ElectraNet

ESCRI-SA BATTERY ENERGY STORAGE PROJECT COMMISSIONING REPORT

From Financial Close to Commissioning

October 2018

In partnership with:

agl

ARENA
Australian Government
Australian Renewable Energy Agency

Advisian
WorleyParsons Group

This activity received funding from ARENA as part of ARENA's Advancing Renewables Programme

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Contents

Glossary of Terms

Term	Description
AC	Alternating Current
AER	Australian Energy Regulator
AEMO	Australian Energy Market Operator
ARENA	Australian Renewable Energy Agency
BESS	Battery Energy Storage System
BOA	Battery Operating Agreement
CAM	Cost Allocation Methodology
CB	Circuit Breaker
CFS	Country Fire Service
CPP	Consolidated Power Projects Australia Pty Ltd
CPS	Customer Performance Standards
DC	Direct Current
DPTI	Department of Planning, Transport and Infrastructure
DTT	Direct Transfer Trip
Dvar	Dynamic Voltage Amp Reactive
EOI	Expression of Interest
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
ITR	Inspection Test Report
KSRG	Knowledge Sharing Reference Group
kV	Kilovolts
MW	Megawatts
MWh	Megawatt hours
NCIPAP	Network Capability Incentive Parameter Action Plan
NCC	Network Capability Component
NEM	National Electricity Market
NER	National Electricity Rules

NPV	Net Present Value
O&M	Operation and Maintenance
PSCAD	Power System Computer Aided Design
PSS/E	Power System Simulator for Engineering
Q&A	Questions and Answers
RIT-T	Regulated Investment Test for Transmission
RoCoF	Rate-of-change-of-frequency
RFT	Request for Tender
R&D	Research and Development
SA	South Australia
SAPN	SA Power Networks
SCADA	Supervisory Control And Data Acquisition
SIPS	System Integrity Protection Scheme
SOC	State of Charge
TBIDS	Topology Based Islanding Detection Scheme
TNSP	Transmission Network Service Provider
TOC	Table of Contents
STPIS	Service Target Performance Incentive Scheme
TUOS	Transmission Use of System
WPWF	Wattle Point Wind Farm
WTG	Wind turbine generators

1. Introduction

Energy Storage for Commercial Renewable Integration, South Australia (ESCRI-SA) is a project (the Project) which 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 WorleyParsons (the Consortium[1]), that jointly explored firstly the business case for such an energy storage device (Phase 1), and now the installation of a BESS (Phase 2).

This Project Commissioning Report (Report) covers the journey from financial close to commissioning of the ESCRI-SA Project, which is part funded by the Australian Renewable Energy Agency (ARENA). This Report represents one of the key Knowledge Sharing deliverables required under Milestone 3 of the funding agreement between ElectraNet and ARENA (the Funding Agreement) and follows on from the "Project Summary Report – The Journey to Financial Close" which was published in May 2018.

The intention of this Project Commissioning Report is to describe the journey and lessons learnt in getting the Project from financial close to Project commissioning. To do this, the Report includes all components of actual Project delivery through to commissioning.

Section 2 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 3 covers the journey from financial close to commissioning, broken out into a number of key areas of discussion.

Section 4 represents the core of the knowledge sharing material in this Report. First, an overview of delays and plan variations are discussed, followed by a detailed list of lessons learnt by category.

Section 5 provides introduces the role of the Project team and provides links to obtain more information about the Project, and to ask questions of the Project Team.

Appendices provide additional supporting material.

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1 The parties and their roles are described in Section 5 along with a contact for Project enquiries

2. Document Purpose and Distribution

2.1 Purpose of Document

This document is a public Report issued as part of the Knowledge Sharing commitments of Phase 2 of the ESCRI-SA Project, in accordance with the Funding Agreement. Knowledge Sharing is an integral component of the Project and a requirement of ARENA, who as 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, with Phase 1 of the Project completed in 2015 involving preliminary business case work and Phase 2 the actual procurement, installation, commissioning and operation of the asset.

The first public report on Phase 2 is the "Project Summary Report – The Journey to Financial Close" which was published in May 2018 detailing the approach and resolution of issues required to initiate the actual Project, [1], which is referred to herein as the "Project Summary Report".

This Project Commissioning Report focusses specifically on core components of the Project delivery, and lessons learnt on the journey from financial close to commissioning, including:

- Procurement
- Project management
- Risk management
- Environmental management
- Safety management
- AEMO Registration
- Commissioning
- Lessons learnt

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), available through the URL http://escri-sa.com.au/ described in Section 5.

2.2 Intended Distribution

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

3. The Journey from Financial Close to Commissioning

3.1 Basic Process to BESS Operation

Financial close for the Project was achieved in October 2017.

The EPC contract for the delivery of the Project was signed on 21 September 2017 between ElectraNet and Consolidated Power Projects (CPP) for a two-stage delivery model that aligned with the ARENA Funding Agreement Milestones 2 and 3. The first stage of this ended at BESS energisation (30 April 2018), with the second at handover for commercial operation (planned for November 2018).

A fast-tracked project delivery was used to align with ARENA's funding schedule and in an attempt to bring the asset on-line as quickly as possible, which meant limited technical analysis or detailed design had been undertaken at the time of financial close. This is not typical of utility projects, but given this, the journey from financial close to commissioning included the development of a detailed technical specification and ultimately a paralleled procurement approach.

This timeline also meant that at the time of site works progressing, network studies were simultaneously undertaken and generator models were developed in order to develop Generator Performance Standards (GPS).

After acceptance of the generator models, BESS commissioning and compliance tests were undertaken – including for connection to the grid, as well as testing of islanding functionality. Note: Integration of Wattle Point Windfarm during islanded operation is the only key outstanding functionality.

3.2 Energisation in the ESCRI-SA Context

A major milestone for the Project was energisation, which occurred on 30 April 2018. The term "energisation" here does not refer to the BESS importing/exporting energy. Rather, the term refers to the on-site transformers and 33kV switchgear being energised and operational.

As the AEMO registration process to allow grid operations had not been completed, the battery could not charge or discharge from/ to the grid. This is discussed further later in this Report.

3.3 Timeline Overview

There have been various delays on the journey to BESS commissioning compared to that expected from financial close, as reported in the Project Summary Report, [1]. An updated timeline with key dates is shown below.

Appendix A provides the final as-built construction schedule through to commissioning which provides more detail on the actual timeline performance.

Work stream / Event	Date
ARENA Funding	
• ARENA Conditional Funding Approval	13 April 2017
• ARENA Funding Agreement Executed	15 Aug 2017
• Amendment to ARENA Funding Agreement (Funding instalment agreement)	16 Oct 2017
• Project Completion Date (following two years of operation)	30 Sept 2020
EPC contract	
• Request for Proposal issued (revised functional specification reflecting updated revenue streams)	30 May 2017
• Request for Tender issued (containing full commercial terms and more detailed functional descriptions)	13 July 2017
• Notice to Proceed - Early works, long lead time items procurement, and design phase	17 August 2017
• EPC contract and Maintenance Service Agreement executed	21 September 2017
• Design work packages progressively completed	Oct 2017 - Dec 2017
• Practical completion	30 April 2018
Battery Operating Agreement executed	21 September 2017
Development Approval received	11 October 2017
Final Investment Decision by ElectraNet Board	October 2017
Undertake Network Studies	Sep 2017 - March 2018
Complete connection application and a complete market registration application lodged with AEMO	27 April 2018
Energisation of BESS	30 April 2018
AEMO review completed for proposed negotiated performance standards	29 May 2018
AEMO Registration Committee approves BESS generation connection	5 June 2018
BESS began taking load	5 June 2018
BESS commissioning and compliance tests	July 2018 - Oct 2018
Commercial Operation	November 2018 (planned)

3.4 Project Management

The Project was delivered in compliance with ElectraNet's normal project management methodology. The summarised plan for this is provided in the ESCRI-SA Project Management Plan provided in Appendix B.

Project delivery was broken down into three stages with the second of these covering the delivery and commissioning. Each stage had an approved budget, schedule and defined set of deliverables that had to be completed before the Project was approved and allowed to proceed to the next stage.

The Project Management Plan covers key elements for an on-time, on-budget and high quality delivery. This includes:

- Articulation of major Project drivers
- Project steering committee
- Key performance indicators
- Project delivery strategy
- Project scope management
- Project time management
- Project cost management
- Project quality management
- Project communication management
- Project risk management (discussed further below in Section 3.5)

