



## **Musselroe Wind Farm**

### **Lessons Learnt Progress Report 2019**



**November 2019**

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# Introduction

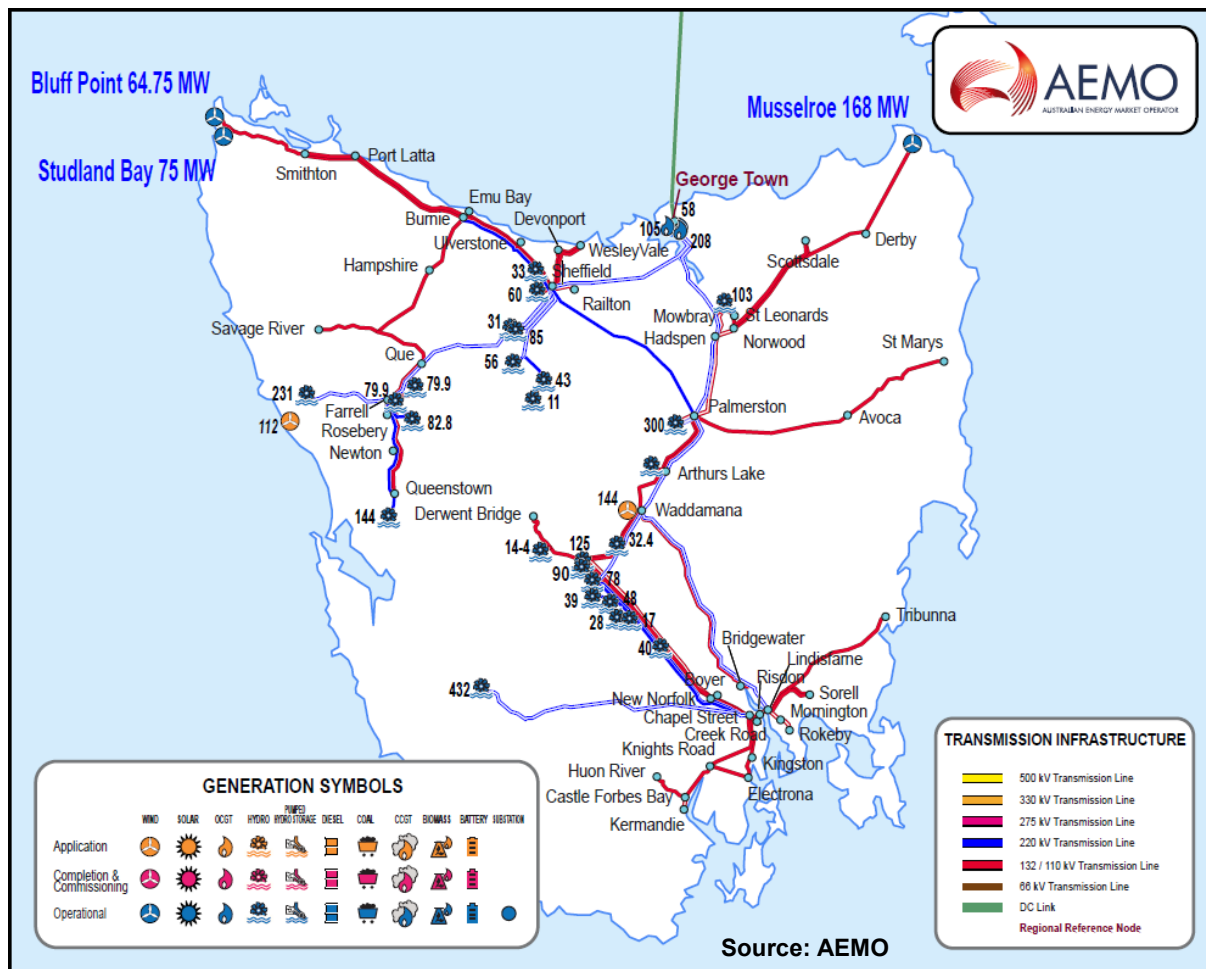
## 1.1 Background

Musselroe Wind Farm (**Musselroe**), located at Cape Portland in the North East of Tasmania comprises 56 V90 Vestas turbines with an installed capacity of 168 MW.

