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HORNSDALE WIND FARM 2 FCAS TRIAL

KNOWLEDGE SHARING REPORT

NEOEN Australia Pty Ltd.

Executive Summary

The purpose of the Hornsdale Wind Farm Stage 2 (HDWF2) Frequency Control Ancillary Services Trial was to determine and demonstrate the extent of the capability for wind farms of similar design and functionality to the HDWF2 and operating in similar conditions to the Hornsdale 2 WF to provide Frequency Control Ancillary Services to the National Electricity Market (NEM).

The Hornsdale Wind Farm controller includes subset of controls and operating modes designed to assist the grid maintain frequency by responding to under and over frequency events. The controller responds to over frequency events by lowering power output and responds to under frequency events by increasing power output. This functionality of the controller was utilised for the HDWF2 trial.

The results from the HDWF2 trial show that wind farms of similar design and functionality to the HDWF2 and operating in similar conditions to the Hornsdale 2 WF can provide FCAS services in 6 of the 8 FCAS markets. This is provided they can meet the relevant requirements of the MASS for registration and testing and operation/post event performance verification. HDWF2 trial did not meet the requirements of AEMO for the fast raise and lower (6 seconds) market: the wind farm does not currently provide adequate active power injection for fast raise (6 seconds) services in the event of a combined frequency and voltage ride through event.

To be able to increase power output in response to under frequency events the wind farm needs to be curtailed with the controller running a spinning reserve function. In this operating mode the wind farm will be generating less than the available power as wind energy is spilled. Due to difficulty in attaining the right conditions for the test schedule, as well as inexperience in co-optimising bidding the trial ran over the expected 48 hours to around 80 hours. This resulted in higher than expected lost production and revenue. In normal market conditions, the opportunities to sell FCAS services as a sustainable source of revenue for a windfarm may be limited. Providing FCAS is most economic under high FCAS prices conditions when it will effectively provide a hedge against high FCAS charges.

Background to Trial

The Hornsdale Wind Farm project includes 99 Siemens Wind Power Direct Drive 3.2 MW wind turbines, the Hornsdale Wind Farm Stage 2 project comprises of 32 of these.

Each wind turbine operates at variable speed and is connected to the grid via a full scale converter to supply 50Hz AC power. The converters are not set to provide synthetic inertia so in simple terms the Wind Farm is “inertia-less”. Therefore the Wind Farm does not assist the grid in resisting frequency changes to maintain transient stability.

The National Electricity Market standards require that the grid frequency is fifty cycles per second. The Australian Energy Market Operator (AEMO) is tasked with maintaining the frequency on the grid to the NEM standards. AEMO uses regulation and contingency Frequency Control Ancillary Services (FCAS) to maintain the frequency on the grid and, following a departure from 50Hz, to restore grid frequency. These services involve adjustment of generated power as grid frequency decreases when the power system load exceeds generation and rises when generation exceeds the system load.

There are eight FCAS markets in the NEM, two for minor increases and decreases in frequency known as Regulation Raise and Regulation Lower. There are six FCAS markets for Contingency events. These are fast raise/lower (6 seconds), slow raise/lower (60 seconds) and delayed raise/lower (5 minute).

The HDWF2 FCAS trial originated through a licence condition in the generation licence from Essential Services Commission of South Australia (ESCOSA). In Mid-2016 ESCOSA with support from AEMO started a review into the possible requirement for inverter connected generation to provide a minimum level of frequency control. During the final stages of the review Neoen requested an inverter based generator license from ESCOSA. Since no wind or solar farm in Australia had previously been registered to provide FCAS, it was proposed that Neoen participate in an end-to-end frequency control demonstration project in collaboration with AEMO and ARENA.

In early 2017 Hornsdale Wind Farm Stage 2 (HDWF2) Pty Ltd applied for funding to the Australian Renewable Energy Agency (ARENA) Advancing Renewables Programme to complete a trial to test if the HDWF2 wind farm could be configured to provide Frequency Control Ancillary Services. The trial is named Hornsdale Wind Farm Stage 2 FCAS Trial, South Australia Contract No. *G00901*.

