Transgrid | Lumea

Commissioning Report

CPEOI190025 Wallgrove Grid Battery

October 2022

transgrid.com.au | lumea.com.au

Copyright & Disclaimer.

The purpose of this document (Report) is to provide a summary of the commissioning of the Wallgrove Grid Battery.

The Report has been prepared by NSW Electricity Networks Operations Pty Limited (ACN 609 169 959) as trustee for NSW Electricity Networks Operations Trust (ABN 70 250 995 390) trading as Transgrid (Project Owner).

While reasonable endeavours have been used to ensure that the information contained in this Report is accurate at the time of writing, Transgrid makes no representation or gives any warranty or other assurance, expressed or implied, as to the accuracy, reliability, completeness or suitability for any particular purpose of the Report or any of the information contained herein.

This Report is for general information only and Transgrid, its related entities and their respective directors, officers, employees, agents, consultants and contractors, do not accept, and expressly disclaim, any liability whatsoever (including for negligence or negligent misstatement) for any loss or damage suffered or incurred arising out of, or in connection with (i) the information, statements, opinions, recommendations and other matters expressed or implied in, contained in or derived from, this Report, (ii) any omissions from the information contained in this Report and (iii) any use of this Report or reliance upon the information contained herein.

This Project received funding from ARENA as part of ARENA's Advancing Renewables Program and from the NSW Government, Emerging Energy Program.

The views expressed herein are not necessarily the views of the Australian Government, and the Australian Government does not accept responsibility for any information or advice contained herein.

The views expressed herein are not necessarily the views of the NSW Government. The NSW Government does not accept responsibility for any information or advice contained herein.

Acknowledgements.

This Project received funding from ARENA as part of ARENA's Advancing Renewables Program and was proudly supported by the NSW Government, Emerging Energy program.

Australian Government
Australian Renewable Energy Agency

ARENA

NSW GOVERNMENT

Acknowledgement of Country.

In the spirit of reconciliation Lumea acknowledges the Traditional Custodians of the lands where we work, the lands we travel through and the places in which we live.

We pay respects to the people and the Elders past, present and emerging and celebrate the diversity of Aboriginal peoples and their ongoing cultures and connections to the lands and waters of NSW.

Contents.

Contents.

Contents.

1. Acronyms

AEMO	Australia Energy Market Operator
ANO	Authorised Network Operator
ARENA	Australian Renewable Energy Agency
BESS	Battery energy storage system
BOP	Balance of plant
CCTV	Closed circuit television cameras
COVID	Coronavirus disease
D&C	Design and construct
DNSP	Distribution Network Service Provider
DTCB	Dead tank circuit breaker
ETMHC	Electricity Transmission Ministerial Holding Company
EPC	Engineering procurement construction
EP&A Act	Environmental Planning and Assessment Act
ESV	Energy Safe Victoria
FCAS	Frequency control ancillary services
FFR	Fast frequency response
GIS	Gas insulated switchgear
GPS	Generator performance standards
GW	Gigawatt
GWh	Gigawatt hour
HMI	Human machine interface
HV	High voltage
ISP	Integrated System Plan

LSBS	Large scale battery storage
LV	Low voltage
MASS	Market ancillary service specification
MW	Megawatt
MWH	Megawatt hour
NEM	National electricity market
NER	National electricity rules
NMI	National metering identifier
OEM	Original equipment manufacturer
O&M	Operations & maintenance
PPC	Power plant controller
PSCAD	Power Systems Computer Aided Design
RAB	Regulatory Asset Base
RIT-T	Regulatory Investment Test-Transmission
RoCoF	Rate of change of frequency
RTAC	Real-time automation controller
SCADA	Supervisory Control and Data Acquisition System
SVC	Static var compensator
SS	Substation
SEPP	State Environmental Planning Policy (infrastructure)
TAT	NSW Electricity Networks Assets Pty Ltd as trustee for NSW Electricity Networks Assets Trust
TNSP	Transmission network service provider
VBB	Victorian Big Battery
VMM	Virtual Machine Mode
WGB	Wallgrove Grid Battery

This Report summarises the development, contracting, construction and commissioning of the Wallgrove Grid Battery (WGB) up to the Commencement of Operations on 22 December 2021.

The WGB is a 50MW/75MWh (1.5-hour duration) Battery Energy Storage System (BESS) located adjacent to the Transgrid Sydney West 330/132kV substation (Wallgrove) in Eastern Creek, NSW. The primary purpose of the WGB is to pilot synthetic inertia from a battery to maintain frequency stability on the network, as well as to enable Iberdrola Australia to control dispatch and participate in the frequency control ancillary services (FCAS) and wholesale energy market for commercial purposes.

The Virtual Machine Mode (VMM) has not been enabled at this point, therefore, this Report does not cover key learnings in relation to the implementation and performance of the capability. The Report does include information on the VMM testing plan and methodology. Observations and analysis of the performance of the VMM will be covered in subsequent operations reports. .

Pilot projects demonstrating new technology for network services can be challenging to implement under the National Electricity Rules (NER) prior to a network need being declared or a Regulatory Investment Test-Transmission (RIT-T) being undertaken. Consequently, the network component of the battery is supported by grant funding. Transgrid expects that this project will demonstrate the ability for grid batteries to provide synthetic inertia network services and will thus support future grid battery projects providing similar inertia services to be assessed under the regulatory framework, negating the need for support grants.

The WGB has an innovative commercial model, designed to minimise costs to consumers through use of the battery for both regulatory and commercial purposes. The regulatory component (network services) of the battery is funded through the NSW Government's Emerging Energy program, Australian Renewables Energy Agency (ARENA) and the Regulatory Asset Base (RAB). The commercial component is based on a contract for use with Iberdrola Australia to trade the spare battery capacity that is not required for network services, with capital provided by Lumea.

At the time of developing this project, all grid-scale BESSs operating in Australia were underpinned by substantial grant funding. Although it was expected that battery costs would reduce, witnessed in 2022 with the further worldwide adoption of battery technology, the cost of lithium batteries has increased significantly in the last 12 months. This places additional pressure on grid-battery projects and their commercial viability without grants.

The WGB was reliant on grant funding from both the NSW Government and ARENA. The resulting commercial framework and contract structure to fund this battery was therefore complex and took considerable time and resources to finalise. The costs for this project progressively increased through the development journey as all parties gained a better understanding of the capability of the BESS and the roles associated with key stakeholders. Funding was also reduced through the contract development journey, making the final business model quite different from the original concept.

The construction phase of the project was completed without major issues. The project was delayed two months by the state-wide shut-down of construction site works due to COVID-19 in July 2021 and incurred less than 10% increase in overall projects costs.

The key to the success of the project delivery phase is the excellent business relationship that was established between Transgrid and Tesla and its subcontractors. However, the project was challenged by a number of requirements pertaining to Transgrid's security and risk management requirements in implementing the new technology.

The grid connection work stream met all project schedule milestones including Generator Performance Standards (GPS) approval in May 2021, registration in October 2021 and Frequency Control Ancillary Services (FCAS) registration in December 2021. A number of challenges were managed effectively during the registration process through good collaboration with the market participant, Iberdrola Australia, and Australian Energy Market Operator (AEMO).

A number of key learnings were obtained for Transgrid as the Transmission Network Service Provider (TNSP) in assessing the commissioning requirements for new technologies being added to the network, which will benefit future proponents seeking BESS connections in NSW.

Important insights and improvements were implemented during the commissioning phase in working with Tesla on the learnings from the Victorian Big Battery (VBB) fire incident. The WGB promptly implemented all recommended improvements and increased its emergency preparedness through Tesla's knowledge sharing and transparency in managing and resolving that incident.

The project commenced commercial operations on 22 December 2021, with only minor defects to be resolved in the following months.

3.1. Purpose of Report

This Report summarises the learnings from the development, construction and commissioning of the WGB, from concept development up to the commencement of operations on 22 December 2021.

It focuses on the following areas relating to the WGB including lessons learnt to date:

- BESS technical specifications
- Project objectives
- Project approvals
- Connection and registration application process
- Project development and delivery
- Ownership, delivery and operational model
- Project delivery team
- Construction and commissioning activities
- Testing and commissioning
- Other lessons learnt and key findings

3.2. Distribution of Report

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

The intended audience includes:

- Project developers
- Renewable energy industry participants
- Network service providers
- General public
- Equipment vendors
- General electricity sector members
- Government bodies
- ARENA

3.3. Knowledge sharing plan

This Report represents one of the deliverables under the Knowledge Sharing Plan that forms part of the funding agreement between Transgrid and ARENA. All documentation associated with the Knowledge Sharing Program for the Project is available from Transgrid's Wallgrove Grid Battery project website (details below).

The knowledge sharing deliverables completed to date are shown in *Table 1* below.

Deliverable	Timeline
Arena 15 min Project Survey	Completed quarterly
Lessons Learnt Report #1	Submitted May 2021
Lessons Learnt Report #2	Submitted January 2022
Stakeholder reference group briefings	SRG meeting #1 03/02/2021 SRG meeting #2 19/10/2021
Attendance at webinar or workshop	ARENA Smart Inverters Webinar participation / presentation 27/05/2021 Presentation in ARENA Grid Forming / Advance Inverters Webinar 09/08/2022
Project website	Accessible via: **https://www.transgrid.com.au/projects-innovation/wallgrove-grid-battery**

Table 1 – Knowledge sharing commitments

Photo 1 – Wallgrove Grid Battery and Sydney West 330/132kV Substation aerial view

4.1. Generation type and location

The WGB is a large-scale battery storage system, charging and discharging to and from the National Electricity Market (NEM), located in the western Sydney suburb of Eastern Creek. The battery is located adjacent to the Transgrid's Sydney West 330kV Substation.