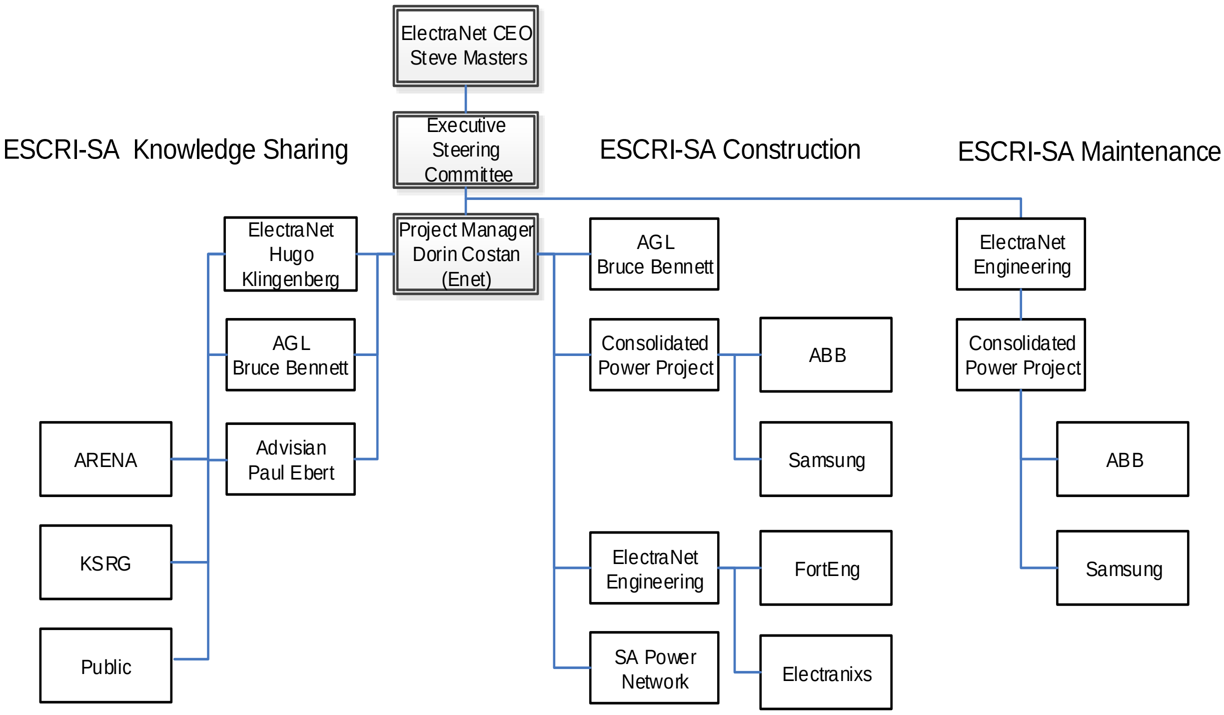
During Project execution the following actions were taken to manage scope, cost and risk:

- Regular review of Project risks as part of monthly Project team meetings or as otherwise required (out-of-ordinary circumstances).
- Regular reviews of Project budget by PM and Project controller.
- Regular (minimum monthly) reports and progress updates by all contractors. Monitoring Project progress by relating contractors' progress reports to baselined schedule and also confirming effective progress via ElectraNet personnel.
- Application of earned value in Project schedule allowing monitoring of Project performance via cost and schedule performance indices. Implementation of risk actions as per risk plan.
- Management of variations – as per ElectraNet policies, with variation claims review performed by Project manager, contract administrator, design manager and finally approved or disproved by contract Superintendent.
- Provided regular updates to Project steering committee; seeking steering committee's support for any situations requiring fast-tracked internal approvals.

- Involving ElectraNet or external resources in technical discussions, design reviews, testing and commissioning as per ElectraNet organisational chart, to ensure adequate Project support by authorised and adequately qualified personnel.
- Enforcing agreed communication protocol (especially for external parties), including implementation of ElectraNet's policies for RFIs and Instructions.
- Storing all agreed Project documentation in accordance with ElectraNet policies in ElectraNet's data management systems.

3.5 Project Delivery Team

The diagram below shows the core Project delivery team from ElectraNet in terms of roles, including the basic interactions with stakeholders and contractors.



3.6 Risk Management

The risk management plan for the Dalrymple Battery Storage Project was intended to develop and implement a process that would:

- facilitate the identification of Project risks that may affect the Project's ability to reach its objectives
- evaluate the likelihood of occurrence of these risks and potential consequences
- propose and implement mitigation strategies to facilitate either a reduction of the likelihood of occurrence or in the consequences that the risks may have on the Project

As part of the risk management plan, a Risk Register was developed that allows a formal recording and tracking of risks, mitigation and contingency plans. The Risk Register at the end of commissioning is provided in Appendix C.

The objectives of the risk management approach were to identify, evaluate, propose and implement mitigating or contingent actions for active risks.

Major Project risks identified in the Project Summary Report included regulatory classification of various assets, Project delays including that in achieving generator registration, development approval timeframes and availability of Project resources.

Since submission of the Project Summary Report, the additional major risks identified include:

- Project whole-of-life costs may exceed initial estimates
- Project revenue may be insufficient / may not cover Project costs
- Project resources may not be available when needed
- Inability to integrate the Wattle Point WF so as to provide seamless transition / operation under islanded conditions
- Gaps between the EPC contract (and associated performance guarantees by EPC supplier
- BESS ability to provide all services committed to by ElectraNet

Mitigation and contingency actions implemented to deal with these risks are detailed in Appendix C.

3.7 Safety Management

ElectraNet's priority is keeping our people safe from harm every day. We are committed to visible leadership in safety and a positive engagement with our contractors and suppliers. We are also committed to excellence in developing our safety management system and have recently been accredited to the new International ISO 45001:2018 safety standard in June 2018 whilst retaining our accreditation to the AS/NZS 4801 safety standard.

Our systematic approach to safety management was implemented on the ESCRI-SA Project in partnership with our Contractors during all phases of the Project.

As the key contractor, CPP developed a Work Health & Safety Management Plan, (refer Appendix D for a table of contents (TOC) of the plan), which defined the specific management for the Work Health and Safety (WHS) objectives and targets in relation to construction activities undertaken by CPP and associated Sub-Contractors with the ESCRI-SA Project, so that risk of injury could be minimised.

The plan set a high standard for this Project and a commitment to achieving it. Its primary objectives were:

- To provide, maintain and deliver a Project safely with a minimum of impact on the environment and to the required level of quality
- Provide a consistent and uniform approach which ensures that the required standards and safety legislation are attained and maintained
- Develop and implement a Safety Management System (SMS) which will guide, monitor, inform and document the delivery of the Project
- Instruct and train personnel in the use and operation of the SMS
- Monitor, audit and modify the SMS during the Project to ensure that the system is being used correctly, efficiently and within the guidelines of the relevant standards

To achieve this, the plan outlines a number of site policies, procedures and statements for all works carried out on the Site (relating to all CPP employees, engaged subcontractors and visitors) which includes:

- Safety performance indicators
- CPP's Safety Management Systems
- Internal audits
- Roles and responsibilities
- Information regarding training and induction
- Hazard Identification, Risk Assessment and Control (HIRAC)
- Event reporting and recording
- Chemicals and hazardous materials
- Traffic management

This Plan was adhered to diligently throughout the delivery of the Project. The below Table summarises the safety incidents recorded during delivery of the BESS, up to finalisation of commissioning.

Category	Number	Description
Material Handling	3	Worker injured finger when trying to catch airborne shrink wrap (while unpacking batteries)
		Worker rolled ankle when stepping on cable during installation
		Worker had hand cut when roof sheet he was carrying was blown by gust of wind
Vehicle accidents	1	Workers were travelling by car and were hit by another car that did not give priority. Incident occurred offsite.

3.8 Environmental Management

ElectraNet is committed to excellence in environmental management, with its Environmental Management System (EMS) having recently been accredited to the International ISO14001:2015 standard. This systematic approach to environmental management was implemented on the ESCRI project, with ElectraNet's expectations communicated to Contractors during all phases of the Project.

A Construction Environmental Management Plan was developed by CPP, (refer Appendix E for a table of contents (TOC) of the plan), describing the environmental strategy, methods, controls, and requirements for the execution of the Project. The goal of this plan was to minimise as far possible, any adverse outcomes (impacts) to the environment, the Project and associated personnel.

This plan explicitly contains plans/procedures related to:

- Soil management
- Flora and fauna management
- Waste management and minimisation
- Contaminated materials and regulated wastes
- Air quality management
- Water quality management
- Spill management
- Noise and vibration management
- Additional environmental, land and heritage management

This plan was followed diligently throughout the course of Project delivery.

Category	Number	Description, consequence and resulting action
Material Handling	1	Diesel spill Amount: less than 10 litres. Spill contained and cleaned up
Native Vegetation	1	One native tree, outside of the approved area was trimmed. The estimate is that ~10% of the overall canopy was trimmed and was deemed unlikely to harm the overall tree health. Action taken to prevent re-occurrence with site contractor

ElectraNet conducted three separate environmental site audits. The second site audit identified Native Vegetation violation. Corrective actions were raised and addressed with the contractor.

3.9 Hardware Procurement

In order to comply with the compressed Project timeframe, equipment had to be ordered without final design completed. In managing this, many work streams which traditionally would follow each other were progressed in parallel.

As a result, CPP under their contract bore the risk of error in hardware procurement, and relied on the experience of key personnel to be able to accurately forecast parameters for key plant.

Difficulties/ delays associated with procurement are discussed in Section 4.2.2.

3.10 Commissioning and Testing Plan

Core Commissioning

A commissioning plan was developed by CPP in order to test key functionality of the BESS. This is shown in Appendix F.

After successful BESS registration, which occurred on 5 June 2018, and following the passing of Hold Point Tests, the BESS could be dispatched by a registered market participant through AEMO's market systems. Therefore, representation from AGL was required throughout the commissioning process.

Hold Point Testing

It is a requirement of registration that during commissioning of plant they undergo Hold Point Tests to prove compliance with the GPS. This process was begun for the Project on 12 July 2018 and was completed on 7 September 2018 in accordance with the Hold Point Test plan.

The results of the initial hold point tests conducted in July showed some partial non compliances to the GPS. This necessitated a further round of parameter changes and associated simulations and review and approval by AEMO and ElectraNet.

The failed hold point tests were then repeated in early September showing improved behaviour with the recommendation that the BESS be accepted for commercial operation.

The results demonstrate that the BESS is capable of supplying the following services.

- 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
- Market trading of electricity within the South Australian National Electricity Market (NEM) region though the provision of market caps and Frequency Control Ancillary Service.

The testing was conducted at Dalrymple North Battery site with representatives from ABB, AEMO, CPP, ElectraNet, and FortEng attending and with support from AEMO and ElectraNet control rooms. The results have been reviewed and accepted by AEMO and demonstrate BESS performance alignment with the GPS/CPS.

