Reactive Technologies PTY LTD

REACTIVE TECHNOLOGIES, SYSTEM INERTIA MEASUREMENT DEMONSTRATION

Lessons Learnt Report #2

Author: Adnan KHALIL

Email: adnank@reactive-technologies.com

Submission Date: 23 October 2023

Project Details

Project Title	Reactive Technologies, System Inertia Measurement Demonstration
Contract Number	2020/ARP002
Recipient	Reactive Technologies Pty Ltd
Primary Contact Name	Adnan Khalil
Contact Email	adnank@reactive-technologies.com
Reporting Period	Milestone 2
Document Ref	Lessons Learnt Report #2

Arena Acknowledgement and Disclaimer

This Project received funding from the Australian Renewable Energy Agency (ARENA) as part of ARENA's Advancing Renewables 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.

This project also received cash funding from the Department of Energy, Environment, and Climate Action (DEECA) state department of Victoria as well as In-Kind contributions from all project partners DEECA, Australian Energy Market Operator (AEMO), Neoen (Owner/operator of Victorian Big Battery - VBB), Melbourne Energy Institute (MEI) University of Melbourne.

List of Abbreviations

AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
ARENA	Australian Renewable Energy Agency
BESS	Battery Energy Storage System
DEECA	Department of Energy, Environment, and Climate Action
ESO	Electricity System Operator
FAT	Factory Acceptance Test
GPS	Global Positioning System
GWs	Gigawatt-second
LAN	Local Area Network
MEI	Melbourne Energy Institute, University of Melbourne
MQTT	Message Queuing Telemetry Transport
NEM	National Electricity Market
Neoen	Owner/Operator of VBB
NSW	New South Whales
PMU	Phasor Measurement Unit
PV	Photovoltaics
QLD	Queensland
RoCoF	Rate of Chage of Frequency
RTAC	Real-Time Automation Controller
SA	South Australia
SATs	Site Acceptance Tests
SIPS	System Integrity Protection Scheme
TNSP	Transmission Network Service Provider
UI	User Interface
UoA	University of Adelaide
UoM	University of Melbourne
VBB	Victorian Big Battery
VIC	Victoria
VPN	Virtual Private Network
VRE	Variable Renewable Energy
XMUs	eXtensible Multifunction Units

Contents

1. Executive Summary

This report provides a comprehensive overview of the progress made in achieving Milestone 1 and Milestone 2 of the project. Milestone 1 involved the deployment of XMUs across 15 DEECA offices in the state of Victoria. Milestone 2 encompassed an extensive testing phase, spanning 250 hours, aimed at measuring both the total NEM Inertia and regional Inertia for VIC.

Interim analysis of the frequency and modulation data gathered at these stages, already demonstrates the value of measuring inertia. For the first time in the Southern Hemisphere, a grid operator gained visibility and insights onto the sizeable amount of unmetered residual inertia originating from synchronous motors in the demand side and synchronous embedded generators. The additional inertia unknown to AEMO accounts to an average of 25%. The benefit in accurately monitoring the residual inertia spans from reduced curtailment of inverter-based resources, reduced spend on procuring frequency response and ancillary services, and improved placement and sizing of synchronous condenser.

In addition to detailing the accomplishments of these project milestones, this report also delves into the lessons learned throughout the various stages of project activities to date. These insights into challenges, successes, and best practices will contribute to the project's success and will inform future decision-making processes. The report serves as a resource for project stakeholders, offering a clear understanding of the achievements, challenges, and continuous improvements made during the project's execution.

1.1 Recommendations

We would like to share our recommendations, which are grounded in both the outcomes of our successful demonstration project and learnings from National Grid UK ESO Real-Time Inertia Measurement commercial service. Below is a summary of the recommendations we can make at this stage of the project:

1. **Modulator**:
    - **Simultaneous Service**: Modulation is a key part of the system. We have demonstrated the capability to provide modulation simultaneous to the delivery of other flexibility services. This capability expands the options for modulation and the capability to reduce costs of modulation by using capacity that can simultaneously deliver other valuable services.
    - **Flexibility of modulation choice:** The project has also successfully demonstrated the use of BESS, for reliable delivery of modulation, as opposed to the use of an ultracapacitor in the UK. Whilst an ultracapacitor has many benefits in terms of robustness of system, the proven ability of BESS to deliver the same modulation quality expands the range of options available to provide modulation, increasing options and flexibility for procurement and/or delivery of the modulation from existing or new assets. It is the case however that for an enduring service local metering and monitoring systems would need to be specified to high requirements. These additional requirements were not necessary for the demonstration project but would add value to an enduring service.
    - **Regional modulation approach:** The overall performance of the system demonstrates that a regional approach to modulation is likely to provide the optimal level of resilience, flexibility, and accuracy for use on the NEM. Typically, we would expect this to require one modulator per Federal state. As the responsibility for monitoring the network and its security sits with the TNSP we propose that the relevant TNSPs should have responsibility for procuring measurement services using modulation via a dedicated asset or alternative shared asset in line with availability and needs requirements. For the ongoing service, there is a requirement for longer operating periods and continuous modulation which may shift the economic balance in favour of ultracapacitors as against BESS, but this can be factored into any design and development decisions.

2. **Frequency Measurement Units**:

    - In the demonstration project, our frequency measurement units (XMUs) were hosted at DEECA offices across Victoria to facilitate data gathering. These have provided a secure and robust measurement array. For an enduring service, we recommend hosting these measurement panels at secure, separate locations, such as cell towers or alternative third-party secure sites. This will provide broader geographical coverage and, with the appropriate third-party siting, will offer secure and reliable power.

3. **Additional inertia present on the NEM**

    - The project has identified that significant distributed inertia, averaging at an additional 25%, from demand side and distributed energy sources is present on the NEM, above that provided by transmission-level generation sources. This result is consistent with the performance and analysis of power grids globally and is supported by the University of Melbourne. It is recommended that relevant organisations, including AEMO, take forward actions to ensure that the level of distributed inertia can be included in future system planning. These actions include establishing enduring regional inertia measurement on the NEM, and relevant changes to planning and operational policy to fully reflect all sources of inertia in security assessments.

2 Background

Maintaining adequate inertia levels is a fundamental requirement for ensuring the secure and stable operation of any power system. Inertia plays a pivotal role in mitigating rapid frequency deviations when unexpected disruptions, such as sudden loss of generation or load, occur. A power system operating with insufficient inertia becomes highly susceptible to these frequency fluctuations. Moreover, regions with low inertia levels can face instability issues if they become isolated from the broader grid.

Traditionally, inertia has been provided by the kinetic energy stored in the rotating turbines of thermal and hydropower generation plants. However, as the energy landscape evolves, the rise of renewable generation sources connected through power electronics, such as wind, solar PV, and BESS, has become more prevalent. These sources use Grid Following Inverters and therefore do not inherently contribute inertia, creating a challenge for grid stability. It is important to note that a limited but growing number of Grid Forming Inverters are being deployed globally, typically with BESS, to provide inertia support and grid stabilising services, although technical requirements and acceptability of Grid Forming Inverter technology to provide inertia support to grid operators varies internationally.

In Australia, the rapid transition from thermal to renewable generation is causing a significant reduction in the overall inertia of the power system. Some regions are already experiencing low levels of inertia, as identified in AEMO's annual System Strength and Inertia Report. As the transition to renewables continues, this trend is expected to drive changes to power system operational approaches globally, with operators implementing stability mitigations and measurement of key parameters such as inertia in order to maintain grid stability.

Addressing these challenges demands the development and implementation of new and advanced tools and solutions for managing system stability cost-effectively. This includes advanced technologies, grid management strategies, and regulatory frameworks that can adapt to the evolving energy landscape and ensure the resilience and reliability of the power grid in an era dominated by renewable energy sources.

Reactive Technologies, in collaboration with AEMO, DEECA, Neoen, and MEI is jointly undertaking a pilot project. The primary objective of this project is to provide accurate measurements of inertia within NEM as a proof of concept. This collaborative campaign places a strong emphasis on demonstrating the capabilities of existing technology for measuring inertia across the entire NEM power system, while also piloting regional inertia measurement within the state of Victoria. Although the project serves as a proof of concept, it is designed to deliver immediate benefits by enhancing the current methodology employed by AEMO to calculate inertia requirements.

Looking ahead, the broader deployment of this technology has the potential to further enable TNSPs in efficiently managing inertia across the Australian power system. This holds the opportunity of substantial benefits, including improved grid stability, enhanced reliability, and greater flexibility in accommodating the ongoing transition to renewable energy sources. The project marks a significant step towards the future resilience and sustainability of the Australian power system.