4.2. Technical details

Technical Parameter	Summary
Nominal discharge power capacity	50 MW
Nominal charge power capacity	47 MW
Registered storage capacity	75 MWh
Power capacity degradation	N/A
Number of Megapacks	36
System voltages	132 / 33 / 0.518 / 0.4 kV
Balance of plant	• 60 MVA 132/33kV power transformer • 9 x 33/0.518/0.518kV coupling transformers • ABB SafePlus GIS RMU switchgear • 500kVA 33/0.400 kV auxiliary transformer • 75kVA isolation transformer for street supply
Point of connection	Sydney West 330/132kV substation – feeder bay 2X
Metering point location	Sydney West 330/132kV substation – feeder bay 2X
Network connection	132kV
Substation	Sydney West 330/132kV substation
National metering identifier numbers	Wallgrove Battery 132kV Revenue: • NTTTW0ZQ90 for import B1 (generation) • NTTTW0ZQ91 for export E1 (consumption) Wallgrove Battery 132kV Check: • NTTTW0ZQ95

Table 2 – Key technical parameters

4.3. Connection date

A connection agreement was completed and notified to AEMO subject to Clause 5.3.7(g) of the NEM Rules, on 17 May 2021. The market participant, Iberdrola Australia, commenced commercial operations of the Wallgrove Grid Battery on 22 December 2021.

4.4. Services and functionality

The WGB will enhance system reliability and security in NSW by operating in the wholesale energy and FCAS markets in the NEM, as well as providing inertia support activities, such as fast frequency response and virtual inertia as network services. The WGB commenced commercial operations in December 2021 and has been operated by Iberdrola Australia in the FCAS and wholesale energy markets since then.

Transgrid is seeking to test the ability of the WGB to provide synthetic inertia in place of the inertia provided by the existing synchronous technologies with rotating mass, such as coal-fired generators, hydro-power generators and gas-fired generators. These generators are synchronised because they all rotate in lockstep at the same frequency of 50 Hertz and work together to contribute to grid inertia. The inertia from these generators represents a source of stored (kinetic) energy that can be tapped for a few seconds to provide the grid time to respond to power plants going down or other system failures.

The physical inertia provided by the rotating masses of these synchronous generators represents the source of nearly all inertia in the NEM today.

Transgrid is aiming to test whether the synthetic inertia provided by the WGB can replace the inertial response provided by synchronous machines. This will be useful to help maintain the 50 Hertz frequency when there is a frequency disturbance in the NEM.

Work is currently underway to develop, achieve approval for, and implement the VMM of operation for the battery to enable the synthetic inertia functionality to be tested. This project will be one of a handful of projects in Australia to run synthetic or virtual inertia services.

4.5. Site layout

Photo 2 below shows the site layout of the WGB and overleaf shows the general arrangement for the project.

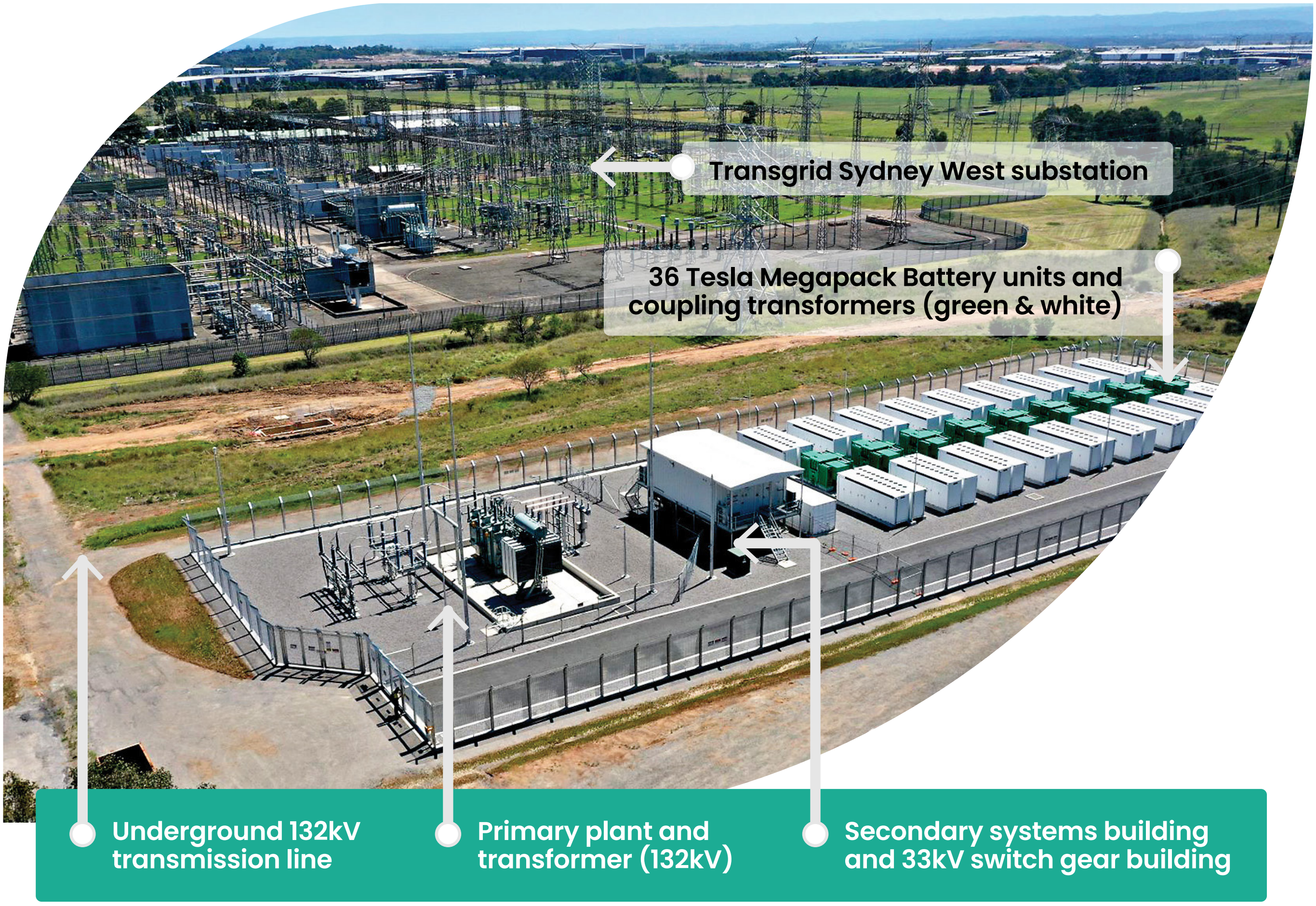


Photo 2 – Wallgrove Grid Battery and Sydney West 330/132kV Substation aerial view

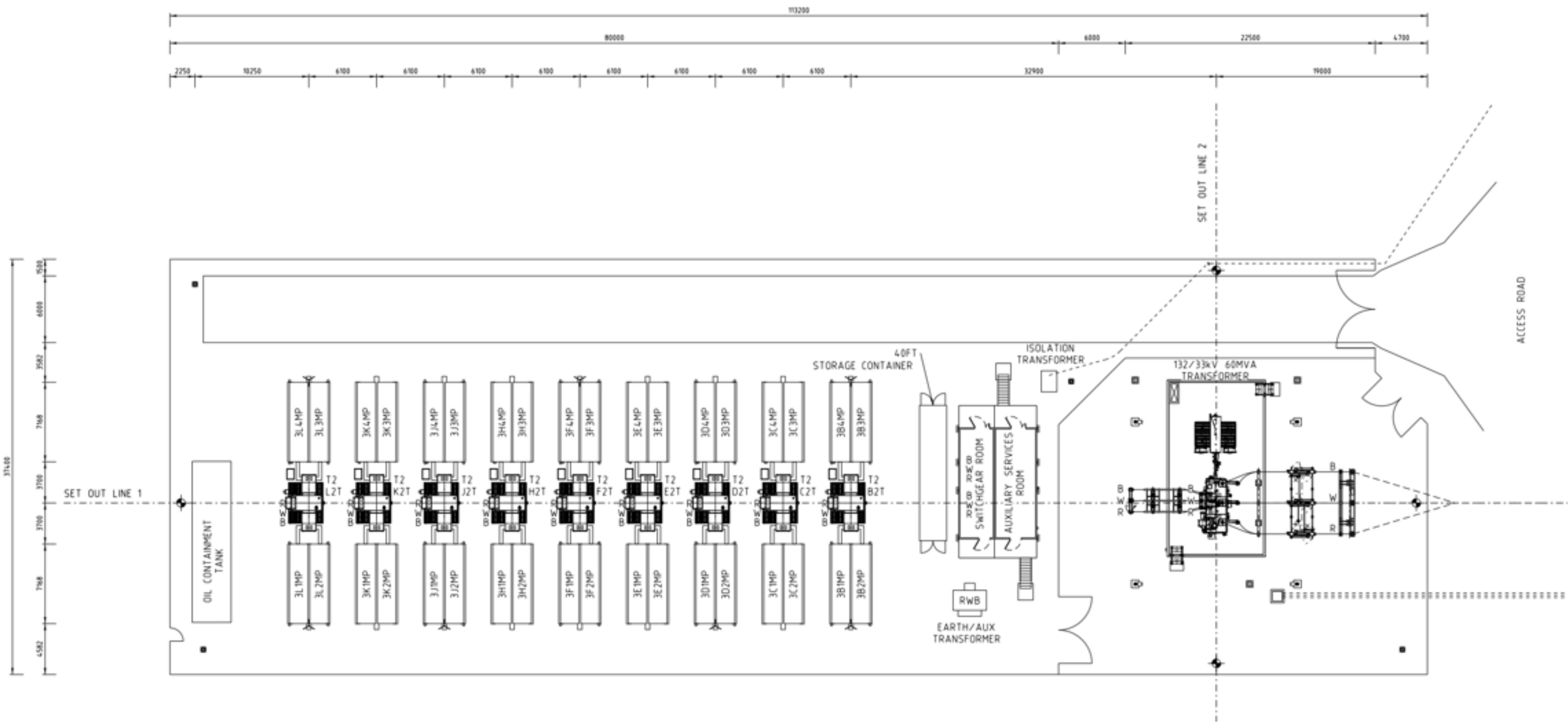


Diagram 1 – General Arrangement

5.1. About Transgrid

Transgrid operates and manages the high voltage electricity transmission network in NSW and the ACT, connecting generators, distributors and major end users. The Transgrid network is the backbone of the NEM, enabling energy trading between Australia's three largest states along the east coast and supporting the competitive wholesale electricity market.