Please see Appendix J for the results of the AEMO Hold Point testing.

The ESCRI-SA Project undertook islanding testing of the BESS in September 2018. These islanding tests demonstrated the BESS capability to supply the load of the Lower Yorke Peninsula region during times when supply to Dalrymple substation is lost, including black start. Islanded testing with the Wattle Point Windfarm is upcoming.

R2 Model Validation

R2 testing is used to validate the generator models submitted to AEMO match the behaviour of the physical plant to a certain tolerance. R2 testing is typically undertaken when all other commissioning tests are completed and all parameter changes are finalised.

R2 compliance is not required prior to market operation, as the generator response to extreme network conditions cannot be validated prior to the event. R2 testing is planned for after the Wattle Point Windfarm islanding testing has been completed.

Islanding Functionality & Wattle Point Windfarm Integration

Successful island tests with load occurred on 20-21 September 2018, this consisted of seamless planned and unplanned island creation and resynchronisation to the grid.

A successful black start test occurred 24 September 2018, this consisted of briefly interrupting the load to the Lower Yorke Peninsula, conducting switching to create an island and then letting the BESS perform load restoration and then resynchronisation in automated and manual modes.

Island tests with the windfarm is still to be conducted. This will consist of similar tests as the 20-21 September tests but with the windfarm connected as well, thus demonstrating the full island capability. These tests are waiting on AGL to install additional protection for the windfarm. Islanded tests should be conducted before R2 testing to allow for any changes to be fed back into this process.

Integration between the BESS and the windfarm park controller has been conducted by Vestas and AGL resources, this allows the BESS to send the windfarm a dispatch target when in islanded operation (the BESS will form the slack). The islanding detection scheme functions that will rapidly open collector group circuit breakers to reduce excess windfarm generation within the island have also been commissioned.

Diesel Generation

In order to reduce the delay in registration, it was specified that charging from diesel generation could be used to enable partial commissioning tests whilst BESS connection to the grid was not yet approved. However, this contingency plan was not executed.

3.11 Commissioning Process and Results

Initial Hold Point Testing

Hold Point 1 testing was carried out 12-13 July 2018. Initial Hold Point 2 testing was carried out 18-20 July 2018.

Some elements of the BESS performance did not match the performance simulated with the R1 Model Parameter Set. However, it was shown that using a Site Model Parameter Set based on values used by ABB on site, the simulations could better match the measured performance.

The BESS maintained stable operation below +24 MW in discharge mode and up to -30 MW in charge mode for the duration of Hold Point 2 testing. (A -30 MW measured output was not attained during Hold Point 2 testing.) When discharging above +24 MW the BESS exhibited active power and reactive power instability.

Additionally, when in voltage control mode, the generating system reactive power rise time for a voltage setpoint change of ±5% was not consistently less than 2.7 seconds as required by the GPS negotiated access standard.

The generating system also did not regulate the voltage at the connection point to within 0.5% of its setpoint.

At dispatch output greater than +24 MW, the generating system did not regulate the power factor at the connection point to within 0.5% of its setpoint.

The generating system maintained stable operation when automatically transitioning from power factor to voltage control mode when the voltage at the connection point deviated outside of ±5% of the site normal operating voltage (1.05 pu to 0.95 pu). However, when discharging, the generating system transitioned from power factor control mode to voltage control mode before exiting the low voltage threshold of 95% of the site normal operating voltage.

Finally, the generating system current limiter was observed to activate at a lower current magnitude than the programmed activation threshold. After the current limiter activated the generating system tripped off. The generating system did not maintain continuous uninterrupted operation when operating into the temporally reduced programmed limits of operation.

As such, further refinement of the control system by ABB was required in order for the BESS to be GPS compliant.

Additional Testing

A post-test workshop was undertaken in Adelaide with representatives from ABB, CPP, FortEng and ElectraNet to discuss the results of the hold point tests. After conducting further studies ABB refined a selection of control systems parameters as well as released another minor model update. FortEng, ElectraNet and AEMO conducted due diligence on the parameter changes in relation to how this had changed the behaviour of the BESS when compared to the GPS. The new parameters were approved for grid connected operation by AEMO and ElectraNet on 4 September 2018. Agreement was also obtained with AEMO about what tests should be repeated.

Hold Point 2 repeat testing was carried out 6-7 September 2018.

The generating system maintained stable operation above and below +24 MW in discharge mode and up to -30 MW in charge mode for the duration of Hold Point repeat testing. During initial Hold Point 2 testing (July 2018), when discharging above +24 MW the generating system exhibited active power and reactive power instability, and when charging it could not reach charging levels beyond ~28.8 MW. These issues have now been resolved with the updated parameter set and no instabilities were observed during the Hold Point 2 repeat tests.

When in voltage control mode, the generating system reactive power rise time for a voltage setpoint change of ±5% was not consistently less than 2.7 seconds as required by the GPS negotiated access standard. These reactive power rise time responses have previously been discussed with AEMO and ElectraNet and this is not considered a significant issue. AEMO and ElectraNet have agreed negotiation of this requirement will be undertaken and the associated GPS has been updated to reflect actual plant performance.

The generating system does not regulate the voltage at the connection point to within 0.5% of its setpoint. The largest average voltage regulation accuracy error observed in steady state after a ±5% voltage setpoint change from normal operating voltage was -0.81% error for a +5% step and +1.64% error for a -5% step. This has previously been discussed with AEMO and ElectraNet and it has been agreed that negotiation of this requirement will be undertaken, and the associated GPS clause will be updated.

The generating system maintained stable operation when automatically transitioning from power factor to voltage control mode when the voltage at the connection point deviated outside of ±5% of the site normal operating voltage (1.05 pu to 0.95 pu). As observed in initial Hold Point 2 discharge tests (July 2018) and observed again during Hold Point 2 repeat tests, the generating system transitioned from power factor control mode to voltage control mode before exiting the low voltage threshold of 95% of the site normal operating voltage for one second.

The generating system maintained stable operation for the duration of the test and when operating into and at its reactive power limiters.

The generating system active power, reactive power and voltage settling times for an equivalent ±5% voltage step with half of the generating units operating at maximum output were less than the GPS required 7.5 seconds.

The generating system operated as expected and the limiters activated correctly at the defined activation threshold at the inverter terminals.

The PSS/e simulation incorrectly activated its reactive power limiter based on the connection point reactive power flow instead of the inverter reactive power flow. This issue may require a minor update to the generating system model and/or model parameters, so the limiters can reference the correct power flow prior to R2 testing. However, it is not considered likely to have significant impact on simulations conducted to date and the site plant has been verified to operate as expected when stepping into its reactive power limiters.

The updated parameters proposed by ABB on 24 August 2018 have resulted in a significant improvement in generating system operation and stability from the R1 settings approved at registration in June.

The Hold Point 2 test report recommended that some GPS clauses are renegotiated with AEMO. This has occurred with an updated GPS version registered with AEMO.

Please see Appendix J for the results of the final AEMO Hold Point testing.

3.12 Community Consultation

The site is isolated and remote. There was no additional community consultation superseding information outlined in the Project Summary Report, [1].

3.13 Stakeholder Engagement

Stakeholders, their interests and expectations are unchanged from previous sections of the Project. Refer to the Project Summary Report,[1], for further information.

3.14 Registration

The process of registration for the Project proved to take longer than anticipated and was a significant hurdle. The key challenges causing the majority of Project delays are discussed further in Section 4.2.1.

End-to-end, the registration process covered the following elements and time period:

- Modelling of the Project to seek compliance/non-compliance with the Rules, and to discern the likely Generator Performance Standards (GPS) (this process began around Oct 2017)
- Connection application received by ElectraNet and AEMO from AGL, including GPS and ESCOSA assessment
- Due diligence of GPS by ElectraNet and AEMO
- Update EMMS and NEMDE constraints to include battery system
- Due diligence of GPS by AEMO to AGL
- AGL submission ESCOSA Generator licensing application

- AGL Sign off metering application
- Submission of Commissioning Test Plan to AEMO
- Completion of SCADA and telemetry works including AGL, AEMO and ElectraNet control rooms
- ESCOSA Board approved BESS generation licence (occurred 16th May 2018)
- AEMO Registration Committee approved BESS registration on 5th June 2018

To achieve the first point above, the Contractor was required to provide a mathematical model of the BESS that represents the structure and performance of the plant and which was suitable for network modelling and studies.

The BESS model was required to show compliance with AEMO's Generating System Modelling requirements, and aligning with the GPS. The BESS could not be connected to the network before it was successfully registered with AEMO.

Present rules dictate that the BESS is to be registered as both a generator and a load due to the bidirectional current flow. A third party was engaged on behalf of ElectraNet to assist ABB in the analysis and development of these models.

ABB (via CPP) was required to provide a power system model of the BESS generating system/ charging load in both PSS/e and PSCAD (two industry-standard modelling software packages), including any MV (11-66 kV) reticulation and zero sequence parameters, with the rest of the NEM represented as a simplified Single Machine Infinite Bus (SMIB) model.

For generator compliance, generator functionalities needed to be demonstrated including:

- Generator model for a given BESS inverter
- Frequency control/ governor model
- Voltage control/ automatic voltage regulation (AVR)
- Over and under-frequency runback/run forward/tripping
- Over and under-voltage tripping
- Damping such as Power Oscillation Damping (POD)/ Power System Stabiliser (PSS), if available
- Park-level coordination control models of the above, as required

3.15 Construction Images and Drawings

A series of construction photographs of the ESCRI-SA facility can be found in Appendix G. The as-built Project Site Plan for the completed ESCRI-SA BESS is provided in Appendix H. The as-built electrical Single Line Diagram for the completed ESCRI-SA BESS is provided in Appendix I.