Reactive Technologies employs a unique approach to measure system inertia by introducing power modulations from a designated power source known as a modulator. This modulator injects controlled power pulses into the grid, and Reactive's technology then captures the resulting alterations in the grid's frequency. In the context of this pilot project, VBB was engaged to fulfill the role of the modulator, generating precise power modulations that caused small yet discernible changes in the grid's frequency.

The alteration in frequency was systematically measured at various locations throughout Victoria using the XMUs. These specialised devices are equipped to accurately record essential power system metrics, including voltage magnitude, phase, and frequency. By analysing these measurements, Reactive Technologies is able to assess and calculate the inertia of the power system, contributing valuable insights into grid stability and performance. This innovative approach exemplifies how cutting-edge technology can be harnessed to enhance the monitoring and management of energy systems.

3 Milestone 1 - XMUs Installation at DEECA Offices

3.1 Category

Supply and Installation

3.2 Objective

The first phase of the pilot project involved the installation and configuration of the XMUs across 15 DEECA office locations within Victoria. The deployment strategy for the XMUs was planned to ensure comprehensive coverage across all regions of the grid. This placement allowed for a holistic assessment of frequency behaviours within the grid, considering various factors such as:

1. **Generation Mix:** Locations with a higher penetration of solar and wind generation were targeted to evaluate the impact of renewable energy sources on grid frequency.

2. **Traditional Generation:** XMUs were strategically placed near coal power plants to monitor frequency changes associated with conventional power generation.

3. **Load Centres:** Large load centres were included to observe how changes in power demand influence grid frequency.

By covering these diverse scenarios, the XMUs provided a comprehensive overview of frequency dynamics within the grid, offering insights into the interaction between different energy sources, generation technologies, and load patterns. This data was instrumental in the project's efforts to measure and understand system inertia effectively.

3.3 Detail

The XMU devices were built into an industrial panel containing 2 XMUs in each panel, a mobile router, a GPS antenna, and other components. All these XMU panels were manufactured at a Melbourne-based electrical panel builder facility in Victoria to Australian standards. The XMU panels were tested for both physical and functional checks. After the FATs, the XMUs were configured by Reactive's operations team remotely and a series of functional and electrical tests were performed before dispatching the panels to DEECA offices.

An installation instruction guide was shared with all installation locations for hassle-free installation, and training was provided to the persons responsible for the installation of these panels at each DEECA office. The panels were made Plug N Play devices, which were only required to be placed in a secure location on an office desk near a north-facing window (recommended) and plugged into a domestic 230V wall socket. As soon as the panels were plugged in and turned ON, they automatically start to report frequency measurements from each location to Reactive's secure cloud GridMetrix ®.

All 15 panels were installed at DEECA offices without any issues, and remote and on-site assistance was provided to the hosts of these devices by a Reactive team member based in Melbourne. Currently, the XMUs are reporting useful frequency data, which is a very important input for analysis by the Reactive team. Reactive has enabled three modules, i.e., GridMetrix ® Frequency Visualisation, Event Analysis, and Inertia Measurement which provide very useful insights to the AEMO operations team on the frequency events on the grid and Inertia values in GWs.

4 Milestone 2 –Testing for Inertia Measurement

4.1 Category

Testing

4.2 Objective

After the successful installation of XMUs, the next phase of the project was to carry out 250 hours of testing for Inertia Measurement. During this phase of the project, Neon's VBB was utilised as a modulator to inject a power signal into the Grid, resulting in a very small but measurable change in the frequency of the grid. This change in frequency was measured by the XMUs installed across VIC and reported to Reactive's GridMetrix ® Cloud platform. Together with this frequency measurement and the modulation power measurements from VBB, Reactive Technologies was able to measure the total NEM Inertia for the periods when modulation was carried out.

4.3 Detail

Initially Neoen's Bulgana BESS was shortlisted to be used as modulator for this demonstration project, but during technical discussions with BESS supplier it was found that the BESS at Bulgana was not feasible for use as a modulator. Therefore, Reactive entered into agreement with Neoen for the use of VBB as a modulator.

There were delays caused to the start of the testing period as it took longer than expected to finalise the agreements for the use of VBB as a modulator. Neoen required to have a letter of 'No Action' from AER and also a consent from VBB lenders before they could commit VBB to be used as a modulator for this Inertia measurement demonstration project. Reactive Technologies stepped up and contacted AER to issue the required 'No Action' letter, which was then submitted to VBB lenders by Neoen to acquire the letter of consent.