5.2. About Lumea

Lumea is a renewable energy infrastructure, telecommunications, and energy services business. We operate in contestable markets across the NEM and are the largest connector of renewable generation in Australia to date. Our mission is to help bring 40GW of renewable energy to market by 2030. We will do this by capitalising on our skills, expertise and heritage as part of the Transgrid Group to help generators, large load customers and governments realise their own clean energy ambitions. Lumea is also proud to be developing its own innovative projects across a variety of new energy assets and services, as well as establishing a pipeline of grid-scale energy storage systems.

5.3. Project context

Australia's energy system transition to distributed renewable energy is expected to accelerate toward the net zero emissions targets announced by both Federal and State Governments. This means the continuing reduction of coal-fired generation, with AEMO's 2022 Integrated System Plan (ISP) forecasting 14 GW reduction in the NEM by 2030[1] under the step change scenario.

The increase in renewable energy generation and withdrawal of synchronous generation from coal-fired generators creates technical challenges which impact the reliability and stability of the network. For example, Transgrid internal forecasts show 31,454 MWs of inertia to be retired by 2036[2].

BESS are increasingly being recognised as potential solutions to those network challenges, as well as providing storage capacity for renewable generation. AEMO anticipates that by 2050, 16GW of storage will be provided by utility-scale batteries and pumped hydro storage[3]. Furthermore, modelling indicates significant savings for NSW electricity customers (between $93m and $135m) from deploying BESS instead of traditional synchronous condensers to perform inertia services[4].

Transgrid expects that an inertia gap will be declared in NSW as existing sources of inertia, predominantly coal-fired generators, are progressively withdrawn from the market. In preparation for this event, Transgrid is investigating alternative technology solutions to establish technically and commercially viable, lower-cost solutions to address the inertia gap, including its first hybrid grid-scale battery – the Wallgrove Grid Battery.

1 AEMO ISP June 2022 (Step change scenario)
2 NOSA-N2415 Rev 0 - Meeting NSW system inertia requirement, 17 June 2021
3 AEMO ISP June 22
4 HoustonKemp, Estimating benefits from proof of concept battery project to provide inertia, 12 June 2021 5.4. Overview of Wallgrove Grid Battery Project

5.4. Overview of Wallgrove Grid Battery Project

The WGB is a 50MW/75MWh (1.5-hour duration) grid-scale lithium-ion Tesla battery and will be the third[5] large-scale grid battery demonstration of synthetic inertia in the NEM. Located at Wallgrove, the WGB is a pilot demonstration of the viability of synthetic inertia from a battery to maintain frequency stability on the network whilst also enabling Iberdrola Australia to control dispatch and participate commercially in the frequency control ancillary services (FCAS) and wholesale energy markets.

The WGB was undertaken as an innovation pilot, to build battery expertise, and to support the development of more efficient synthetic inertia technologies in different locations on the grid and higher population density. The commercial model combines funding to maximise battery utilisation for network and commercial purposes.

The WGB can provide both network services (including inertia and Fast Frequency Response (FFR)) and market services (including energy and FCAS), and accesses corresponding regulated and unregulated revenue streams in a hybrid commercial model. Less than 5% of energy storage capacity is reserved for the provision of network services. The project enables the TNSP, Transgrid, to explore this approach as a credible option to address the forecast inertia shortfall in NSW/ACT following the retirements of coal-fired plants such as Liddell, Eraring and Vales Point Power Stations, and support the NSW Government's plan for a reliable, affordable and sustainable electricity future that supports a growing economy.

Information is being shared as part of the trial to support future projects and improve understanding of battery technology as a low cost and technically viable solution to the emerging challenges created by the transformation of the generation sector. The project also demonstrates a revenue stack and commercial arrangements that provide grid benefits in a way that is cost effective for consumers.

The trial will provide valuable technical information about the actual operation of the WGB, including how often it will be needed for fast frequency response and how much electricity it is able to store and dispatch under different conditions, relative to commercial demands.

As more wind and solar power replace fossil fuel generation, less mechanical inertia is available on the grid, removing a natural stability buffer in the case of a grid disturbance. As these fossil fuel generators retire from the NEM, alternative solutions are needed to ensure stability. The WGB will demonstrate the use of Tesla's Virtual Machine Mode (VMM) to address these stability challenges by virtually emulating mechanical inertia. VMM is undergoing final technical assessments in conjunction with AEMO prior to operation to ensure a strong commissioning approach.

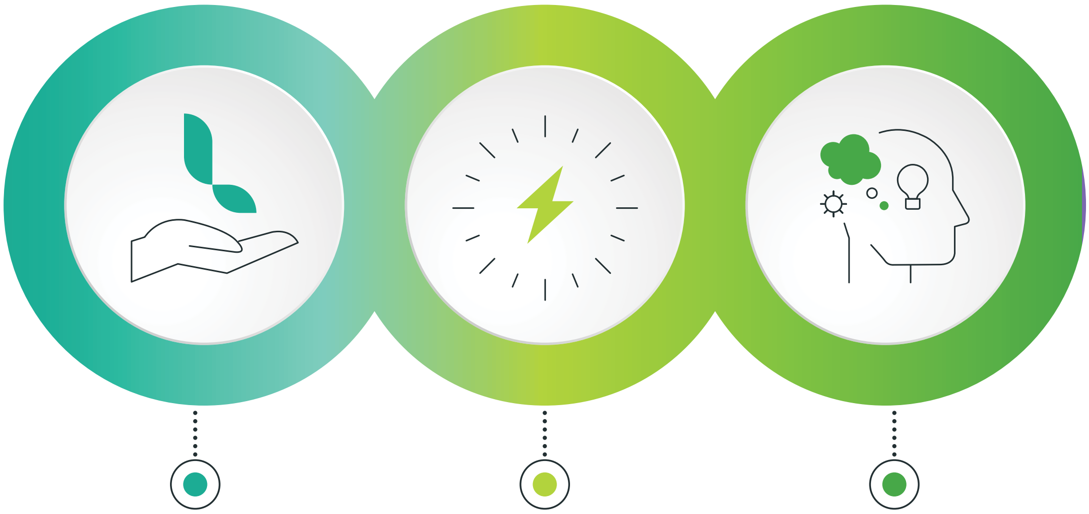
The WGB received funding from ARENA's Advancing Renewables Program and the NSW Government as part of the Emerging Energy program. The WGB has successfully been constructed, registered, tested and commissioned, and commenced Commercial Operations in December 2021. To 1 September 2022 it has exported 18.4GWh[6] of energy, supplying the equivalent of the energy needs of 4,850 NSW households[7].

5. Wallgrove will be the third BESS in the NEM to demonstrate synthetic inertia. ESCRI (30MW) and Hornsdale Expansion (150MW) are the first and second.

6. https://www.Trangrid.com.au/media/i25ndg0l/2022-08-02-operations-data-2021-12-23-to-2022-07-13.csv and https://www.Trangrid.com.au/mediahfbcd3s4/07092022-operations-data-14072022-to-01092022.csv

7. https://cdn.ausgrid.com.au/-/media/Documents/Data-to-share/Average-electricity-use/Ausgrid-average-electricity-consumption-by-LGA-2021-pdf

Project benefits



Enhanced reliability

The battery will provide a new source of system stability services.

More affordable power

Finding lowest-cost ways to maintain frequency, while also increasing the supply of dispatchable power to the market, puts downward pressure on energy bills.

New knowledge

The trial will provide valuable technical and commercial insights which will be shared across the energy industry – helping to identify the lowest cost technology for future network needs.

5.5. Key Project Objectives

The project's objectives, as agreed with NSW Government and ARENA

ARENA	NSW Government
Supporting technical innovation: Improved understanding of the ability of FFR services and Tesla's Virtual Machine Mode to substitute for inertia and help meet Transgrid's requirement to manage RoCoF in NSW with transferable learnings across the National Electricity Market. Support inclusion of LSBS projects in the Recipient's regulatory submission: The Project will help support Transgrid's vision to include ~240 MW of LSBS projects in its revenue submission to the AER for the upcoming regulatory period (2023/24 to 2027/28). New commercialisation pathway: The Project will contribute to the development of a new commercialisation pathway for LSBS by leveraging regulated network expenditure to provide a clear pathway to commercialisation for LSBS. Improving supply chains: Relatively few LSBS projects have been installed. Supporting LSBS will improve supply chains and reduce costs for OEMs and balance of plant providers.	Enhance system reliability and security in NSW by operating in the wholesale energy and frequency control ancillary services markets in the NEM, as well as provide inertia support activities including fast frequency response and virtual inertia; Promote competition through its contracting arrangement with Iberdrola Australia which will operate the project to firm variable renewable energy generation in NSW to supply retail customers Promote diversification of electricity supply in the NSW region of the NEM by deploying a lithium-ion battery system in the NEM that is dispatchable and capable of firming variable renewable energy generation Assist in the operation of a low emissions NSW electricity system by firming Iberdrola Australia's variable renewable energy output from their portfolio Provide value to NSW and the NEM by sharing key learnings to reduce the risk and encourage further investment in utility scale battery energy storage systems in NSW.

5.6. Project partners

The project partners in the Wallgrove Grid Battery are:

- Iberdrola Australia is the registered market participant for the project, contracted with Transgrid under the Grid Battery Agreement, supported by the Iberdrola Australia-ARENA-Transgrid tripartite deed.
- Tesla as the selected Engineering Procurement Construction (EPC) contractor for the project, is contracted under a Design & Construct (D&C) contract, as well as the maintenance services contract.
- UGL Engineering as the selected subcontractor for the project to Tesla.

5.7. Project delivery model

Transgrid had not previously developed and delivered a grid-scale storage asset and this opportunity provided new challenges for the organisation. In addition, grid-scale battery technology was in its infancy at the time of developing the project. This project was the first grid-scale battery to be connected into the NSW transmission network.

