incident resulting in a significant amount of generation loss in SA to trigger the BESS response to the SIPS command.

5. Demonstration of Key BESS Market Services

5.1 General Financial Performance

The BESS has continued to perform well over the past 6 months, generally autonomously. There has seldom been a need for AGL or ElectraNet to take operational action in response to a fault, meaning the battery has been highly available and well placed to perform its market services. To date, this has primarily been the provision of contingency FCAS.

For the six-month reporting period up until 14 June 2020:

1. The charging cost for the BESS was approximately $76,000
2. Discharge revenue earned by the BESS was approximately $102,000
3. The BESS required an average daily charge of approximately 8.2 MWh
4. Average charge cost was approximately $415 per day
5. FCAS revenue was approximately $15.6 million (about a fourfold increase from the previous 6 months – see Section 5.2.2 for more details). Average daily FCAS revenue was approximately $84,550
6. FCAS recovery paid was approximately $45,100. Average daily FCAS recovery paid was approximately $245

5.2 BESS Value Streams

The two market revenue streams for the BESS utilised in the last six months of operations were energy arbitrage and provision of FCAS services to the market. In this period, the majority of revenue earned from the BESS was through the provision of FCAS services, as it was for the first two six-month periods of operation.

The total revenue earned from energy arbitrage and FCAS services combined was again much greater than expected when compared to this period in the business case, entirely driven by significantly higher FCAS revenue than expected.

Charging costs for the battery were around $76,000 overall for the six-month period – this is required both for energy arbitrage opportunities (being able to charge during low priced periods and discharge during high priced periods), and for providing FCAS services (see further 5.2.2 below).

5.2.1 Energy Arbitrage

Energy arbitrage has continued to provide less value than estimated in the business case. Revenue from energy arbitrage has continued to remain low in favour of maintaining optimal availability for contingency FCAS services.

There was one significant day of value from Energy. On 19 December 2019 South Australia experienced extremely hot weather with temperatures in Adelaide exceeding 45°C, and the battery discharged in the early evening to prices that reached $14,700, resulting in significant revenue earnings from Energy on that particular day.

5.2.2 FCAS Services

The majority of the BESS's current financial value continues to be derived from trading in the FCAS markets. During this 6-month operational period, FCAS trading revenue was approximately $15.6 million. This was composed of ~$9.8 million of contingency raise services and ~$5.8 million of contingency lower services. In order to provide these contingency services, the BESS needs to be kept in a state where it can either charge (for lower services) or discharge (for raise services) in order to help return the frequency to the normal operating band following a credible contingency event.

There was an incident on 31 January 2020 that involved the non-credible loss of both the Moorabool – Mortlake and the Moorabool – Haunted Gully – Tarrone 500 kV transmission lines (a number of transmission towers collapsed during a period of thunderstorm activity with high winds) that resulted in the separation of the Victorian and South Australian regions.

The Moorabool – Haunted Gully line was restored using temporary towers on 17 February 2020 and the Moorabool – Mortlake line was restored on 3 March 2020. During this period (especially before the first line was restored), both raise and lower FCAS prices in SA were frequently high leading to unexpectedly high revenue to the BESS.

