ElectraNet

ESCRI-SA Battery Energy Storage Project Operational Report #2

Second six months (14/6/2019 – 14/12/2019)

February 2020

In partnership with:

agl

Advisian
WorleyParsons Group

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The purpose of this document is to provide a summary of the second six months of commercial operation of the ESCRI-SA Battery Energy Storage Project.

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"

One public report on Phase 3 has 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

This Project Operational Report is the second 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 5 of the Funding Agreement between ElectraNet and ARENA. It covers the journey and lessons learnt for the second 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.

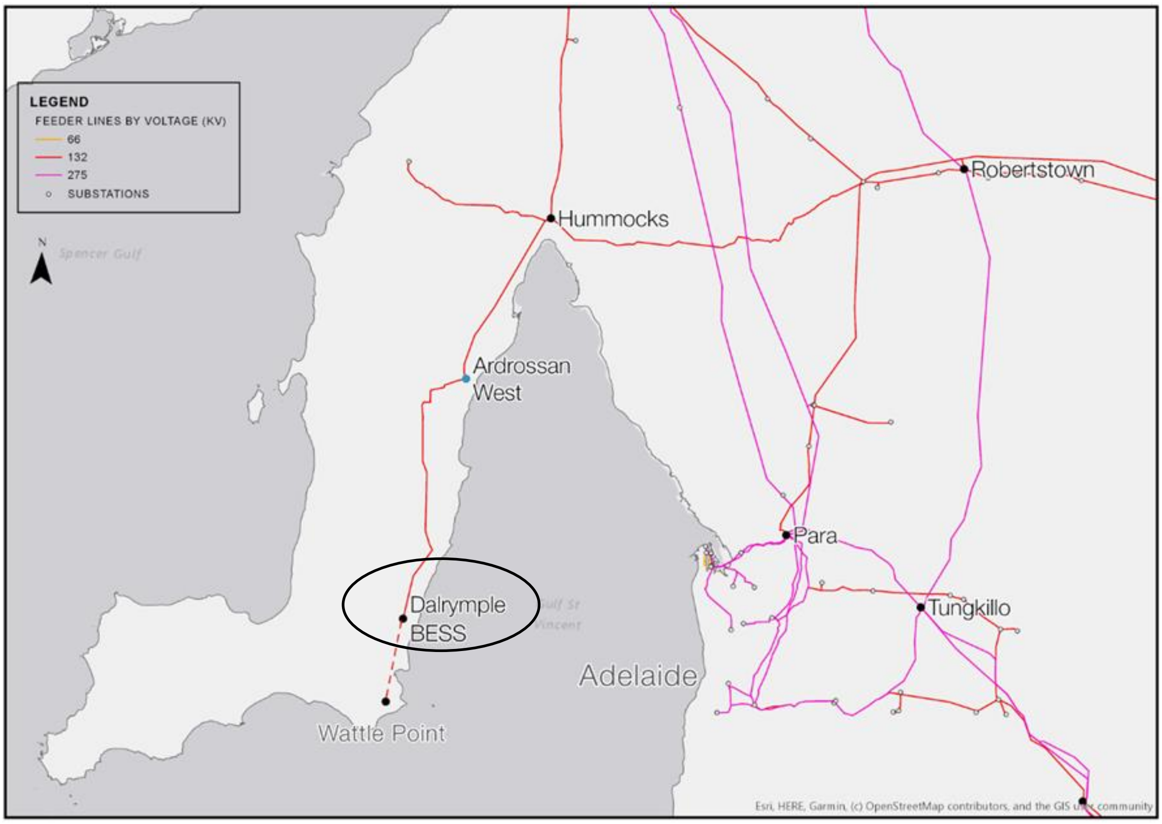

Figure 2-2: Dalrymple connection point relative to existing transmission assets

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.

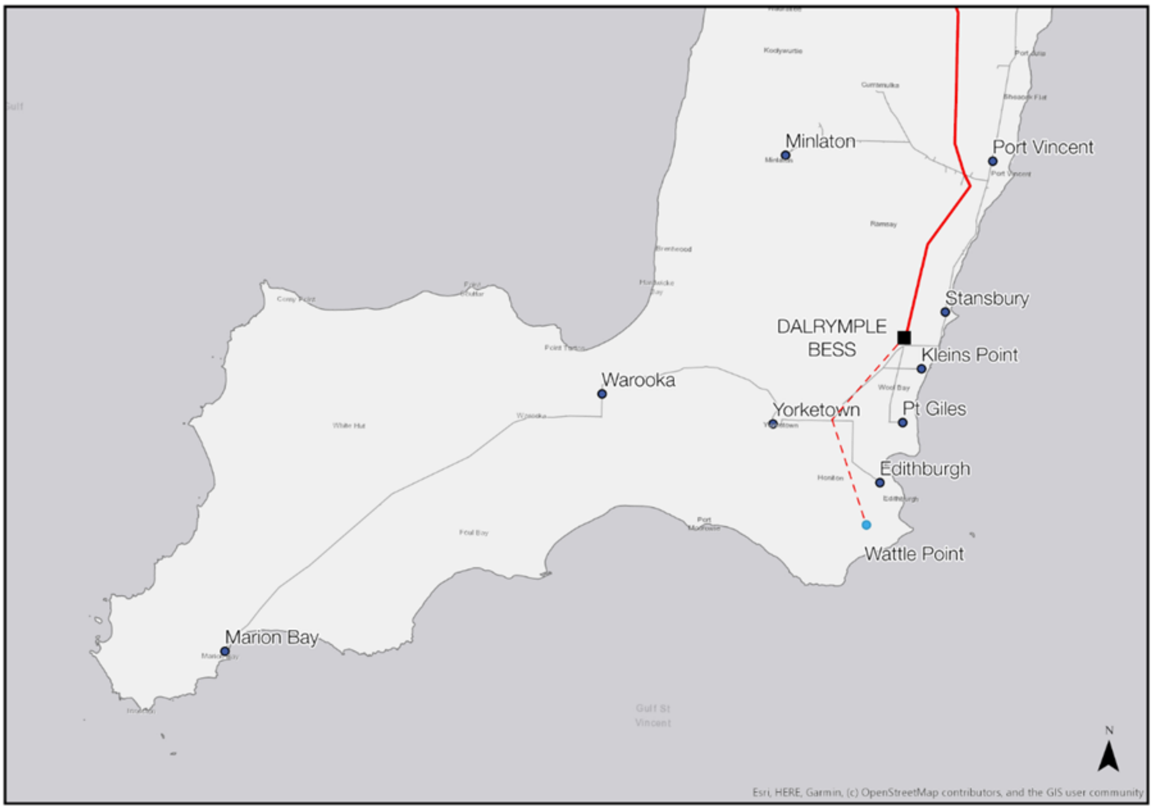

Figure 2-3: Region supported by the Dalrymple battery during an islanding event

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.

In the first Operational Report it was reported that AGL and ElectraNet agreed to a modified BESS reserved energy discharge limit due to the Wattle Point Wind Farm (WPWF) islanding integration testing being delayed at the time. This testing has since been successfully completed and the modified discharge limit removed.

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 first Operational Report:

- ElectraNet and its consultant completed the R2 model validation testing in April 2019. The validation report has been delayed but is planned to be finalised shortly
- AGL and ElectraNet agreed to a modified BESS reserved energy discharge limit due to the Wattle Point Wind Farm (WPWF) islanding integration testing being delayed at the time of the first Operational Report. This testing has since been successfully completed and the modified discharge limit removed, and
- AGL has submitted a WPWF non-compliance issue with AEMO in relation to WPWF wind turbine over-frequency protection settings. AGL is working with AEMO to address the non-compliance and resolve any issues

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 12 months of operation from 14 December 2018 to 14 December 2019 respectively, are shown in Table 3-1.

Table 3-1: Key Performance Metrics for First 12 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)
Average BESS Availability	98.01%	97.35%
Total Energy Consumed	1,370 MWh	2,006 MWh
Total Energy Exported	160 MWh	768 MWh
Average auxiliary load and losses (% of 30 MW rated capacity)	2.19%	2.25%
Number of Charge and Discharge Cycles (per BOA definition)	2	4
BESS Charging Cost	$120,000	$101,000
BESS Discharge Revenue	$116,000	$97,000
FCAS Revenue	$1.33m	$3.73m

The average BESS availability for the period was 97.35%, which is greater than the 96% Guaranteed Annual Availability required under the Battery Operating Agreement. The slight reduction in availability compared to the first 6 months is a due due to a planned outage of a few days which resolved some of the issues discussed in section 6, (i.e. teething issues of the first 6 months of operations).

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. 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 $3.73 million compared to $97,000 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 14 operational system events. Eleven of these events were single-line trips or a frequency event and high-speed data recordings from Power System Performance Monitor (PSPM) confirmed the BESS successfully rode through the fault or responded as required.

The other three events were more significant and led to the BESS supplying load to prevent or reduce the duration of an unserved energy event. These events were reported on in the first Operational Report.

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

3.3.1 Planned Outages

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

3.3.2 Unplanned Outages

On 13 June 2019, during protection tests at WPWF, a direct inter-trip signal to Dalrymple was accidentally initiated. This resulted in the Dalrymple 132/33 kV TF2 tripping and subsequent maloperation of the IDS resulted in the tripping of Dalrymple 132/33 kV TF1.

The BESS successfully transitioned to islanded operation and continued to supply the local load until the System Operator restored all outage elements approximately half an hour later. No load was lost as a result of the incident.

This event was reported in the first Operational Report, however, at the time data had not been downloaded for this event. The following graphs illustrate how the BESS performed during this outage.