In addition to the delay caused by these approvals, further delays were caused as VBB has been reserved for providing SIPS services during Australian summers i.e. from 1st November - 31st March each year, during this time VBB cannot be used for any other services.

Following the successful completion of the SATs, the project transitioned to the normal testing phase, commencing on June 5th, 2023. During this phase, modulation activities were systematically carried out to encompass a wide range of grid conditions, ensuring comprehensive testing and measurement of the system's inertia under various scenarios. These included:

1. **High Demand with High VRE:** Testing was conducted during periods of high electricity demand, coupled with high levels of variable renewable energy generation from sources like solar and wind.

2. **Low Demand with Low VRE:** Testing under conditions of low electricity demand and minimal variable renewable energy generation.

3. **Low Demand with High VRE:** Evaluating system behaviour during low demand periods while experiencing substantial variable renewable energy contributions.

4. **High Demand with Low VRE:** Assessing the system's response when demand is high but variable renewable energy generation is relatively low.

5. **High Export from VIC:** Focusing on situations where Victoria experiences high electricity exports to neighbouring regions.

6. **High Wind and Solar Generation:** Testing under conditions of significant wind and solar energy production at a general range of demand levels.

7. **Low Wind and Solar Generation:** Evaluating system performance when wind and solar energy generation is minimal at a general range of demand levels.

8. **Weekday/Weekend Coverage:** Analysing the system's behaviour on both weekdays and weekends to account for variations in demand and grid activity.

9. **Different Times of the Day:** Testing was conducted at various times of the day to assess how system behaviour varies with diurnal patterns.

The testing was carried out from 5th June - 28th September 2023. During testing, the positive support from all stakeholders was instrumental in identifying and resolving issues promptly. Their open communication, willingness to provide feedback, and active involvement in the testing process created an environment where challenges such as maintenance activities at VBB, modulation power data unavailability, and PMU data for boundary flows were addressed proactively, and solutions were implemented efficiently. This collaborative approach not only ensured the successful completion of the testing phase but also strengthened the overall project. Throughout the testing phase of the project, AEMO played a pivotal role in facilitating the modulation activities by providing a fixed modulation run schedule for the month of June, as well as a 3-day-ahead schedule for the subsequent period of modulation. This forward-looking scheduling approach aimed to optimise modulation planning and forecasting to accommodate various grid scenarios effectively.

Throughout the testing period, a series of technical workshops were conducted, involving collaboration between Reactive Technologies and AEMO project team members. These workshops provided a platform for in-depth discussions and analyses of the results obtained for Total NEM Inertia. During these workshops, various aspects related to the measurement of total NEM Inertia were discussed. This included the examination of trends in residual inertia within NEM, an assessment of how the grid's inertia was evolving over time, and comparisons with data and insights from the National Grid in the UK.

5 Lessons Learnt

5.1 Site selection for XMU deployment

In the planning phase, before securing funding approval from ARENA, Reactive's Power system engineers conducted comprehensive studies of the Victorian Grid models. These studies were instrumental in informing critical decisions for the project.

Based on the outcomes of the grid analysis, a strategic approach was taken to select 15 DEECA offices across Victoria as hosting sites for the frequency measurement panels. The selection process was meticulously guided by several important considerations:

1. **Geographical Spread:** The chosen hosting sites were strategically spread across the region to ensure an appropriate geographical distribution. This approach allowed for a more comprehensive understanding of frequency behaviours across the Victorian Grid.

2. **Key Grid Infrastructure Locations:** To capture data related to both power generation and demand, the hosting sites were selected to cover key strategic grid infrastructure locations. This included areas with significant electricity generation capacity and high demand centres.

3. **Duration of Hosting:** Discussions were initiated with DEECA in the early project stages to confirm that the identified public offices could host the XMU panels for the entire duration of the pilot project.

4. **Connectivity Requirements:** Ensuring reliable data transmission was essential. Therefore sites were selected that had access to both Wi-Fi and Cellular/4G internet services. Additionally, strong GPS signal reception was necessary for accurate timestamping.

