PO.042

# Active maintenance optimisation of a large offshore wind farm based on mesoscale day-ahead power forecasts

**Ken TAY, Qadir SINGAPORE-WALA, Rebecca SYKES**
Lloyd's Register

Lloyd's Register

## Abstract

The scheduling of planned maintenance for offshore wind farms often does not take into account the value of the energy lost whilst maintaining individual wind turbines. Typical strategies involve the use of a passive scheduling strategy : this work demonstrates that the passive approach is inefficient based on real offshore wind farm data and quantifies the benefit of active optimisation strategies.

We developed a methodology to actively schedule maintenance activities based on a day-ahead power forecast. In the study, we use a physics-based mesoscale model to simulate a month-long case study of a mid-latitude offshore wind farm in the summer and winter. We then compare the following maintenance scheduling approaches: ACTIVE, ADVERSE and REALISTIC.

## Objectives

The purpose of this study is to

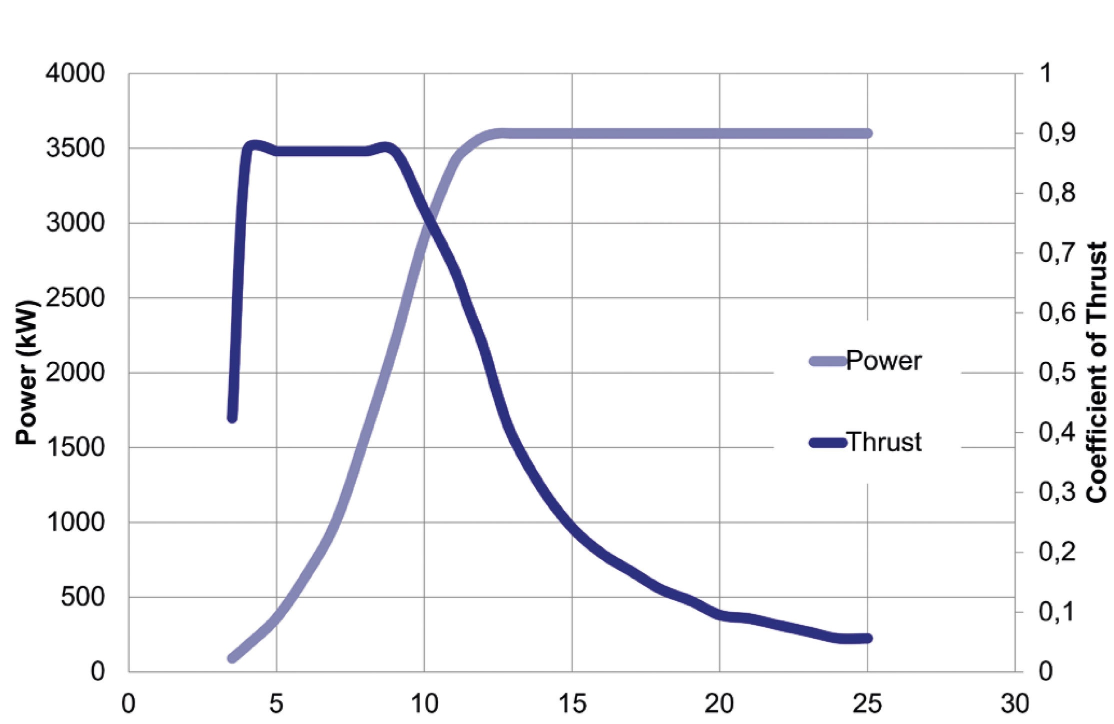
- Investigate the suitability of WRF for forecasting offshore wind farm power production in an operational setting.
- Investigate the suitability of using SCADA-generated Power and Thrust curves, in the absence of manufacturers' information.
- Quantify the potential savings in implementing an active maintenance optimization strategy.