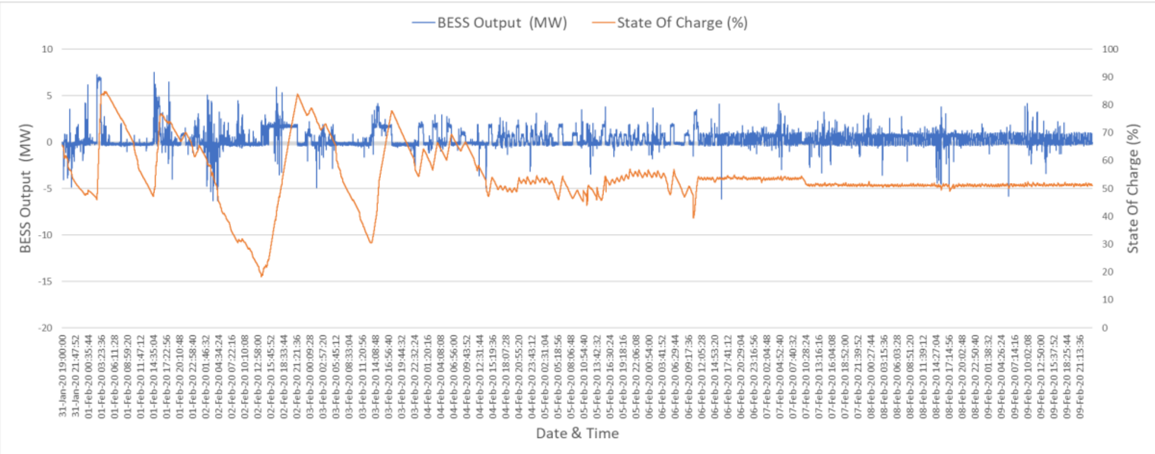

Figure 5-1: BESS active power response and State of Charge during SA islanding event

The separation event required local FCAS services in South Australia to maintain the system in a secure state, resulting in significant FCAS volatility. AEMO issued an unprecedented number of system security directions to maintain the security of the South Australian Island, which also incorporated Mortlake Power Station and the Portland smelter, a configuration never previously experienced.

Between 2 Feb 2020 14:20hr and 2 Feb 2020 16:15hr the BESS was directed to take the following action to restore and maintain a secure operating state.

> *On the Dalrymple North battery maintain between 45% and 55% of maximum charge. On the following units, to bid DALNTH01: Contingency FCAS R5, R60 and R6 to full availability, Regulation FCAS is to be bid to zero DALNTHL1: Contingency FCAS L5, L60 and L6 to full availability, Regulation FCAS is to be bid to zero AEMO will apply an energy constraint of +/- 2 MW on the Dalrymple North battery*.

This direction did not result in a change in the operating regime of the BESS, as the direction was consistent with the AGL operating strategy at that time. As AGL's operation of the BESS was consistent with AEMO's objective of maintaining the system in a secure operating state, there were no further system security directions placed on the BESS.

A number of manual interventions (rebids) were required to maintain optimum availability across the six contingency FCAS services during the period where the BESS was directed. The team responsible for the development of the automated bidding system was charged with modifying the software to manage the state of charge (SOC). This software update was installed on 4 Feb with further enhancements on 6 Feb. This enabled the trading team to set the desired SOC to optimise FCAS availability, especially the delayed service which is the first to be affected by a SOC change.

There was also an equipment failure at the Heywood substation on 2 March 2020 that resulted in SA electrically separating from the rest of the NEM leading to further high FCAS prices and high revenue to the BESS.

The average summed price across the contingency FCAS services over this 6-month period was ~$190, far higher than the prices that were observed in the first year of the BESS operation. It is to be noted that this was largely due to the very particular and unlikely circumstances noted above.

5.2.3 Future Revenue Streams and Rebidding

While future revenue streams could include selling cap derivative products, AGL has not offered these products from the BESS to date.

AGL has developed an automated rebidding system which ensures timely and accurate information is sent to AEMO regarding the physical capabilities of the BESS.

The rebidding system was the Minimum Viable Product (MVP) required for National Electricity Rules (NER) compliance whilst trading in the NEM. The MVP software does not optimise energy arbitrage value (energy versus FCAS). It is anticipated that a comprehensive optimisation module will be required prior to the commencement of five-minute settlement in July 2021.

6. General Operational Issues

6.1 ElectraNet, ARENA and AGL Agreements

The Funding Agreement between ARENA and ElectraNet includes a provision for ARENA to recoup part of any potential upside return from the commercial operation of the BESS. Since AGL operates the BESS, a tri-partite agreement was also entered into to include AGL into this arrangement.

It was identified that the wording of the agreement should be clarified. At the same time the agreements were also updated to reflect the commercial operation date of 14 December 2018 and align the delivery dates of future milestones with the above commercial operation date.

6.2 ElectraNet - AGL Battery Operating Agreement

The Battery Operating Agreement (BOA) is structured as an energy storage services agreement which requires the parties to enter an Operating Protocol for the asset. The Operating Protocol sits behind the BOA and may be updated or amended if required to ensure the facility operates in accordance with the terms of the BOA, without amendment of the BOA. The BOA and Operating Protocol provide the ongoing contractual basis for AGL's operation of the BESS as well as the regime of payments and an availability guarantee.

Under the BOA an annual User Fee payment is due. ElectraNet and AGL have come to agreement on the method of calculation of the Availability Guarantee and ElectraNet provides monthly updates to AGL which give an indication of how the battery is tracking against the Availability Guarantee.