5.2 Access to sites for XMU panels installation and troubleshooting

Recognising the potential challenges associated with requiring office staff to carry out complex installations, the project team took steps to address this and ensure a safe and straightforward installation process, the following measures were implemented:

1. **Plug N Play Design:** The XMU industrial frequency measurement panels were designed as 'plug N play' devices. This approach simplified the installation process significantly, making it user-friendly and eliminating the need for office staff to engage in complex electrical works.

2. **Safety Assurance:** These panels were engineered to be completely safe when plugged into standard 230V wall sockets within office environments. Safety considerations were paramount.

3. **Configuration and Testing:** Prior to shipment to each hosting site, the XMU frequency measurement panels were pre-configured and tested. This ensured that they were fully operational and ready for immediate use upon arrival.

4. **4G Connectivity:** To facilitate data transmission, 4G SIM cards were inserted into the panels. This step enabled the panels to establish reliable connections to transmit frequency measurement data to Reactive's secure cloud platform.

By adopting this approach, the project was able to minimise complexity. The 'plug N play' design and thorough pre-configuration and testing procedures contributed to a streamlined and hassle-free installation process.

To ensure the successful installation of the XMU frequency measurement panels and the effective gathering of frequency data, a comprehensive approach was taken:

1. **Installation Instruction Guide:** Each XMU panel was accompanied by an installation instruction guide. This guide included step-by-step instructions, presented in a user-friendly format with pictorial illustrations. This approach made it easy for the hosting office staff to understand and execute the installation process.

2. **Training:** Beyond the written instructions, training sessions were conducted for relevant hosting offices. This training provided hands-on guidance and practical knowledge to ensure that the panels could be installed correctly.

3. **Monitoring and Support:** Reactive Technologies assumed an active role in monitoring the system's performance. Any issues related to internet connectivity or power supply were promptly addressed in collaboration with the hosting department team members. This proactive approach ensured that the data gathering process remained uninterrupted.

The combination of clear installation instructions, hands-on training, and ongoing support contributed to the successful installation of the XMU frequency measurement panels. It also fostered a collaborative relationship between Reactive Technologies and the hosting offices, ensuring that any technical challenges were resolved swiftly, and that data collection proceeded smoothly.

5.3 Internet availability and IT security

Industrial XMU frequency measurement panels have multiple options for internet, i.e. site fixed LAN, Wi-Fi, and Cellular 4G. All XMU panels have been configured prior to sending them to office locations to work with all types of internet connections and have redundancies set.

If there are issues with site Wi-Fi, the panels will change over to the use of 4G and continue to work. Initially, the default internet type was set to site Guest Wi-Fi, but due to intermittent issues with connectivity priority was given to Cellular 4G, with failover redundancy set to site Wi-Fi. The hosting site's internet setup and configuration of company-specific access and cyber-security required meaningful effort from both DEECA and Reactive IT teams to complete.

5.4 Project stakeholder discussions and forums

Reactive took a proactive approach by organising regular stakeholder meetings to maintain ongoing engagement and sustain positive momentum throughout the project. Initially, stakeholders convened on a weekly basis to ensure effective communication and collaboration. As the project phase progressed, the frequency of these meetings transitioned to a bi-weekly schedule. This adjustment was made to accommodate reduced activities during the later stages of the project, which were necessary for addressing technical and commercial issues related to the BESS chosen as the modulator for this pilot demonstration project.

In addition to this senior-level engagement was undertaken with project stakeholders and TNSPs to share the project's aims, data, and learnings as the project progress. This resulted in additional engagement and parallel agreements to measure inertia within two other regions of NEM, the learnings from which will add to the overall benefits of the project.

5.5 Modulator Requirements

During the initial planning phase of the project, which took place before securing funding from ARENA, a series of critical grid studies were conducted. These studies aimed to ascertain the specific requirements for a modulator tailored to the size and geographical spread of the Australian grid.

Once the technical specifications for the modulator were finalised, they were shared with the System Operator, AEMO. AEMO used these specifications to conduct its own modelling and assessment to ensure that the operation of the modulator, with the recommended signal parameters, would not have any adverse impacts on the grid or nearby generators. Early in the project, detailed specifications, encompassing signal amplitude, frequency, waveform, and interface requirements, were also shared with Neoen, allowing Neoen to scope and plan their activities, particularly in terms of implementing the necessary modulator control logic in partnership with Tesla, the BESS supplier.