Introduction

The FCAS Trial was performed in collaboration between ARENA, AEMO, SIEMENS-GAMESA RE (as manufacturer of the turbines and provider of the technology installed on site) and NEOEN (as the owner of the Hornsdale Windfarm 2) to assess and prove the ability of the wind farm to provide FCAS services on the market.

This trial was performed between August 2017 to February 2018 and was seen as an opportunity for Neoen, on the behalf of the wind industry, to prove that wind generators have the potential to participate in supply of grid stability services. On top of its willingness to confirm the technical capacity of its windfarm, Neoen has seen this trial as an occasion to study new commercial opportunities for the Windfarm and assess their sustainability.

After the detailed definition by all the parties of the objectives and intended outcomes of the trial, the following implementation strategy was developed:

- Definition, implementation and then testing of the specific upgrades/changes that were required to be completed on the wind farm to be able to perform the trial;
- Definition of the capacity the Wind farm could register under v5 of MASS in the different FCAS market services. Once this was completed, finalisation of the testing plan and completion of the AEMO registration process occurred; and finally
- Live market Trial and assessment of the results.

This report summarises the main outcomes of the different steps followed during the trial process, to present from Neoen's point of view any roadblocks encountered during the trial and also the potential incentives to the windfarm for the provision of FCAS services on a longer term.

Activity Objectives and technical requirements

A. Objectives

The purpose of the HDWF2 FCAS Trial was to demonstrate that similar wind farms can provide FCAS to the National Electricity Market. The overall objectives and outcomes are listed in the Table 1 at the end of the document.

B. Technical upgrades

The following technical and communication changes were required for the wind farm to provide FCAS in the NEM:

- Configuration of the wind farm plant controller's frequency control functions. Note, the HDWF2 wind farm plant controller includes specialised frequency controls designed to assist the grid and maintain frequency.

The following technical and communication changes were required in order for AEMO to facilitate the delivery of FCAS from the wind farm:

- Programming the new Electranet and AEMO SCADA databases and operational functionality in the wind farm remote terminal unit (RTU) to allow transmission of the incoming and outgoing control signals from the AEMO Automatic Generation Control (AGC) and EMS systems via the Electranet RTU;

- Updating the wind farm supervisory control and data acquisition system (SCADA) to include the new functionality in the wind farm. This included adding graphical functionality, database updates and control of the wind farm plant controller.
- Update the wind farm historian system and database to capture information for reporting;
- Updates to the wind farm control room market monitoring systems to allow the regulation services to be activated and monitored during the trial periods.

C. Description of works undertaken

To fulfil the requirements listed above, a number of key steps were taken by Siemens and Neoen to enable the FCAS service to be provided:

- Investigation and modelling of the expected capabilities to ensure the control systems were able to achieve a desirable response in each of the contingency markets. The regulation market provision capability was not modelled given active setpoint target follow capability had been continuously displayed whenever a semi-dispatch cap was received from AEMO, hence it was clear active power management, even at 4 sec durations, could be expected;
- Modifications were made to the SCADA points list at the site with Electranet and AEMO to ensure adequate and AEMO required elements were included (e.g. AGC Status, High and Low limits etc);
- The frequency control modules within the wind farm controllers were enabled (this was able to be achieved remotely); and
- Some additional information displays were created for the Neoen control room to ensure they could monitor and manage FCAS enablement adequately.

Main technical outcomes and challenges

A. Main outcomes

The results from the HDWF2 trial show that HDWF2 and similar wind farms can provide FCAS services in 6 of the 8 FCAS markets. The HDWF2 trial did not meet the requirements of AEMO for the fast raise and lower (6 seconds) market (for further information, please refer to "*Siemens Gamesa - Hornsdale 2 – Frequency Control Ancillary Service Trial Knowledge Sharing Report* - 8.1.2" or "*AEMO Knowledge Sharing Article* - 2.1.3").