The facility is owned and operated by Woolnorth Wind Farm Holding Pty Ltd (**WNH**) who also own and operate the Studland Bay (75 MW capacity) and Bluff Point (65 MW capacity) wind farms located in the North West of Tasmania. *Figure 1*

Musselroe is connected to the Tasmanian network via a 48km 110 kV single circuit dedicated transmission line from the wind farm to the Tasmanian shared network at Derby, approximately 120km from Georgetown, the Regional Reference Node (RRN) for Tasmania.

Figure 1 NEM Network Connections – Tasmania

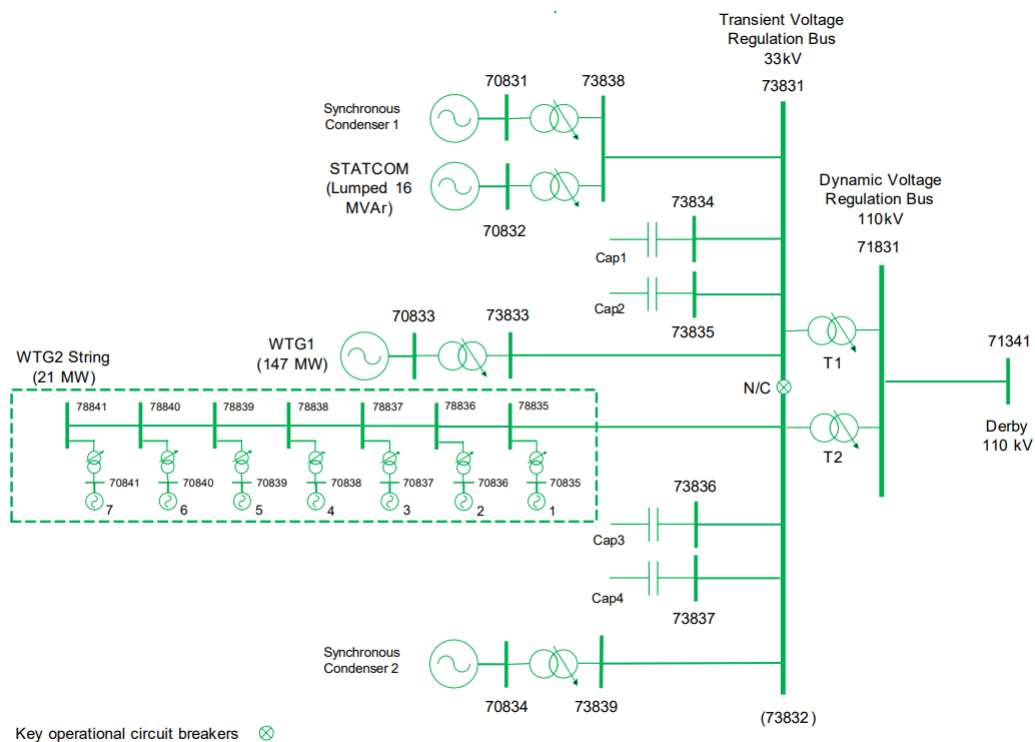


Musselroe was commissioned in 2013 with significant network management equipment, due to its size, network connection arrangement and location. The Connection Point at the Derby Substation has a very low fault level (360 MVA) resulting in Short Circuit Ratio (SCR) range at the wind farm of 2.1.

To meet the performance standards the reactive and generating plant comprises 4 x 4.0 MVar STATCOMs, 4 x 10.0 MVar Capacitor Banks and 2 x 14.0 MVA Synchronous Condensers, together with the 56 V90 3.0 MW double feed induction wind turbines.