4. Knowledge Sharing and Lessons Learnt

4.1 Knowledge Sharing Plan Overview

Knowledge Sharing activities have received specific focus during the Project and will continue until two years post commercial operations starting.

The ESCRI-SA Project has a strong knowledge sharing focus with associated objectives and activities. In summary, these aim to:

- Demonstrate the equipment, services and role of transmission level batteries in the NEM
- Improve understanding of technical constraints and actual performance of battery assets in providing both market facing and regulated services
- Demonstrate experience with and improved understanding of the elements which come together to deliver a utility level battery storage asset
- Improve public awareness of battery assets
- Development of the ESCRI-SA data portal, now available at www.escri-sa.com.au. Its functionalities include SCADA-style display of the BESS and surrounding assets, downloadable data sets and access to additional knowledge sharing information.

Knowledge sharing material is now accumulating on the Portal, with specific information now available at https://www.escri-sa.com.au/knowledge-sharing/.

4.2 Delays and Variation to Plan

There have been a number of delays and associated causes. These are outlined in the following sections.

4.2.1 GPS and Registration Delays

Generator modelling, GPS and registration delays comprised the majority of Project delays post financial close, adding approximately four months to the Project schedule. As this transpired, the delay was difficult to estimate and continued to grow. Additionally, the rework required throughout this process added costs to the Project.

Key reasons for this delay were:

- Battery technology and the subsequent demonstration of BESS Generator Performance Standards is still new to the industry, including AEMO
- The Project contains added complexity over a normal grid-connected asset, as the battery must also show compliance with islanding functionality which is a first within the NEM for battery systems
- Requirements for off-grid operation drives some of the requirements for on-grid operation, so the battery must always be ready for off-grid behaviour

- BESS features required for islanding did not always equate to an optimised solution for grid-connected capability, and design iterations were required which needed to be updated in the models
- After updating the model to reflect control system updates, it was difficult to isolate model implementation issues from those arising from functional changes
- Model debugging and validation by ABB and partner consultants were based on network assumptions which were different to the assumptions used by client consultants
- Loss of version control - there was a multitude of circulating versions, considering the joint effort to finalise models
- Communication delays (e.g. the formality of going through third parties to access specific external personnel)
- Limited familiarity with the Frequency and Power clauses of the NER within ElectraNet – typically such areas are not reviewed by a Network Service Provider

The modelling delays masked a small number of equipment delays, although they did not impact on the Project as they were not on the critical path.

4.2.2 Procurement Delays

Station Transformer

Transformer delivery time is traditionally 6-8 months, and circuit breakers approximately 6 months. Orders needed to be placed on these key items prior to a detailed technical specification of the BESS being developed, trusting that adequate back-engineering would be possible.

The largest risk borne by CPP was sizing the AC supply, before the technical specification was completed. Prior to completion of this specification, the station transformers could not be rated accurately, as the required load could not be forecast, neither could its required sensitivity to fluctuations. Station transformers were commissioned during energisation of the BESS.

To adhere to the Project timeline, CPP ordered transformers identical to those supplied from the vendor previously (i.e. ABB), with CPP having to adapt the BESS designs to suit the transformer. Had CPP required a newly-design custom transformer, it is certain that the 8-month Project deadline would be overrun.

There were small delays associated with the transformer delivery due to the long lead-times of the assets. However, the transformers were not on the critical path due to the delay which occurred in relation to the GPS.

Bus Duct

Customised bus ducts were sourced from the Czech Republic. Due to this being a customised design, with a special 90 degree bend to suit the BESS layout, CPP was required to work with the supplier to ensure the customised requirements could be met. Due to a long winter, there was a logistical delay in shipping from the port.

Fortunately, the bus ducts were not on the critical path due to the delay with resolving the GPS.

Design Standards - Cabling

A design standard deviation was requested from CPP in order to enable timely delivery of the Project. As a result, one cable approximately 30m in length is aluminium, not copper as per ElectraNet's design requirements. Aluminium cable is roughly three times faster to procure.

Had this standard deviation not been approved by ElectraNet, it is possible cable procurement would have assumed the critical path.

Battery Control Panels

Difficulties were noted with the development of Battery Control Panels (BCP), which were designed by ABB. It was found that there was little electrical equipment rated to handle inherent characteristics of batteries connected in parallel. For example, traditional solar circuit breakers cannot tolerate the high short circuit capacity. Most equipment is rated for a short circuit current for approximately 3 seconds (as per IEC standard). However, batteries exhibit 2-3ms battery overcurrent and the BCPs required large disconnectors and added research.

It is believed that Samsung and other vendors are now selling battery units along with BCPs, removing this issue for future projects.

The BCP's were not on the critical path due to the delay with GPS.

4.2.3 Logistical Delays

Staged design was required due to faster delivery timeframe. The Project team had to define a minimum set of requirements to be able to purchase equipment, and any level of error was borne by the Project.

Earthing and fire suppression requirements were large considerations for the design.

No delays were noted for logistical reasons.

4.2.4 Commissioning Delays

Model Discrepancy

During commissioning (prior to Hold Point Testing) it was noted that there was a discrepancy in parameter settings from FAT, PSS/E and PSCAD models.

This required a number of parameter changes to align the models, and then additional simulation to ensure that these changes resulted in no adverse behaviour, resulting in significant rework and delays.

Oscillations in Islanding Mode

It was noted during PSCAD studies that oscillations appeared in islanded mode, under certain situations with the R1 parameters.

These oscillations were also evident during a failed island test on 10 July 2018.

The subsequent parameter updating to remove this and requisite studies caused commissioning of this section to be moved back in the schedule.

The test plans were later modified to stage the tests with the load and then with the windfarm, this change in methodology lead to detection of further oscillations in simulation which were resolved with a single parameter being adjusted. AEMO provided approval for change on 19 September 2018.

The oscillations are related to an interaction with transformer saturation evident when at low active and reactive power levels within an island.

SCADA Delays

AEMO requires an explicit set of SCADA values to be made available to them at all times. These include the available capacity of the BESS (see Rules clause 5.2.6.2 [2]). Due to a miscommunication, the length of time for commissioning of these SCADA points was underestimated.

Additionally, some of the AEMO SCADA requirements were only confirmed as part of this Project and were slightly changed when compared to other similar projects.

This accounted for a delay in registration of approximately one week.

Plant Difficulties

An AC breaker was noted as broken during the commissioning phase. This equipment has very low failure rates, and therefore no on-site spares were kept. Commissioning was able to proceed without this breaker, and this did not delay the Project.

Additionally, two of the inverters (out of a total of 32 x 12 in use) failed during commissioning. However, ABB had adequate spares on site and there was no Project delay. Should spares have not been kept on site, the inverters would have taken approximately 2-3 weeks to arrive.

There was a static VAr compensator out of service at the Wattle Point Wind Farm during the integration testing. However, no delay was caused.

Firmware Upgrades

ABB has built custom interfaces to match specific battery brands currently available. During commissioning, a battery firmware upgrade was required by Samsung, which required a re-build of the battery interface. This caused a delay of approximately one week.

4.2.5 Unforeseen Technical Issues

In reviewing the commissioning results, it has come to light that the fast frequency response of the BESS may lead to transient overloads of the batteries when the BESS is already discharging into the grid at the time. CPP and ABB are investigating this and a targeted test is planned to determine whether this is a concern or not.

4.3 Lessons learnt

There are two categories of lessons learnt from this Project:

- Lessons learnt specific to the fast-tracked timeline.
- Lessons learnt due to the inherent nature of the Project, and it being one of the first of its kind in the Australian context.

These are summarised in specific categories in the following Sections.

4.3.1 Generator Modelling and GPS

The majority of delay in the Project has been from difficulties with acceptance of the generator models. Specific lessons learnt include:

- Contractor should demonstrate model compliance prior to contract award.
- It is crucial for the Original Equipment Manufacturer (ABB) to have a working understanding of the regulatory requirements (i.e. Chapter 5 of the NER) and any jurisdictional requirements 2 (i.e. ESCOSA license conditions in SA).
- Start early engagement with AEMO.
- Models are repetitive in nature, and it is likely that models will pass compliance testing faster if the company has demonstrated experience in the NEM and AEMO is familiar with the generator configuration.
- Ensure tight version control of models.
- Model development must be closely coupled with control system development, and between PSSE and PSCAD - so during times of any control system development, ensure a model design freeze.
- Ensure clear and direct lines of communication between teams working on the models, even if from different companies.

4.3.2 Scope Definition

Given the very ambitious timeline of the Project, the engineering contract specification used for the original tender included some requirements that were not fully defined. These requirements were then refined during the design phase of the Project. The general lesson learnt is that the more complete the original specification is, the less issues present themselves during project execution.

One example is the holding of critical spares. The tender requirement was for the BESS to have an availability of 96%. Tender responses complied with this requirement, but assumed that critical spares would be available. This resulted in additional negotiations to obtain the required critical spares.

4.3.3 Project Management

The co-operation required in this Project due to its innovative nature technically and commercially, is relatively unique, meaning roles are sometimes blurred. For example, contractually AGL is the market participant so is responsible for market registration of the BESS. However, ElectraNet were proactive in engaging third party assistance (supported by AGL) to help with model development and are managing day-to-day activities. Therefore, accountabilities are difficult to ascertain. A specific lesson learnt was to ensure clear ring-fencing of accountabilities in the Project scope and associated contract documentation.

4.3.4 Clarification of Project Specifics

The Sections below out-line key components of the ESCRI-SA Project which would have benefitted from clearer specifications. These detail of these specifications were not known during contract award as most were developed as part of the Project. Attention should be paid to the below components in future projects, with clear definition and expectorations early in the Project.

