nationalgrid

Date of Submission

July 2015

Network Innovation Allowance Closedown Report

Notes on Completion: Please refer to the appropriate NIA Governance Document to assist in the completion of this form.

Network Licensees must publish the required Project Progress information on the Smarter Networks Portal by 31st July 2014 and each year thereafter. The Network Licensee(s) must publish Project Progress information for each NIA Project that has developed new learning in the preceding relevant year.

Project Closedown

Project Title	Project Reference
Impact of extreme events on power production at the scale of a single wind-farm	NIA_NGET0028

Project Licensee(s)	Project Start Date	Project Duration
National Grid Electricity Transmission	Jan 2013	18 Months

Nominated Project Contact(s)

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Scope

The post doctoral research assistant will be encouraged to examine innovative ways to process the data provided to minimise forecast error. Suggested techniques include calculating rate of change and integrals of parameters in addition to using the explanatory variables directly. It is expected that this work will both improve the accuracy of the wind power predictions as well as improve the expression of the range and degree of uncertainty in forecast values.

The effect of wind shear across a wind farm is of particular interest. The particular behaviour of individual turbines as well as the aggregated power output of the wind farm in relation to small scale and rapidly changing wind phenomena is currently not well understood.

Objective(s)

The objective of this project is to develop advanced models that have the capability of forecasting wind power output more accurately.

Success Criteria

- Conference-style paper summarising literary research
- Deliver Model Code
- Provide presentation of code results
- Full project report delivered describing method, approach, findings and areas of interest for future research

Performance Compared to the Original Project Aims, Objectives and Success Criteria

"NGET ("NG") has endeavoured to prepare the published report ("Report") in respect of Impact of extreme events on power production at the scale of a single wind-farm NIA_NGET0028 ("Project") in a manner which is, as far as possible, objective, using information collected and compiled by NG and its Project partners ("Publishers"). Any intellectual property rights developed in the course of the Project and used in the Report shall be owned by the Publishers (as agreed between NG and the Project partners)

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Project Outline

The large scale increase of wind capacity presents a number of challenges for National Grid, the system operator required to deal with the variability and uncertainty in the generation. In particular, in order to ensure the safe and economic operation of the system, there is a need for accurate predictions of the power output of each individual wind farm. This is becoming increasingly important given the recent trends towards larger single turbines and ever larger offshore wind farms (i.e. Sheringham Shoal (317 MW), London Array (630 MW) and Greater Gabbard (504 MW)).

National Grid forecast the power output of a wind farm at 30 minute intervals using the forecast hub height mean wind speed, in conjunction with a simple wind farm power curve derived from metered data. This study has shown that this approach can lead to large power forecast errors - for a single mean wind speed there can be a large spread in the metered power output as other meteorological parameters affects the wind farm's performance. Furthermore, it is not possible to apply this method to wind farms in the planning or construction phases as there is no metered data available to derive the power curve.

This study has developed a new tool which can be used to estimate the power output of any offshore wind farm for a wide range of meteorological conditions. Given the wind forecast currently obtained by National Grid, the model estimates the wind speed variability from turbine to turbine using a technique known as canopy modelling. The power output of each turbine is then estimated (using individual turbine power curves) and aggregated to determine the wind farm power output.

Research Aims

1. Investigate which meteorological parameters affect the power output of large offshore wind farms.
2. Develop a model which can be used to estimate power output of offshore wind farms using the wind forecast currently obtained by National Grid.
3. Test the model for a range of farm designs and meteorological conditions to quantify the reduction in power forecast error.
4. Identify potential future research areas.

Headline Results: Power forecast error

The first stage of the project investigated whether the power forecast error of large offshore wind farms could be reduced by incorporating more detail about the true nature of the flow.

- Data analysis showed that for a given mean wind speed there can be a large range in the actual power output of a wind farm. This range is mainly due to variability in other meteorological parameters, such as wind direction, turbulence intensity and atmospheric stability, and the turbine availability.
- Wind direction was shown to be an important parameter as it dictates the location of the turbine wakes. Wakes can be characterised as regions of reduced wind speed and increased levels of turbulence. The energy output of a turbine located in the wake of a neighbouring device is significantly reduced.
- National Grid now applies separate transfer functions for different wind directions; this reduces the power forecast error associated with the wake effects. However, this approach requires a significant amount of sufficient generation data from the farm for different wind speeds and directions and therefore cannot be applied to new farms.