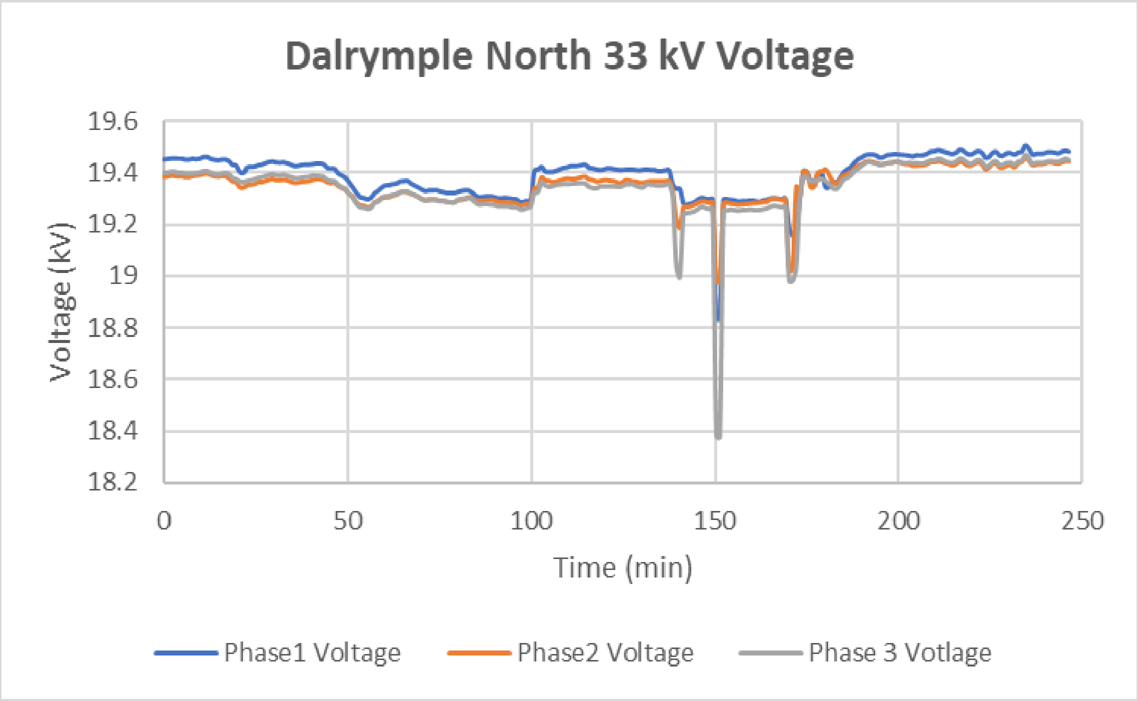

Figure 3-1: Dalrymple 33 kV voltage measurement during the event

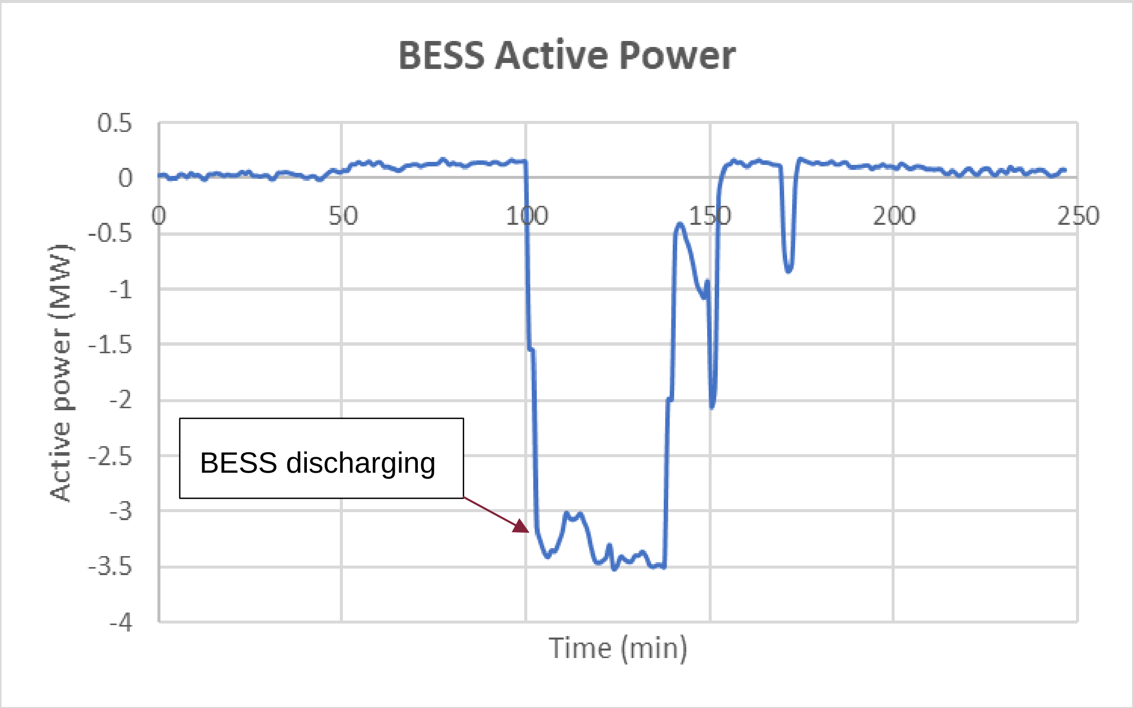

Figure 3-2: Active power output from the BESS during the event

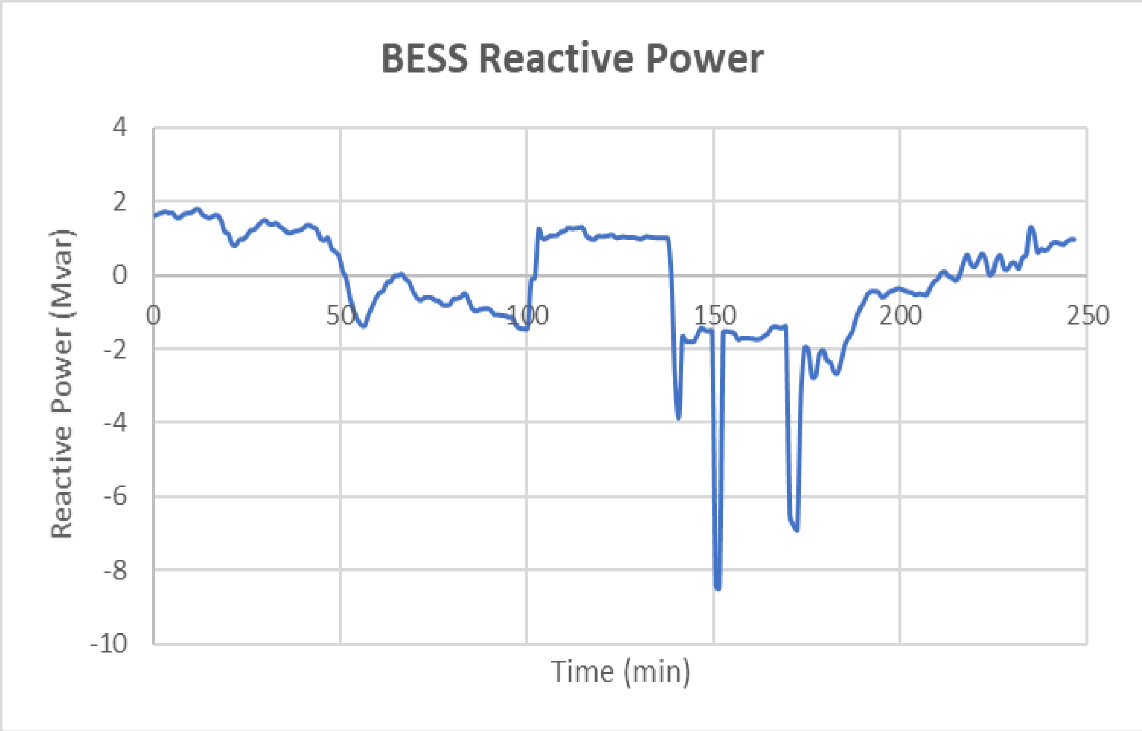

Figure 3-3: Reactive power output from the BESS during the event

Based on the data recorded for the unplanned outage, it indicated that Dalrymple BESS successfully transited to islanding operating and supplied the local Dalrymple 33 kV load during the outage. No load was lost as the result of this unplanned outage event.

No unplanned outages relevant to the Dalrymple BESS occurred during the second reporting period.

3.3.3 Transmission Network Faults

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

- On 1 September 2019 at 17:57, the Davenport – Olympic Dam West 275 kV line reclosed successfully following a single phase – ground fault
- On 6 October 2019 at 3:35, the Hummocks - Waterloo 132 kV line reclosed successfully following a single phase – ground fault
- On 1 November 2019 at 20:20, the Waterloo – Templers 132 kV line reclosed successfully following a single phase – ground fault
- On 1 November 2019 at 23:20, the Murraylink sever tripped following a successful reclose on the Monash – Berri #2 132 kV line due to a single phase – ground fault whilst the North West Bend – Monash # 1 132 kV line was out of service, and
- On 16 November 2019 at 20:05, the 500 kV double circuits connecting Heywood tripped in Victoria resulting in South Australia islanding from the NEM

High speed data recorded at Dalrymple substation has been downloaded by ElectraNet and plotted for the transmission network fault events. These are shown in Figure 3-4 to Figure 3-18.

This 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.

In the first Operational Report two system events were reported for May 2019. At the time high speed data for the two faults were yet to be downloaded from site. Unfortunately the high speed recording device had a failure and had to be replaced, which resulted in the data for these two events being lost.

3.3.3.1 Davenport – Olympic Dam West 275 kV line, single phase to ground fault

On 1 September 2019 at 17:57, a single phase to ground fault occurred on the Davenport - Olympic Dam West 275 kV line. 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.