At the concept development stage of the project, the number of delivery partners with BESS generation delivery experience in the market was limited to the BESS OEMs. Transgrid had minimal experience with BESS technology and engaged the market BESS OEMs by competitive tender for a D&C contract. Tesla was successful in the tender as the supplier of the BESS equipment and engaged UGL as the installation contractor and principal contractor. UGL also delivered the designs for the WGB.

To enable the grid connection to the Wallgrove BESS, a new point of connection at Sydney West 330/132kV substation was required. Any alteration to the transmission network is non-contestable, and therefore the bay connection works were delivered by Transgrid. Transgrid was the principal contractor for Sydney West Substation works and delivered the bay connection works utilising a combination of Transgrid workforce and subcontractors.

The project delivery model is shown in *Diagram 2.*

One of the keys to the success of the project delivery model was the excellent business relationship that was established between Transgrid and Tesla and its subcontractors. Throughout the project delivery, both Transgrid and Tesla worked exceptionally well together with no commercial disputes.

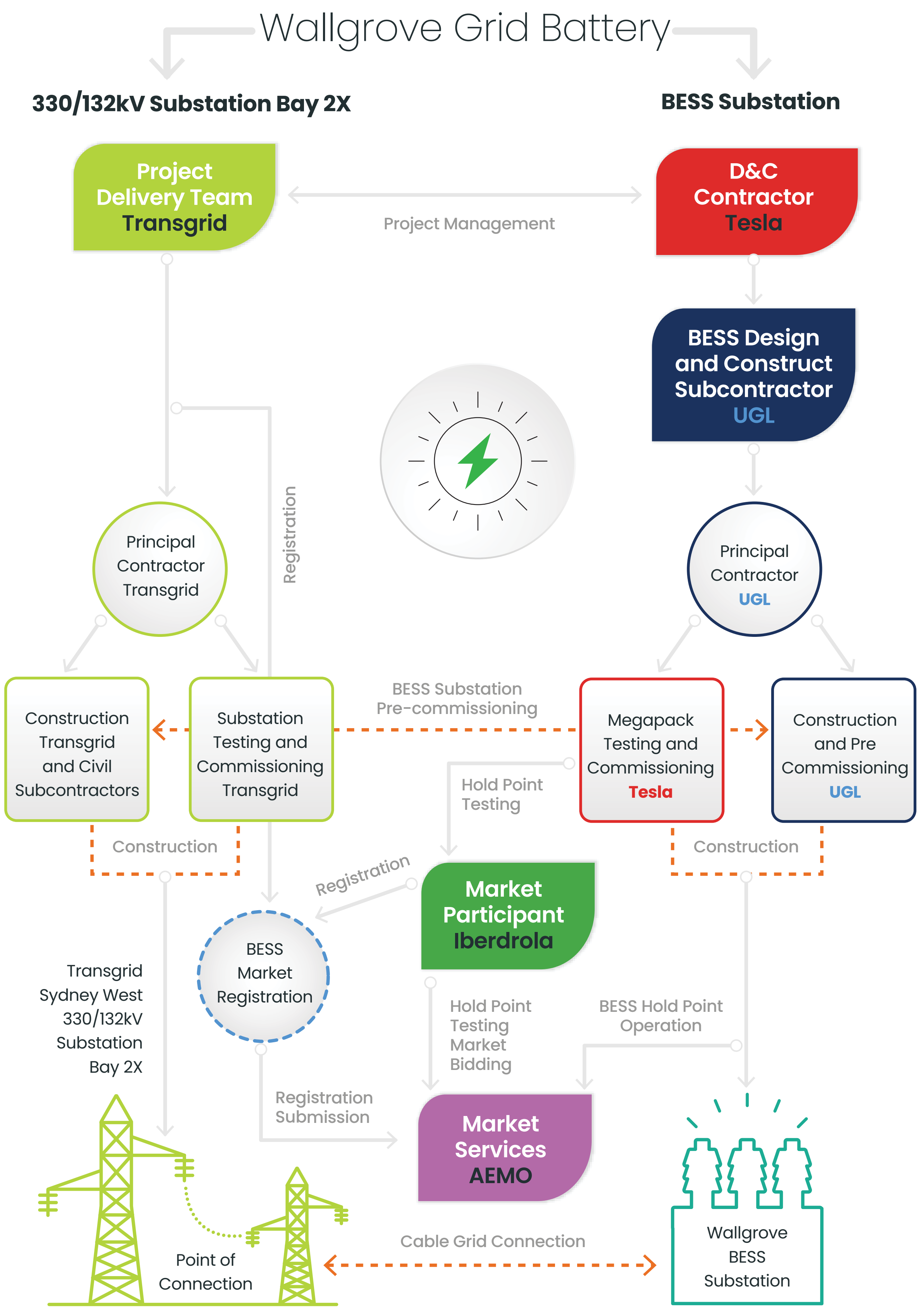


Diagram 2 – Operational model flowchart

5.7.1. Lesson Learnt: alignment of financial and physical responsibility for assets

Tesla was the head contractor for project delivery, with design and construction works subcontracted to UGL. One approach to manage risk for projects of this nature is to have a single delivery partner provide a fully wrapped EPC and Operations & Maintenance (O&M) solution, helping to minimise the risk of gaps in the technical solution. However, for this project the scope of the O&M services and ongoing performance guarantees for the supplier were limited to the battery units, leaving a gap between the assets required for a fully operational BESS and those where performance is guaranteed by the supplier.

Such a model was considered by Lumea to be suboptimal. Lumea assumed commercial responsibility for operation and maintenance of more of the Balance of Plant (BoP) to ensure the financial and physical responsibility of assets were closely aligned, and risk was allocated to the party best able to manage BoP failure. The service partner for these services is Transgrid. Lumea and Transgrid are part of the Transgrid Group.

The WGB experience on the full wrap resulted in changes to contract structure in relation to risk allocation and is emerging as a market standard, allowing delivery partners to focus on core product. Future BESS projects should seek to ensure that financial and physical responsibilities are aligned.

5.7.2. Lesson Learnt: lack of market maturity for battery projects in the NEM

The Transgrid Group recognised that it had limited experience with BESS technology, and therefore sought a supply partner that could bring technical expertise to the project. This related not only to the physical supply and installation of the battery, but also to the connection and interface with the NEM. Whilst a number of suppliers were able to respond to a tender process for supply of the battery, few could demonstrate a comprehensive understanding of how the battery would connect to and operate in the NEM while meeting AEMO's requirements. Selecting a supplier that could not provide a complete solution presented a significant risk to the project success.

A previous BESS project (which never reached financial close) lesson was that the most effective way to determine the appropriate BESS solution would be to ask respondents to propose the specifications and commercial model for a BESS that would be able to trial inertia, while earning revenue indirectly through market revenue streams, rather than specifying a specific solution. However, what was discovered through this approach was that the supplier market is still immature and only a limited number of suppliers had the capability and risk appetite to be able to provide a fully scoped proposal. Due to the lack of mature contracting models in this space and limited supplier experience, the tender and contracting period was significant, compared to traditional technology solutions, causing significant project cost increases as the technical and commercial specification for the full solution was developed and confirmed.

This situation will change over time as new and more mature BESS suppliers enter the Australian market and expertise develops for BESS suppliers, TNSPs and Distribution Network Service Providers (DNSPs) in connecting these assets, and with AEMO in connecting, registering and operating BESS in the NEM. Future projects will be able to leverage the learnings and market developments that this project has enabled.

5.8. Commercial model

The WGB commercial model provides a hybrid approach to funding and revenue. It is designed to minimise cost to consumers through use for both regulatory and commercial purposes. The regulatory component (network services) of the battery is funded through the NSW Emerging Energy Program, ARENA, and Transgrid's RAB. The commercial component is based on a contract for use with Iberdrola Australia to trade the spare battery capacity that is not required for network services, with capital provided by Lumea security holders. Optimising capacity not required for network services avoids funding 100% through the regulatory processes.

The project is an innovative model of private and public funding working in unison to drive greater benefits at lower costs for NSW electricity consumers. As a result, NSW energy consumers receive:

- A more reliable grid from the pilot of synthetic inertia
- Reduced network service charges through the support of State and Federal funding agencies
- Lower energy costs from increased competition and diversity in the supply of electricity
- Firming to support increased renewable energy generation
- Long term benefits through the transition to cleaner energy systems

5.8.1. Transgrid's role and responsibilities

The WGB is part of the NSW transmission system. As such it is 100% owned by the NSW state-owned Electricity Transmission Ministerial Holding Corporation, which leases it to NSW Electricity Networks Assets Pty Ltd as trustee for NSW Electricity Networks Assets Trust (TAT) under the 99-year network lease. TAT subleases the battery to NSW Electricity Networks Operations Pty Ltd as trustee for NSW Electricity Networks Operations Trust (Transgrid). Transgrid retains the right to use the battery to provide specific transmission network services. Lumea's role in the project is management of the unregulated portion of the battery on Transgrid's behalf – management of the customer relationships and administration of the contracts that are associated with the unregulated portion of the battery.

5.8.2. Iberdrola Australia's role and responsibilities

The battery services agreement with Iberdrola Australia Wallgrove Pty Ltd (a subsidiary of Iberdrola Australia Limited) gives Iberdrola Australia the rights and responsibilities to:

- Dispatch control of the WGB in the NEM
- Retain all commercial revenues (and all pay costs) related to the WGB's operation in the NEM (excluding repayments to ARENA if revenue thresholds are exceeded)
- Be the registered participant (as an intermediary) for the WGB in the NEM
- Pay Lumea a fee for the right to use the WGB
- Retain energy storage capacity for network services as a priority

5.8.3. Hybrid model

The commercial model demonstrates that regulated and non-regulated revenues can co-exist in the same revenue stack for the benefit of consumers and the network. A network service provider solving the network need alone would have passed higher costs to consumers through increased allocation to the RAB and may not have met the regulatory investment tests in place at the time of investment.

By offsetting the costs with a complementary role for private funding and competitive market revenues, the hybrid commercial model creates a stronger network and provides the technology that supports the increasing penetration of renewable generation, while creating more competition that reduces costs to consumers. The additional support of ARENA and the NSW Government directly reduced the burden on bills for NSW energy consumers and provided innovation to support future projects for the transition to renewables.

