Options Evaluation Report (OER)

NSW Oscillation Monitoring
OER- **N2636** revision 1.0

Ellipse project no(s):

TRIM file: [TRIM No]

Project reason: Imposed Standards - Communications Systems to meet AEMO requirements

Project category: Prescribed - Security/ Compliance

Approvals

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Date submitted for approval	6 September 2022	

Change history

Revision	Date	Amendment
0	15/07/2022	Original Version
1	06/09/2022	Revised for latest OFS estimate.

Executive summary

AEMO has issued the notice under clause 4.11.1 (d) for oscillation monitoring at a number of Transgrid sites. The notice requires Transgrid to either install a number of phasor measurement units or replace the existing units so that AEMO can remotely monitor the performance of Transgrid's transmission system.

As per clause 4.11.1 (e), Transgrid is required to comply with the notice. Non-compliance is subject to a civil penalty under the National Electricity Regulations.

Under the notice, AEMO has identified critical locations in the New South Wales network at which high-speed monitoring of power system data is required for wide area monitoring system (WAMS). This will enable AEMO to have greater visibility of the power system and help them to assess oscillatory behaviour in real time and facilitate the development of accurate oscillatory models of the power system network.

The scope of works is based on installation and configuration of phasor measurement units as per Appendix B and they are broken down in stages as per Table 1 below. There are 41 individual sites in total needing installation and configuration of PMUs. The project also requires an upgrade of the communication link and the completion dates are set as per the high, medium and low priority sites as defined by AEMO.

The relevant options for this project are:

- Do nothing. Non-compliance is subject to Tier 3 civil penalty under the National Electricity Regulations up to $170,000, plus $14,400 per day for continuing breaches.
- Option A as per below with a weighted NPV value of $19.2M.

Therefore Option A is recommended to be actioned to comply with the National Electricity Rules.

Table 1 - Evaluated options

Option	Description	Direct capital cost ($m)	Network and corporate overheads ($m)	Total capital cost[1] ($m)
Option A	**Stage 1A** – high priority sites requiring upgrade, modification or replacement of existing PMUs and HSMs – AEMO required need date 31 Dec 2023 excluding the sites addressed by N2192. **Stage 1B** – High priority sites requiring replacement of existing high speed monitoring devices with PMUs – AEMO required need date 31 Dec 2023. **Stage 2** – Medium priority sites requiring installation and configuration of new PMUs – AEMO need date 31 Dec 2024. **Stage 3** – Low priority sites requiring installation and configuration of new PMUs – AEMO need date 31 Dec 2025.	8.7	2.8	11.5

[1] Total capital cost is the sum of the direct capital cost and network and corporate overheads. Total capital cost is used in this OER for all analysis.

1. Need/opportunity

AEMO has issued the notice under clause 4.11.1 (d) for oscillation monitoring at a number of Transgrid sites as per the specifications set out in Appendix A. As per this, AEMO requires Transgrid to either install a number of phasor measurement units or replace the existing Qualitrol HSMs in order to remotely monitor the performance of Transgrid's transmission system.

AEMO currently has extremely limited real-time visibility of emerging power system stability phenomena, primarily related to low system strength, low system inertia and higher penetrations of inverter-based generation. Low system strength has been shown through theoretical simulations as well as actual observations to cause instability, such as voltage oscillations, which can be a threat to power system security and the problem is exacerbated by low minimum demands currently being experienced.

