# Aeolius Wind Systems Wind Forecasting Demonstration Project

# LESSONS LEARNT REPORT 4.

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## EXECUTIVE SUMMARY

Key learnings arising from the construction and delivery of the Doppler lidar System(s) for use in the Dual Doppler Forecast demonstration are discussed. Significant time delays were experienced with finalising the construction of the two purpose-built lidars for use in the Dual Doppler Forecaster. The delay was primarily the result of supply chain disruption and the loss of a key staff member because of the COVID-19 Health Crisis. Further time delays with the installation of the first lidar system at Macarthur wind farm occurred due to damage to the lidar during its transport to Australia.

Solutions for addressing the underlying causes are discussed along with insights into the required information for installing and operating the technology in the application. A proposal to facilitate the development of *Best Practice Guidelines* to accelerate the use of the technology in the industry sector is suggested.

## 1) Introduction

The Aeolius Wind Systems project aims to demonstrate two innovative and complementary energy forecasting technologies for use in the National Electricity Market (NEM). The technology comprises an advanced laser radar (lidar) system, designed to provide a minimum of five minutes' notice of changes in the power output of wind turbines, by measuring the wind field upstream from wind farms.
The second forecast technology involves the use of neural network and/or Linear model wind forecasting technology using data collected by the Supervisory Control and Data Acquisition System (SCADA) on wind farms. Here the historical trends in wind behaviour are analysed using a to generate the five-minute ahead forecast.

## 2) Background

A short-range (2 km to 5 km) scanning Doppler lidar sourced from a commercial manufacturer was trialled at Macarthur wind farm in 2020. The objective was to evaluate the instrument's range measurement capability under the prevailing meteorological conditions at the site. Measurement range and scanning speed are important considerations in 5-minuteahead wind energy forecasting. A further objective was to test the skill of our (Aeolius Wind Systems) proprietary data post-processing software for resolving the two-dimensional wind field using the lidar output.

Analysis of the one-month-long data set showed that the instrument's range capability across the full range of atmospheric conditions was suboptimal for the intended application. Further, the scanning speed of the lidar was too slow to enable full coverage of the measurement domain within the required 10-minute time frame.

Notwithstanding the above, the wind vector retrievals from the software closely matched measurement data from nearby masts. This provides confidence in the skill of the retrieval algorithms for use in future forecast applications. Valuable insights were also obtained on the behaviour of the wind field within Macarthur Windfarm. The information was used to identify “optimal” locations for installing the two lidars to be used in the Dual Doppler forecast demonstration (discussed further below).
The skill of four machine learning models was also evaluated in the previous stages of the project using data from the Macarthur wind farm and Hallet Hill wind farm in South Australia. The forecast models were successful in predicting the broad trend in the incoming wind field in the 5minute ahead time frame, however failed to capture the turning points with the required level of accuracy. It was concluded that further model development is required to improve forecast skills to allow the use of these tools in operational settings.

Details of the above trials can be found in the Aeolius Wind Systems Wind Forecasting Demonstration Project - Lessons Learnt Reports 1, 2 & 3.

## 3) Lesson Learnt

Project activities in the current reporting period (Jan 2021 – February 2024) focused on the completion of the lidar hardware build in the USA, the delivery of the two lidar systems to Australia, and the installation and commissioning of the first lidar at Macarthur windfarm.

The key learnings and insights arising from these activities are described below:

- **Supply Chain Challenges**

The two lidar systems to be used in the Dual Doppler forecasting demonstration were purpose -built in the USA by our US affiliates. The design incorporated the learnings from a prototype forecast system installed at a commercial wind farm on the Caribbean Island of Aruba in 2014. To our knowledge, Aeolius Wind System pioneered the use of the technology in this application.

The new, higher-powered fiber lidar technology incorporates novel innovations to improve measurement sensitivity, and allow faster scanning, and operator flexibility, compared to commercial products currently on the market.

Significant challenges were encountered with completing the construction of both lidars, because of the Covid 19 health crisis. This included long-time delays in sourcing critical electro-optical components from specialised manufacturers in the US aerospace and defence sectors. Restrictions with obtaining access to advanced laboratory facilities to align the laser telescope, and the unplanned retirement of a senior software engineer due to ill health exacerbated the delay.

Whilst the pandemic was (fortunately) a rare event, the outcome demonstrated the vulnerability of manufacturers in adopting the *just-in-time* delivery strategy for essential components. Greater emphasis has to be placed on sourcing electronic components from several sources and establishing an in-house inventory, where financially and practically viable.

Over-reliance on specialised manufacturing and testing facilities, or third-party engineering expertise to construct a high-tech product like a Doppler lidar system presents a high risk. Aeolius Wind Systems in moving forward with plans to manufacture the product in Australia will work with experienced partners on an appropriate risk management strategy.

- **Equipment Damage During Shipping**

The lidars comprise delicate electro-optics and mechanical subsystems that can be damaged by physical impact, heat, or high-frequency vibration. These factors are considered in the design processes and engineering solutions employed to manage the risk. However, the solutions can only go so far and cannot prevent accidental damage, negligence, or gross abuse by third parties during transport from the factory to the operating site.

This was the case with the delivery of System 1 to Australia where the purpose-built packing crate had been mishandled. During the unpacking and inspection process, the laser transceiver was found to have separated from its mountings severing optical cables and damaging the other system components.

The damage could only have occurred if the crate was laid on its side during transport. Unfortunately, the lidar Transceiver had to be removed and returned to the USA for repair as the required facilities are currently unavailable in Australia.  Apart from the time delay with the return of the transceiver, the incident had financial implications for the project budget.