5.8.4. Lesson Learnt: operational model

The WGB project is a first for the Transgrid Group where it is the owner of a generation asset as well as being the Transmission Network Service Provider (TNSP). Usually, Transgrid provides a point of connection for the customer, and the generation or grid battery assets are owned, managed, and operated by a third party.

After a successful tendering process, Iberdrola Australia was contracted to operate the asset in the NEM under a commercial arrangement. Transgrid has a contractual obligation to provide a minimum availability of the BESS equipment.

As the asset owner, Transgrid is responsible for the operation and maintenance of the BESS equipment and ensuring the generators maximum availability. Transgrid has engaged Tesla to operate and maintain the Megapacks under a service agreement and provide a minimum availability, which aligns with the Transgrid-Iberdrola Australia agreement. The remaining BoP, communication, and control and automation systems remain the responsibility of Transgrid.

Any incident response and/or plant disruptions due to the Megapacks are managed under the service agreement between Transgrid and Tesla. An incident response plan has been developed, with Tesla having the capacity to carry out Megapack diagnostics and maintenance remotely via a remote connection, anywhere within Australia. An event that cannot be resolved remotely will be further escalated with Tesla and/or Transgrid technicians attending site to resolve the issue.

The key lesson learnt is to minimise the complexity of the operations and maintenance, specifically in regard to the number of stakeholders involved.

Condition Precedent was achieved on 18 October 2020, ahead of contracts commencement on 22 October 2020.

6.1.1. Grid connection process

Transgrid initiated the studies to support the connection application package in May 2020 and engaged with AEMO to clarify some of the key technical requirements for the connection application. Early engagement with AEMO ensured Transgrid remained on schedule in meeting GPS work stream milestones and commercial operations date. During the process AEMO was very supportive in assisting Transgrid through the early connection process.

6.1.2. Procurement

Transgrid embarked on an ambitious timeline for the delivery of the project, with commercial operations scheduled to commence 12 months after the commencement of contracts. To ensure that this timeline was met, Transgrid procured long lead items prior to the commencement of contracts. To achieve the program, Transgrid commenced the procurement for the Dead Tank Circuit Breaker (DTCB) for the 132kV feeder bay, and the BESS auxiliary earthing transformer.

6.1.3. EPC tender process and award

Transgrid's project team faced several challenges in delivering its first BESS, including having to define the scope for a type of project that the organisation had never delivered, and engaging the market via the standard tender process with limited understanding of the technology and requirements for associated control systems. To tackle this issue, the project team engaged as early as possible with the market-leading BESS suppliers. Using a high-level scope, Transgrid focused on the intended purpose of BESS and pre-selected a preferred supplier to work through the technical details as part of the EPC contract negotiation. Tesla was selected as the preferred D&C contractor.

Transgrid conducted a two-stage competitive tender for a 50MW BESS and conducted a number of site inspections with battery suppliers to better understand the technology and become more familiar with the equipment. When reviewing the vendors' proposals, there were differences, varying capacities on offer and varying O&M costs. There were also differences in warranty and other services offered between the parties.

At the contract negotiation stage, the Transgrid project team worked closely with Tesla and UGL to understand the detailed technical aspects of the BESS offer and how it integrated within Transgrid's standards and substation systems. There was initially a long list of non-standard items in the EPC proposal. Through continuous collaboration and a number of workshops, the items were reviewed based on their extent of departure and value for money. Transgrid's project team accepted a number of departures that provided cost savings yet mitigated all critical compliance issues and met the design philosophy for substation systems.

6.1.4. Lesson Learnt: complexity of commercial model

The commercial model to fund the WGB project was complex, given the pilot nature and the four different revenue sources (ARENA, NSW Government, regulated revenue and lease revenue from Iberdrola Australia). Twelve separate contracts were negotiated with four counterparties with varying contract terms and risk profiles. The project also undertook parallel discussions with the AER and AEMO given the intended network use of the WGB.

All contracts had to be finalised in parallel and drafted to align across separate companies' commercial interests, as well as the priorities and expectations of two separate grant funding bodies. The lesson learnt is that pilot projects involving multiple revenue sources and stakeholders will involve complex contracting and commercial models. Each additional counterparty adds a significant layer of costs and complexity to a project and should be minimised to the extent possible.

There were complexities associated with defining and allocating risks. They were identified and managed during the negotiations and, in some cases, execution. This was largely unavoidable due to the novelty and complexity of the technologies and commercial model deployed for the WGB project. Other proponents of complex/novel projects should expect such "unknown unknowns" and allow additional time and cost in the project development schedule to deal with them or consider strategies to discover them sooner so they can be dealt with earlier and more efficiently

7.1. Grid connection location considerations

The location of the WGB was selected based on the following considerations:

- Infrastructure efficiency: Close proximity to Transgrid's 330kV Sydney West substation enabled a reduced cost for connecting the underground 132kV transmission cable.
- Voltage Stability: Sydney West Substation has a Static var compensator (SVC) installed, which provides excellent voltage stability on the 330kV and 132kV Bus. This voltage stability reduces the voltage fluctuations on the BESS equipment, ensuring stable operation for the market participant.
- Strong Network Node: The location in the network is an extremely strong network node (one of the strongest in the network) enabling unrestricted operation (charge/discharge) of the battery, without being impacted by network constraints. This provides revenue certainty to the market participant.
- Property ownership: The property was already owned by Transgrid, enabling accelerated development and delivery of the project. The WGB is connected to the grid by a short cable route within Transgrid's property boundary which further reduces the operational risk due to accidental damage.
- Reduced project delivery costs: The Sydney Metropolitan location for the battery enabled reduced costs in project delivery such as accommodation and travel, which are common impacts in connection projects located in remote areas in NSW.

7.2. Project approvals and community consultation

Transgrid is an authorised network operator and was required to complete an environmental assessment under Part 5 of the EP&A Act, in accordance with the New South Wales Code of Practice for Authorised Network Operators (the Code). The appropriate assessment and approvals process in accordance with the Code for the proposed project was determined to be Class 3 – Summary Environmental Report (SER), given the works were within Transgrid's existing property boundary, surrounded by industrial land uses.

The proposed activity was permitted without development consent from Council in accordance with State Environmental Planning Policy (Infrastructure) 2007 (the Infrastructure SEPP), and the proposed activity was therefore subject to the assessment requirements of Part 5 of the EP&A Act.

Transgrid, is an Authorised Network Operator (ANO) under the Electricity Network Assets (Authorised Transactions) Act 2015. Transgrid is also a prescribed determining authority under Section 5.6 of the EP&A Act and Clause 277(5) of the Regulation, for development for the purposes of an electricity transmission or distribution network that is permitted without consent (within the meaning of State Environmental Planning Policy (Infrastructure) 2007) and is operated or to be operated by the ANO.

Clause 42 of the Infrastructure SEPP provides that written notification must be given to the local Council and adjoining occupiers for the development for the purposes of a new or existing electricity substation of any voltage. The provisions require that those notified were given a reasonable opportunity (no less than 21 days from the date on which notice was given) to make submissions on the proposed activity.

Additionally, consultation with local Council was also required to meet the provisions of section 45(4) of the Electricity Supply Act 1995, which requires councils are given 40 days to make submissions on the proposed activity.

Written notification was provided to Blacktown City Council and adjacent landowners on 14 February 2020. No responses were received.

7.3. Project delivery team

The Diagram Below details the size of the delivery team, the roles and responsibilities and their relationships.

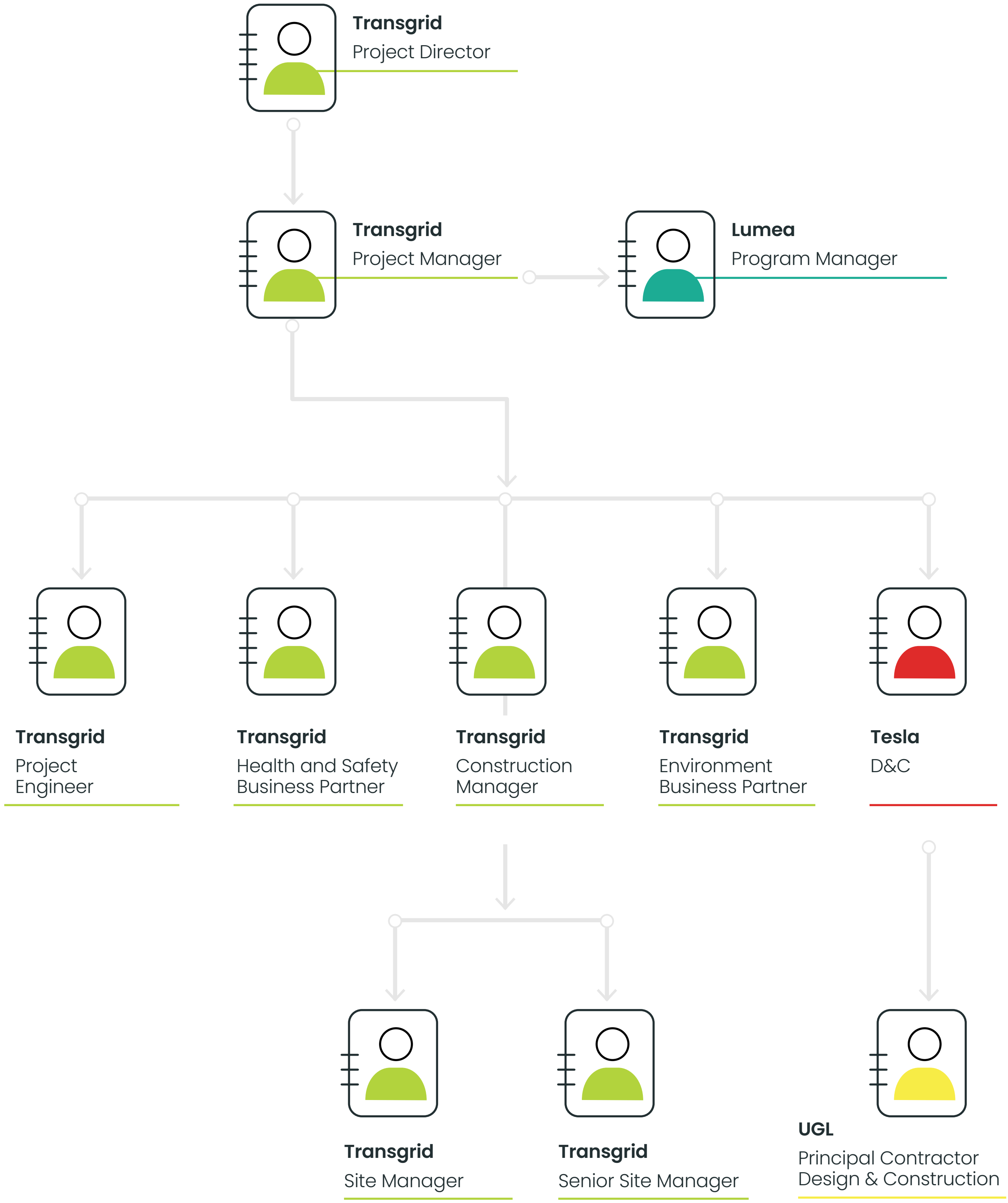


Diagram 3 – Project delivery team

7.3.1. Project team details

The project development team mostly comprised employees residing in NSW, with one full-time employee located interstate. The Transgrid project delivery team were all local residents in Sydney.