Although it was not further investigated in this trial due to time and cost considerations, further attention could be given to the challenges around Fast FCAS.

Regarding the quality of the FCAS services provided, the speed of the Regulation FCAS response from the HDWF2 wind farm was approximately 0.325 seconds based on the time taken for the wind farm controller to respond to the external AEMO AGC request, calculate new set points and then communicate with each wind turbine. This does not take into account the measurement delays due to signal filtering, calculations of the frequency from the voltage zero crossing measurement and external communication system delays. Overall the wind farm's response time was short relative to the inherent latency in the AGC signals.

The wind farm demonstrated the ability to respond to a Lower Contingency event (see AEMO report) when frequency went above 50.15Hz. During the trial the wind farm did not have the chance to demonstrate a response to a Raise Contingency event as there were no such events whilst HDWF2 was suitably enabled with adequate Raise Contingency MW headroom.

B. Limitations and challenges

The following limitations were identified to HDWF2 in providing FCAS services in the National Electricity Market (NEM) in accordance with AEMO's Market Ancillary Services Specification (MASS).

1. The wind farm did not provide fast raise (6 second) services because modelling could not demonstrate the fast raise contribution in the event of a combined under frequency and voltage ride through event. This is due to the obligation for the wind farm to stay connected and support the network voltage during disturbances.
    a. It is noted that fast raise (6 second) services could possibly be provided by the HDWF2 in the event of a combined under frequency and voltage ride through event, if additional voltage management plant was designed and installed to provide the voltage support but this was outside the scope of this assessment.
2. The management of upper limits of the plant based on current, live wind power needs further refinement. The upper angle for the FCAS trapezium has been set rather conservatively based on the MASS and the Verification Tool which limits the amount of FCAS that can be provided relative to the amount that must be curtailed to provide the service. We understand is looking to review the MASS in the future.
   AEMO's self forecasting process is likely to give greater certainty of the wind farm's capabilities over the dispatch interval, allowing a tighter headroom and less curtailment to provide FCAS.
3. Despite technical capability at the plant to run at near 0MW, the testing regime proposed did not contemplate providing FCAS from 0MW. The plant registration has minimum enablement set at 15 MW which means that limited Raise FCAS can be offered in low wind conditions. Given actual outcomes and success at these levels, we would look to register the minimum enablement level to 0MW to capture the full capability at lower wind speeds.

In addition of the points listed above, AEMO has also identified two other outcomes from the Market Trial:

FCAS and Energy Cost Co-optimisation

4. For 5.8% of the trial periods, no FCAS was enabled because the overall cost of enabling the wind farm to provide FCAS was greater than the FCAS price due the low or negative energy price offering from the wind farm.

FCAS Stranding

5. For 11% of the time the wind farm was not enabled for one or more frequency control ancillary services because the energy being produced by the wind farm at the start of the dispatch cycle was outside of the maximum and minimum enablement limits of the scaled FCAS trapezium.

Regarding the registration process itself, registering with AEMO for the provision of FCAS was relatively straight forward and consistent with other market operator processes. It is important to note that the actual determination of the values required specialist consultant analysis. It is possible that this process would be much easier in future with the learnings gained by AEMO, Siemens and Neoen.

The challenges around the MASS registration were largely similar in nature to the challenges associated with the Hornsdale Battery that are subsequently in the process of being addressed by AEMO and the AEMC in recent publications.

Whilst there appeared to be no roadblocking organisations, people or systems per se, perhaps the greatest challenge in the project was around the depth of understanding within the owner and vendor organisations. Despite FCAS being in the market for the past 20 years, the level of technical understanding in this technical area is limited, sometimes resulting in the need for significant education.

Similarly, within Neoen, there was a need to create interim systems to be able to manage the enablement and optimisation during various trial periods, as typical wind farm operational systems do not currently cater to this form of operation.