Headline Results: The Model

Following the results of the literature review, a model was developed which estimates the power output of a wind farm taking into account the impact of wind direction on the spatial variability of the wind speed across the farm.

- The input of the model is the wind forecast data (wind speed and direction) and the wind farm configuration.
- The model has been used to estimate the power output of two large offshore wind farms in a range of meteorological conditions.
  - Wind farm A: the model predicted power output was within 10% of the measured data for all 8 meteorological scenarios considered and for 6 cases the error was below 4%.
  - Wind farm B: the use of the model to estimate the energy production over a 5 day period results in a 5% error, in comparison to a 7.3% error with the current National Grid method. This represents a 32% reduction in the forecast error.

Headline Results: Model Applications

The model has been designed for a range of applications:

- Power output time series: The model can be run in real-time using the wind forecast (i.e. the wind speed and direction data) to produce a power output time series.
- Wind farm directional power curves: For each UK offshore wind farm the model can be run to determine a wind farm power curve for a range of wind directions. These curves can then be used in the National Grid Energy Forecasting System (EFS). Additionally, the model can be used to determine adjusted wind farm power curves for periods when some of the turbines are not operating.
- Determine the power curve of future wind farms: At present it is difficult to predict the power output of a wind farm which is newly commissioned, as there is no data to generate a statistical power curve. Consequently, there is a reliance on data from other farms which have different turbine configurations. If the design of the wind farm is known, the canopy model could be used to generate directional power curves for the installation.

Project Activities

The main activities can be summarized as follows.

- Literature review
- Develop canopy modelling tool to estimate the wind speed variability across a large offshore wind farm
- Gathering wind power output data from a real wind farm. On a turbine by turbine basis.
- Validation of the model and comparison with real world results.
- Publication of the results and recommendations for future work.

Previous Progress reports

The project is on schedule as detailed in the project plan. To the end of the financial year, the following deliverables have been received:

- Literature review report (completed May 2013)
- Results disseminated to academic and industrial audience at International Conference on Energy and Meteorology (June 2013)
- Results from the model presented at regular (3 monthly) formal meetings at National Grid
- Full project report (completed December 2013)
- Full model code delivered to National Grid (December 2013)

Required Modifications to the Planned Approach During the Course of the Project

Changes to scope and approach

No changes have been required to the scope and approach of this project

Changes to cost

No changes have been required to the cost of this project

Changes to programme

No changes have been required to the project programme

Lessons Learnt for Future Projects

Project outcomes

- A review of the latest scientific evidence has been produced, which describes the impact of different meteorological parameters on the power output of large offshore wind farms.
- A model has been developed in MATLAB, which estimates the power output of any offshore wind farm based on the wind speed, wind direction and the wind farm configuration.
- The full model code has been given to National Grid.
- The details of the model have been presented to National Grid at regular meetings and other academics at several international conferences. The paper included in the Proceedings of the 11th UK Conference on Wind Engineering is reproduced in Appendix B.
- With the ultimate aim of enabling National Grid to characterise the possible power output of the clusters of offshore wind farms (outlined in the Round 3 developments), prior to the availability of detailed metered data, the results from this research has provided the foundation for a new project:
  - “Clustering Effects of Major Offshore Wind Developments” (NIA NGET0128)

Review of benefits case

The main benefit of an improvement in wind power forecasting accuracy is still to be realized but this research sets out a good path to

achieve this. The model has clearly shown that it can achieve greater accuracy and can complete calculations in a matter of minutes rather than the hours of computer time required by other methods.

Next steps

To realize the improved forecasting accuracy that this technique promises the following steps will need to be taken.

- Conversion of the model code into R so that it is easier to implement in National Grid systems.
- Further validation with real data from other wind farms.
- An internal project will need to be raised to make the appropriate changes to National Grid systems so that the output of the new model can be utilized in Control Timescales. It is likely that this will be implemented in the Energy Forecasting System (EFS)
- The model will need to be run in parallel with the existing forecasting techniques to verify that the improved forecast accuracy has been achieved relative to existing forecasting techniques.

Note: The following sections are only required for those projects which have been completed since 1st April 2013, or since the previous Project Progress information was reported.

The Outcomes of the Project

Project outcomes

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Planned Implementation

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Other Comments

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