The D&C contractor and subcontractors engaged to deliver the construction works comprised of employees and contractors with the workforce residing in NSW, interstate, and one from New Zealand.

Project team size	Number of People	
Project team size - Development phase	3	
Project team size - Project delivery	9	
Project team engagement	Full time project allocation	Part-time project allocation
Development	3	1
Delivery	2	7

Table 3 – Project Team Size

7.3.2. Types of roles

The different types of roles involved in the development and execution of the WGB are listed in the table below:

Project roles		
Project Director	Site Manager	Protection Technician
Project Manager	Construction Manager	Substation Technician
Project Engineer	Health and Safety Business Partner	Communications Technician
Project Developer	Environmental Business Partner	
Design Engineer	Control Technician	

Table 4 – Project Roles

7.3.3. Resource requirements

Table 5 below details the total number of hours was carried out during the development and delivery of the WGB. The hours are reflective for the Transgrid delivery of the bay connection and exclude the hours of the D&C contractor.

Project phase	Approximate Work Hours
Project development hours	4,500
Project delivery hours	24,300

Table 5 – Transgrid Project resource hours

7.4. Procurement strategies

As well as conducting early procurement activities to mitigate risks to the schedule, Transgrid utilised its well-established period order agreements (panel of suppliers) for most BoP equipment. This allowed Transgrid to procure equipment without having to engage the market via a standard procurement process. To maximise the benefits of the period order agreements, Transgrid's strategy was to free issue the auxiliary transformer and other 132kV bay equipment, which are considered standard Transgrid equipment. This reduced the delivery time of equipment by up to three months. This arrangement reduced lead times and ensured the lowest-cost solution.

As the power transformer for the WGB was bespoke, the decision was made to incorporate the delivery of the power transformer under the D&C contract. All other BoP equipment was procured by the D&C contractor.

All equipment on period order agreements have completed a rigorous process of technical and commercial evaluation and are compliant with Transgrid's stringent standard requirements. Other assessments are also made on cost and availability. The selection panel does not limit one piece of equipment to one supplier, and therefore it provides the opportunity to select balance of equipment from a range of suppliers, in the event there is a disruption to one of the vendors' supply chains.

All other equipment included with the D&C contract was at the discretion of the D&C contractor, provided it met Transgrid standards, unless deviations were accepted with commercial advantage without increasing residual risk.
All transformers that were procured were manufactured in Australia. The benefit of this was that manufacturing was local, minimising any logistical disruptions due to the COVID-19 pandemic, and reducing the risk on the project delivery.

7.4.1. Availability of components and technologies

The procurement of the key items was the responsibility of Tesla as the D&C contractor, and therefore the associated strategies and risk for the procurement of key plant was Tesla's responsibility. The Tesla Megapacks used at the WGB were manufactured in Tesla's Gigafactory in Nevada, USA. At time of delivery no shortages in components or equipment were experienced, and while there was some uncertainty about shipping timeframes issues did not eventuate. *Table 6* illustrates the source location for the major equipment at the WGB.

Equipment	Location of manufacture
Megapacks	USA
132/33kV 60MVA power transformer	New South Wales
Coupling transformers	New South Wales
Auxiliary transformer	Victoria
Isolation transformer	New South Wales
Switch room & auxiliary services building	Adelaide
33kV GIS switchgear	China
High voltage cables	China

Table 6 – Equipment manufacturing locations

7.4.2. Changes in costs of components and technologies

At the commencement of the delivery of the WGB project Transgrid and Tesla worked collaboratively to identify cost savings opportunities, whilst not compromising safety, reliability, or security of the asset. The outcome was that minor savings were achieved on equipment, and as such deviations to Transgrid's power transformer specifications were accepted at a commercial advantage without compromise.

As the D&C contract was fixed price after contract award, there were no observed additional expenses due to components or technological changes during the project delivery. The only minor change was the slight exchange rate movement between tender and award. While the project encountered some cost overrun as a result of COVID-19 and connection complexity, this strategy helped Transgrid manage exposure to cost increases.

7.5. Construction activities

Below are a list of construction and installation activities conducted for the delivery of the WGB:

- Construction of Sydney West 330/132kV Substation Bay 2X
- WGB site clearing
- Construction of High Voltage (HV) and Low Voltage (LV) cable routes between Sydney West 330/132kV Substation (SS) and WGB SS
- Construction of HV and LV cable routes within WGB SS
- Establishment of alternate supply from Endeavour Energy
- Construction of 1 x power transformer plinths and spill oil containment bund
- Construction of transformer spill oil tank
- Switch room and auxiliary services building
- Delivery and installation of 36 Megapacks & 9 coupling transformers
- Construction of auxiliary and isolation transformer plinths
- Design, construction and testing of secondary, control and communication systems
- Implementation and testing of Autobidder
- Installation and testing of Closed Circuit Television (CCTV) and security systems
- Establishment of the access road
- Establishment of fencing and gates

7.6. Commissioning activities

Below are a list of testing commissioning activities conducted for the delivery of the WGB (further detail is contained in the Testing and Commissioning section):

- Sydney West 330/132kV Substation Bay 2X
- 132kV and 33kV and low voltage cables
- Sydney West 330/132kV SS bus differential
- Transformer differential
- Voltage transformer and current transformer
- 33kV GIS switchgear
- Intertrip systems
- Protection, control system, automation testing
- Tesla site controllers and Human Machine Interface (HMI)
- Tesla Autobidder and AEMO market integration
- Revenue and power quality meters
- Transgrid HMI and integration to systems control
- CCTV and security systems
- Hold point testing

8.1. TNSP registration considerations

The Transgrid Group undertook a significant amount of research to ascertain how to register the WGB, especially given that as a TNSP, Transgrid would own the battery but would not have dispatch control of the BESS in the NEM. To assist with this process, Transgrid sought guidance from ElectraNet on the approach used to register and create a valid connection agreement for the Dalrymple ESCRI-SA Battery Project (ESCRI BESS). Transgrid was aware that ElectraNet had participated via ARENA's knowledge sharing process.

ElectraNet provided guidance on the approach taken to register the ESCRI BESS in the name of the third party, which operated the BESS in the market. ElectraNet advised Transgrid that this was a very nascent process and that each time a utility-scale battery was registered, AEMO and industry learned and adapted the process.

Transgrid followed ElectraNet's advice and engaged AEMO at the early stages of the project ensuring a smooth process. Initially, Transgrid had sought to register the WGB with Transgrid as the owner, operator and controller, but AEMO advised that this was inconsistent with the operations of the NER as Transgrid could not:

- enter into a connection agreement with itself
- operate the BESS in the NEM
- could not hold itself accountable for any non-compliances with the Generator and Customer Performance Standards agreed to under clause 5.3.4A of the NER

Transgrid revised its approach and engaged an intermediary to trade in the NEM. As such, Transgrid was required to engage an intermediary to submit registration applications for the roles of a generator and customer in the NEM while Transgrid would submit an exemption application for its role as an owner and operator of the WGB. The exemption application was to be submitted at the same time as the generator and customer applications were registered with AEMO.

In addition, for the registration applications to be valid, the connection agreement had to be between Transgrid as the network service provider and the intermediary, ensuring that Transgrid was not entering into a contract with itself for the operation of the BESS. The intermediary would be held accountable by AEMO for any operational non-compliances with any Generator and Customer Performance Standards that were agreed in accordance with clause 5.3.4A of the NER. The connection agreement between Iberdrola Australia and Transgrid was developed as part of the grid battery contract and was completed on 22 October 2020.

8.2. Customer and generator registrations

A battery that is electrically connected to the grid is currently considered as a generating unit when it exports electricity but considered as a load when it imports from the grid. AEMO has recommended that a standalone battery, greater than 5MW must be classified as a scheduled generating unit and a scheduled load, which will be bid/offered and dispatched separately.

There were three applications that were required to be submitted to register the WGB. These include:

- Customer application – to be completed by intermediary (Iberdrola Australia)
- Generator application – to be completed by intermediary (Iberdrola Australia)
- Exemption application – to be completed by Transgrid

This process was complex but simplified by the guidance provided by both ElectraNet and AEMO. Transgrid and Iberdrola Australia (as Transgrid's intermediary) successfully submitted the Generator, Customer and Exemption applications to AEMO on 12 May 2021.

8.3. Market ancillary services

Market ancillary services are acquired by AEMO as part of the spot market. FCAS are market ancillary services. The market ancillary services are (detailed under clause 3.11.2 of the NER):

- the fast raise service
- the fast lower service
- the slow raise service
- the slow lower service
- the regulating raise service
- the regulating lower service
- the delayed raise service
- the delayed lower service

The WGB had to meet dual requirements to operate in the market ancillary services market. The WGB was required to be registered and classified as a Market Generator in order to classify the generating units as ancillary service generating units, and also had to be classified as a Market Customer in order to enable market loads to operate as ancillary service loads.