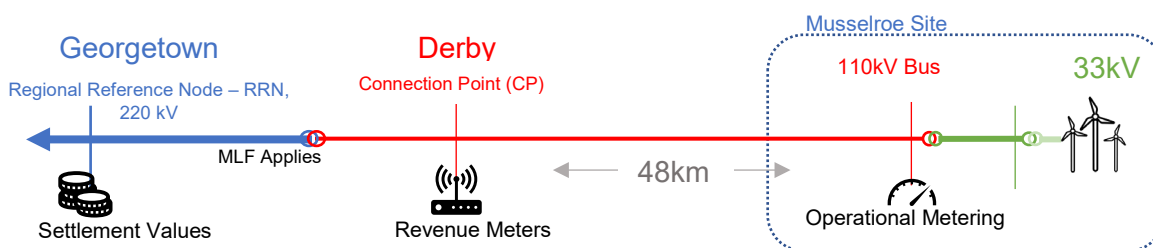
The control system is comprised of various components as seen in Figure 2. The wind turbines are managed via a Vestas Power Plant Controller (PPC).

Figure 2 Musselroe simplified Single-Line Representation



The plant within the generating system is connected to a 33kV collector network. This 33kV collector network is connected to a 110kV transmission line via 2 x 33/110kV 90MVA step-up transformers, with the energy transmitted to Derby, Indicative locations for both revenue metering and operational metering are also shown for reference as represented in Figure 3.

Figure 3 Overall Connection Schematic



Musselroe also has a frequency response capability via the 56 V90 3.0 MW Vestas turbines. The frequency response capability was tested during the R2 validation by injecting a series of artificial frequency events.

The results showed that the frequency response capability can be substantial, however, actual enablement of Frequency Control Ancillary Services (**FCAS**) capability was not a project deliverable at that stage primarily due to the wider FCAS economic conditions.

## 1.2 Activity

In conjunction with the Australian Renewable Energy Agency (ARENA), this project has been implemented to improve the understanding of the economic and commercial case for FCAS participation to support the business case for current and future participants seeking to participate in this market.

The critical outputs of the project include;

- a) demonstrating the ability of an existing wind farm with Vestas turbines to deliver FCAS and undertake a series of tests in consultation with TasNetworks and the Australian Energy Market Operator (AEMO);
- b) summarise the commercial and economic assessment of wind farm participation in the FCAS market;
- c) the requirements for interfacing with AEMO for the purposes of control, communications and wind forecasting;
- d) the technical impact of enabling FCAS in an existing wind farm rather than a new build wind farm;
- e) evaluating the installation of utility-scale battery storage as a means to provide FCAS; and
- f) detailing Musselroe's participation in the FCAS market.

This project has a further 12 months of work to reach completion. This report is a summary of the progress to date, highlighting the lessons learnt.

## 2 Project Activities to date

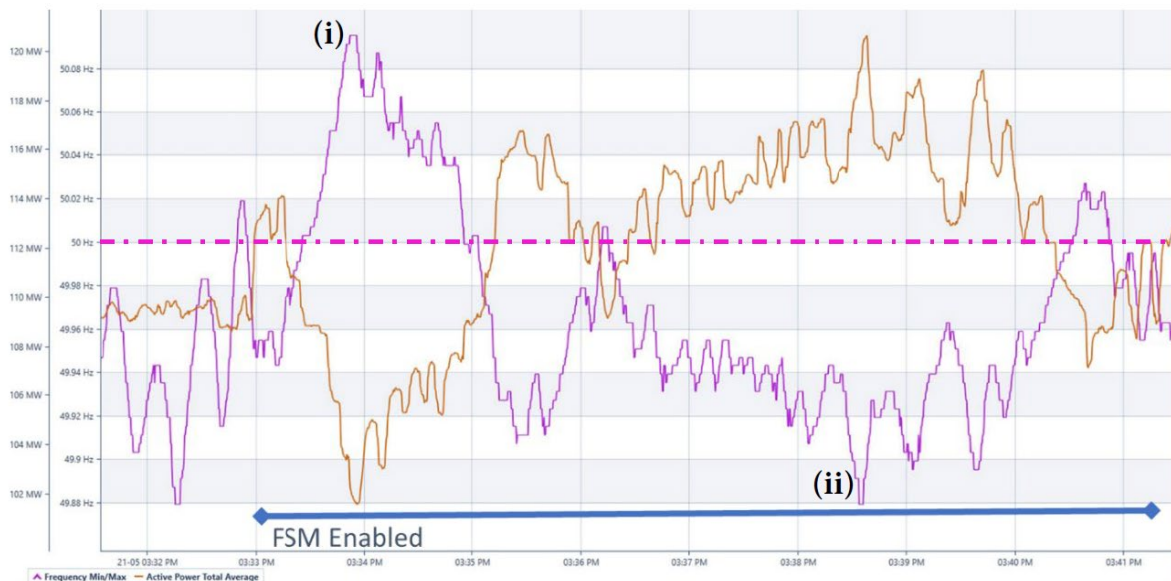
Key activities for this project that have been completed to the end of November 2019 include:

