NIA Project Close Down Report Document

Notes on Completion: Please refer to the appropriate NIA Governance Document to assist in the completion of this form. The full completed submission should not exceed 6 pages in total.
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.

Date of Submission

Jan 2024

Project Reference Number

NIA2_NGESO022

Project Progress

Project Title

BC Forecasting

Project Reference Number

NIA2_NGESO022

Project Start Date

November 2022

Project Duration

1 year and 3 months

Nominated Project Contact(s)

Daniel Drew

Scope

Four main work packages and one optional work package will form the basis for the project plan. These are as follows:

- **WP1** – Knowledge exchange and exploratory data analysis. Exploratory data analysis will be performed, looking at the current and proposed datasets in depth to determine what may be useful, and any limitations of the data, or additional processing needed. NGESO will explain the models they have developed and make them available to Hartree as code to ensure they can run these as a baseline for subsequent work
- **WP2** – Improve existing time series models. Ways of improving existing ARIMA models will be explored. The exact areas explored will depend to some extent on the findings of WP1, but it is likely to include; (1) Systematically exploring the choice of parameters trends and (2) the use of additional datasets as regressors. If successful the model can be run in parallel to the existing model, demonstrating the improved forecast.
- **WP3** – Improve temporal resolution of models. Adapt the models from WP2 to run at daily resolution, using similar approaches to WP2. Initially use the same models as in WP2, then adapt them for higher spatial and temporal resolution. This will likely entail a step up in computing power to allow the models to run in a reasonable time frame (although optimisation is included as a later work package). If successful the model can be run in parallel to the existing model, demonstrating the improved forecast.
- **WP4** – Exploration of alternative modelling approaches. This work package will focus on application of machine learning techniques such as Convolutional Neural Networks, Deep auto-encoders, and Recurrent Neural networks, to model and make predictions of balancing costs. Depending on the volume and type of data for each variable a suitable technique for each dataset will be selected for the modelling and prediction processes according to the literature. The performance of these models will be assessed and if they are not satisfactory alternative modelling techniques will be implemented to improve the results. If the model output is satisfactory techniques such as Monte Carlo sampling will be explored, to generate a probabilistic outcome for the trained models.
- **WP5** (Optional) – Code Optimisation. If runtime optimisation of the developed model is required, a code review and profiling pass will be carried out before preparing a detailed work plan.

Objectives

The objectives for the project are as follows:

- Develop a model to forecast balancing costs for 1-12 months ahead at a monthly resolution which uses more advanced statistical techniques than the current NGESO model and/or additional datasets.

- Produce a balancing cost forecast model with better temporal resolution (ideally daily) than current NGESO model.

Success Criteria

The project can be deemed successful if:

- The new balancing cost model delivers higher accuracy forecast in comparison to the existing NGESO model.
- The new balancing cost model provides higher granularity output (target is daily) than the existing NGESO model.
- The improved model is deployable in a way which meets NGESO's business needs (e.g. ease of use, run time, practicality, cost).

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

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Overview

The project objectives and success criteria have largely been met. A new forecast model has been produced which captures the relationships of the drivers to the balancing costs in a moderately improved way to the current ESO model but makes a negligible difference when used to produce forecasts. A model has been created which forecasts at a daily granularity, which is a higher temporal resolution than the existing monthly model. Both of these models are sufficiently simple to run to meet the ESO's business needs.

Work Package 1

Work Package 1 progressed in line with the project aims and objectives. The ESO model was successfully implemented in the Hartree Centre and a comprehensive exploratory data analysis was undertaken. A well-documented summary of the data analysis was completed, in line with the objectives.

Work Package 2

The focus of Work Package 2 was to improve the existing time series model by:

1. Better capturing the relationship between the predictor variables of wholesale price and renewable proportion of demand with the target variable of balancing costs. The open-source forecasting package "Prophet", developed by Facebook, was used. This captured trends and seasonal effects in the relationships of the causal variables, and allowed for change points, such as the increase in size and volatility of wholesale electricity prices since Autumn 2021. This approach slightly improved on the accuracy from the existing model when using actual variables (rather than forecast variables, as would be used if the model were run operationally).
2. Improved forecasting of explanatory variables, particularly the wholesale price, which account for a large component of forecast error. GARCH modelling was investigated, in which the volatility of the wholesale price can change stochastically. This approach needs further investigation to determine if it gives an improvement over the stochastic differential equation utilised at present.

Work Package 3

In Work Package 3 models were produced to forecast balancing costs at a daily granularity, up to 31 days ahead, meeting the relevant project objective. Both a Linear plus ARIMA approach and "Prophet" were analysed, giving similar results.