Measures to prevent the reoccurrence of the damage in future shipments are required. This includes using trusted shipping agents that employ strict protocols on the handling of delicate cargo, training programs for their forklift operators and truck drivers, and employing *Chain of Custody* protocols at all stages in the shipping process.  Importantly, accelerometers were fixed to the outside of the shipping crate to record shock and make it obvious to shipping staff that the goods need to be handled gently.

There was a further delay with installing the lidar at Macarthur wind farm on the return of the Transceiver to Australia in late 2023. This was due to the inability to secure an accredited contractor to assist with the installation and administrative changes at the wind farm.  The net result of the above challenges pushed out the project timeframe by over two years.


*Figure 1 The Aeolius Wind Systems Long Range Doppler Lidar Forecaster (System No.1) at Macarthur Wind Farm, December 2023. The turn-key lidar performs all required tasks to generate the forecast within the system itself thus avoiding potential security breaches with data products and removing reliance on third-party service providers.*

**4) Insight into Installation & Commissioning**

A Doppler Lidar Forecast system is a sophisticated instrument requiring trained and experienced operators to install, configure, operate, and maintain. It is not simply a “put in place, switch-on, run and download data” technology as is largely the case with the current generation of wind measurement devices such as mast anemometry, acoustic sounders, or lidar vertical wind profilers.

There are many factors requiring consideration with the Lidar forecaster installation, commissioning, and operation. They include:

- The broadscale (synoptic) meteorological conditions affecting energy production at the wind farm. There will be periods in the forecast continuum where it is (more) important to get the forecast “right”. For example, during the approach of a strong frontal system with the potential to affect the wind farm's power output significantly, or cause damage to capital infrastructure.

Such events are often difficult to forecast accurately using conventional strategies (e.g. Persistence and numerical modeling) and can involve abrupt changes in the wind farms' power output. Failing to accurately predict such events at the *5-minute scale* can have significant implications for the wind farm's revenue.

- The predicted performance of the lidar forecaster under the atmospheric conditions at the site over a full 12-month period. Factors to consider include the range measurement capability of the instrument using the required scanning pattern. Range measurement, scanning speed, and capacity to derive 2-D wind vectors in near real-time are important factors in meeting the 5-minute ahead forecast requirement.

- Siting options for the forecaster within the windfarm, or “upstream” of the windfarm. Ideally, the operating site(s) should be at an elevated location with a clear line-ofsite above vegetation, buildings, or hills which will block the laser beam. Access to power and communication infrastructure is of paramount importance, as is access to the site for vehicles, and site security.

- Availability of qualified, experienced, and competent personnel to undertake the installation and configure the forecaster for optimal operation at site. The “optimisation process” involves a test procedure to evaluate range measurement skill using different instrument settings, scanning patterns, and data post-processing and forecast strategies.

- Access to trained technical personnel at the site to adjust lidar settings and undertake maintenance at short notice (discussed further below).

**5) Best Practice Guidelines**

The knowledge base for the use of long-range Scanning Doppler lidar in forecaster applications in the wind energy sector is in its infancy. Apart from the experimentation with the technology within the Advancing Renewables Program, there is a limited skill base in Australia.

Several commercial lidar manufacturers based in Europe and China are offering lidar products with known wind measurement capabilities. However, there is no transparency regarding the skill of associated data post-processing for deriving a forecast. Furthermore, there are significant differences in the design and performance of lidar products including the ability of the operator to adjust instrument settings to optimise performance under changing atmospheric conditions.

The above situation is likely to change in the next 3 years once the financial benefits from using the technology are fully demonstrated and industry participants become more familiar with the operating and maintenance procedures.

To accelerate the uptake of the technology, an initiative to develop "Best Practice Guidelines" for Lidar forecasting is worthy of consideration. The proposed Guidelines would address a range of issues including forecast accuracy, instrument installation, commissioning and operating procedures, technical training, and certification.

The documentation could be developed by an industry working group (potentially based in Australia) and follow a similar pathway employed by the International Energy Agency (IEA) for the use of Lidar technology for Wind Energy Resource Assessment.

**6) Next Steps**

The next steps in the project include:

- Evaluate the range measurement performance of both lidars in the operational setting. Perform various scans, collect and analyse data under a range of meteorological conditions.

- Perform a single Doppler lidar forecast using both systems separately. The objective is to evaluate the skill of each forecast for comparison with the Dual Doppler output at a later time;

- Configure the individual lidars for use in Dual Doppler configuration. This involves the installation of software to allow communication and data transfer between the systems, connection to the windfarms SCADA, testing of scanning patterns, and analysis of forecast skill;

- Conduct a workshop at Macarthur Windfarm to update staff on progress with the forecast demonstration, and familiarise technical staff on the operation and maintenance requirements of the technology;

- Communicate the results of the forecast demonstration at the Australian Wind Energy Conference in Melbourne in July 2024.

## 7) Summary

The first of the two lidars for use in the Dual Doppler Forecast demonstration was successfully commissioned at Macarthur Windfarm in December 2023. The second lidar is on schedule for installation in February 2024, with the system testing and integration into the Dual Doppler configuration to follow in late March 2024.

There was an extended delay with the completion of the lidar systems builds in the USA and their delivery to Australia. The delay was primarily the result of the impact of the Covid-19 health crisis on the supply chain and damage to the first lidar during its transport to Australia.

Insights into factors requiring consideration with the installation and commissioning of the technology at the site are offered, along with a suggestion for the development of Industry Guidelines for the Forecast technology.