Following this trial and the main outcomes of it, AEMO has developed and added technical testing and simulation requirements to the existing process for wind farms registering for contingency FCAS.

Economic Outcomes of the Trial

A. Lost Revenue

Curtailed generation associated with the 80 hours of trial amounted to 987 MWh. The spot market value of this energy was approximately $83,000 (note: This does not include the value of LGCs which was approximately $85/MWh). This was only offset by $24,000 of FCAS revenue; broken down in the table below.

	RAISE 6SEC	RAISE 60SEC	RAISE 5MIN	RAISE REG	LOWER 6SEC	LOWER 60SEC	LOWER 5MIN	LOWER REG
Revenue total ($)	0	329	458	10,822	0	20	62	12,517
Weighted average market price ($/MW-h)*	N/A	1.3	2.8	47.6	N/A	0.1	0.2	43.7
Average dispatch capacity (MW)	N/A	6.5	4.2	12.4	N/A	11.3	11.6	14.6
Average amount of curtailment (MW)	N/A	9.4	6.0	18.7	N/A	N/A	N/A	~7.0

** Note: The regulation average prices during the whole trial is skewed by the event of the 14th of January. Outside of this particular event the average prices were: RaiseReg: 16.9 $/MW-h & LowerReg: 16.2 $/MW-h*

It is important to note that the Hornsdale Windfarm was contracted to a PPA provider during the whole duration of the trial. The financial impact to the PPA was noted by the PPA provider, but the provider was satisfied that the impacts were small enough in the circumstances. For future FCAS enabled farms, this may not be the case.

B. Impact on Causer Pays Factors

The Enabled Market Participant Factors (MPFs) published after trialling Regulation were positive, suggesting good performance from the wind farm when offering Regulation FCAS.

The raw data factors across the 10 December 2017 – 7 January 2018 period, showed positive contributions in LEF and REF factors for HDWF2, compared to HDWF1 and HDWF3, as shown in the table below.

DUID	LEFa	LNEFa	REFa	RNEFa	N(LEFa)	N(REFa)	N(REFa)	N(RNEFa)
HDWF1	0	-11.0685	0	-9.1927	0	-11.068	0	-9.1927
HDWF2	2.3606	-6.13962	8.8269	-14.2882	0	-6.1396	0	-14.2882
HDWF3	0	-11.8533	0	-18.5206	0	-11.8533	0	-18.5206

There may be an improvement in overall monthly factors when enabled for Regulation due to the reduced duration of non-enabled assessment. The overall duration of enablement was quite small compared to the 4 week assessment period though. The positive enabled factors cannot net off the negative non-enabled factors.

Overall there was no statistically significant change in CPF due to the trial.

For more information on FCAS Regulation recovery methods see AEMO's Ancillary Services Causer Pays Contribution Factors Procedure.

C. Factors affecting the economic viability of providing FCAS

In general the market price for FCAS is much lower than that of Energy. For a generator with minimal operating costs it is nearly always preferable to offer Energy over FCAS.

There are however times where FCAS prices reach the market cap and there is a strong incentive to offer FCAS. Such an event occurred on the 14th of January 2018 when SA had a credible contingency period. During this period, SA was required to source 35 MW of Raise and Lower Regulation FCAS internally. Normally during these periods price is set close to the market cap despite a substantial oversupply of this service. As a wind farm with a poor Causer Pays Factor, the Hornsdale wind farms are liable for a substantial portion of the FCAS Regulation costs associated with the high prices. In January, HDWF2 bid up to 10 MW into the Regulation markets assisting in maintaining the price below $300/MWh. Although FCAS revenues were largely offset by lost Energy revenue, the savings associated with the reduced Regulation prices were significant. Other SA wind farms and SA consumers also benefitted from the savings. Post event analysis revealed that either HDWF2 or HPR could have single-handedly reduced the extreme prices and that Neoen had offered more volume than the efficient optimum. However, the event did demonstrate the abilities of both wind farms and batteries to deliver FCAS services at critical times.