6.3 Primary Frequency Response

The Australian Energy Market Commission (AEMC) has made a final ruling to require all generators in the National Electricity Market (NEM) to support the secure operation of the power system by responding automatically to changes in power system frequency through provision of Primary Frequency Response (PFR).

ElectraNet, in conjunction with Consolidated Power Projects (CPP) and ABB Power Grids Australia, have considered the implications of the rule change on the Dalrymple North BESS (ESCRI) facility.

The BESS is a modern flexible facility utilising grid forming inverters. Hence, it can provide some of the functions required as part of the PFR rule change.

However, implementing PFR requires changes to the internal logic and control loops of the BESS. Since the controls of the Dalrymple BESS are finely tuned to provide a wide range of services already, it would require significant amount of work and testing to implement this additional functionality.

6.4 EPC Contract and Defect Resolution

The EPC contract reached practical completion and commercial handover on 14 December 2018.

At commercial handover of the BESS on 14 December 2018 there were 11 listed defects with the system. Of these, three remain outstanding as of June 2020. Significant items on this list are covered below.

6.4.1 Additional Cooling Requirements

Excess heat generated during maximum charge and discharge, combined with high ambient temperature, has been an ongoing issue that is still being worked on to be resolved.

Two 150 kW air conditioning units were installed in March 2020, as a replacement for two faulty units, currently totalling to four air conditioning units per inverter room. These modifications have considerably reduced the number of high temperature alarms.

Additionally, a faulty air conditioning condenser fan and faulty condenser coil were replaced in April 2020.

Further work is being undertaken to optimise the cooling effect of the installed air conditioners, to direct the majority of the airflow directly towards the inverters, with the intention of improving the cooling effect during discharge / charge cycle. This will be by installing ducting to distribute cold air directly onto the inverters of each power store. Trial ducting is to be installed on one inverter, which if successful, will be implemented on all power stores. It is expected that these actions will be sufficient to fully resolve the over-temperature issues.

6.4.2 BESS Capability to Maintain Maximum Discharge at 30 MW

The capability of the BESS to maintain maximum discharge at 30 MW is restricted due to a temperature de-rating factor. The installation of the additional air-conditioning units and associated circulation fans and duct work changes, as detailed in Section 6.4.1, will further reduce the risk of temperature de-rating under maximum discharge. Testing is planned for when all the duct work has been completed. At the time of writing and under full discharge conditions, maximum output is within 1 MW of design.

6.4.3 R2 model validation

ElectraNet’s consultant has submitted the R2 model validation report, which has identified some shortcomings in the model. ElectraNet has provided details of the shortcomings in the models for the BESS in terms of meeting the required +/- 10% accuracy required under the Power System Model Guidelines (PSMG). CPP and ABB are currently investigating the causes of this and will respond in due course.

6.5 Facility Maintenance Contract

On 14 December 2018 the ESCRI-SA facility maintenance contract commenced with Consolidated Power Projects Pty Ltd (CPP). Under the contract, CPP is required to carry out routine maintenance of the system, provide a first call response service, as well as respond to all breakdowns and other maintenance requirements.

Routine maintenance carried out under the contract to date has comprised monthly visits to the site to inspect and test the on-site diesel generator and check and test the BESS fire suppression system.

CPP's maintenance team is based in Adelaide, around 200 km and a 2.5-hour drive from the ESCRI-SA system at Stansbury. As a result, each maintenance call-out requires a significant response time.

In the period from 14 December 2019 to 14 June 2020, the BESS system has been performing as per design.

6.5.1 Communications

Some communication issues have been experienced when downloading data from the high-speed recorder remotely, this is being followed up with the meter vendor and CPP.

6.5.2 Air-Conditioning Operation

In late August 2019, two new air-conditioning units were installed by CPP in the inverter rooms to resolve the cooling capacity of the system. However, one of the air conditioning units had an internal fault on a condenser coil, thereby causing it to run at 50% while the other unit had a faulty condenser fan. Both units were replaced in March 2020.

6.5.3 Air-Conditioning Alarms

A minor issue with alarms caused by the air conditioning units short cycling has been reported. Nonetheless, the air conditioning units have performed well and no derating due to heat was experienced over the six month reporting period.

6.5.4 Component Failure and Changeover

In February and April 2020, it was reported that inverters had tripped, due to the imbalance in charge issue that was discussed in the last report, whereby ABB was required to dial in and reboot individually.