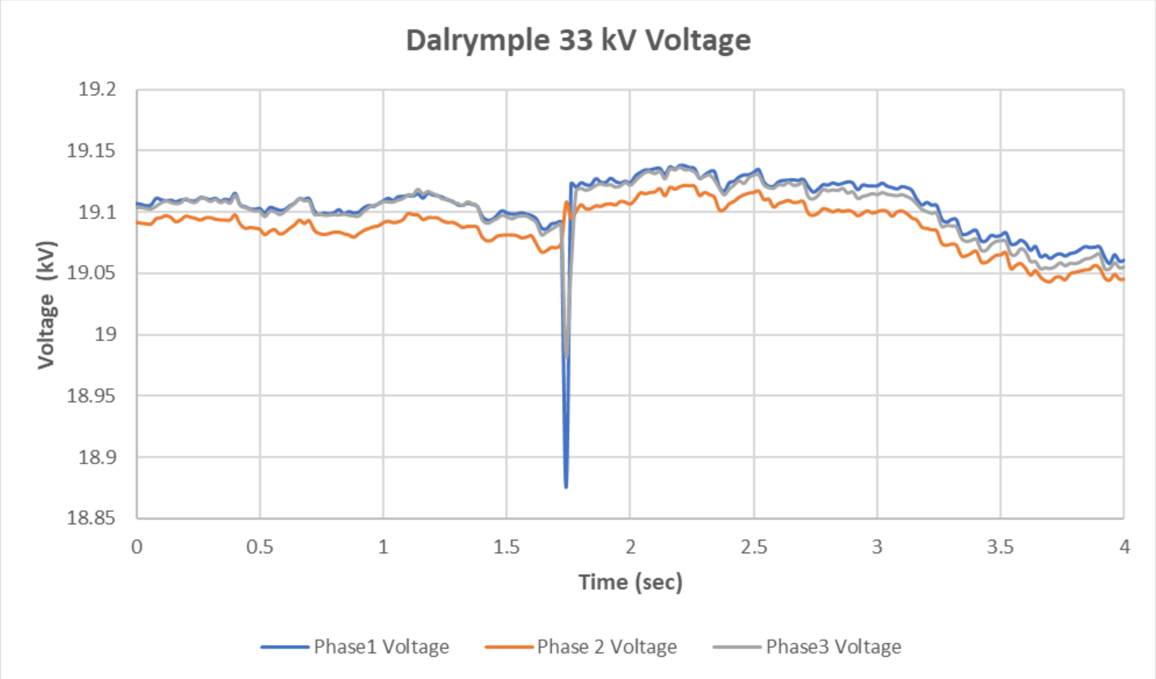

Figure 3-4: BESS Voltage measured at the Dalrymple 33 kV substation

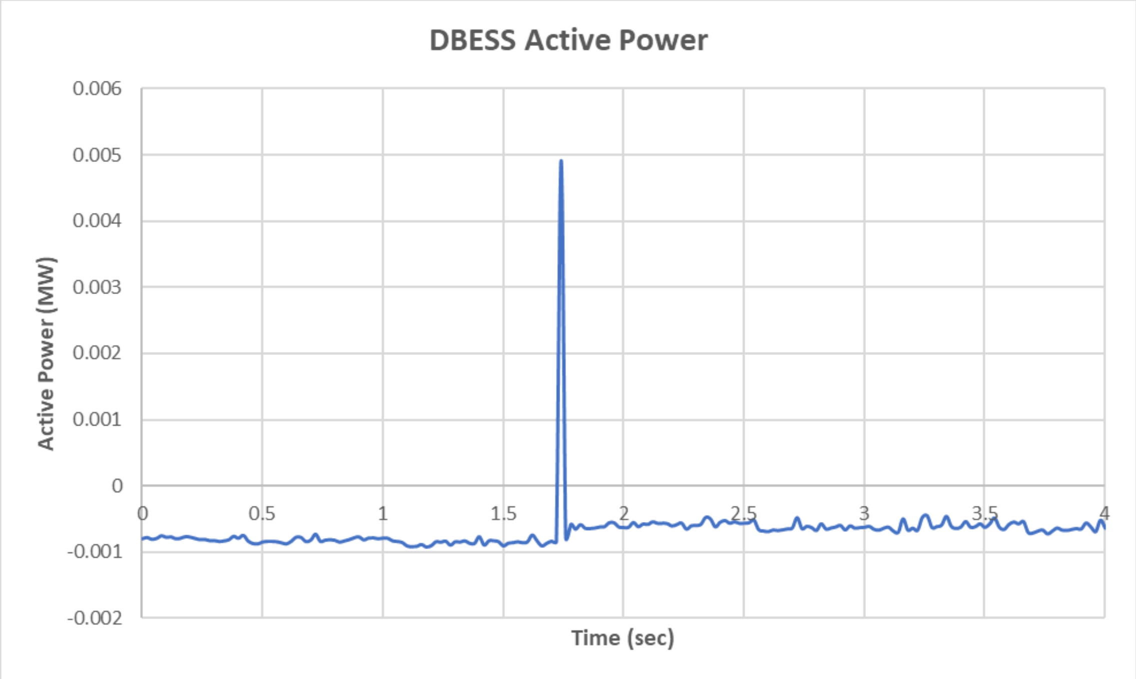

Figure 3-5: BESS active power output measured at the Dalrymple 33kV substation

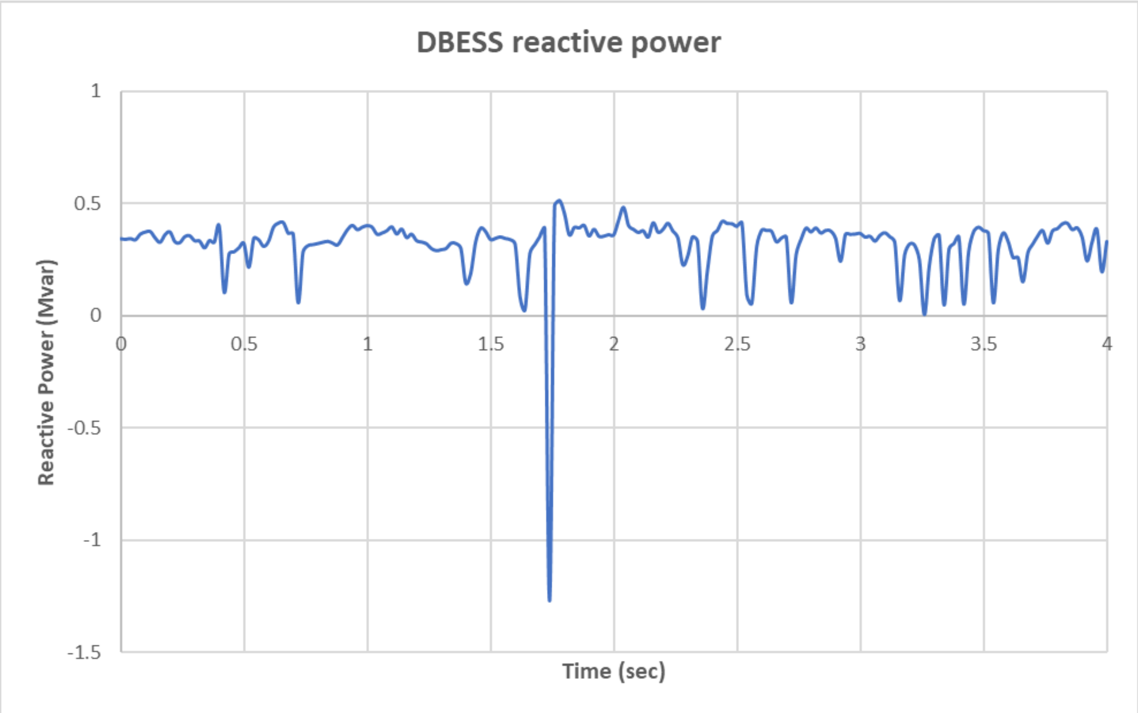

Figure 3-6: BESS reactive power output measured at the Dalrymple 33kV substation

3.3.3.2 Hummocks – Waterloo 132 kV line, single phase to ground fault

On 6 October 2019 at 03:35, a single phase to ground fault occurred on the Hummocks – Waterloo 132 kV line. 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.