Given the recent increase in Regulation capacity from HDWF2 and HPR the case for more wind farms providing this service has been diminished.

The wind farm could offer Lower Contingency FCAS without greatly impacting energy production, however the price of these services is generally close to zero. However, use of Lower Contingency service settings would be far preferable than the Over-Frequency Generator Tripping Scheme that is currently under consideration in South Australia.

Conclusion

The main observation from a technical perspective is that the trial showed that with the implementation of the required upgrades, the windfarm was able to provide FCAS services (especially in the regulation market) of sufficient quality. As operator of the windfarm, Neoen has confidence that the windfarm will respond reliably if Neoen wants to keep providing services on the FCAS market.

The duration of the trial impacted the farm through significant Energy revenue loss given we had to force the dispatch outcomes to ensure the tests occurred. Under normal market operation, we would not expect this to be the typical outcome, and we could have the capability activated and ready in case FCAS prices were extremely high,

Self hedging against high FCAS prices was however a major commercial benefit to come from the trial. For this purpose, HDWF2 has more than enough capacity to protect all three stages of the Hornsdale project so there would no particular need for HDWF1 & 3 to self hedge at this point.

To go further…

As part of the trial 2 results report were written by AEMO and Siemens.

For more information about the technical and communication upgrades required in order for Hornsdale to provide FCAS, the challenges to retrospectively configure an existing wind farm to provide FCAS services, and how this will influence the design of future and, finally, the performance of the WF FCAS response, please refer to *Siemens Gamesa - Hornsdale 2 – Frequency Control Ancillary Service Trial Knowledge Sharing Report*.

For more information about regulatory and technical requirements for implementing provision of FCAS services for existing and future wind farms, the technical and communication upgrades required in order for AEMO to facilitate the delivery of FCAS from HWF and the identified limitations to HWF providing FCAS services in the NEM, please refer to *AEMO Frequency Control Ancillary Service Trial Knowledge Sharing*.

Thank you for the efforts of our project partners in achieving this outcomes of this trial….

- Siemens Gamesa
- CPP
- LR Synergy
- Greenview Strategic Consulting
- GHD
- ARENA
- AEMO

Table 1 - Objectives and Outcomes

Item	Objectives and Intended Outcomes	Outcomes
1	To model, implement and test the capability of Hornsdale 2 WF to be remotely controlled by AEMO to provide Frequency Control Ancillary Services {FCAS);	At the time of writing this report, the wind farm is currently providing FCAS to AEMO in 6 of the 8 FCAS markets.
2	To determine the types of FCAS for which the Hornsdale 2 WF can have its generating units classified in accordance with NER 2.2.6;	The Hornsdale 2 WF can have its generating units classified in the following FCAS 6 markets. Regulation lower and raise, Slow lower and raise, Delayed lower and raise.
3	To successfully complete a 48 hour trial of bidding and operating in the FCAS markets for which Hornsdale 2 WF can be registered, or where Hornsdale 2 WF cannot be classified, successfully complete a market simulation trial. For the avoidance of doubt, successful completion of the trial means that the Recipient has fulfilled its obligations under the Detailed Test Plan;	The Hornsdale 2 WF demonstrated it can remain connected in a wide range of frequency conditions and the Wind Farm Technology is able to meet the requirements of the minimum and automatic standards.
4	To determine the delayed response time and the accuracy of Hornsdale 2 WF's response to the regulation set-point changes;	The wind farm frequency controller takes some time to respond and calculate new set-points and is modelled as Td_input with a value of 0.125 seconds. This value has been developed from wind farm testing. The wind farm also takes some time to send new set-points to each turbine in a wind farm. This is modelled as Td_Psp_Park and is modelled as 0.2 seconds this is mostly due to the time that is taken to pole each turbine in the wind farm. There are also some measurement delays due to the required signal filtering and calculation of the frequency from voltage zero crossing measurement.