- a) Detailed review of the existing design, operating system specifications, Power System Simulation for Engineering (Software) (PSS/E) modelling, and previous testing to identify opportunities to enable frequency control;
- b) Engagement with Original Equipment Manufacturer (OEM), network specialists and regulatory bodies;
- c) Review of the market and regulatory requirements for FCAS registration;
- d) Development of an FCAS Test Plan with the assistance of AEMO, TasNetworks, Entura and Greenview Strategic Consulting;
- e) Test plan approval by AEMO in August 2018 for multiple frequency control mechanisms (both at the PPC and Wind Turbine Generator (WTG) level of control).
  - (a) This test plan was recently revised for testing the PPC frequency control mechanism only, *see h*);
- f) Modifications implemented to the Supervisory Control and Data Acquisition (SCADA) system to accept Automatic Governor control (AGC) control signals from AEMO. Initial

end-to-end testing has been completed with a full market test to be completed once FCAS registration has been provided.

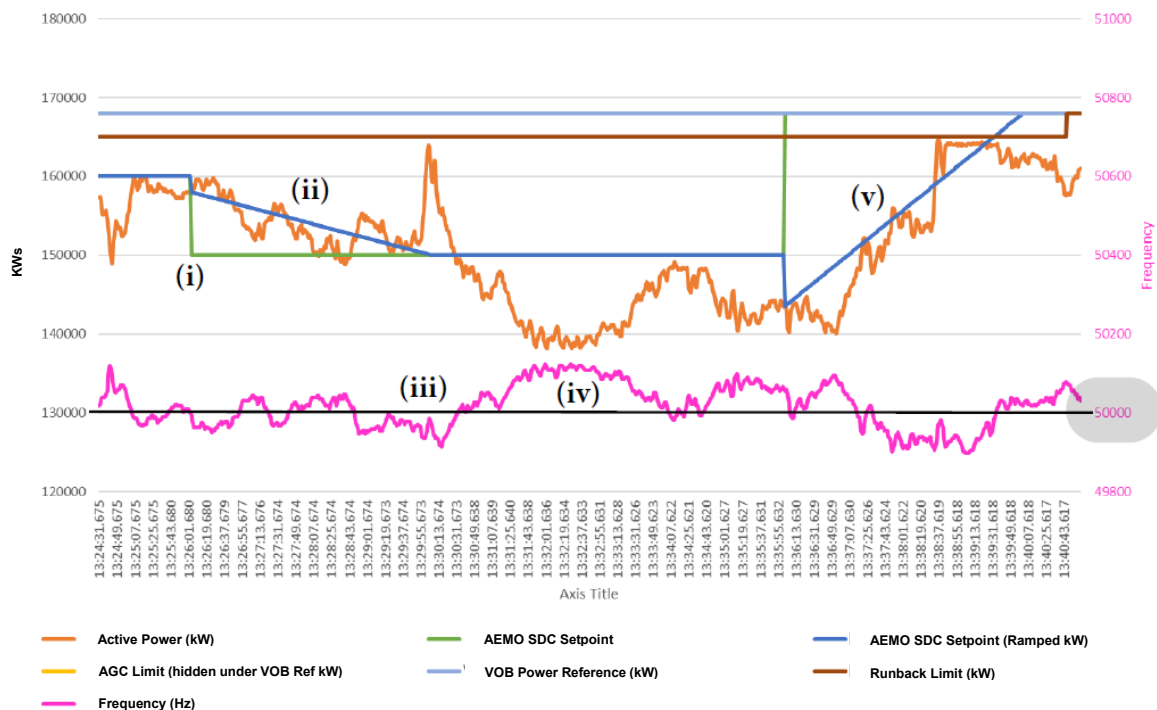
- g) Obtaining access to the market system IT applications and portals for real time analysis and the ability to manage plant availability.
- h) Numerous documents and manuals were studied, and workshops held with Vestas, to understand the frequency control capability at both the PPC and WTG level including AP management of plant limits and network setpoints.
  - (a) The WTG controller design and maintenance manuals supplied with the project indicated a capability to provide a frequency response at the individual generator level.
  - (b) Earlier versions of Vestas turbine controllers have a frequency controller.
  - (c) On-site testing was conducted in February and March 2019 to enable the frequency controller an individual turbine controller at WTG D08 (Circuit D / number 8) by parameter applying changes to the WTG controller. The test results determined that the frequency controller function built into the individual WTG controllers cannot be enabled.
  - (d) Despite engagement with Vestas Australia and their control experts from Denmark in May and July 2019, Vestas were not able to verify the reason for the turbine controller discrepancies. Vestas also responded that they do not support enablement of frequency control at the WTG level. The Musselroe project team ceased pursuing the enablement of the WTG controllers.
- i) On-site tests were conducted in May 2019 to test the PPC Active Power (AP) and dispatch controller functionality.
  - (a) It was discovered that the existing PPC AP dispatch controller logic, when being enabled for frequency control, did not adhere to plant limits, differed from the Functional Design Specification (FDS) and prevented safe operational control. This outcome required further work to scope a PPC software and logic change - see point l) below.
  - (b) A trial was conducted under supervised controlled conditions that successfully demonstrated the existing PPC being enabled for frequency control for a period of 60 minutes. *Figure 4* shows an 8-minute period of the Frequency Sensitive Mode (FSM) test results, noting test pre-curtailment was manually applied due to the PPC configuration issues listed previously.
    - i. When frequency was above 50 Hz, generation decreased.
    - ii. When frequency was lower than 50 Hz, generation increased.