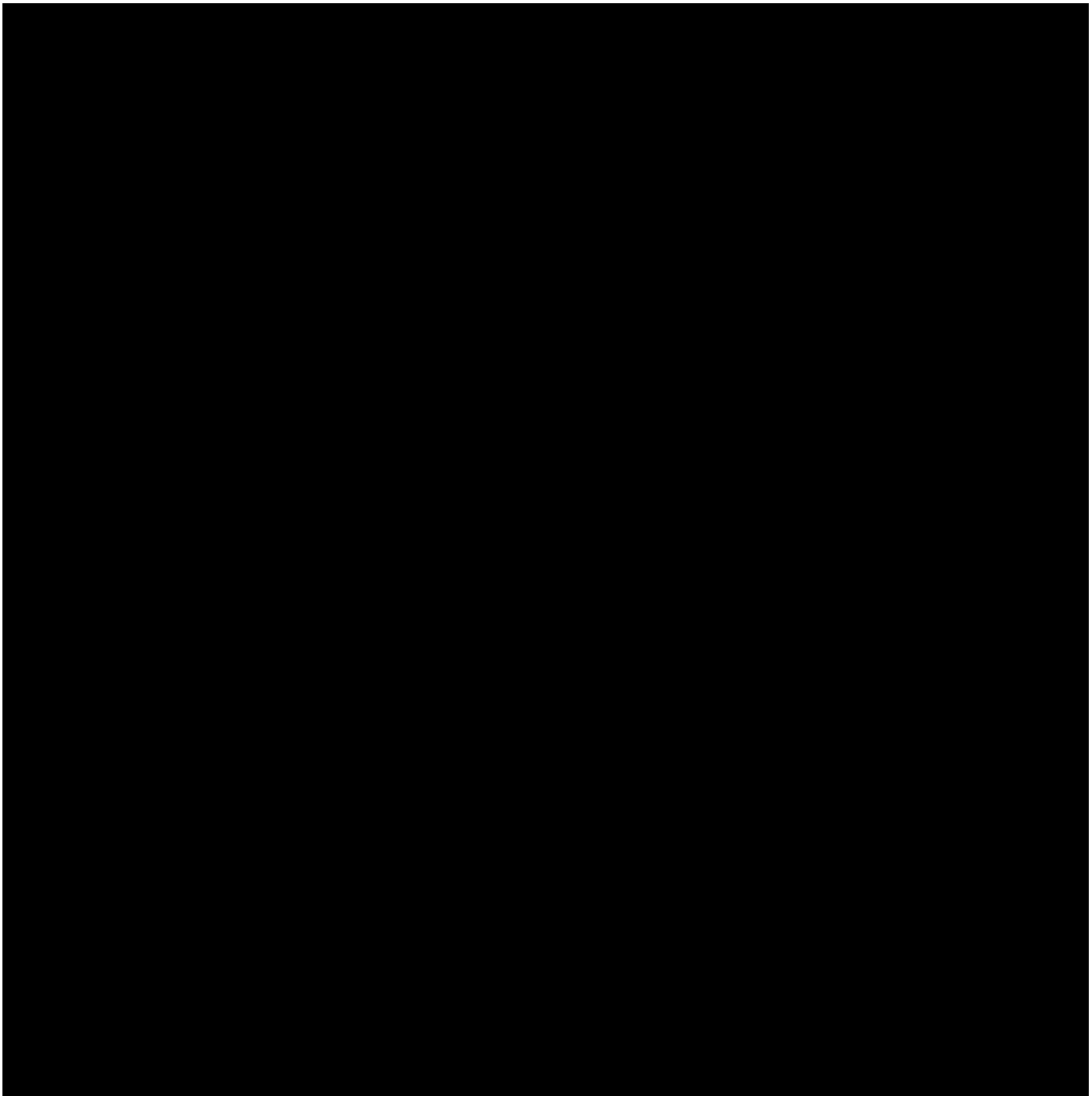
In addition, the magnitude of un-damped inter-area electromechanical oscillations has been increasing due to a reduction of synchronous machines with power system stabilisers online. As more inverter-based generation connects and new Synchronous Condensers are installed in network for improving system strength, these power system security issues will become more common and important to address.

Existing SCADA systems are unable to detect and respond to these power system phenomena. Without any visibility, the control room cannot determine power system security in real-time and would need to pre-emptively constrain inverter-based generation or direct on synchronous generation. Both actions can have serious market and political implications.

WAMS (Wide Area Monitoring System) is a smart-grid technology that allows real-time detection of these issues by utilising a network of high-speed monitoring devices. Installation of high-speed streaming devices (such as phasor measurement units, or PMUs) throughout the power system will provide the required data for WAMS, enabling AEMO to detect and respond effectively to rapidly developing power system issues and more accurately model the power system.

This need is identified as compliance as per AEMO's notice under Clause 4.11.1 (d) of the NER. This need also requires communications link between Transgrid and AEMO as per below.

Figure 1 Proposed Communications link between TransGrid and AEMO



2. Related needs/opportunities

Transgrid is currently working on a project (under need N2192) to install high resolution disturbance recorders at selected sites in South West NSW. This involves the installation of disturbance recorder class monitors sourced from CT metering cores, as well as a separate phasor measurement units (PMU) to stream synchrophasor measurements to two data concentrators. The disturbance recorders will be compatible with Transgrid's existing disturbance monitoring systems and AEMO's High Speed Monitoring system. The sites were subject to an earlier AEMO direction.

These new recorders and PMUs will be set up to monitor the following:

[redacted]

The current estimated costs for the N2192 is $1.07M.

Transgrid is also presently undertaking a project (under need N2666) to investigate a solution to Telstra's change in Wireless and PSTN telephony systems. The purpose of the investigation is to investigate a solution that enables Transgrid to provide metering data to the relevant third parties and meet the NER metering requirements. It is expected that the network architecture established under Need N2666 will be replicated for the PMU devices.

It is also recommended that a reliable communication channel between the substation and the Phasor Data Concentrators (PDC) be established in order to transmit the required data from Transgrid to AEMO.

3. Options

3.1. Base case

The base case is a do nothing option. Failure to comply with the AEMO notice is breach of regulatory requirement for the purposes of the National Electricity Law and subject to a Tier 3 civil penalty under the National Electricity Regulations up to $170,000, plus $14,400 per day for continuing breaches.