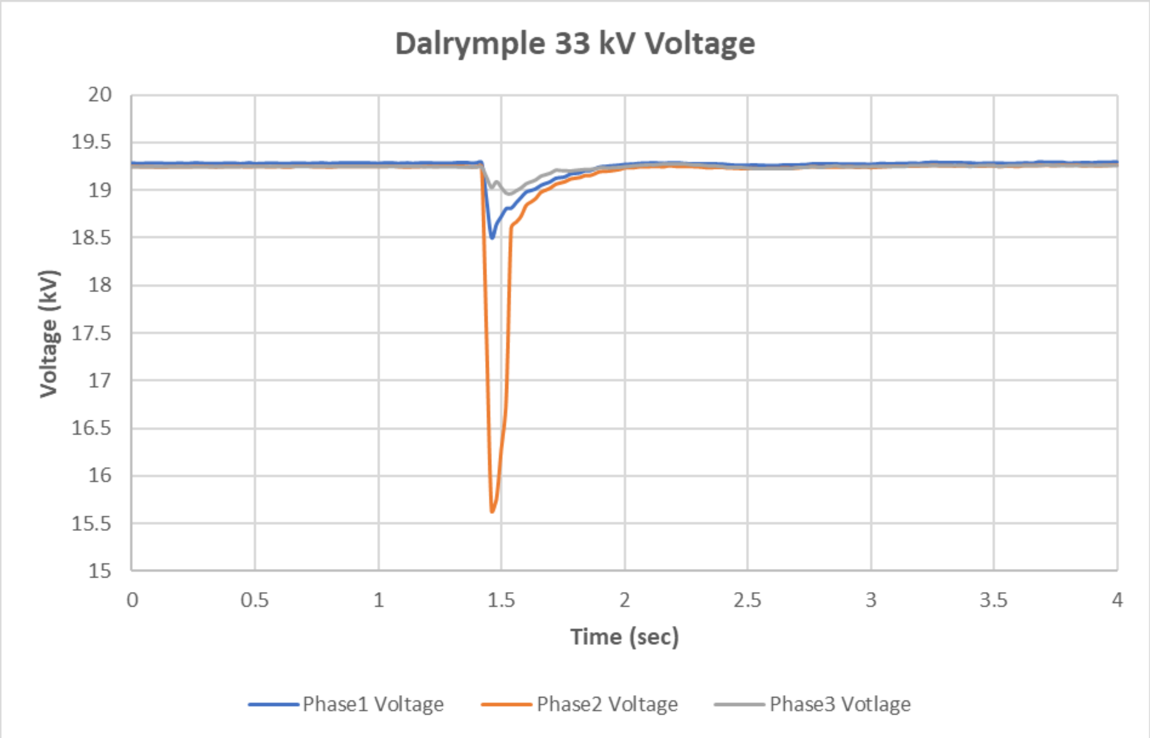

Figure 3-7: BESS voltage measured at the Dalrymple 33 kV substation

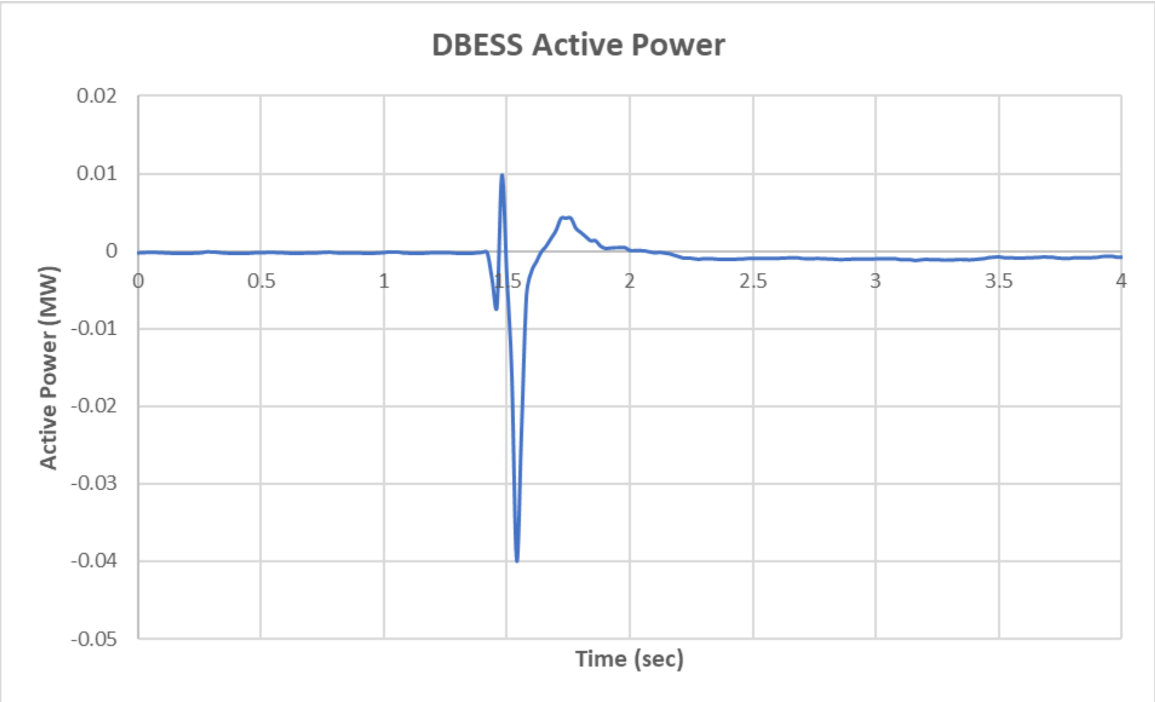

Figure 3-8: BESS active power output measured at the Dalrymple 33 kV substation

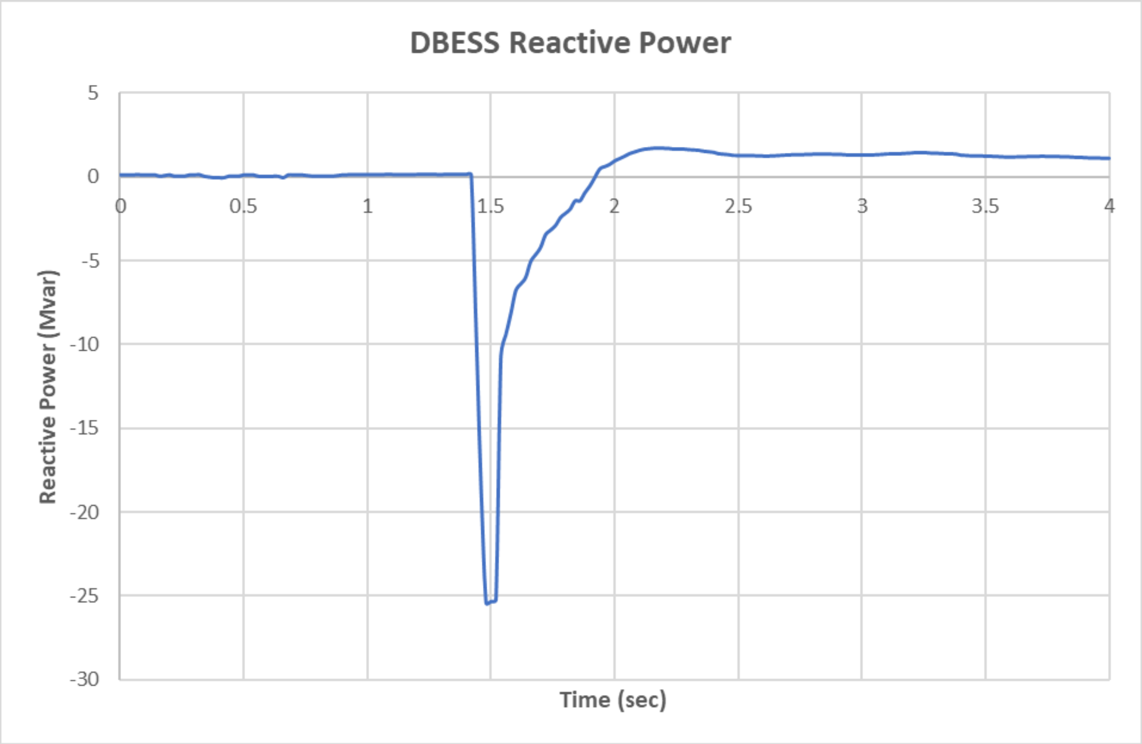

Figure 3-9: BESS reactive power output measured at the Dalrymple 33 kV substation

3.3.3.3 Waterloo – Templers 132 kV line, single phase to ground fault

On 1 November 2019 at 20:20, a single phase to ground fault occurred on the Waterloo – Templers 132 kV line. 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.