Classifying a generator as a Market Generator with ancillary service generating units was completed as part of the application to register as generator in the NEM application form. Currently, a battery system can only be classified as an ancillary service load to provide FCAS while importing from the grid if registered as a Market Customer.

8.3.1. Participation in the Frequency Control Ancillary Services (FCAS) market

To participate in the FCAS market, the WGB was required to meet the requirements of AEMO's published Market Ancillary Service Specification (MASS) and participate in central dispatch for FCAS.

AEMO permitted that some of the FCAS testing could be completed with the hold point testing, but not all the tests. The completed commissioning, (hold point 2 testing) of the WGB was a prerequisite for carrying out the remaining tests required to achieve FCAS registration. With detailed planning, the final FCAS testing only took one day (after the WGB was fully commissioned) to complete. AEMO provided the approval for the WGB to bid the battery in all FCAS markets in mid-December 2021, leading up to final approvals and commercial operation on 22 December 2021.

8.4. Connection application approvals

Preparation of the connection application for the battery commenced in May 2020 with research, development and discussions with AEMO.

As part of the GPS and registration phase of the BESS, AEMO requested that the technical due diligence be performed by two teams within Transgrid, with an information barrier between them. One team represented Transgrid as a Proponent and the other team represented Transgrid in its role as a Transmission Network Service Provider. Transgrid established this structure and engaged a grid consultant to assist with the preparation of the proponent's connection application.

The preparation of the Generator Performance Standards formally commenced on October 2020, at contract commencement. They were approved by AEMO and Transgrid (as the TNSP) on 11 May 2021. The approval of the GPS was a significant milestone within the project, which was completed within the scheduled timeframe.

9.1. Pre-commissioning

Overall, the pre-commissioning of the BESS and point of connection equipment worked exceptionally well considering the complexity of the delivery model and the number of stakeholders involved.

To enable the connection point to the WGB, Transgrid was responsible for the design, construction, and commissioning of the point of connection in Transgrid's substation. The works involved for this section included testing and commissioning of disconnector earth switches, DTCB, bay controller, as well as metering and quality of supply, and its integration into the Transgrid system control. Standard bus differential testing was carried out to ensure that the bay was ready for service. These are considered standard activities for Transgrid's technicians, with the only change being power quality meters installed in the auxiliary building, which did not pose any additional challenges.

Tesla engaged UGL for the construction and installation of civil structural, primary, secondary and auxiliary systems of the WGB. UGL was responsible for high voltage cable testing, protection testing, testing of communications and control systems. The high voltage switchboard was procured with a relay that was non-standard for Transgrid, which caused complications when integrating with the Transgrid SCADA. Transgrid was required to work with UGL for the transformer protection testing. One of the lessons learnt is that any future non-standard protection relay that is being integrated into the Transgrid SCADA system should have bench testing conducted prior to installation, to reduce the risk of delays, and improve the efficiency of fault finding and implementation on site.

Tesla was responsible for the pre-commissioning of the Tesla Megapacks prior to AC energisation. As part of the Megapack pre-commissioning and prior to the commencement of hold point testing, Tesla updated the firmware inside the Megapacks and ran diagnostic tests to ensure the equipment was ready for service.

Considering the challenging timeframe to deliver the pre-commissioning activities, the testing and commissioning teams collaborated well, making the pre-commissioning process run smoothly and ensuring the project remained on schedule.

9.2. Hold point testing and commissioning

The WGB was the first battery to undergo commissioning in the Transgrid network. This meant that Transgrid, in its role as the transmission network service provider (TNSP) had to adapt its approach to commissioning to test the new technology.

Transgrid's commissioning team had to understand the performance and operation of the battery, to develop and assess the commissioning plan. Each battery OEM has a different product, which means that the TNSP must learn the nuances of each product, to determine how to test it. The OEM (Tesla) had to educate AEMO and the TNSP of the performance and functionality of the BESS, as these features differ between BESS products. This is important as the AEMO and TNSP teams had to understand how to assess the actual performance of the BESS during commissioning so that the performance could be assessed against the Generator and Customer Performance Standards and the model overlays. Transgrid, as the TNSP, also sought some guidance from AEMO and ElectraNet regarding the best tests to perform to commission the WGB.

Transgrid was able to work with AEMO and ElectraNet (which has experience connecting other Tesla batteries), using ARENA's knowledge sharing processes to gain some insight on the best method for commissioning the battery. Transgrid also learned about how to commission the battery from multiple discussions with the OEM. Using this information, Transgrid was able to develop a document for commissioning test requirements that outlined recommended tests for each of the hold point stages during commissioning. AEMO agreed with these requirements, and the OEM, that was performing the commissioning on behalf of the proponent, was able to incorporate this information into their commissioning plan.

As at the time there was limited precedent for grid-scale batteries connected to the NEM and none in NSW. This necessitated a significant effort to establish the requirements for the technical due diligence and commissioning process stages of the connection. These included: the process to provide and amend the Power systems computer aided design (PSCAD) models submitted as part of the technical due diligence part of the connections process; each party's obligations under the NER for commissioning a grid-scale battery; the commissioning approvals process; and how to prepare commissioning and hold point testing reports in accordance with AEMO Guidelines. This process was a steep learning curve for the OEM, AEMO, Iberdrola Australia and Transgrid, and would not have been possible if there had not been regular communication, flexibility and a willingness to cooperate and compromise by all parties.

9.2.1. Lesson Learnt: identification of hold point tests required

One of the lessons learnt was the need for early engagement with AEMO and the TNSP to ensure the project-specific requirements for hold points are established prior to contract award. This is necessary so they can be adequately scheduled in the delivery program. Hold point testing is a series of tests with pre-defined constraints on power output. The constraints are progressively lifted, however they are subject to agreement with AEMO and the TNSP. Tesla was responsible for delivering the hold point testing in conjunction with Transgrid as the TNSP, Iberdrola Australia, and AEMO. As the WGB is a relatively small generator compared to some of our other connections, the TNSP and AEMO agreed to have fewer commissioning hold points. We also arranged for fewer commissioning hold points to expedite the commissioning process. This is done for generators where the plants are relatively small in size and the TNSP and AEMO do not think there will be any risk to the network.

9.2.2. Lesson Learnt: FCAS test requirements

Another learning curve as part of this process was in relation to readying the WGB for operation as a FCAS provider. As a TNSP, Transgrid has never before had to prepare and test a generator/load to enable it to participate in the FCAS market. Transgrid staff had to research the FCAS requirements to understand what equipment, testing and registration processes would be required for the WGB to be operated by the Intermediary in the FCAS market.

To ensure that Transgrid was ready to prepare for FCAS, prior to lodging the connection enquiry for the WGB, Transgrid held discussions with AEMO to understand the technical requirements to participate in the FCAS market, and discussed the equipment, the registration and FCAS testing processes. Conducting this additional investigation ensured the WGB was ready for operating in the FCAS market prior to the contractual date for commencement of commercial operations without any delays.

One of the key learnings from the project is that Transgrid gained insight into the various pitfalls, delays, risks, and complexities that each of its customers go through as part of the connections process. As well as providing insight on the technical performance on batteries, from being on the other side of the connections process Transgrid gained insight on where process improvements can be made. This includes providing "how to" documents, templates and guidance for customers to ensure that the connections process runs more smoothly and efficiently in the future.

Traditionally, system inertia (together with system strength) has come from large synchronous generators. However, with the progressive transition away from fossil fuels and the subsequent planned closure of several coal-fired power stations, AEMO has already advised of inertia shortfalls within South Australia and has forecast similar shortfalls in other states in coming years.

The only technologies currently filling this gap are synchronous generators or synchronous condensers. However, such equipment is very expensive (both for initial purchase and then in ongoing operational costs), with correspondingly long lead times for installation.

Rather than commit to the acquisition of such equipment, Transgrid embarked on the WGB project to explore synthetic inertia using specialist firmware to mimic the “swing equation” that governs the rotor dynamics of a synchronous machine. This product is manufactured by Tesla and, when configured to deliver synthetic inertia, is described as operating in VMM.

Currently the project is progressing a NER 5.3.9 application to modify the Generator Performance Standards to enable synthetic inertia.

10.1. VMM testing plan

The aim of the VMM testing plan is to satisfy the below objectives:

- **Objective 1:** To test the hypothesis that a BESS operating with synthetic inertia capabilities can provide a useful inertia service to the power system.
- **Objective 2:** To demonstrate the above whilst the BESS is in normal commercial operation.

10.2. Key findings from the testing plan

10.2.1. Trigger events

A system event likely to invoke a response from an inertia source is referred to as a “trigger event” and would normally be due to a significant frequency deviation, as might be caused by:

- The loss of a large (or multiple smaller) generating unit(s) exceeding 500MW.
- The loss of a large load (such as multiple pot lines at an aluminium smelter exceeding 500MW), or
- A system separation event, resulting in significant generation / load imbalance between the two islands in excess of 500MW.

Such trigger events are not commonplace, typically occurring less than 10 times per year. Provided the relevant performance data is adequately captured, this should still be sufficient to provide a very clear picture of whether an inertia response is being delivered by the BESS when operating in VMM.

A significant voltage disturbance in the proximity of the WGB would also be expected to produce a VMM response. In practice, Sydney West Substation is an extremely strong part of the Transgrid network and so it is unlikely that a credible fault in its vicinity would cause the required level of voltage disturbance. However, for a non-credible fault (e.g. a busbar fault or multiple single-circuit faults) a VMM response might occur and so significant faults in the vicinity of Sydney West Substation will be considered as potential “trigger events” and the BESS response recorded.

10.2.2. Measuring the inertia response

With much of the system inertia traditionally supplied by large synchronous generators, there is a clear expectation of the type of response that would be anticipated from such machines. By using power electronics and sophisticated control schemes (as used in VMM), a similar response might be obtained from a grid-connected BESS. To prove such a response would require careful measurement, particularly in the critical 0 - 4 second period immediately following a system event.