3.2. Assessed options

One option has been evaluated for the installation and configuration of PMUs at various locations throughout Transgrid's network.

Option A — Upgrade, install, modify or replace existing PMUs as per the AEMO notice

Stage 1A: Upgrade, modify or replace remote monitoring equipment, being the existing PMUs at [redacted] so that they comply with AEMO specifications by 31 Dec 2023. [redacted] is covered by the N2636 however other sites are addressed separately under N2192.

Stage 1B: Install PMUs complying with AEMO specifications to replace the existing Qualitrol HSMs and remotely monitor the performance of Transgrid's transmission system at selected high priority locations by 31 Dec 2023. The locations are listed in Appendix B.

Stage 2: Install PMUs complying with AEMO specifications to remotely monitor the performance of Transgrid's transmission system at selected medium priority locations by 31 Dec 2024. The locations are listed in Appendix B.

Stage 3: Install PMUs complying with AEMO specifications to remotely monitor the performance of Transgrid's transmission system at selected low priority locations by 31 Dec 2025. The locations are listed in Appendix B.

Option A Costs

The cost estimates for this option in the table below have an uncertainty of ± 25%, and are inclusive of all stages of the option including [redacted]. The works under the notice for [redacted] under Stage 1A are covered by N2192.

Table 2 – Option A expected expenditure

Estimated Cost non-escalated	Total Project Base Cost ($M)	2022-23	2023-24	2024-25	2025-26
Total Project Cost	**11.5**	1.63	4.74	3.4	1.73

It is estimated that an amount up to $1.6 million is required to progress the project from DG1 to DG2, which is included in the estimated cost set out above. This is to cover activities such as site assessments, the development of concept designs, the commencement of project approvals, and the early procurement of long lead-time items as required.

Option A Benefits

The benefits of the PMU installation have been provided by AEMO in their recent report *PMU Cost Benefit Analysis for NSW Region*. The benefits included in the evaluation are summarised below.

Scenario	Central	Low	High
Benefit ($M per annum)	3.2	3.0	3.4

Note the benefits do not include the SW region which is covered under the need N2192.

4. Evaluation

4.1. Commercial evaluation methodology

The economic assessment undertaken for this project includes three scenarios that reflect a central set assumptions based on current information that is most likely to eventuate (central scenario), a set of assumptions that give rise to a lower bound for net benefits (lower bound scenario), and a set of assumptions that give rise to an upper bound on benefits (higher bound scenario).

Assumptions for each scenario for this project are set out in the table below.

Parameter	Central scenario	Lower bound scenario	Higher bound scenario
Discount rate	4.8%	7.37%	2.23%
Capital cost	100%	125%	75%
Operating expenditure	100%	125%	75%
Scenario weighting	50%	25%	25%

Weighting of each scenario reflects their likelihood of occurrence. The central scenario is most likely to occur and has therefore been given a higher weighting of 50 per cent based on available information at this time. The lower and higher bound scenario is expected to be equally likely to occur and has been weighted

accordingly at 25 per cent. Since the central scenario represents the most likely scenario to occur, we have weighted it at 50 per cent. The other two scenarios reflect extreme combinations of assumptions designed to stress test the results. Accordingly, these scenarios are weighted at 25 per cent each.

Parameters used in this commercial evaluation:

Parameter	Parameter Description	Value used for this evaluation
Discount year	Year that dollar values are discounted to	FY22
Base year	The year that dollar value outputs are expressed in real terms	FY22 dollars
Period of analysis	Number of years included in economic analysis with remaining capital value included as terminal value at the end of the analysis period.	15

The capex figures in this OER do not include any real cost escalation. An opex cost estimate of $230k per annum has been included for the evaluation.

4.2. Commercial evaluation results

The commercial evaluation of the technically feasible options is set out in Table 2. Details appear in 0. The base case option of “Do nothing” is not a feasible option as this will lead to non-compliance. Hence this option is not considered for NPV analysis.

Table 3 - Commercial evaluation (PV, $ million)

Option	Capital Cost PV	OPEX Cost PV	Central scenario benefit NPV	Lower bound scenario benefit NPV	Higher bound scenario benefit NPV	Weighted benefit NPV	Ranking
Option A	8.7	1.7	18.7	10.5	29.2	19.3	1

4.3. Preferred option

The preferred option is Option A for the installation of PMUs. The base case do nothing option is not considered viable as it is non-compliant and is expected to incur a penalty.

Capital and Operating Expenditure

The preferred options are estimated to cost $11.5 million ±25% based on typical installation and configuration of high speed monitoring devices. It is estimated that an amount up to $1.6 million would be required to progress the project from DG1 to DG2.