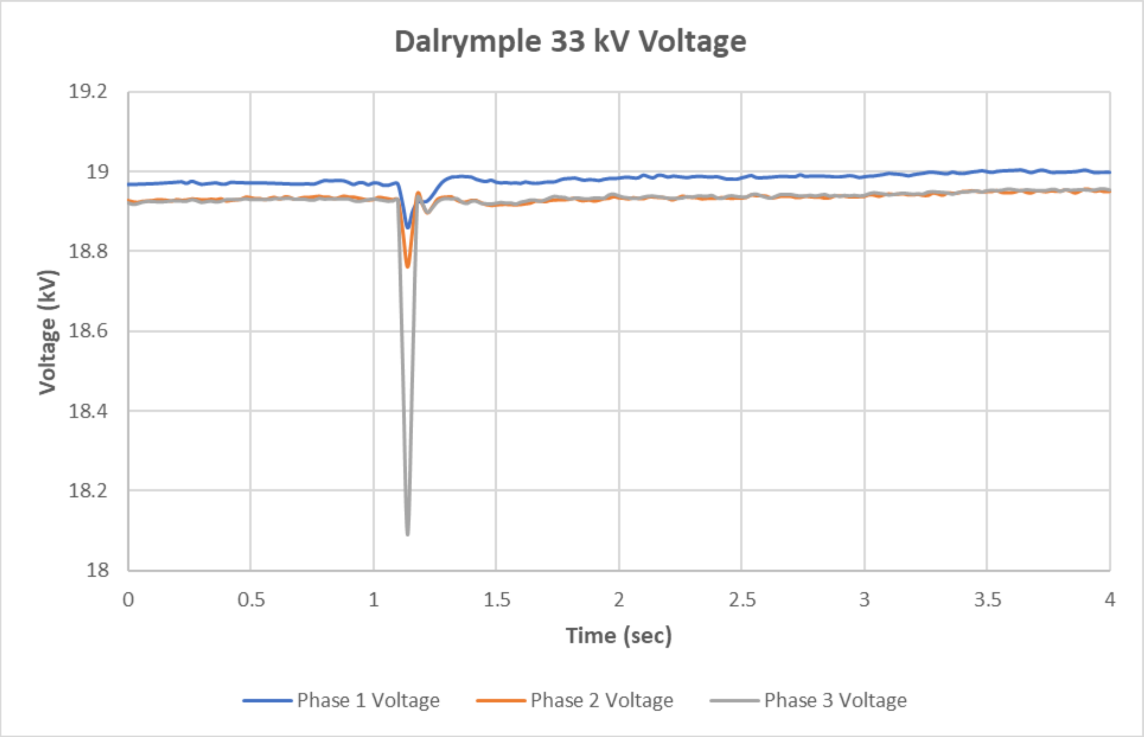

Figure 3-10: BESS voltage measured at the Dalrymple 33 kV substation

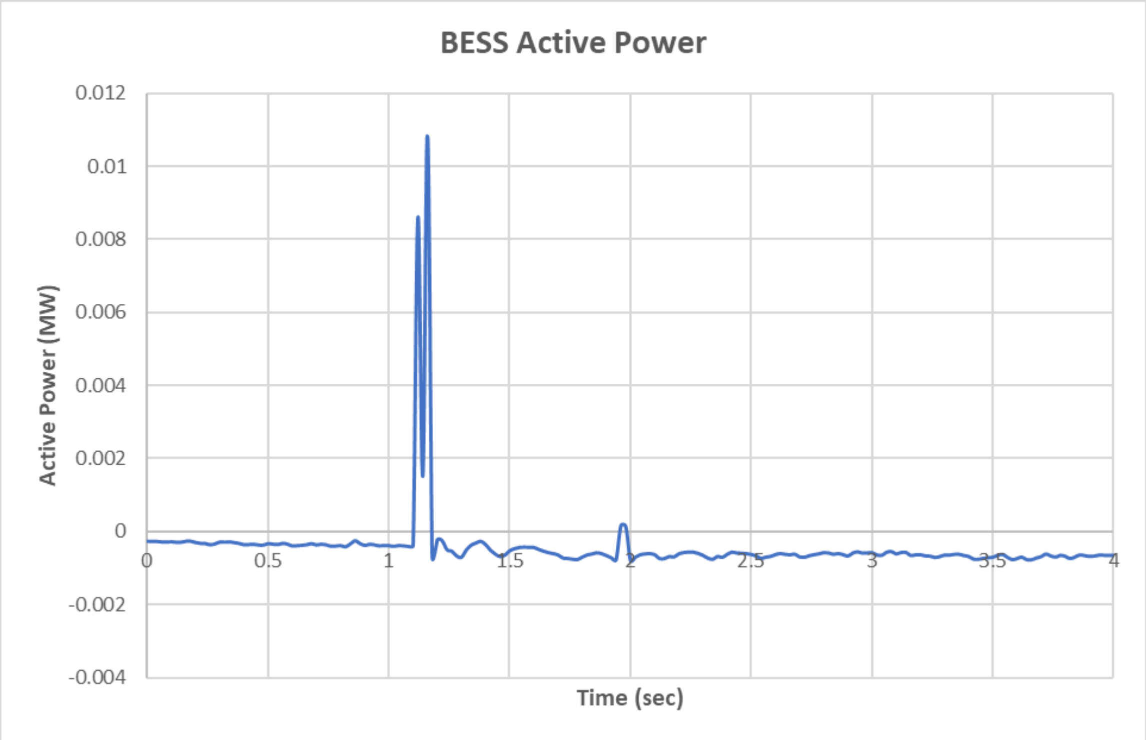

Figure 3-11: BESS active power output measured at the Dalrymple 33 kV substation

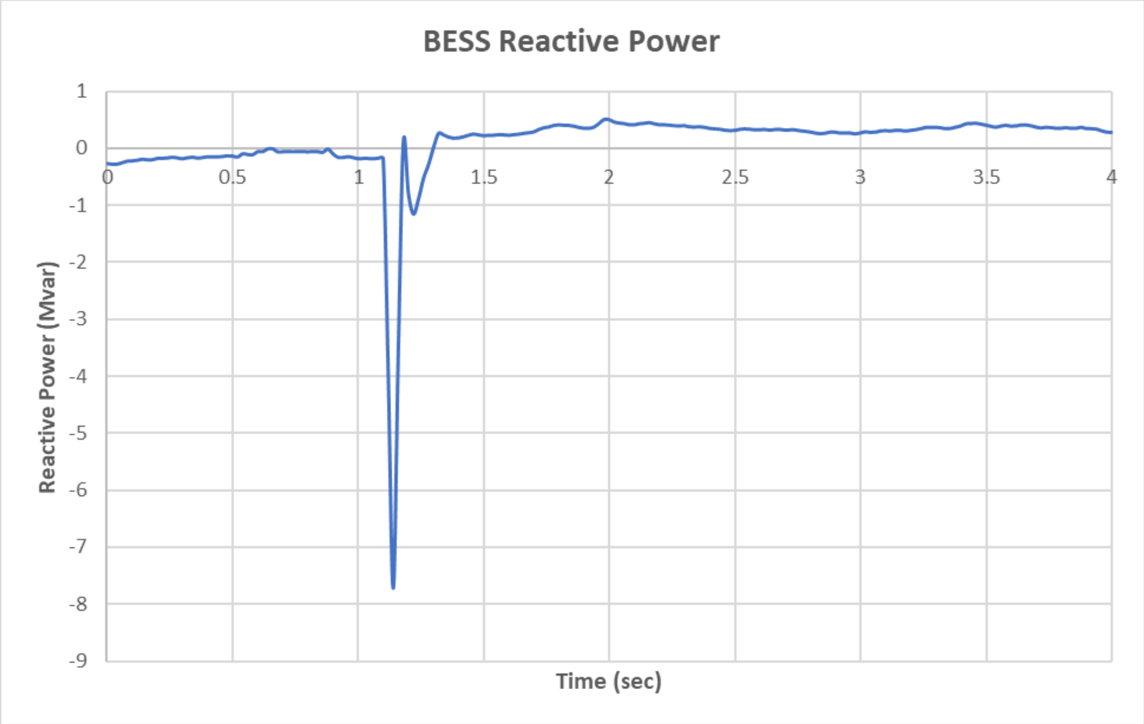

Figure 3-12: BESS reactive power output measured at the Dalrymple 33 kV substation

3.3.3.4 Murraylink sever tripped, 1 phase to ground fault on the Monash – Berri #2 line

On 1 November 2019 at 23:20, a single phase to ground fault occurred on the Monash - Berrie # 2 132 kV line. The fault was cleared and the line successfully reclosed, whist North West Bend – Monash #1 line was out of service. As a result of the fault, Murraylink was tripped. High speed data recorded at the Dalrymple 33kV bus indicated the Dalrymple BESS successfully rode through the fault as shown below.

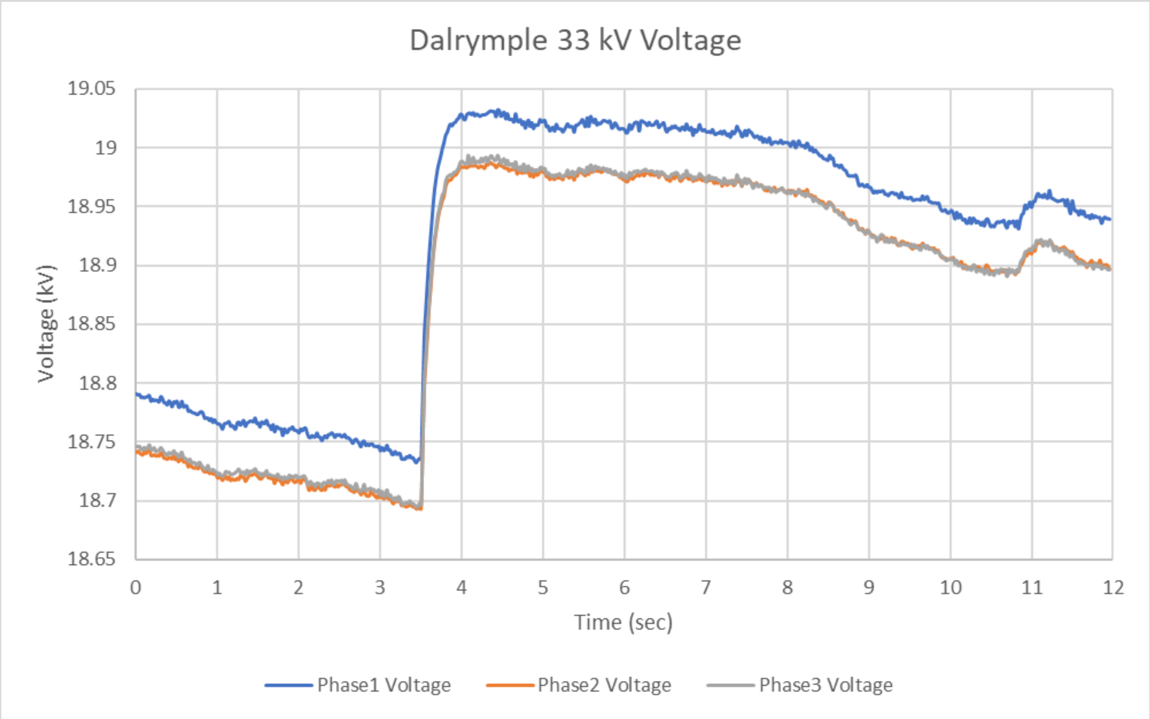

Figure 3-13: 33 kV Voltage measured at the Dalrymple 33 kV substation

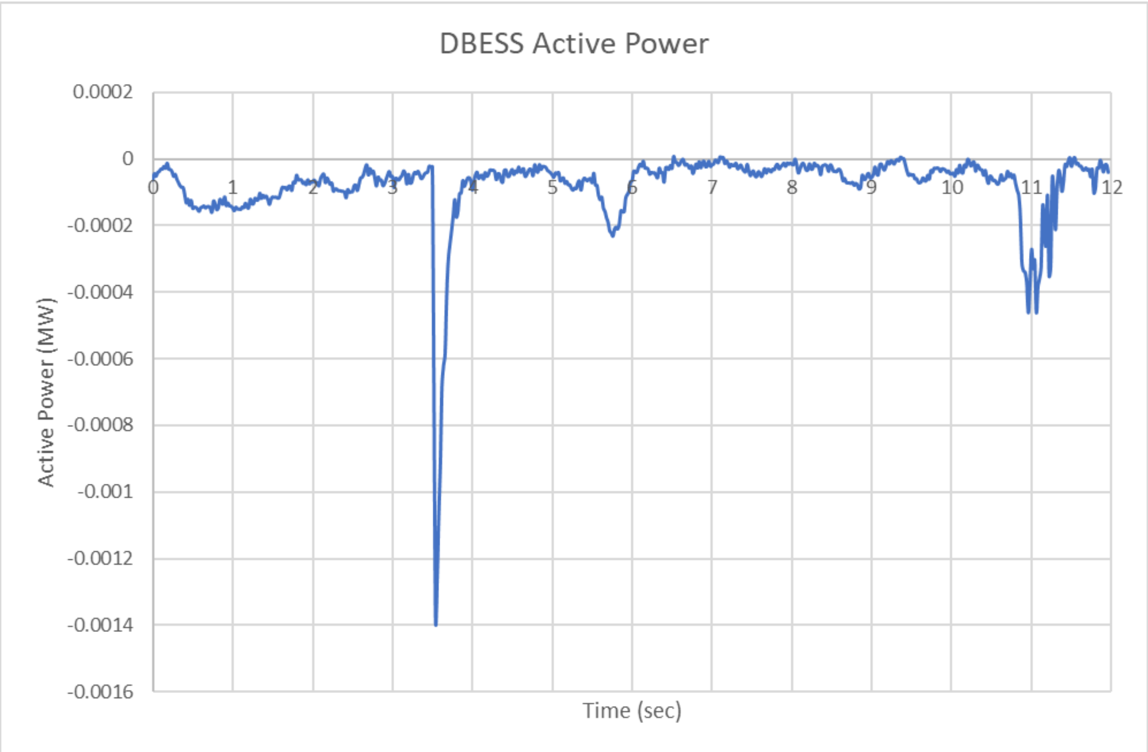

Figure 3-14: BESS active power measured at the Dalrymple 33 kV substation

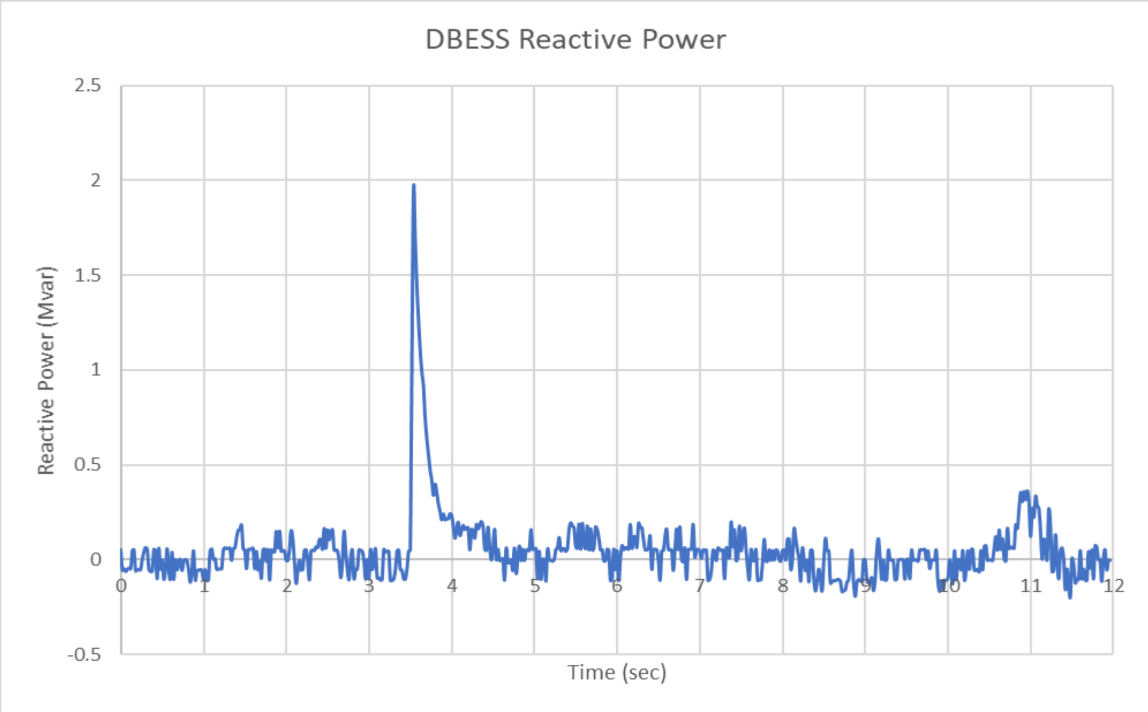

Figure 3-15: BESS reactive power measured at the Dalrymple 33 kV substation

3.3.3.5 500 kV Double circuit connecting Heywood tripped in Victoria resulting in South Australia islanding from the NEM

On 16 November 2019 at 18:06, the 500 kV double circuits between Heywood and Moorabool were tripped as the result of a fault. The Heywood interconnection between South Australia and Victoria was lost and the SA transmission network transitioned to an islanded condition with SA exporting approximately 300 MW at the time of the event. High speed data recorded at the Dalrymple 33kV bus indicated the Dalrymple BESS responded to the event as shown below.