Figure 4 PPC Test – May 2019 - High Speed data logging



- j) SCADA Control Logic requirements were assessed and upgrades developed in conjunction with Vestas, Consolidated Power Projects Australia Pty Ltd (CPP) and Entura.
- k) Modelling of the Control logic was requested and remains in progress.
- l) SCADA Control Logic changes to the PPC and Real-Time Automation Controller (RTAC) were implemented in October 2019 that allowed for effective management of overall site limits, AEMO dispatch targets and frequency control enablement.
  - (a) Testing was successful as noted in *Figure 5* :
    - i. A change in AEMO dispatch cap whilst frequency control is enabled;
    - ii. Linear ramping for the revised AEMO dispatch cap;
    - iii. Frequency decreases resulting in a positive active power response;
    - iv. Frequency increases resulting in an active power decrease;
    - v. Release of AEMO dispatch cap, plant returns to the network limit (which was artificially low for test purposes), noting that the plant continued to respond to frequency changes (particularly high frequency).
  - (b) Further improvements to the loop control functionality were identified and requires refinement prior to undertaking the FCAS registration and market testing.

Figure 5 PPC, RTAC Tests October 2019 – consolidated logging



m) Initial market registration documents have been submitted to AEMO in conjunction with Musselroe’s National Electricity Market (NEM) intermediary.

### 3 Key issues and challenges

Material findings and challenges of the project to date include:

- a) Technical resource limitations:
  - a. Access to experienced local engineering support with the detailed knowledge of the control system, grid and market requirements is limited due to the infancy of FCAS enablement on large scale wind farms in Australia and the pace of new developments. It has been extremely difficult to obtain specialist knowledge within Australia. PPC control system requirements required an overseas engineer to travel to Australia to design and implement the upgrades.
  - b. Rapid technological change has impacted the OEM capabilities to retain experienced engineering support capability for the older generating platforms and their associated control systems.
  - c. OEM knowledge of the Australian grid and market requirements is limited, bringing people both locally and overseas up to speed resulted in considerable project delays;
  - d. Multi-vendor control systems and the need to coordinate with numerous engineering and regulatory staff added to delays in implementing SCADA changes.