Tesla, as the BESS supplier, conducted comprehensive lab tests to validate and confirm that the BESS could indeed fulfil the specified modulator functionality. This comprehensive validation process provided assurance that the modulator would perform as required and contribute to the success of the project's objectives.

5.6 Site selection – BESS (Modulator)

The initial plan for the Inertia Measurement pilot demonstration involved using Neoen's Bulgana Battery as the Modulator. AEMO, Reactive, and the UoA conducted studies and assessments to ensure that the integration of the Bulgana Battery as the Modulator would not have any adverse impacts on the grid. However, as the project progressed, certain technical limitations were identified by the Bulgana wind farm, which rendered it unsuitable for use as a modulator. These limitations, which were beyond Reactive's influence, prompted a change in the project's direction.

The change in asset from Neoen's Bulgana Battery to the VBB necessitated negotiations with Neoen to secure the services of the VBB as a viable modulator alternative. While this change allowed the project to move forward, it did introduce a significant delay of approximately one year to the start of the project's testing phase. This delay was primarily attributed to three key reasons:

1. **Existing Commitments (SIPS Contracts):** VBB was already engaged in other contracts, specifically the SIPS, which limited its availability for use in the pilot demonstration project. As a result, it could only be utilised during the Australian winter season, requiring the project to align its schedule accordingly.

2. **Revised Studies and Modeling:** The change in the modulator asset from Bulgana Battery to VBB necessitated a reassessment of the project's studies and modeling. This included evaluating the impact of the new asset's location on grid operations and ensuring that all technical aspects were considered and addressed.

3. **Modulation Functionality Testing:** To confirm that the VBB could effectively serve as the modulator for the pilot demonstration project, it was essential for its supplier, Tesla, to conduct thorough testing of the modulation functionality. This testing and confirmation process required time to ensure that the VBB could meet the project's specific requirements.

Due to the unavailability of live modulation power measurements directly from the VBB, Neoen and Reactive Technologies engaged in a collaborative effort to obtain the modulation power data offline after each modulation run. This cooperative approach allowed the project to continue, despite the absence of real-time data. The absence of real-time data had no impact on the outcomes for the trial.

Once the modulation power data became accessible, Reactive Technologies carried out the necessary offline analysis to calculate the inertia values. Subsequently, these calculated inertia values were published to the GridMetrix ® UI. This enabled both AEMO and the regional TNSPs to access and review the Inertia measurement results for past modulation runs.

In terms of learnings for requirements for enduring service, the key lesson is on ensuring the installation of appropriate power metering infrastructure at the modulator site. This infrastructure will enable the acquisition of real-time measurements of modulation power, allowing for the provision of Real-Time Inertia Measurement—a critical component for grid stability and management. In addition to this, for regional measurement, the real-time exchange of boundary power flow data will be necessary.

Despite these challenges and other understood limitations of the modulation signal capable of being delivered from the BESS, superimposition of the modulation signal over normal services provided by VBB was successfully delivered. In a broader context, the modulator, represented by VBB, performed well for the purpose of the demonstration project, particularly in measuring the total NEM Inertia. However, given that South Australia contributes a smaller proportion of the system's inertia, and the modulator power flows are distributed accordingly, detecting, and measuring the inertial response of South Australia posed challenges. To overcome these challenges, an extension of the measurement computation time window length was implemented, ensuring that the accuracy of results could be maintained.

Throughout the testing period and through thorough analysis, it became evident that the majority of the power flows induced by the modulation were occurring from VIC into NSW and QLD, which are known to be the regions contributing the most to the generation inertia and with higher demand. That meets expectations, as the modulation-induced power flowing into/out of a region is proportional to its share of the total inertia. That is because the frequency deviation induced by the modulation signal is perceived similarly and simultaneously by all synchronous machines in the system, inducing a release/absorption of kinetic energy proportional to their spinning mass. As the swing equation holds for a single machine as for groups of machines (e.g. those confined into a region), it is expected that the inertial response power movement of either is proportional to their inertia. The lessons learned from this demonstration project will inform proper modulator sizing and location selection, ensuring that the system operates optimally and effectively – in particular the use of regional modulation, each of smaller size, to deliver local accuracy and resilience.

5.7 Grid consultancy studies

A part of the grid studies was outsourced to the University of Adelaide to carry out small-disturbance studies of NEM power system to assess the likely impact of proposed tests of an Inertia measurement system on the grid. This activity was carried out in the early stages of the project to avoid any technical issues in the later stages of the project once testing is started. The results of these studies showed no adverse impacts on the grid operations which paved the way to navigate to the next phases of the project.