Regulatory Investment Test

Based on the information provided by AEMO, a regulatory investment test (RIT-T) is not expected to be required. Regulations will engage with the AER to confirm this.

5. Optimal Timing

The timing of this need is driven by the AEMO notice requirements. Transgrid has developed the program schedule to meet the requirements by the expected dates.

6. Recommendation

The recommendation is to install and configure PMUs as per the options listed in Table 1 above. The project is expected to incur a total cost of $11.5 million.

Appendix A – Option Summary

Project Description	**NSW Oscillation Monitoring**		
Option Description	**Installation of Phasor Measurement Units**		
Project Summary			
Option Rank	1	Investment Assessment Period	15
Asset Life	*15*	NPV Year	*2022*
Economic Evaluation			
NPV @ Central Benefit Scenario (PV, $m)	18.7	Annualised CAPEX ($m)	1.09
NPV @ Lower Bound Scenario (PV, $m)	10.5	Network Safety Risk Reduction ($m)	N/A
NPV @ Higher Bound Scenario (PV, $m)	29.2	ALARP	N/A
NPV Weighted (PV, $m)	19.3	Optimal Timing	2023 – 2025 as per AEMO request
Cost			
Direct Capex ($m)	8.7	Network and Corporate Overheads ($m)	2.8
Total Capex ($m)	11.5	Cost Capex (PV,$m)	8.7
Terminal Value ($m)	3.1	Terminal Value (PV,$m)	1.6

Appendix B – Summary of AEMO Notice

Under the notice, AEMO requires Transgrid to:

- Upgrade, modify or replace remote monitoring equipment, being the existing PMUs at [redacted] so that they comply with the AEMO specification by 31 December 2023.
- Install PMUs complying with the AEMO specification to remotely monitor the performance of Transgrid's transmission system at the selected locations by 31 December 2023.
- Install new PMUs complying with the AEMO specification to remotely monitor the performance of Transgrid's transmission system at the selected locations by 31 December 2024.
- Install new PMUs complying with the AEMO specification to remotely monitor the performance of Transgrid's transmission system at the selected locations by 31 December 2025.

High Priority	Medium Priority	Low Priority
[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		

Appendix C – AEMO Phasor Measurement Unit Specifications

1.1. Measurement quantities

A Phasor Measurement Unit (PMU) must measure the quantities specified in section 3. Each quantity must be provided as 3 x single phase rms phasors as defined in IEEE standard c37.118. Voltages must be provided in volts as phase-to-ground measurements. Currents must be provided in amps. All phasors must be provided in polar format.

Frequency and rate-of-change-of frequency must also be provided in accordance with IEEE standard c37.118. Calculation of these Frequency and Rate-of-change of frequency quantities must be automatically performed by the PMU.

For each substation, two independent voltage measurements should be located so as to provide coverage in the event of bus reconfiguration.

All quantities must have a 50Hz sample rate.

It is preferred to obtain current measurements from metering current transformers (CTs) to maximise overall accuracy of measurements. If the requested current measurements are not readily available from metering CT cores or would require excessive cost and complexity then, subject to a demonstration that confirms this meets requirements and with AEMO's written agreement, current measurements may be obtained from protection CT cores.

1.2. Accuracy range

The PMU device must meet the accuracy requirements set out in the IEEE standards C37.118.1-2011 and C37.118.1a-2014. For reference the standard specifies the following steady-state accuracies:

• Voltage: ±1% TVE1

• Current: ±1% TVE

• Angle: ±1% TVE

• Frequency accuracy: ±0.005 Hz

• Frequency range: 45-55Hz

Note: This is accuracy of the monitor.

1.3. Time measurement

[redacted]

2. System requirements

2.1. Monitor hardware

[redacted]

[redacted]

2.2. Existing Qualitrol (HSM) Devices

As part of this request, all existing Qualitrol HSM devices are to be decommissioned in coordination with AEMO and replaced with PMUs as the Qualitrol devices have reached their end-of-life.

Where a PMU is to be installed to replace a Qualitrol device, the CTs, VTs, cabling and other infrastructure facilitating the HSM may be reused for the PMU. An outage of high-speed data is acceptable to facilitate cutting over from the HSM to the PMU, provided it is no longer than 14 days.

Following installation of all PMUs, the OPDMS / participant batcher system shall be decommissioned.

2.3. Monitor software

[redacted]

[redacted]

[redacted]

2.4. Data transfer requirements

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

2.5. Performance & Reliability

[redacted]

2.6. Cyber Security

[redacted]

2.7. Maintenance requirements

Maintenance of a PMU and associated equipment including communications equipment to the TransGrid/AEMO interface including response to failures, outage co-ordination, data management and co-ordination, and testing to confirm compliance must be in accordance with section 2.5.

Configuration of phasor data concentrators and commissioning of data transfer will be performed in association with AEMO.