1. Use of Voltage Source Inverters (VSIs)

   Power System inverters such as those in grid-connected solar farms are traditionally configured as Current Source Inverters (CSIs). However, the ESCRI-SA BESS has been configured to operate as a Voltage Source Inverter (VSI), enabling regulation of the voltage and frequency (grid forming) on the lower York Peninsula when operating in islanded mode.

   The Voltage Source characteristic is an intrinsic element of the hardware, existent even when not operating in islanded mode.

   VSIs, in comparison to CSIs, typically consume a higher auxiliary load in these high-speed switching environments. This impacts the minimum round-trip efficiency which is guaranteed by ElectraNet and ElectraNet will have to pay close attention to this during the operational phase of the Project.

2. Overload Capacity

   It was assumed by AGL, that AGL would be able to benefit from the overload capacity of the BESS, as the requirements for FFR are assessed across the portfolio of a market participant (not on a per-generator basis). However, the Samsung battery cells have no overload capability.

The inverters have a 200% overload capability, and this can still be used for reactive power which is useful for protection measures in the event of a fault. But there is no capability to provide overload real power.

A lesson learnt for future projects is to differentiate overload capability of a Project into real and reactive power to avoid confusion.

3. Definition of BESS Cycle

The “definition of cycle” is a critical component of BESS operations and contracting. According to the Battery Operating Agreement as it currently standards, a “cycle” constitutes a discharge of the BESS of more than 2.4MWh that passes through a state of charge of 2.4 MWh. Cycles are counted in both grid connected and islanded modes, and there is to be no more than 250 cycles per year.

As the Project implementation progressed it became clear that the definition of a cycle has some limitations. This current definition was based on the knowledge that limited degradation occurs between 60-90% state of charge. However, this did not account for the ability to then undertake heavy cycling in the upper half of the BESS. Although less degradation occurs when the BESS is between 60-90% state ofcharge, this value is still non-zero and therefore must be accounted for. Currently, the Contractor (CPP) absorbs the risk of guaranteeing battery capacity after 12 years based on this limited definition of cycle.

A lesson learnt for future projects is that a more granular usage definition should be used which can ensure that no project participants are exposed to unnecessary risk. This adjusted definition could instead rely on the total MWh throughput.

4. Resting Requirements of Battery

Recent information from Samsung shows that the batteries require “Resting Time” after a fast charge. A fast charge is likely to be initiated when the battery is significantly depleted and a high wholesale price is considered likely in the near future, or when there is a floor wholesale price at the time of charging.

In guaranteeing 30 MW capacity after 10 years, CPP have placed an upper limit of 250 Cycles per year, which includes up to 35 fast charge cycles.

ElectraNet has guaranteed an asset availability of 96% and a minimum cycle roundtrip efficiency. However, the information regarding resting requirements was not known at the time of calculating an availability guarantee.

If the resting requirement does not impact on the availability guarantee, it will still impact AGL as there is an opportunity cost whilst the BESS is not available. Note that the resting requirement was not included in the operating contact, although it was listed in the functional description.

A lesson learnt for future projects is that resting requirements exist for batteries, which if not complied with can accelerate battery degradation. Ensure all information is sourced prior to procurement and accounted for in planning.

4.3.5 Fire Suppression

Meeting relevant fire suppression standards impacted a large component of the final design. CSIRO assisted with the fire-related studies, which was discussed with the South Australian Country Fire Service (CFS).

A thorough analysis of the intensity, bi-product and propagating potential of a thermal runaway of the battery was conducted. As a consequence of these studies, the design of the building was changed.

The final design utilises a compartmentalised layout with the inverters in separate rooms to the battery cells. The design uses an inert gas for fire suppression, which allows humans approximately 30 seconds to exit the enclosure, with redundancy for supplying gas bottles.

Additionally, CPP had to demonstrate to the CFS that the BESS would:

- Withstand an ember attack, and that no thermal runaway on-site would occur due to an external fire.
- No internal fire within the BESS could propagate to external fields.

Lessons learnt include:

- Place high importance on understanding the local fire-related standards as it is likely that these requirements will govern the basis for Project design.
- Converters will not catch fire unless fire is propagated to them.

4.3.6 Interaction with Vendors

Language Barrier

CPP noted a language barrier with vendors, where identical vocabulary indicated differing items/meanings which contributed to Project difficulty with an inability to confirm design inputs. Lessons learnt include:

- Be explicit and consistent with vocabulary usage from the start, backing up specifics with diagrams or relevant explanatory material where possible.

After-Sales Service

CPP had difficulty in obtaining information pertaining to the battery cells once the units had been procured. This related to three particular issues:

- Specialised switch gear in-between the battery and inverters had to be designed and sized, based off short circuit current and associated aspects.
- CPP obtained information about the resting phase after a fast charge, and required more information to understand the impact on the Project.
- Information regarding maintenance schemes for the cells.

Outside of language barriers and a different working culture, delays were noted due to unexpected holidays in South Korea, where the batteries were manufactured. Lessons learnt include:

- Be cognisant of public holidays and differing working schedules of vendor home countries.
- Prior to procurement, discuss with vendor the appropriate way to obtain any post-sale assistance or information - although this is non-binding, it will allow for a common understanding.

4.3.7 Commissioning and Testing

Communication & Coordination

One of the biggest challenges during commissioning was communication between the interfacing parties. Contractually, companies had to go through official channels to communicate at the managerial level.

- Lesson Learnt – For quicker communication between parties, develop a clear commissioning lead from each team/company (single point of contact for each company), with individual roles more rigorously defined, and an org chart well displayed and enforced.

At times there were noted communications breakdowns, pertaining to protection system testing/assessment, SCADA and on-site support at interfacing plant locations.

- Lesson Learnt – Be cognisant of AEMO's required SCADA points under Clause 5.2.6.2 of the Rules. Engage AEMO early to ensure on-time collaborative commissioning of these points.

Additionally, one Inspection Test Report (ITR) was slightly delayed due to an underdeveloped risk assessment for interfacing plant, where the fault current to trip the Wattle Point Wind Farm had not been calculated during the planning phase, and it was not understood if the wind farm could be black-started from the BESS.

- Lesson Learnt – Initiate weekly meetings earlier in the Project process, involving commissioning team representatives as well as the asset owner and market operator. (This will help develop buy-in and accountability from stakeholders during ITR development, as well as a common understanding of all tests.)

Adjusting of Models during Commissioning

As noted throughout the Report there were numerous changes in models and parameters during the Project. Lessons learnt include:

- Be cognisant of how to deal with changes in parameters and how it complies with the GPS. Main changes were due to physical limits of the plant, some relate to speed of response (inertia gains), and some relate to voltage control (changeover, droop and bandwidth).
- Model/parameter changes are the responsibility of the contractor, ElectraNet, FortEng and AEMO to assess these changes for compliance. There may be a

temptation by those assessing the changes to propose solutions but it is best if the contractor is left to address these lest the lines of responsibility be blurred.

- Performance standards can be negotiated (within limits).

Registration of Asset

ABB ran approximately five weeks of tests before export to the grid, which could have been conducted in parallel to generator registration proceedings if initially registered as a load. (For this, the batteries would charge and discharge to each other to test charging characteristics). This will also save on diesel, as the auxiliary load could become grid-connected earlier. Lessons learnt include:

- If possible, register the BESS as a load prior to registration as a generator such that initial testing can be undertaken as soon as possible. This would have mitigated the impact of registration delays which were significant in this Project.
- Note – New exemption pathways for BESS's as load for early testing are underway by AEMO.

Interfacing with Local DNSP

ElectraNet does not have authority to operate SA Power Networks (SAPN) equipment, so CPP was required to submit notices to SAPN and request available personnel. Ample notice was required for these events, with the dates being inflexible such that small delays were often amplified (having to re-submit the request and wait for personnel availability).

Additionally, CPP could not obtain the circuit breaker states of SAPN's network. This required more complex design work using load and current estimations.

- Lesson Learnt – Give ample notice to local NSPs regarding works, understanding that these dates are inflexible once accepted. If these dates require changing, the DNSP may not be able to shift linearly with the schedule delay.

Plant Interfaces

The Islanding Detection Scheme (IDS), was delivered by ElectraNet and interfaces with the BESS control scheme (opens circuit breakers to create the island and tells the BESS when it is in an island), over the evolution of the Project, additional actions were transferred to the IDS from the BESS control scheme. This caused some misalignment between the various parties which resulted in late changes.

The Wattle Point Windfarm is an aged asset with limited support available.

- Lesson Learnt – The interface between plants represents an area of high risk. Documentation on IDS functionality changes could have been improved. Initial discussion with AGL regarding potential bench testing/offline testing could have commenced earlier.

Plant Interface Risk Analysis

After analysis, it was found that the inrush current (when energising a transformer) for the windfarm transformers were rated three times higher than the BESS. Given this, without intervention the inrush current if energising the transformer from the BESS could trip the BESS. A new relay was used to stop this inrush.

- Lesson Learnt – There are additional risks borne by assets due purely to plant integration, and these risks must be assessed by all parties.

Offline Testing Facility

ABB conducts desktop testing of their equipment in their Darwin testing facility. This proved to be very beneficial for the Project. It was comprised of a small cut down version of the ESCRI-SA system - 1 inverter, one Powerstore controller, 2x feeder controller, wind controllers and network controllers.

Therefore, ABB was able to run all test cases on a smaller scale system, with the results of the Factory Acceptance Testing (FAT) able to be back-fed into the models.

Firmware Upgrades

During commissioning, a battery firmware upgrade was required by Samsung, which needed a re-build of the battery interface and caused a minor commissioning delay.

- Lesson Learnt – Limit as far as reasonable the chance of firmware upgrades from battery providers. Implement design freezes.