## Methods

### Wind-Turbine Model Configuration

SCADA information is used to reconstruct

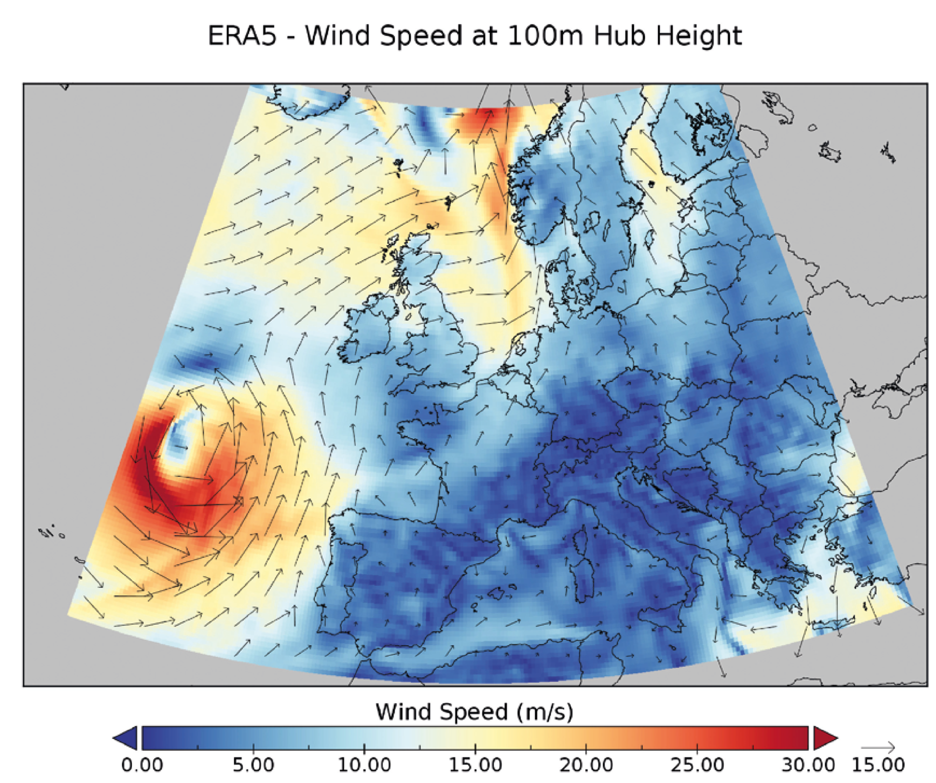
- Power Curve – correlating power output with wind speed measurements.
- Thrust Curve – using a unsteady Blade-Element Method [1], the aerodynamic characteristics of the wind-turbine is recreated to match SCADA measurements.




## Methods

### Mesoscale Model Configuration

- Mesoscale Model: WRFV3.7.1




- ERA5 initialization dataset shown above

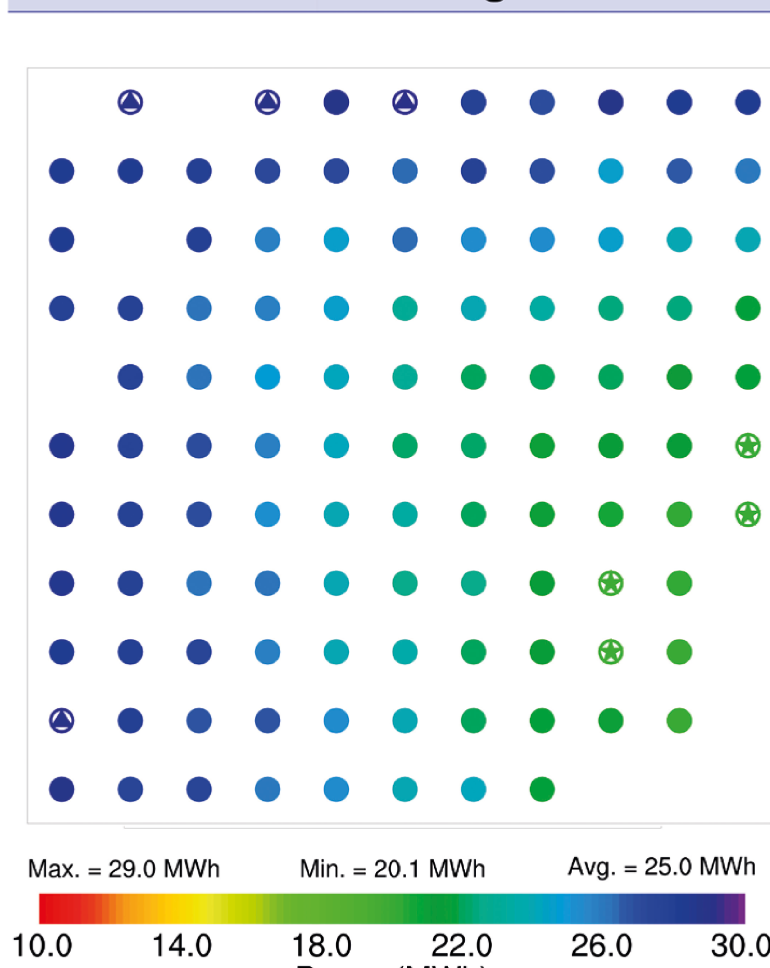
| | |
|---|---|
| **Initializing Dataset** | ERA5 |
| **Time Period** | JAN 2016<br>JUL 2016 |
| **Number of Domains** | 3 |
| **Domain Size** | 100x100x60<br>($N_x$ x $N_y$ x $N_z$) for all |
| **Domain Resolution** | 25 km, 5 km, 1 km |
| **PBL Scheme** | MYNN2.5 |
| **Wind Farm Parameterization [2]** | Enabled |