5.8 Regulatory requirements for the use of BESS as a Modulator

At a later stage in the project phases, a new requirement raised by the VBB lenders was to get approval from the AER for VBB to be used as a Modulator. Preparing the documentation for submission to AER to request approval and AER performing its due diligence was a lengthy and time-consuming activity. As this approval was not envisaged in the early stages of the project, this task added to the delay in the start of the project testing phase for measuring Real-Time Inertia in the NEM.

5.9 Regular meetings with BESS supplier/operator

Throughout the project, regular meetings were carried out with the VBB supplier and operator to discuss the logistical and technical issues and work together for their timely resolution. During the technical discussions, it was confirmed at every stage of the project ahead of time that the BESS would function as a modulator according to the specifications shared with the Neoen. Lab tests were performed in advance to confirm the functionality of the BESS by Tesla. The engagement with the BESS supplier and operator from the start of the project proved very effective and efficient in confirming the working of the modulator.

5.10 Powerlink QLD and ElectraNet SA

During the demonstration project, Powerlink QLD and ElectraNet SA expressed keen interest in participating in the Inertia measurement campaign. For both TNSPs, the motivation was to gain a deeper understanding of the parameters, and advantages of inertia measurement (as opposed to estimation) and of Reactive Technologies' solutions that could assist them in their goals of transitioning to the network operator of the future and optimise their asset utilisation through adoption of advanced technology and new ways of working. The overarching benefit of the roadmap was to outline and pinpoint the most effective pathways and opportunities for both Powerlink and ElectraNet to expand the utilisation of grid intelligence solutions. Specifically, the aim was to enable these organisations to gain control over inertia management within their respective states or regions. By charting out these strategic directions, the roadmap provided a clear and structured approach for Powerlink and ElectraNet to enhance their grid operations, maximise the utilisation of advanced technologies, and ultimately contribute to the optimisation of the energy network in their areas of operation. As part of their project scope, both Powerlink and ElectraNet undertook the installation of five XMUs each within their respective network infrastructures. These XMUs served as critical components for accessing Reactive's GridMetrix® services, which encompassed Frequency Visualisation, Event Analysis, and Inertia services.

A significant milestone in this collaborative effort was the agreement reached among AEMO and all the regional TNSPs. This agreement allowed for the sharing of frequency data generated by the XMUs installed in all mainland NEM regions. This data sharing initiative was undertaken to gain deeper insights into the frequency and RoCoF trends occurring across different TNSP areas of operation. It represented a cooperative approach to enhancing the overall understanding of grid dynamics and facilitating more informed decision-making in the realm of power system management.

Reactive Technologies achieved a significant success by utilising the same Victorian Modulator to measure regional Inertia not only for the VIC region but also for SA and QLD. This extension of the modulator's functionality added substantial value to the Inertia measurement demonstration project. Originally, the project was designed with the goal of measuring the total NEM Inertia and the regional Inertia of VIC.

By expanding stakeholder engagement and using the modulation signal to reach SA and QLD, the project has added value to the inertia measurement demonstration project, which was originally planned only to measure the total NEM and VIC regional inertia. Reactive Technologies demonstrated its adaptability and effectiveness in enhancing the project's scope and objectives. This accomplishment showcased the versatility and efficiency of the technology, underscoring its potential for broader applications in the energy sector. The ability to measure regional Inertia in multiple areas further enriched the project's outcomes and highlighted the innovative contributions of Reactive Technologies to the field of grid management and Inertia measurement.

6 Next Steps

In the upcoming phase of the project, Reactive Technologies is poised to share the outcomes of the extensive 250 hours of testing with MEI for their validation of Inertia measurement results. To facilitate this validation process, MEI will require access to models and data from AEMO. Confidentiality agreements are currently in the finalisation stages between MEI and AEMO to ensure the secure exchange of this information.

MEI's role will involve two components:

1. A comparison of the Inertia measurement results obtained by Reactive Technologies during the demonstration project testing period with the models and data provided by AEMO to validate and confirm the results.

2. A detailed assessment and cost-benefit analysis of using Inertia Measurement in Australia.

Final knowledge sharing reports will be provided by MEI as part of the project deliverables under the ARENA agreement.