4.3.8 Safety and Islanding Detection

Islanding was one of the most complicated areas of the Project and brought up many unforeseen issues. This included the inability to provide sufficient fault current to support protection mechanisms during an islanding event if the BESS lost two or more (of six) transformers.

Consequently, the BESS is required to implement anti-islanding procedures for this and other scenarios.

If fault current is not adequately implemented, then the system will not be able to identify between high load current and fault current. As such, this becomes a safety concern.

Additionally, the electricity network on the Yorke Peninsula is weak, and power swings could simulate islanding. Given this, the team has used a topology-based methodology to identify when islanding is occurring. This is reliable, but computationally expensive regarding the number of switchgear configurations.

- Lesson Learnt – Network analysis and investigation of fault current requirements should be undertaken early into the Project where islanding is envisaged.

If infrastructure changes in SA Power Networks distribution system were to be large, this would have required large cost. Fortunately, only relatively minor changes were required.

4.3.9 Hierarchy of Constraints

There has been hierarchal requirements which have governed the way components of the BESS Project were designed. If the hierarchy is clearly understood during early design phases, final designs can be achieved in a rapid timeframe by remaining cognisant of and integrating parent requirements.

- Lesson Learnt –The below outlines this hierarchy of influence as observed for the ESCRI-SA Project.

    1. Operational Requirements.
    2. Battery configuration by Samsung (Information on stacks, width, orientation).
    3. Fire related insights (Detection of fire and suppression method).
    4. Shed size and compartmentalisation.
    5. Position of inverters inside shed and placement of transformers outside of shed.
    6. Link between transformers and inverters, requiring bus duct design.

4.3.10 Additional Information / Learnings

The complexity of developing an integrated grid and island BESS solution was underestimated in time, effort and cost, resulting in setting very ambitious expectations for the Project.

This included:

- Modelling and commissioning of the BESS system to meet NER requirements
- Expertise and experience of this type and application of a BESS in the NEM has resulted in multiple model revisions
- Deeper network changes on the planned island distribution network (local load)
- Integration with the Wattle Point Wind Farm, due to the age and lack of available models of the wind farm

Concerns for Market Operator

The ESCRI-SA BESS is more energy constrained than other dispatchable plant on the network. Even when fully charged it can only generate at full output for approximately 15-20 minutes and, when the battery is fully discharged, it can no longer be bid into the market as a generator.

AEMO systems are not able to fully integrate the dispatching of such plant at this stage, as 30 minute bids are submitted.

AGL is currently developing new bidding software to provide automatic rebidding, which was not available during initial commissioning. A manual workaround was used during commissioning until the final bidding system was complete.

- Lesson Learnt – Re-bidding capability required for assets with lower energy capacity. Therefore, AGL must re-bid in the market given updated knowledge of BESS available energy capacity.

Shed Design

The timeframe for delivery of containers would have taken approximately 6-8 months to get to site which would have made the Project timeframe unfeasible. This forced the development of the co-location of the batteries and the inverters in a permanent shed.

Each container would have needed its own fire suppression system, duplicated air conditioning and other elements. However, for a building redundancy could be built into the design as a whole, not on a per-container basis. The equivalent of the ESCRI-SA shed building solution was a 24 container design.

- Lesson Learnt – Container vs. shed design must be assessed on a project-basis. Different conditions favour different selections.

Air Conditioning Requirements

There are options for fluid-based heat exchanges for plant cooling. However, traditional air conditioning methods were used for the ESCRI-SA design. Lessons learnt include:

- Do not underestimate the load for air conditioning. ESCRI-SA air conditioning contains 10 x 150 kW of heat transfer, resulting in approximately 1.5 MW electrical load when at maximum capacity, which occurs during a major charge/discharge event.
- Cooling is not necessarily driven by ambient temperature, but more cycling and losses from the batteries themselves.
- Temperature control is not just for cooling the devices down. Below 21 degrees the batteries used for the Project degrade, they must be kept within 23-28 degrees.

Lack of Incentive for Suppliers

This Project naturally required a sense of urgency given the tight timeframe.

Despite the high profile-nature of the Project, when the total delivery of the Project is broken down into individual components and associated values, it is minor for large factories that typically produce the required equipment. Given this, there was no special incentive to apply any fast-tracking for equipment supply from suppliers, and any accelerated vendor delivery relied on special relationships between ElectraNet, CPP, ABB and Samsung.

Better Understanding of Droop Characteristics

Until a separate category is created for them, batteries must be registered as both a generator and a load in the AEMO market systems.

The battery must satisfy the specific performance standards for a generator to get registered. This includes responding to frequency droop, where the asset can provide continuous frequency response at extreme frequencies.

AEMO have recently managed to apply the rules to the ESCRI-SA battery in a way that avoids impacting its ability to register the full 30 MW for Frequency Control Ancillary Services without conflicting with generator registration obligations.

Lessons learnt include:

- Droop characteristic generator requirements can reduce available BESS capacity to be bid into the FCAS market.
- It is possible to negotiate a mutually beneficial output requirement with AEMO.

5. 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), we are a critical part of the electricity supply chain. We build, own, operate and maintain 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 will own and maintain the 30 MW 8 MWh battery, which will provide 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. Our 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. When complete, AGL will operate the battery to provide competitive market services.
Advisian WorleyParsons Group	Advisian is the advisory and specialist consulting arm of WorleyParsons, who have 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 Advisian is the Knowledge Sharing Partner for the Project.

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

This Portal contains a range of information relevant to the Project, 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
- The ability to ask questions of the Project team through an on-line Q&A process

6. References

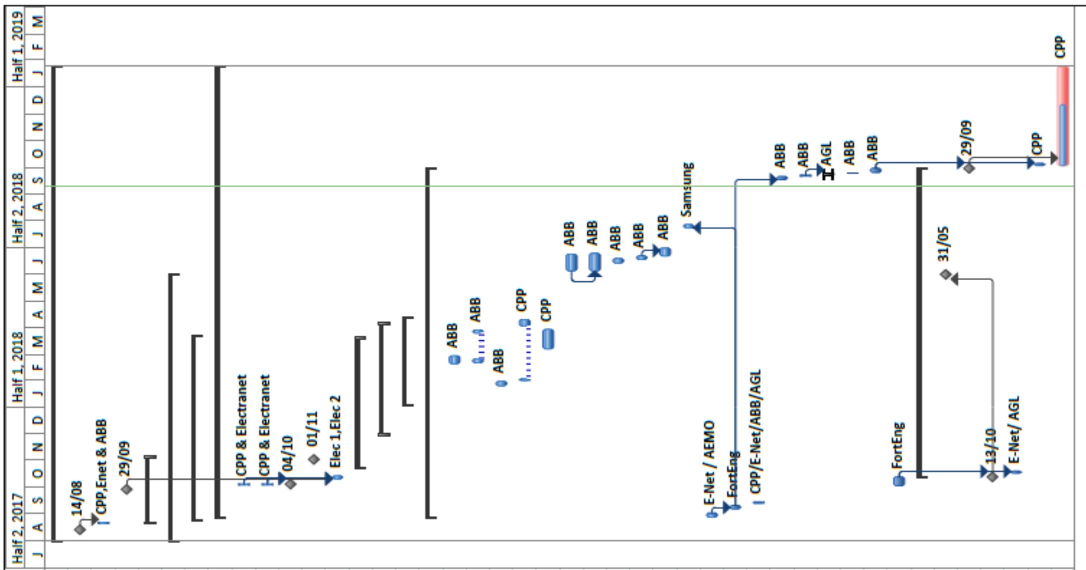
[1] “ESCRI-SA Project Summary Report”, ElectraNet, May 2018

[2] “National Electricity Rules Version 111”, Australian Energy Market Commission, 2018, see https://www.aemc.gov.au/regulation/energy-rules/national-electricity-rules/current

Appendices

Appendix A As-built Construction Schedule

ID	Task Name	% Complete	Duration	Start	Finish
1	ESCRI Early Energisation	98%	295.2 days?	01/08/17	23/01/19
2	Contract award	100%	0 days	14/08/17	14/08/17
3	Kick Off meeting	100%	0.8 days	21/08/17	21/08/17
4	DA Approved	100%	0 days	29/09/17	29/09/17
5	Management plans	100%	44 days	22/08/17	04/11/17
14	Design	100%	167.2 days	01/08/17	31/05/18
37	Procurement	100%	115.2 days?	25/08/17	22/03/18
64	Construction	93%	280 days	28/08/17	23/01/19
65	Construction risk workshop- Part 1	100%	0.8 days	04/10/17	04/10/17
66	Construction risk workshop- Part 2	100%	0.8 days	04/10/17	04/10/17
67	Possession of site	100%	0 days	04/10/17	04/10/17
68	Construction ITPs- Civil	100%	0 days	01/11/17	01/11/17
69	Mobilisation	100%	2.4 days	11/10/17	13/10/17
70	Civil Works	100%	80.8 days	23/10/17	20/03/18
86	Electrical Install	100%	65.6 days	30/11/17	05/04/18
102	BESS Install	100%	55.2 days	03/01/18	12/04/18
142	Commissioning & Energisation	60%	224 days	28/08/17	29/09/18
143	Pre -commissioning Power Stores 1-6	100%	6.4 days	19/02/18	27/02/18
144	Pre -commissioning BCP's 1-6	100%	6.4 days	20/02/18	29/03/18
145	AC distribution board commissioning	100%	1.6 days	25/01/18	29/01/18
146	HV Switchboard Commissioning	100%	5.6 days	31/01/18	10/04/18
147	Dalrymple Protection	100%	12 days	08/03/18	29/03/18
148	ITR-034 Power store commissioning	100%	10.4 days	05/06/18	23/06/18
149	ITR-035 RTU Panel commissioning	95%	11.2 days	05/06/18	24/06/18
150	ITR- 036 Control System Commissioning	99%	2.4 days	14/06/18	18/06/18
151	ITR- 037 PowerStore Parmetersation	100%	3.2 days	18/06/18	21/06/18
152	ITR- 038 Isolated BESS	99%	7.2 days	22/06/18	30/06/18
153	Samsung Battery Performance testing	100%	3 days	24/07/18	27/07/18
154	PSCAD / PSSE review period	75%	4 days	28/08/17	01/09/17
155	Hold Point Testing- Repeat	0%	4 edays	06/09/17	10/09/17
156	ITR Pre -works Workshop day.	0%	1 day	13/09/17	14/09/17
157	ITR- 040- Part 1- Planned Islanding tests	0%	3 days	17/09/18	20/09/18
158	ITR- 040- Part 2- Un- Planned Islanding tests	0%	0.8 days	21/09/18	21/09/18
159	Re-Testing of Cap Trading / FCAS	0%	1.6 days	22/09/18	23/09/18
160	ITR- 041 Black Start	0%	2 hrs	24/09/18	24/09/18
161	ITR- 039- Partial Islanding tests with WPWF	0%	4 days	25/09/18	29/09/18
162	GPS Compliance Testing	0%	10 edays	03/10/17	13/10/17
163	Documentation / Training / Approvals	0%	196.8 days	13/10/17	29/09/18
164	PC 1	100%	0 days	31/05/18	31/05/18
165	PC 2	0%	0 days	29/09/18	29/09/18
166	Receive Generation license	0%	0 days	13/10/17	13/10/17
167	On site Training	0%	2 days	17/10/17	19/10/17
168	Demobilise & Punch list items	0%	2 days	03/10/18	05/10/18
169	As-Built Submission	70%	8 wks	03/10/18	23/01/19