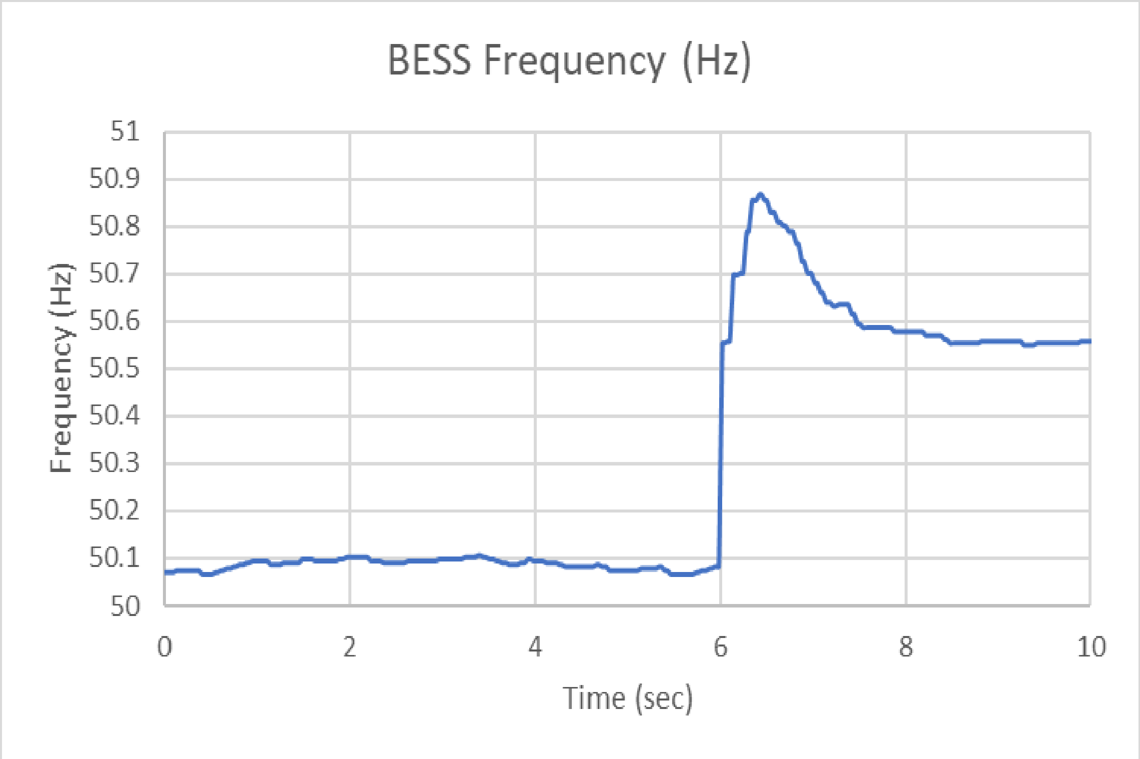

Figure 3-16: Frequency measured at the Dalrymple 33 kV substation

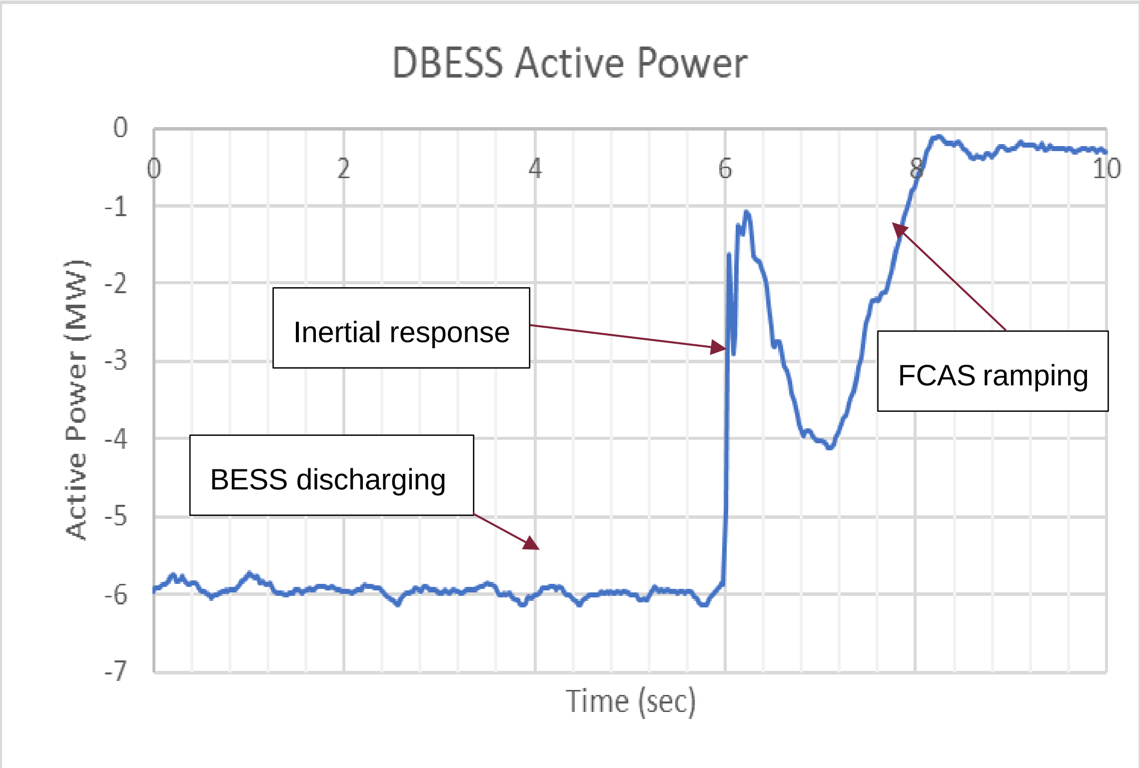

Figure 3-17: BESS active power response measured at the Dalrymple 33 kV substation

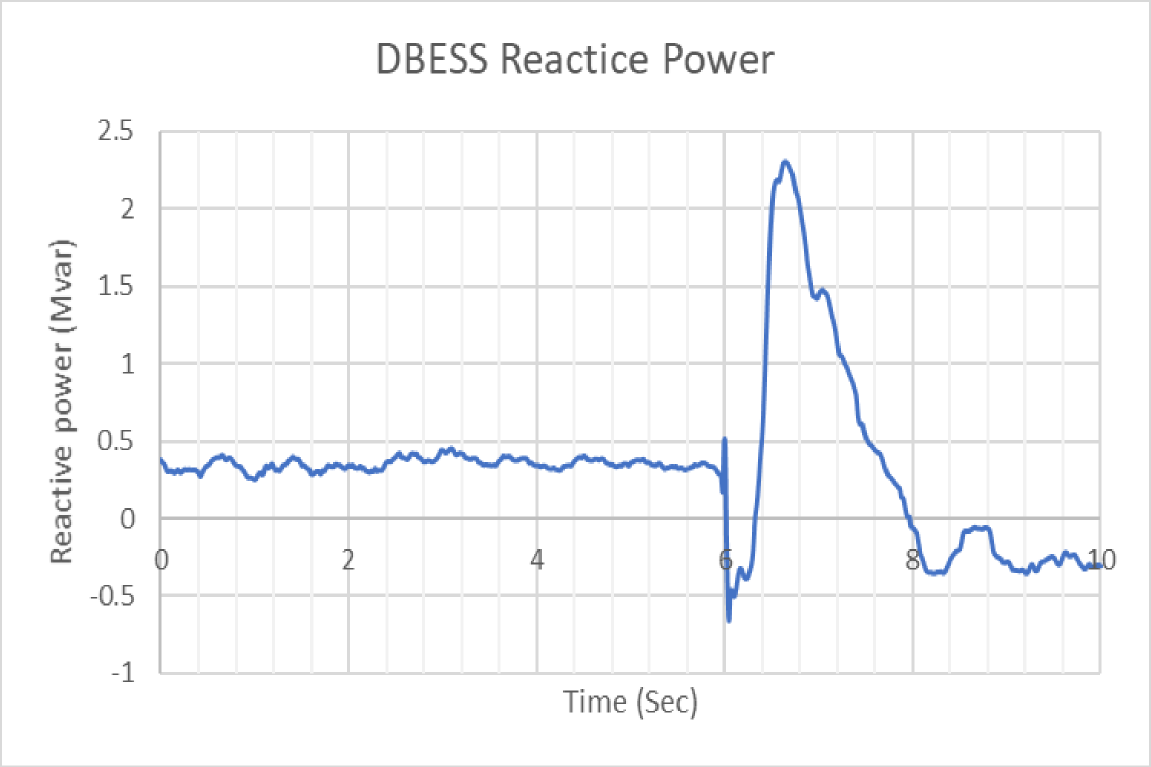

Figure 3-18: BESS reactive power response measured at the Dalrymple 33 kV substation

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 3-19: 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 December 2019, Google Analytics shows that the site has been visited 2040 times from interested parties from 20 countries, with the number of views peaking in January 2019, May 2019 and October 2019. 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 3-20 to Figure 3-22 and Table 3-2.