In May 2020, the BESS system was shut down for a few hours for maintenance works on batteries and inverters. Additionally, in May 2020 a software glitch was reported (watchdog timer fail requiring restart) and inverter module PCS 100 was changed out. During the reset after the inverter module change, the step-up transformer tripped due to a malfunction with a insulation protection relay.

6.5.5 Spare Parts Inventory

SCADA spares have been ordered and are expected to be received in August 2020.

6.6 Safety Incidents

There were no safety or environmental incidents reported during the third six months of commercial operation.

6.7 Stakeholder Management

There were no stakeholder management complaints reported during the third six months of commercial operation.

6.8 Market Non-Compliance Incidents

All market performance requirements such as FCAS and energy trading functionality of the BESS have been tested as part of the commissioning test program. Test results confirmed that the BESS can respond to market dispatch signals as required by the Rules.

The technical performance requirements of the BESS under the NER have been tested and it has been confirmed that correct operations have been achieved. Since the BESS has been in commercial operation, no system event has occurred to indicate any non-compliance with market dispatch signals.

7. Observations

This section contains observations about activities and engagements related to the BESS and summarises new lessons learnt during the past six months of commercial operation.

7.1 Knowledge Sharing

The ESCRI-SA Project continues to be sought out by industry and others for insights and learnings. Knowledge sharing activities include presentations at industry events, engagements with stakeholders and technical papers. A sample of knowledge sharing activities is provided below:

- Presentation on the ESCRI-SA BESS at the Australian Power Institute Summer School in February 2020
- Presentation by ElectraNet and ABB at a webinar in April 2020, arranged by the SEPA Energy Storage working group (SEPA: US based Smart Electric Power Alliance)
- ElectraNet shared its ESCRI-SA experience with the US utility PSE&G during a discussion facilitated by the UMS Group

7.2 New lessons learnt

The lessons learnt that were documented in the first and second Operational Reports are still relevant and will not be repeated here.

The past six months presented two key learnings:

- The implications of the Primary Frequency Response (PFR) rule change on the ESCRI-SA BESS facility were considered. Although the BESS is a very flexible facility, utilising grid forming inverters, implementing PFR requires changes to the internal logic and control loops of the BESS. Since the controls of the Dalrymple BESS are finely tuned to provide a wide range of services already, it would require significant amount of work and testing to implement this additional functionality
- The 2020 Integrated System Plan, published by AEMO in July 2020, is indicating the growing importance of FFR that can be provided by grid-scale batteries with frequency control in the NEM

8. Associated Parties & Project Contact Details

ElectraNet	ElectraNet powers people's lives by delivering safe, affordable and reliable solutions to power homes, businesses and the economy. As South Australia's principal Transmission Network Service Provider (TNSP), ElectraNet is a critical part of the electricity supply chain. It builds, owns, operates and maintains high-voltage electricity assets, which move energy from traditional and renewable energy generators in South Australia and interstate to large load customers and the lower voltage distribution network. ElectraNet owns and maintains the ESCRI-SA 30 MW 8 MWh battery, which provides both regulated network services and competitive market services.
agl	AGL operates the country's largest electricity generation portfolio and is its largest ASX-listed investor in renewable energy. AGL's diverse power generation portfolio includes base, peaking and intermediate generation plants, spread across traditional thermal generation, natural gas and storage, as well as renewable sources including hydro, wind, landfill gas, solar and biomass. AGL operates the battery to provide competitive market services.
Advisian Worley Group	Advisian is the advisory and specialist consulting arm of Worley and has been involved with the ESCRI-SA Project since its inception in 2013. This work included significant input into the technical and project management components of Phase 1. In Phase 2 and 3 Advisian is the Knowledge Sharing Partner for the Project.

For more information on the Project, please log into the ESCRI-SA Project Portal located at the following address: www.escri-sa.com.au.

The portal contains the ability to ask questions of the project team. It also contains relevant information including:

- Access to live and historical data from the operational BESS
- Images of the Project construction and operation
- All publicly published Knowledge Sharing material, including key reports, operational updates and presentations
- Information from the ESCRI-SA Knowledge Sharing Reference Group, which has been formed to share information about the Project, to discuss issues relevant to large scale batteries in the NEM, and to inform key stakeholders

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