- e. This and similar projects are pushing the local and international technical knowledge boundaries for vendors, clients and specialised consultants. There are only a handful of wind farms around the world that are enabled for all the FCAS and energy services contemplated in this project. More generally, this type of capability is largely without precedent in Europe (including Ireland which is generally held up as the gold-standard for wind farm frequency control).
- b) Control system limitations:
- a. The existing plant configuration did not facilitate the AP dispatch accuracy and upper generation site limit management under FCAS enablement requiring extensive control system changes;
  - b. Latency of the OEM control system design limits the FCAS enablement capability;
  - c. Complexity of multiple control systems implemented as a result of the low SCR levels in a weak connection arrangement adds to the limits on the FCAS enablement capability;
  - d. Pre-emptive curtailment and the management of site limits is not inherently well understood by wind OEM's given the traditional 'must generate at maximum levels at all times' philosophy.
  - e. This project required a heavy control system knowledge that is deeper and more complex than the FDS describe.
  - f. Access to the control systems source code is restricted preventing detailed understanding and optimisation;
  - g. Access to the PSS/E modelling of the control system, being generic, prevents detailed analysis of the control system design

The above points subsequently resulted in the need to test and verify control system logic in small steps to ensure system security and generation reliability.

- c) Connection arrangements – weak grids:
- a. Low Voltage Fault Ride Through (LVRT) remains a primary issue for all inverter-based equipment that must be managed at all times in conjunction with frequency control. This means that within weak networks it is not possible to look at AP or frequency control in isolation - the voltage control strategy must be also be carefully maintained and monitored. The PPC is designed to suspend any AP control during voltage disturbances. Due to filtering of the voltage signal in the PPC and inherent latency, a blocking/freeze function is required to prevent excited active power oscillations post a fault. This potentially limits enablement of 6 second contingency frequency services at Musselroe.
  - b. The PPC blocking/freeze functions cannot be changed without careful assessment as seen in *Figure 6* , which shows the high speed data-logging screenshot of a fault ride through response of Musselroe to an actual network event. The network in Tasmania possess unique challenges in meeting grid stability requirements that the wider NEM are yet to experience. As the wind farm is large relative to the size of the Tasmanian power system, inertia, Rate of Change of Frequency settings and voltage regulation require careful consideration. Accurate PSS/E modelling, especially in weak grids is required to ensure the performance of the generating plant meets all its performance standards under all operating conditions. Manufacturers and equipment suppliers are reluctant to provide detailed modelling information on their plant

and associated control due to intellectual property concerns making it difficult for owners of the generating plant to optimise their assets. In the case of Musselroe, even where extensive network models were developed, they require updating and to date are inadequate and still not detailed enough for frequency control assessment, resulting in additional delays and complexities for the project.

Figure 6 Conceptual change to the LVRT Freeze function



c. Extensive interaction with the Transmission Network Service Providers and AEMO has been required to ensure compliance standards are maintained, coordination of testing occurs, and control system changes are well understood. As the energy transition continues more detailed studies will be required especially as the displacement of the traditional hydro generating assets impacts the system inertia and voltage regulation.

d) Commercial considerations:

- a. Entry into new markets posed several challenges and delays to the project as a result of assessing pre-existing agreements, although specific details are not able to be detailed due to commercial sensitivities. Participants may need to consider their;
  - i. NEM Registration requirements including Intermediary arrangements;
  - ii. Power Purchase arrangements;
  - iii. Competition law;
  - iv. Operation and Maintenance agreements;
  - v. Counterparty capability or scope
  - vi. Market interface access

e) Regulatory considerations:

- a. The market regulation area of the industry and business is constantly changing, thereby competing for already limited resources within all the partnered business. Re-evaluation of the technical requirements and economic benefits analysis has added complexity to the project. Examples include:
  - i. Changes to the Frequency Operating Standard for Tasmania;