- 10-min frequency output used in analysis.

### Active Maintenance Strategy

All simulated turbines are kept operating 24/7 to calculate opportunity cost of power production during actual downtime. We assume on each day, 4 selected turbines are shut-down and maintained for 8 daylight hours.

| | Turbine Selection Criteria |
|---|---|
| **ACTIVE** | 4 Lowest yielding turbine |
| **ADVERSE** | 4 Highest yielding turbine |
| **REALISTIC** | • Daily list of turbines generated from SCADA measurements.<br>• Power forecast is compared against maintaining the same number of turbines on that day using the ACTIVE strategy |




Example of a day-ahead power forecast, showing a subsection of 100 turbines

★: Lowest yielding turbine

▲: Highest yielding turbine

## Results

### Mesoscale Model Accuracy

As the maintenance strategies outlined rely on the accuracy of the forecasts by WRF, the average error for each turbine is quantified:

| | WIND | POWER |
|---|---|---|
| **BIAS** | - 0.40 m/s | - 0.18 MWh |
| **MAE** | 2.28 m/s | 0.59 MWh |
| **Correlation** | 0.77 | 0.77 |
| **RMSE** | 3.12 m/s | 0.95 MWh |

These metrics are in line with similar studies such as the NREL WIND toolkit validation study [3] and deemed acceptable.

### Comparison of Maintenance Strategies

The theoretical maximum savings based on **ACTIVE** and **ADVERSE** is shown here:

| | JAN | JUL |
|---|---|---|
| **ACTIVE (MWh)** | 1635.43 | 893.79 |
| **ADVERSE (MWh)** | 2108.67 | 1438.97 |
| **Reduction in Downtime Loss (MWh)** | 473.24 | 545.18 |
| **Reduction in Downtime Loss (%)** | 22.4 | 37.8 |

The **REALISTIC** comparison based on SCADA:

| | JAN | JUL |
|---|---|---|
| **ACTIVE (MWh)** | 2223.06 | 560.27 |
| **REALISTIC (MWh)** | 2529.30 | 830.77 |
| **Reduction in Downtime Loss (MWh)** | 306.24 | 270.5 |
| **Reduction in Downtime Loss (%)** | 12.1 | 32.5 |

## Conclusions

The current WRF configuration, together with the SCADA reconstructed power and thrust curves, is shown to be an acceptable model for day-ahead power forecasts.

There are quantifiable savings to be gained through an active maintenance strategy approach.

Further improvements to mesoscale modelling of wind farms and optimization of active scheduling approaches can result in further reduction in downtime loss, hence increasing project revenue

## References

1. Singapore Wala, A. A (2017, May).Aerodynamics modelling of floating offshore wind turbines. Phd Thesis. *Nanyang Technological University*
2. Fitch, A. C., Olson, J. B., Lundquist, J. K., Dudhia, J., Gupta, A. K., Michalakes, J., & Barstad, I. (2012). Local and mesoscale impacts of wind farms as parameterized in a mesoscale NWP model. *Monthly Weather Review*, *140*(9), 3017-3038.*l*
3. Draxl, C., Hodge, B. M., Clifton, A., & McCaa, J. (2015). Overview and meteorological validation of the wind integration national dataset toolkit. *NREL/TP-5000-61740. Golden (CO): National Renewable Energy Laboratory (forthcoming), Tech. Rep.*