10.2.3. Methodology description

A brief overview of the proposed methodology to achieve Objective 1 is as follows:

- Connect such monitoring equipment in the vicinity of the WGB as is required to monitor an inertia-type response
- Obtain data from the whole power system following a trigger event, to enable modelling of the exact conditions that occurred at the time of the event
- Create a system model of the event
- Determine the output that would be expected from an "inertia source" from the model, (i.e. BESS operating in VMM)
- Compare the actual output of the BESS with this model, to establish the amount of useful inertia that has been delivered

To achieve ***Objective 2***, the above must be demonstrated during normal commercial operation.

In practice, it is highly unlikely that the commercial operators of the WGB would operate at maximum transfer (import or export) for extended periods of time due to the energy limitations of the installation (1½ hours at full output). It is anticipated that it would usually be more commercially advantageous to operate below full output, exploiting the opportunity to bid into the FCAS market. The consequence of this would be that the "headroom" required for the FCAS provision would be sufficient to provide an observable inertia response from most trigger events.

10.3. BESS storage reservation for non-market ancillary services

A portion of the WGB's energy storage capacity is reserved to ensure there is always sufficient energy available to deliver inertia and fast frequency response in case of a significant frequency disturbance. Iberdrola Australia is required to maintain an agreed margin from the minimum and maximum states of charge, to ensure that the BESS is always able to deliver frequency response in either direction in the event of a significant frequency disturbance. These margins are agreed in terms of MWh (not in terms of %) and will always comprise less than 5% of the battery's usable energy storage capacity. The amount of energy reserved is significantly more than required to deliver inertia (delivered within the first 0.5 seconds) and FFR (delivered within the first two seconds).

This additional capacity ensures the BESS will be able to continue providing frequency response after the inertia and FFR has been delivered, i.e. it will also be able to provide contingency FCAS for at least 60 seconds (and probably for several minutes). It also allows some safety margin in case of multiple disturbances, inaccurate state of charge measurement, or extended periods, during which it is undesirable or impossible to import energy from the grid to maintain the required minimum state of charge.

The agreed margin already allows for the provision of inertia via VMM and hence there is no need to change the margin once VMM is enabled.

10.4. VMM GPS and commissioning tests

As part of the 5.3.9 application for the implementation of VMM mode, the GPS compliance studies have been revisited to identify any potential changes to the agreed GPS of the plant. The associated 5.3.9 study package is currently going through AEMO/Transgrid (TNSP) due diligence review. As part of the GPS compliance assessment conducted by Lumea/Transgrid, the potential impact of VMM mode on a number of GPS clauses were assessed: S5.2.5.3, S5.2.5.4, S5.2.5.5, S5.2.5.7, S5.2.5.8, S5.2.5.11, S5.2.5.12, S5.2.5.13 and S5.2.5.14.

The results demonstrated that the plant can still meet the access standard levels of the originally agreed GPS for the majority of clauses, except S5.2.5.5 on rise and settling time. Due to fact that the WGB is mimicking the behaviour of a synchronous machine with the implementation of VMM, slower active power recovery time and reactive current settling time were observed, as expected. An updated negotiated access standard was proposed for clause S5.2.5.5 of the agreed GPS including the changes. The TNSP and AEMO are reviewing these changes and they will be approved if the performance is greater than that in the minimum access standard.

The commissioning test plan for the implementation of VMM mode is currently being prepared by Tesla.

11.1.1. Lesson Learnt: schedule impacts of extreme weather and COVID-19

The WGB is the first project where Transgrid constructed, tested and successfully commissioned a storage asset and network connection assets, using emerging technology. This was a significant achievement for Transgrid and included a large number of unknowns and associated risks.

There were challenges for Transgrid in developing a specification for a Grid Battery system, developing a project budget and timeline for a new asset type. In order to mitigate project risks, Transgrid utilised its corporate Risk Management Framework and Project Risk Management procedures, along with Transgrid's extensive proven systems and procedures. Despite these systems, the project encountered many unexpected external environmental conditions and risks, which were not fully mitigated by in the commercial framework or project risk processes.

Severe wet weather during the construction phase resulted in utilisation of all of the wet weather contingency in the project. Additional wet weather was not an allowable delay in the upstream contract. As part of Transgrid's risk assessment process, a considerable amount of wet weather allowance was allowed for, and although wet weather contingency was exceeded, the project was able to mitigate any further delays by seizing the opportunity of working weekends.

In addition to the unusual weather, onsite construction commenced February 2021, the second year of the COVID-19 pandemic. Initially the project was able to safely manage the COVID-19 controls and restrictions imposed by NSW Health with minimal impact. However, with the occurrence of the Delta outbreak of July 2021, the project also experienced the almost daily changes in rules for construction sites imposed by NSW Health, including all non-essential construction in the Greater Sydney area being paused for three weeks. All works at WGB were required to cease.

At the same time as the restrictions were lifted, Transgrid received approval for an exemption. Transgrid, in partnership with its D&C contractor, introduced their own COVID-19 Response Plans and Work Instructions, putting additional controls in place. The introduction of weekly testing for all personnel was one of the additional controls. With all the controls in place the project managed to successfully keep all its work crew safe, with none of its team contracting the virus for the duration of construction. Although the impact of the COVID-19 outbreak had a considerable effect on the project timeline and budget, the project was able to minimise the impact of incurring a two month delay to the project. Ongoing considerations of including additional flexibility in contracting arrangements is recommended as the global situation with COVID-19 continues to develop.

11.1.2. Lesson Learnt: BESS fire risks, mitigation and management

In July 2021, Neoen's Victorian Big Battery (VBB) project incurred an incident on 30 July 21, involving a fire which destroyed two Megapack units, resulting in significant adverse media coverage and an approximately two month delay to that project's commissioning[8]. The WGB was scheduled to be the next Tesla Megapack project to be commissioned, after the VBB incident.

This occurrence caused considerable additional technical, safety and risk assurance reviews across Transgrid, which added unplanned cost to the project for Transgrid's internal resourcing. Transgrid worked closely with Tesla throughout the process to understand and manage the implications of the VBB incident. Energy Safe Victoria (ESV) completed an independent safety report and was satisfied that the VBB could be re-energised. Transgrid implemented all of the controls that ESV required for VBB. Several joint Tesla-Transgrid lessons learnt workshops were conducted to review documentation from off-site testing. This process included key stakeholders across the business (Lumea, Infrastructure Delivery, Asset Management and Plant Engineering).

8. The Independent Report on this incident, published by ESV is available via this link: https://victorianbigbattery.com.au/wp-content/uploads/2022/01/VBB-Fire-Independent-Report-of-Technical-Findings.pdf

The required corrective actions were all implemented prior to energisation and included procedural improvements, firmware upgrades, development of mock thermal runaway response drills, procedure updates for unit inspections and the conduct of commissioning activities. Fire and Rescue NSW's dedicated battery fire response unit was engaged and conducted a site review, which resulted in the updating of Transgrid's emergency response plan. An incident media response plan was also developed to ensure appropriate communication with key stakeholders and the public in the event of an incident at Wallgrove. All the learnings from the VBB incident improved Tesla's Megapack safety processes, Transgrid's technical knowledge, preparedness and awareness of site safety and emergency management on site.

11.1.3. Lesson Learnt: cyber security and Tesla automation and control implementation

Iberdrola Australia uses the proprietary Tesla Autobidder solution to bid and trade market services. This requires four interfaces for successful operation of the WGB. These include Transgrid as the TNSP, Iberdrola Australia as the market participant, Tesla as the operation and bidding system, and AEMO as the market operator.

To satisfy Transgrid's cyber security policies and TNSP licence obligations, Transgrid had to develop a highly specialised networking hardware and software solution. This solution was to allow for continuous monitoring of Megapack batteries and export of operational and bidding data via the internet to remote servers, without exposing the Transgrid network infrastructure to the risk of a cyberattack. In addition to export of telemetry data, Transgrid also had to develop a process and system to allow Tesla to remotely connect to the Megapack battery system for maintenance and troubleshooting activities, thereby reducing downtime and increasing customer revenue and network stability.

Transgrid faced a number of challenges in this work stream during this project construction phase. A lack of specialist skilled personnel, combined with an internal restructure and COVID-19 restrictions during the construction phase, all resulted in delays to the system development.

Despite these challenges, the end result was the successful implementation of networking hardware and software for the integration of the WGB into the existing Transgrid communications network, providing all stakeholders the required information, without exposing the NSW Transmission network to additional cyber security risks.

The communications equipment installed to enable the WGB to participate in the market has been designed with sufficient spare capacity to allow the inclusion of future additional Transgrid-owned grid battery assets.

The remote maintenance connection protocol, which was deprioritised during the construction program due to resource limitations, is currently in the process of being designed and implemented. Whilst this delay has not impacted the commencement of commercial operations of the WGB, it will impact the speed of Tesla's assessment and resolution of issues or outages, as they are required to attend site to conduct system diagnoses, rather than log in remotely.

Many lessons were learnt during this project, including knowledge and awareness of different types of communication technologies, upskilling and retaining of specialist key personnel and integration with BESS infrastructure and technologies.

11.1.4. Lesson Learnt: secondary system design

Transgrid's project developers faced several challenges in delivering Transgrid's first BESS, including having to define the scope for a type of project that the organisation had never delivered, and engaging the market with limited understanding of the technology and requirements for associated control systems. In the initial scoping phase, little was known about how the Transgrid system would integrate with third parties to successfully implement a BESS.

There were numerous items that were not included as a requirement when engaging the market, and as such the secondary system design integration works were not clearly defined in the project scope. This included the local control and monitoring facility as required for hold point testing and maintenance, the integration with Transgrid's HMI, and the power plant controller required to comply with AEMO's requirements. One of the key learnings from the WGB is a clearer definition of project scope when engaging the market, and thus minimising risks to increased project costs, and potential project delays.

Transgrid

Lumea

transgrid.com.au | lumea.com.au