Project: 10715 D&C tender progra
Date: 10/09/18

Task | Split | Milestone | Summary | Project Summary | External Tasks | External Milestone | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | Deadline | Critical | Critical Split | Progress

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Appendix B Project Management Plan Table of Contents

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Appendix C Project Risk Register at end of Commissioning

Risk				Mitigation
Project whole-of-life costs (including O&M components) may exceed initial estimates	D: Possible (20-50%)	4 - Major	D4 High	Undertake rigorous assessment during RFP screening phase/ tender process. Establish selection criteria to understand whole-of-life costs Develop a (as possible) detailed specification Use RFI system during TIR screening/ tender process to clarify Project costs
Project revenue may be insufficient / may not cover Project costs	D: Possible (20-50%)	4 - Major	D4 High	Review predicted Project revenue/ check with AGL lease agreement/ ARENA funding/ anticipated regulated funding
Project resources - both before and after contracts execution - may not be available when needed, with impacts for all major project drivers (technical, quality, costs / variations, time / delays, GPS registration)	F: Almost Certain (95%-100%)	4 - Major	F4 Very High	Identify work streams/ packages via work breakdown structure Where gaps (including skills gaps) will be identified and/or internal resources will not be available, engage external resources For all resources intended to be used (internal or external): resource profile and mandatory selection criteria should be based on proven, practical experience in the field/ area of work where they are intended to be used. Attempt to cover any skills gaps by specifying technical requirements at system level Implement O&M contract, so as to have uninterrupted coverage for the duration of the Project for the OEM
Inability to integrate the Wattle Point WF so as to provide seamless transition / operation under islanded conditions	E: Likely (50-90%)	3 - Moderate	E3 High	Define technical requirements - as committed to by ElectraNet Check offers by BESS proponents and ensure that they can meet technical requirements prescribed by ElectraNet
Gaps between the EPC contract (and associated performance guarantees by EPC supplier - for the duration of the BESS design life) and the AGL lease contract - with potential financial consequences for ElectraNet	E: Likely (50-90%)	4 - Major	E4 High	Review all EPC offers to ensure that as many details as possible are included in the final EPC contract (as a collation of technical requirements from ElectraNet and also from what is offered by the EPC proponents) - first level of gap analysis Perform cross-referencing of contracts at Project, technical and commercial levels - second level of gap analysis Perform gap analysis by at least two people so as to avoid 'blind spots' if analysis performed by only one person

Risk				Mitigation
BESS ability to provide all services committed to by ElectraNet	D: Possible (20-50%)	4 - Major	D4 High	Identify all Project deliverables committed to by ElectraNet - to AGL, ARENA and for regulatory services Perform studies to define in a quantifiable way the associated BESS performance requirements Perform inter-disciplinary review to ensure that the basis for analysis and the results of the studies which define BESS performance requirements are solid / valid Issue formal report (internal) to confirm BESS requirements Include performance requirements in BESS technical specification Develop BESS testing requirements to ensure that the specified quantitative and quantifiable technical requirements can be checked / proven (or disproven) via testing Ensure that commercial side of the contract allows enforcement of performance requirements
EPC OEM supplier may default after BESS goes into operation	B: Rare (1% - 10%)	4 - Major	B4 Medium	Selection of preferred EPC OEM supplier should take into account history and likelihood of having the respective supplier in business for the duration of the BESS operational life Use guarantees / checks as part of the contract
Project learnings are considered inadequate or irrelevant	C: Unlikely (10- 20%)	4 - Major	C4 High	Agreed Knowledge Sharing Plan with ARENA and Stakeholders that clearly defined sharing objectives, outcomes and expectations that are likely to meet stakeholder expectations. Ensure specific commitments are outlined and agreed, avoiding ambiguity or interpretation difficulties. Provide a dedicated sharing entity, independent of asset owners or commercial interests, to manage sharing outcomes during sharing period.
Spillage of chemicals from the batteries either during delivery, installation, commissioning or operation of the BESS	D: Possible (20-50%)	3 - Moderate	D3 Medium	Undertake Safety in Design process with the view of identifying ways of preventing chemical spillages and / or method of containing spillages Implement prevention and containment methods - e.g. bunds, spillage containment kits etc.
Significant Contractual dispute with EPC Contractor	C: Unlikely (10- 20%)	4 - Major	C4 High	Procurement selection criterion will include previous history and references of Contractor(s), the form and nature of guarantees (etc.) in contract terms, and the willingness of the Contractor to negotiate towards mutually agreeable settlement.

Risk				Mitigation
Breach of ARENA Funding Agreement	C: Unlikely (10- 20%)	3 - Moderate	C3 Medium	Negotiate Funding Agreement with the view of ensuring that ElectraNet responsibilities are understood/ agreed prior to Funding Agreement execution.

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Appendix F Commissioning Plan

Inspection and Tests undertaken as part of the BESS commissioning:

- ITR-031 PowerStore Pre-commissioning
- ITR-032 Network Panel Pre-commissioning
- ITR-034 PowerStore Commissioning
- ITR-035 RTU Panel Commissioning
- ITR-036 Control System Commissioning
- ITR-037 PowerStore Parameterisation
- ITR-038 Isolated BESS Testing
- ITR-039 Partial Island with Wattle Point Windfarm (not complete, scheduled for November 2018)
- ITR-040 Grid Connected Operation
- ITR-041 Islanded Operation with Wattle Point Windfarm (scheduled for November 2018)
- Hold Point 1 Tests (to demonstrate grid operation up to +-15 MW)
- Hold Point 2 Tests (to demonstrate grid operation up to +-30 MW)
- R2 Tests (to follow)

Appendix G Construction Images

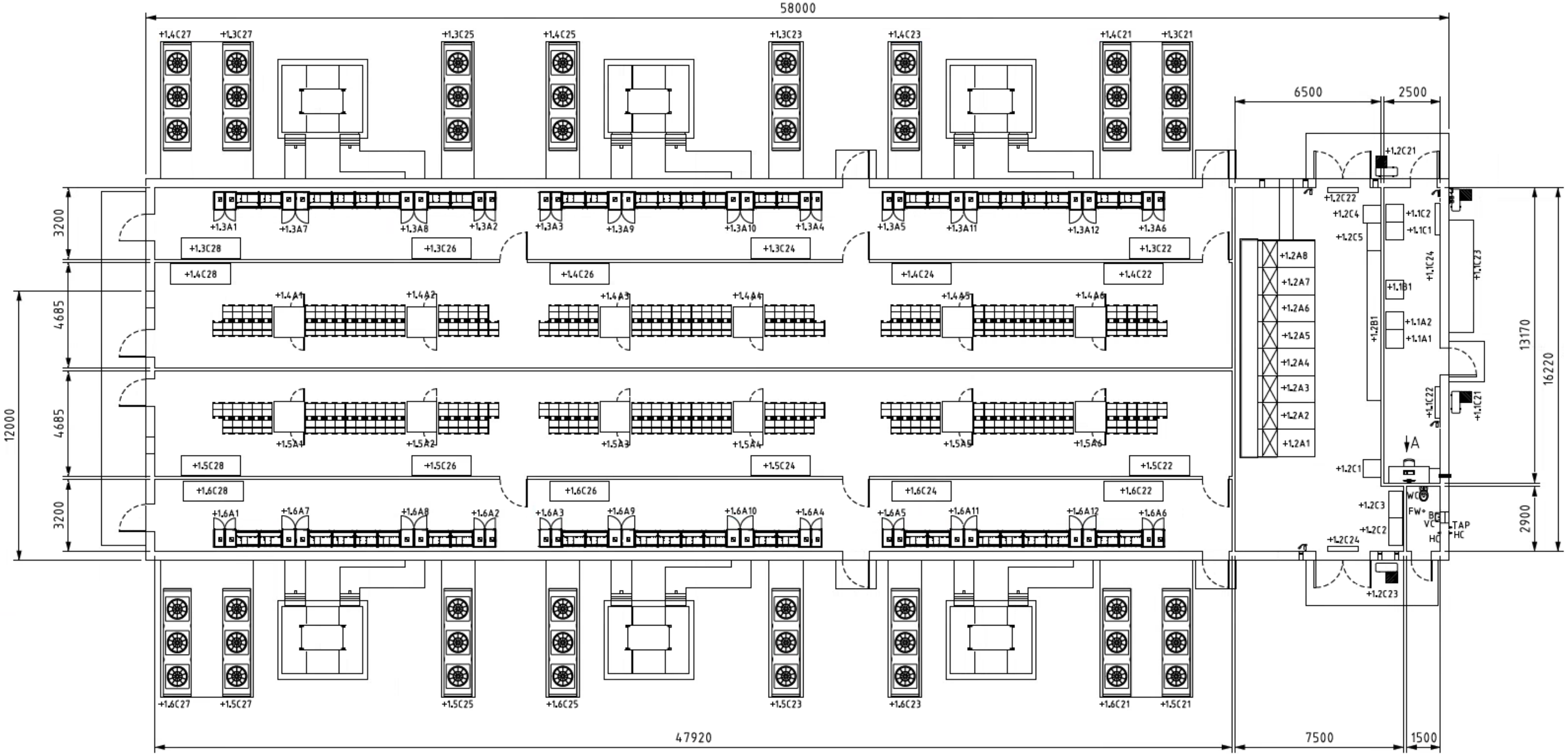
Dalrymple North Battery Energy System Storage Site – *Shed and Site Construction Progress*