- ii. Mandatory Primary Frequency Control rule change proposed by AEMO and what it means for WNH other wind farms and the market in general; and
  - iii. Consultation on the Market Ancillary Services Specification (MASS), Marginal loss Factor (MLF) and Coordination of Generation and Transmission Investment.
- f) Forecasting, Dispatch and Operational considerations
  - a. Operational forecasting and dispatch were disconnected from the real time SCADA, impacting the:
    - i. dispatch conformance;
    - ii. FCAS enablement; and
    - iii. commercial outcomes
  - b. SCADA updates and gaining access to the market data/portals were required.
  - c. Coordination of the pre dispatch planning, central forecasting, real time operational activities and central dispatch signal latency is an area that Musselroe is continuing to address.

## 4 Resolution Strategies and implications for other participants

The following key issues and challenges need to be well understood by others attempting projects with this level of complexity.

- a) Modifications to control systems take time and must be signed off by the relevant authorities. Importantly this includes intermediary and counterparty implications due to the complex interaction of all generating systems and market interfaces:
- b) The following additional SCADA elements were added to enable FCAS Regulation:
  - a. Possible Power;
  - b. Local Limit;
  - c. AGC Upper Limit;
  - d. AGC Lower Limit;
  - e. AGC Ramp Up;
  - f. AGC Ramp Down;
  - g. AGC Status; and
  - h. Frequency Control Enablement state.
- c) The PPC and RTAC system were modified to enable FCAS Contingency, including management of all site maximum generation limits:
  - i. PPC software was upgraded; and
  - j. PPC and RTAC control logic modified to ensure FCAS contingency pre-emption was not interpreted as a hard limit (AEMO setpoints effectively implemented as a 'soft limit')
- d) Vendors and OEM's can be challenged both from their technical understanding and specialist resourcing aspects. Access to Vendor source code or detailed modelling or system information can be problematic.

- e) The importance of linear trajectories for AP ramp up and down is essential for management of dispatch and power system security. All participants should make sure their control system is in line with the market systems.
- f) Participants considering enablement should assess their existing contractual and registration arrangements to ensure an effective implementation.
- g) Existing Functional Design Specifications, agreed Generator Performance Standards, Site Data Sheets and modelling may require detailed reviews and updating.
- h) Enhancement of internal knowledge and capability, where plant operation and market outcomes become more intertwined, will result in less reliance on the vendor, especially in a changing market environment.
- i) Market forecasting and Dispatch offers should be aligned with the real time generation activities, coupled to the control systems and a constant monitoring and alerting system implemented.

## 5 Next steps

Throughout 2020, the next steps for the project are:

- a) Active Power Loop control commissioning and testing
- b) Forecasting and Dispatch accuracy
- c) FCAS capability test to MASS required parameters
- d) Finalise Registration
- e) FCAS Market test
- f) Updating of FDS's
- g) Drafting an updated SDS/GPS
- h) Energy Storage assessment
- i) Finalise project

## Abbreviations

AEMO	Australian Energy Market Operator
AGC	Automatic Generation Control (AEMO)
AP	Active Power
ARENA	Australian Renewable Energy Agency
CPP	Consolidated Power Projects Australia Pty Ltd
FCAS	Frequency Control Ancillary Services
FDS	Functional Design Specification
FSM	Frequency Sensitive Mode (a PPC frequency control mode)
LVRT	Low Voltage Fault Ride Through
MASS	Market Ancillary Services Specification
MLF	Marginal Loss Factor
Musselroe	Musselroe Wind Farm
NEM	National Electricity Market
OEM	Original Equipment Manufacturer
PPC	Turbine Power Plant Controller
PSS/E	Power System Simulation for Engineering (Software)
RTAC	Real-Time Automation Controller
SCADA	Supervisory Control and Data Acquisition
SCR	Short Circuit Ratio
TNSP	Transmission Network Service Providers
WNH	Woolnorth Wind Farm Holdings
WTG	Individual Wind Turbine Generators on site