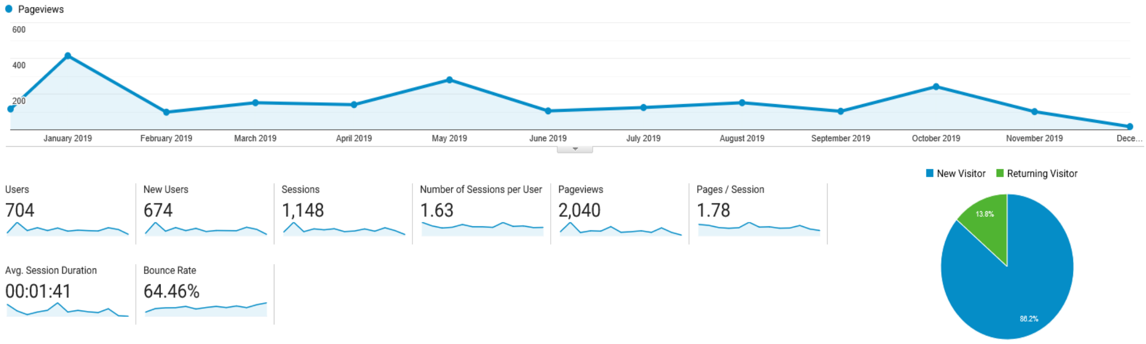

Figure 3-20: ESCRI-SA portal page views (12 months)

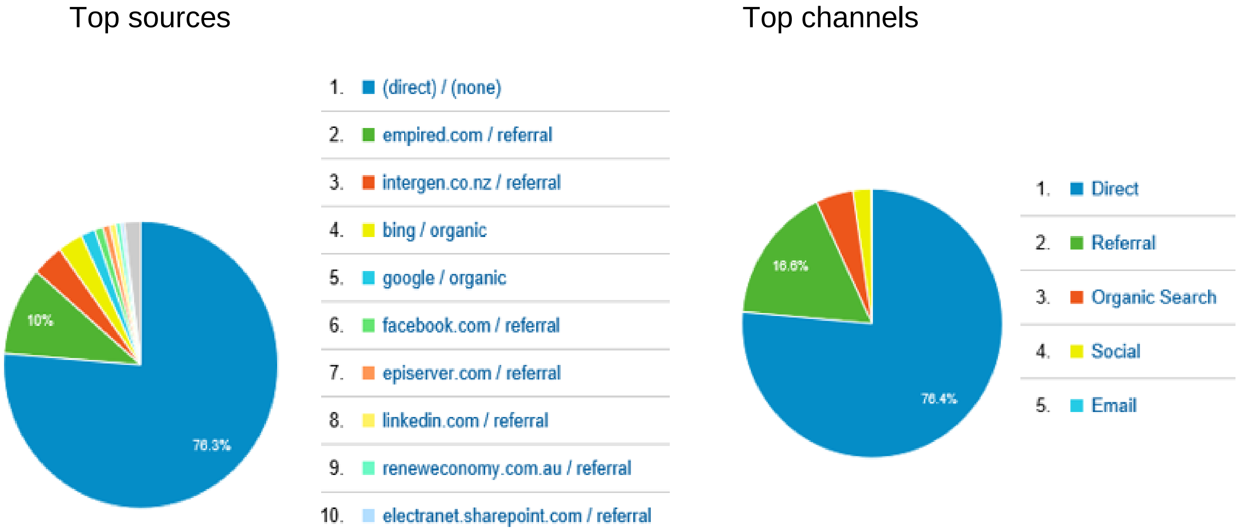

Figure 3-21: Top sources and channels used to locate ESCRI-SA portal (12 months)

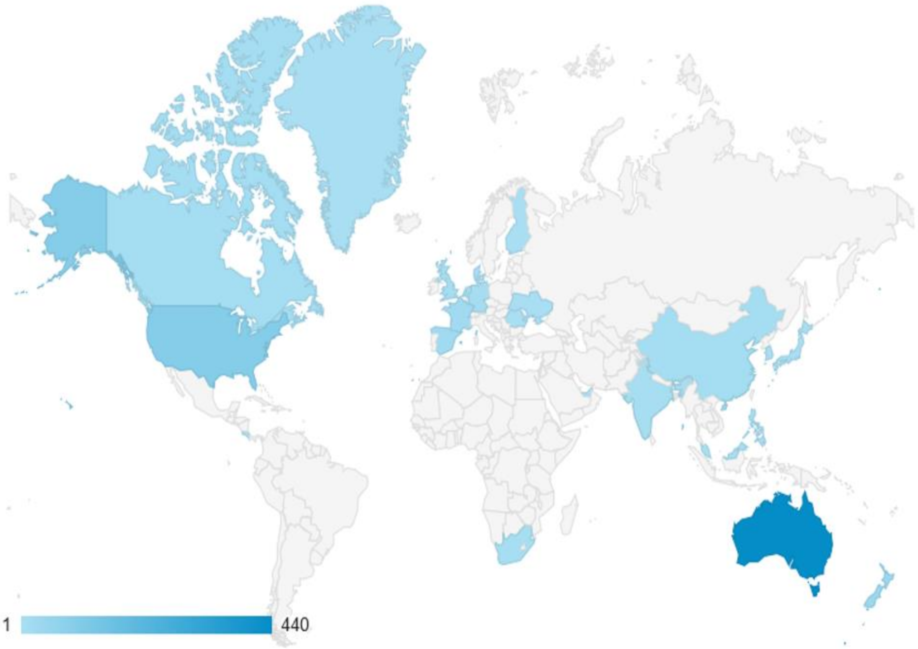

Figure 3-22: Geolocation of ESCRI-SA portal users (12 months)

	14/12/2018 to 14/06/2019	14/06/2019 to 14/12/2019	Total 14/12/2018 to 14/12/2019
Page views	1241	799	2040
Unique page views	984	666	1650
Average time on page	1:54	2:14	2:01
Number of report/presentation downloads	76	47	123
Number of data downloads	230	103	333

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 June 2019 to 14 December 2019, there have been no planned or unplanned outages requiring the BESS to supply the local load as an islanded network.

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 one system frequency event due the loss of the South East – Heywood Interconnector on the 16 November 2019 to confirm the actual operation of the FFR function of the BESS.

During the second six months of operation the RoCoF constraint has not bound. Without the BESS in service, it is estimated the RoCoF constraint would have bound for about one hour and 25 minutes.

For the system separation event on 16 November 2019, the system frequency increased to approximately 50.9 Hz following the loss if the South East – Heywood Interconnector, while SA was exporting about 300 MW. The plots presented below indicate that the Dalrymple BESS responded to this frequency rise event by reducing its discharge level from 6 MW to 0 MW almost instantly following the contingency event.

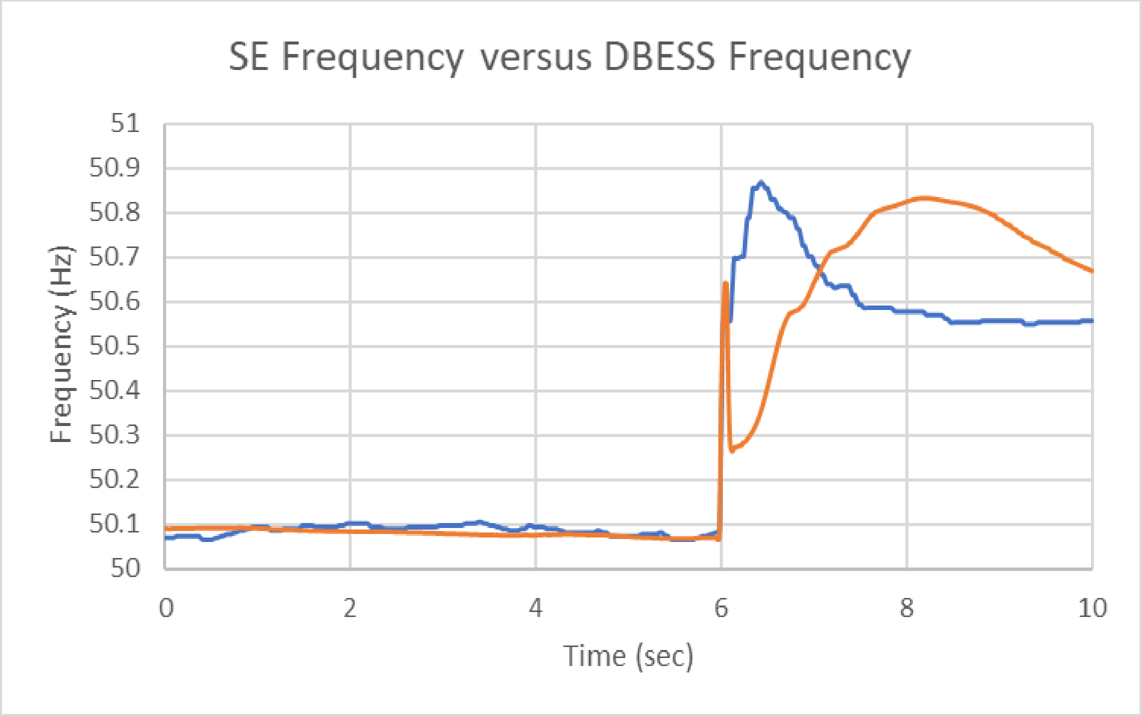

Figure 4-1: System frequency rise measured at the Dalrymple 33 kV substation

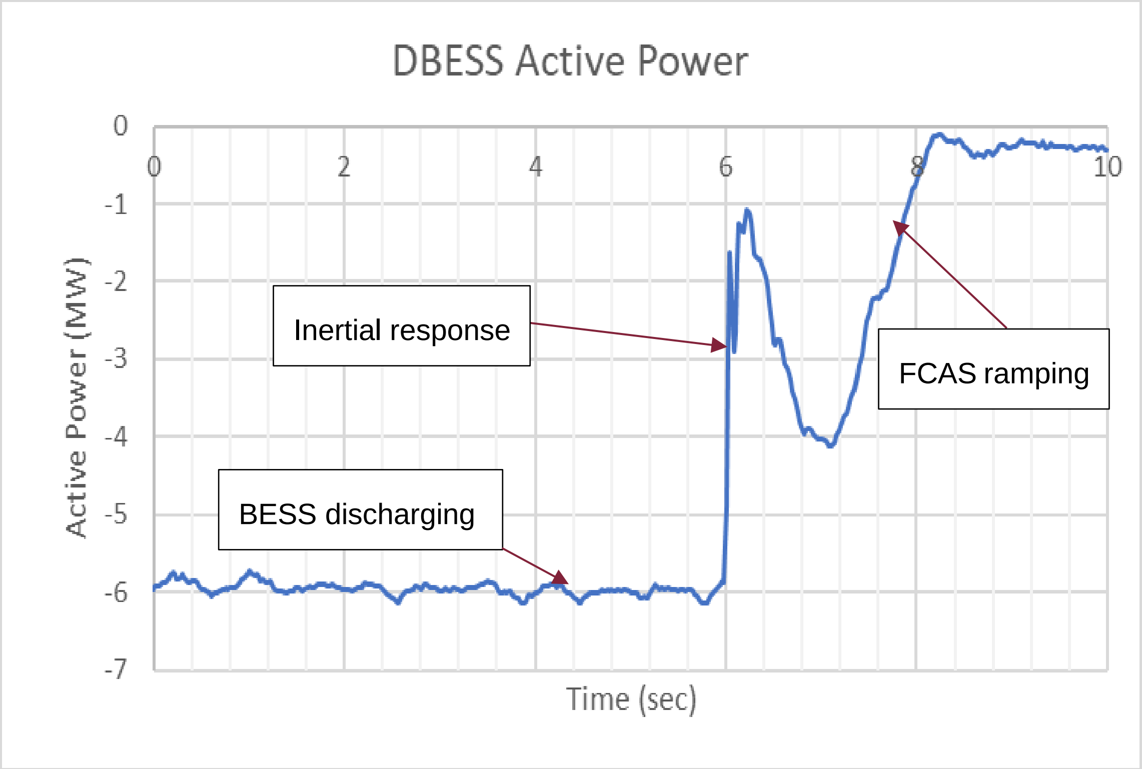

Figure 4-2: BESS active power response due to system frequency rise event

The above event data confirm 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 its 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 six 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 second six-month reporting period up until the end of the first year of commercial operation (14 June 2019 to 14 December 2019):

- The charging cost for the BESS was approximately $101,000
- Discharge revenue earned by the BESS was approximately $97,000
- The BESS required an average daily charge of approximately 10.25 MWh
- Average charge cost was approximately $555 per day
- FCAS revenue was approximately $3.73 million (180% increase from the previous six months – see s.5.2.2 for more details). Average daily FCAS revenue was approximately $20,449 and
- FCAS recovery paid was approximately $29,000. Average daily FCAS recovery paid was approximately $159

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 provision of FCAS services, as it was for the first six-month period of operations.