33 kV Transformers

Invertor Room Installation

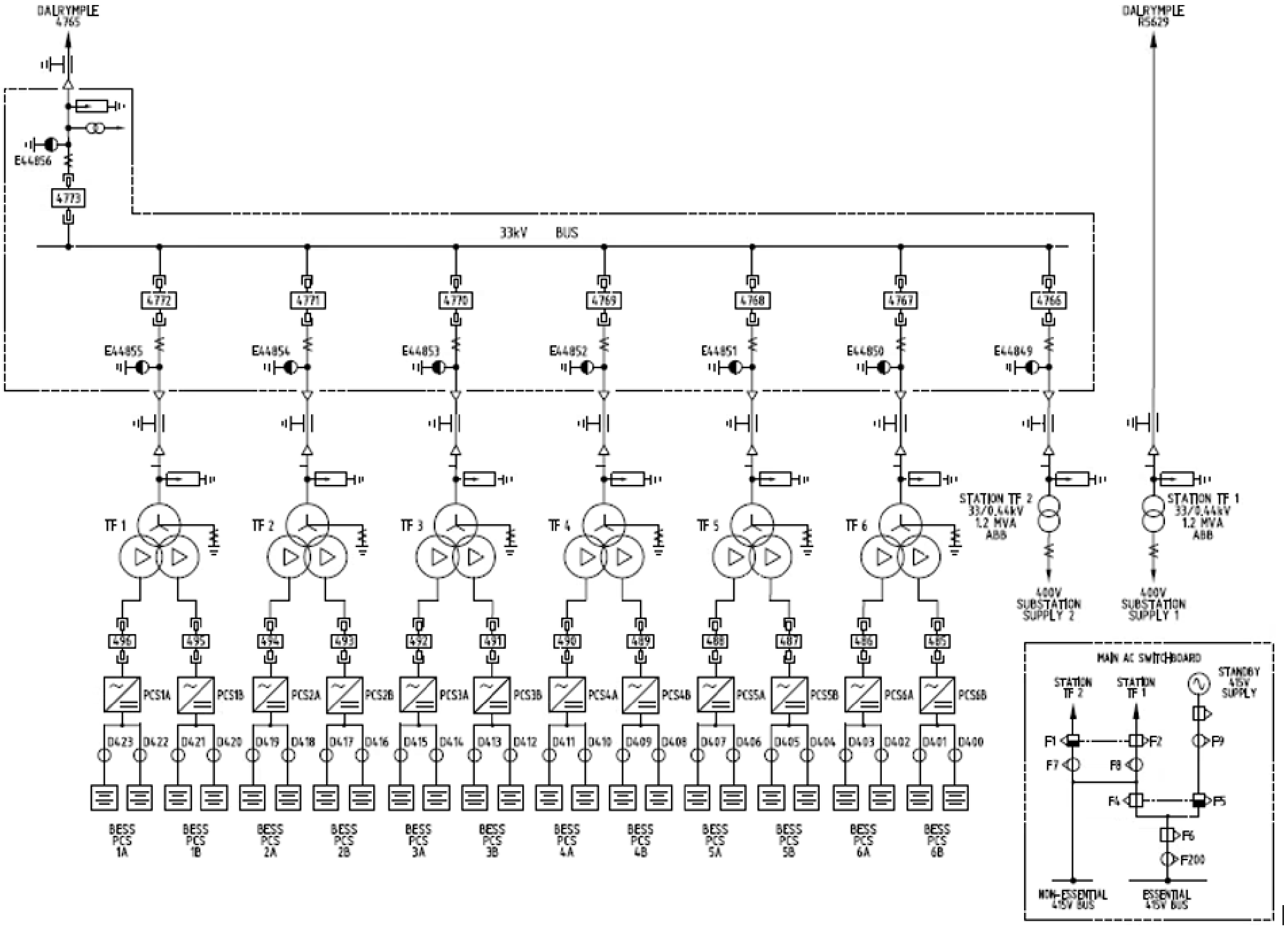
Battery Racking and Battery Installation

Appendix H As-built Project Site Plan



PLAN VIEW
SCALE 1:125

Appendix I As-built Electrical Single Line Diagram



Appendix J Hold Point Test Results

Test Condition	Tests	Relative GPS Clauses	Results
Offline	Background Harmonics	S5.2.5.2	To be determined post GPS Compliance Assessment Testing
	Signal Injection – Frequency Protection	S5.2.5.3	Protection settings confirmed. GPS compliance to be determined in GPS compliance assessment testing.
	Signal Injection – Voltage Protection	S5.2.5.4	Protection settings confirmed. Manufacturer certified and confirmation of final inverter protection settings pending. Long term compliance monitoring required.
Online in Discharge Mode (Synchronised to Power System and exporting active power)	Reactive Capability	S5.2.5.1, S5.2.6.1, 4.11.1	Hold point test results demonstrate GPS compliance
	Active Power Steps (Power Factor Control Mode)	S5.2.5.14, S5.2.6.1, 4.11.1	Hold point test results demonstrate GPS compliance
	Active Power Steps (Voltage Control Mode)	S5.2.5.14, S5.2.6.1, 4.11.1	Hold point test results demonstrate stable behavior, Voltage regulation accuracy requirements of the GPS re-negotiated
	Voltage Steps	S5.2.5.13, S5.2.6.1, 4.11.1	Hold point test results demonstrate stable behavior and compliant settling times. Voltage regulation accuracy and reactive power rise time requirements of the GPS re-negotiated.
	Power Factor Steps	S5.2.5.13, S5.2.6.1, 4.11.1	Hold point test results demonstrate stable behavior and GPS compliant regulation accuracy

Test Condition	Tests	Relative GPS Clauses	Results
	Partial Load Rejection (FCAS Mode)	S5.2.5.7, S5.2.5.11, S5.2.6.1, 4.11.1	Hold point test results demonstrate stable response. GPS compliant behavior has been observed but is dependent on FCAS controllers raise and lower settings. Further tests pending in GPS compliance assessment testing.
	Partial Load Rejection (SIPS Mode)	S5.2.5.7, S5.2.5.11, S5.2.6.1, 4.11.1	SIPS Control correctly has priority over FCAS response
	OEL Step Response Tests (Voltage Control Mode)	S5.2.5.13, S5.2.6.1, 4.11.1	Hold point test results demonstrate limiter correct activation and stable response. GPS compliant settling times stepping into limiter to be attempted to be determined in GPS Compliance Assessment Testing.
	UEL Step Response Tests (Voltage Control Mode)	S5.2.5.13, S5.2.6.1, 4.11.1	Hold point test results demonstrate limiter correct activation and stable response. GPS compliant settling times stepping into limiter to be attempted to be determined in GPS compliance assessment testing.
Online in Charge Mode (Synchronised to Power System and importing active power)	Reactive Capability	S5.2.5.1, S5.2.6.1, 4.11.1	Hold point test results demonstrate GPS compliance
	Active Power Steps (Power Factor Control Mode)	S5.2.5.14, S5.2.6.1, 4.11.1	Hold point test results demonstrate GPS compliance
	Active Power Steps (Voltage Control Mode)	S5.2.5.14, S5.2.6.1, 4.11.1	Hold point test results demonstrate stable behavior, Voltage regulation accuracy requirements of the GPS re-negotiated

Test Condition	Tests	Relative GPS Clauses	Results
	Voltage Steps	S5.2.5.13, S5.2.6.1, 4.11.1	Hold point test results demonstrate stable behavior and compliant settling times. Voltage regulation accuracy and reactive power rise time requirements of the GPS re-negotiated.
	Power Factor Steps	S5.2.5.13, S5.2.6.1, 4.11.1	Hold point test results demonstrate stable behavior and GPS compliant regulation accuracy
	Partial Load Rejection (FCAS Mode)	S5.2.5.7, S5.2.5.11, S5.2.6.1, 4.11.1	Hold point test results demonstrate stable response. GPS compliant behavior has been observed but is dependent on FCAS controllers raise and lower settings. Further tests pending in GPS compliance assessment testing.
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	UEL Step Response Tests (Voltage Control Mode)	S5.2.5.13, S5.2.6.1, 4.11.1	Hold point test results demonstrate limiter correct activation and stable response. GPS compliant settling times stepping into limiter to be attempted to be determined in GPS Compliance Assessment Testing.

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