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 FCAS revenue significantly higher than expected.

Charging costs for the battery were around $101,000 overall for the second six-month period – this is required both for energy arbitrage opportunities (being able to discharge at times of high prices), and for providing FCAS services (see 5.2.2 below).

5.2.1 Energy Arbitrage

Energy arbitrage has continued to provide less value than estimated in the business case. In the first six months, as described in the previous report, the delay in establishing effective control system coordination with Wattle Point Wind Farm resulted in contractual limitations which limited the value of energy arbitrage (due to increased capacity reserved for network services).

Since then, despite the lifting of this constraint, revenue from energy arbitrage has remained low in favour of maintaining optimal availability for contingency FCAS services.

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 the second six-month operational period, FCAS trading revenue was approximately $3.73 million. This brings the Year 1 total FCAS revenue to approximately $5.06 million, a significant increase from the business case.

Of the FCAS services, the majority of revenue earned by the BESS has been in offering contingency raise services (87%). However, in order to be physically capable of maximising enablement of those FCAS services (especially the delayed raise service), the BESS needs to be kept in a high charge state.

Accordingly, value trade-offs are continually being made as to whether the greater value lies in discharging the BESS for energy arbitrage activities (and thereby reducing the capability of maximising raise service enablement), or actively participating in the FCAS raise markets.

To date, AGL has continued to observe that the greater value has been in providing FCAS services. During the second six-month period, it has emerged that it is often optimal to leave a small amount of headroom at the top of the charge range in order to provide full enablement of the six and 60 second lower contingency services, at the expense of delayed raise contingency (5-minute).

One of the main features of the past six months has been a series of FCAS "events" in South Australia. Between September and November, there were six days where at least one of the continency services had a price greater than $10,000/MWh for at least one 5-minute dispatch interval. There was also the equivalent of approximately 20 hours of 5-minute dispatch intervals with a price greater than $1000/MWh across all services within this six-month period, compared to zero hours in the previous six months.

The FCAS events were generally related to either planned local contingency requirements in SA (due to upgrades on the transmission network close to the Heywood Interconnector), or due to the trip of Heywood on Saturday 16 November 2019 when Murraylink was also out of service on planned maintenance.

The average summed price across all contingency services for the first six-month period was about $15/MWh vs. almost $50/MWh in the second six months of operation. Given the nature of the high prices and the specific network circumstances to which they related, it would appear unlikely that we would see a repeat of this most recent period.

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. This may be adjusted for performance / non-performance of the asset if availability parameters are met or not met as the case may be. Losses beyond an agreed amount are also factored into any User Fee adjustments. During the second six months of commercial operation, there has been ongoing cooperation between AGL and ElectraNet to finalise and reach an agreement on the method of calculation of the Availability Guarantee in the BOA, in particular how the availability parameters are to be measured given the BESS configuration. ElectraNet has now invoiced AGL for the first contract year. Payment has been received.

6.3 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 December 2019. Significant items on this list are covered below.

6.3.1 Additional Cooling Requirements

Excess heat generated from the battery modules during maximum charge and discharge, combined with high ambient temperature, has been an ongoing issue that is currently being resolved.

The original BESS system included 10, 150kW (cooling power) air-conditioning units to maintain the temperature within the desired operational target of 26^{o}C in the battery rooms and 35°C in the inverter rooms. An additional two, 150kW air-conditioning units were installed in February 2019.

A further two, 150kW air-conditioning units were installed in August 2019. The air conditioning units were further tuned to the control system and additional alarms were installed. In addition, duct work is being installed within the rooms to better deliver air flow to the hot sections of system. It is expected that these two actions should be sufficient to fully resolve the over-temperature issues.

6.3.2 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 which reduces the 15-minute, full capacity discharge to approximately 28 MW by the end of a 15-minute discharge during onerous conditions (high ambient temperatures or usage). The installation of the two additional air-conditioning units and associated circulation fans and duct work changes, as detailed in Section 6.3.1, should further reduce the risk of temperature de-rating under maximum discharge.

6.3.3 Island Detection Capability using Vector Shift Relay

ElectraNet operates a topology-based Island Detection Scheme (IDS) which examines the status of all relevant switches and will perform all the necessary actions to create an island when required.

As part of the specification the contractor was required to also include a separate local island detection system to provide a level of redundancy. The vector shift relay system used for this has not proved to be successful as there are both conditions where there is false operation (indicating the creation of an island when it is not required) and areas where islanding is not detected when it should.

The vector shift relay has been disabled with the IDS relied upon to perform the island detection function. In situations where the IDS is out of service the BESS is also to be taken out of service.

6.4 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 June 2019 to 14 December 2019, the BESS system has been performing as per design.

In late August 2019, two new air-conditioning units were installed in the inverter rooms.

6.4.1 Communications

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

A bug was reported on the ABB control system which leads to an unscheduled reboot in the inverter, and hence is under investigation.

6.4.2 Air-Conditioning Operation

The ESCRI-SA system has struggled to maintain temperature within the desired operational band.

The air-conditioning units in the ESCRI-SA system are an inverter type with a 3-phase compressor. In general, the more efficient inverter mode is used to hold the temperature at the set point, while the compressor mode kicks in to provide extra cooling power when the temperature strays further from the set point.

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 are scheduled to be replaced early 2020.

6.4.3 Air-Conditioning Alarms

ElectraNet, in conjunction with CPP and ABB, is currently working to develop self-resetting alarms on the BESS and air-conditioning units. BESS alarms can presently be reset remotely but at this stage this is not available on the air-conditioning units.

Furthermore, CPP is currently considering purchasing a network interface card to enable remote access and operation of the air-conditioning units.

6.4.4 Suspect Data

Over the first six months, the analogue values in the BESS system were occasionally exceeding 100% due to floating point conversions. As a result, for those periods, the remote Terminal Unit (RTU) had flagged the BESS availability (plausible) and BESS availability (max capacity) as “over-range” in the DNP3 protocol, indicating suspect data.

The PLC’s on site were updated by ABB to cap the values in the system as 100%, and hence this issue has been resolved.

6.4.5 Component Failure and Changeover

A high-speed recording device failed and was replaced under warranty.

6.4.6 Spare Parts Inventory

Under the facility maintenance contract, CPP is required to carry a spare parts inventory covering inverter, battery interface, panel and container spare parts. This does not currently include carrying spare parts for the SCADA system or spare battery modules.

ElectraNet has purchased the SCADA spares parts from ABB through CPP.

CPP is currently in discussions with Samsung around holding battery spares. The lead time for battery modules is at least 7-8 weeks as they are sourced from South Korea via sea freight. They could not be air freighted for safety reasons. There is the possibility that AWR Group (the Australian distributor for Samsung batteries) may be able to hold batteries at their Sydney facility to significantly reduce the lead time.

CPP is also exploring the possibility of holding some hot spare battery modules on-site. Replacing battery modules is not as simple as a direct replacement as the float level needs to be balanced (equalised) to the bank voltage, the battery module is charged and continually monitored as the voltage is increased to the acceptable voltage limit. An annual testing is due by Samsung shortly.

CPP is finalising their recommendations with Samsung on the management of hot-spares, potentially including a strategy of rotating hot-spares to ensure that the wear level of the spares is consistent with the active batteries.

6.5 Safety Incidents

There were no safety incidents reported during the second six months of commercial operation.

6.6 Stakeholder Management

One complaint was received which related to a noise issue from the BESS. This was thoroughly investigated, with noise measurements taken at the site found to be well within requirements.

6.7 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 Innovation Awards

The ESCRI-SA Project has been recognised more broadly by winning two innovation awards:

- Energy Networks Australia: 2019 Industry Innovation Award, and
- South Australia Premier's Award: 2019 Energy Sector - Transformational Innovation

The awards recognise leadership in the design, development and application of a ground-breaking Australian energy network initiative, technology, service or solution.

The success of the project required significant innovation leadership including:

- development of a first-of-its-kind commercial model to support the provision of regulated reliability and security services alongside competitive market services
- navigating the NEM registration, licencing and connection processes for the first time, paving the way for others to follow, and
- largest autonomous regional micro-grid development to date co-optimised for both grid-connected and islanded operation with 100% renewables

7.2 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 conferences, engagements with stakeholders and a technical paper. A sample of knowledge sharing activities is provided below:

- ElectraNet hosted a visit by a Western Power delegation who plan to use similar technology for a small rural community and provided some detail measurements to assist Western Power in their analysis
- ElectraNet has been assisting ARENA and the South Australian Government in discussions to identify how grid scale BESSs can be of further assistance in the energy transition
- ElectraNet and AGL provided input to the ARENA commissioned report "Large-Scale Battery Storage Knowledge Sharing Report, September 2019"
- A technical paper was presented at the 18th Wind Integration Workshop in Dublin, Ireland – "A 30 MW Grid Forming BESS Boosting Reliability in South Australia and Providing Market Services on the National Electricity Market", and
- Presentation on the BESS at the Cigre Substations 2019 conference in Hobart.

7.3 New lessons learnt

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

The key learning over the past six months was the value of close co-operation between ElectraNet and AGL to work through some minor technical details identified through the calculations and agreement of the first year's energy, losses and availability values. These values were required to determine the final invoice amount for the first year's lease payment. For future BESS agreements, these measuring and reporting issues may be addressed upfront.

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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