These models were also investigated at a longer forecast horizon, of up to 12 months, to see if aggregating a daily forecast to monthly values would improve on forecasting monthly variables directly. This approach was found to be unsuccessful, as is common with timeseries models, but was a useful exercise.

Work Package 4

Several machine learning techniques were investigated to predict daily balancing costs, in line with the work package objective. These included Gaussian Processes, Simple Recurrent Neural Networks (RNN), Long Short-Term Memory (LSTM) models, and Gated

Recurrent Unit (GRU) models, with the LSTM approach was found to be the most promising. Different LSTM model architectures were explored and hyperparameter tuning was undertaken, but the models were found to perform less well than the "Prophet" model implemented in Work Package 3.

Work Package 5

This optional work package was not undertaken. The "Prophet" model (WP2 & WP3) performed better than the LSTM (WP4), and did not require an additional work package to optimise runtime and performance.

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

The planned approach had Work Packages 2 and 3 as distinct, by first improving on the ESO model with monthly input data, and then extending this to consider daily input data. It was decided that combining these work packages would be beneficial, to allow for the more granular daily data to be used earlier in the project.

Lessons Learnt for Future Projects

In terms of how the work packages were planned, the differences between Work Packages 2 and 4 were not as clearly defined as first thought. Machine learning is a wide field and it made sense to apply these techniques within Work Package 2 alongside other approaches. Work Package 4 has therefore focused on neural networks as a sub-category of machine learning. Potential overlap has been managed through collaboration between the two teams working on these packages and ensuring there are enough people reviewing to spot any repeated work.

In terms of modelling approaches, the "Prophet" package explored in WP2 is an approach that could apply to other time series forecasting projects within the ESO.

In terms of the variety of modelling approaches, performing initial comparisons with existing models and evaluating performance at an earlier stage facilitates a quicker transition to alternative approaches.

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

The project improved the understanding of the drivers behind the ESO's current model, and after thorough investigation of many different approaches identified some avenues for further investigation whilst ruling out many others:

- The variables with the best predictive power are the ones used in the live model (renewable generation as a proportion of demand and wholesale electricity prices).
- The best modelling technique was the 'Prophet' modelling package. This gave a modest improvement in accuracy compared to the existing model. Over the testing period (Apr-21 to Nov-22), the Prophet model gave a mean absolute error of £73 million, compared to £78 million (per month) using the existing model. However, this is based on using actual (rather than forecast) values for the input variables. When using forecasts instead, the accuracy difference between the models is negligible (£208 million with Prophet, and £209 million with the existing model).
- GARCH modelling showed some promise for simulating wholesale prices, as it allows for volatility that changes over time. This is an area that needs more research to determine if this method gives an improvement over the existing one.
- Daily granularity forecasts were produced but were not able to capture the volatility in daily costs enough to provide useful insight. Aggregating these forecasts up to monthly level did not give increased accuracy over just producing a monthly forecast directly.

More details on the project outcomes can be found in the final report published on the Smarter Networks Portal.

Data Access

Details on hownetwork or consumption data arising in the course of NIA funded projects can be requested by interested parties, and the terms on which such data will be made available by National Grid can be found in our publicly available "Data sharing policy related to NIC/NIA projects" and https://www.nationalgrideso.com/future-energy/innovation.

National Grid Electricity System Operator already publishes much of the data arising from our NIC/NIA projects at smarter.energynetworks.org. You may wish to check this website before making an application under this policy, in case the data which you are seeking has already been published.

Foreground IPR

All relevant project reports and will be published on the Smarter Networks Portal.

Planned Implementation

The monthly 'Prophet' model developed as part of WP2 slightly improved on the accuracy from the existing model. However, this improvement is only seen when the model uses 'actual' input variables (rather than forecast variables, as would be used if the model were run operationally). Therefore, choosing whether to switch to the new prophet model is not a simple decision. Our plan is therefore to run both models in parallel to determine if the improvement is tangible enough to justify increasing model complexity. The implementation into parallel run will be done by the team within the ESO who own the existing balancing cost model.

GARCH modelling showed some promise for simulating wholesale prices, as it allows for volatility that changes over time. This is an area that needs more research to determine if this method gives an improvement over the existing one.

Daily granularity forecasts were not able to capture the volatility in daily costs enough to provide useful insight, and aggregating these up to monthly level did not give increased accuracy over just producing a monthly forecast directly. Therefore, we do not recommend implementing this model for Live use.

No policies or standards need to be updated for implementation.

Other Comments

The Project outcomes and results contain confidential information and intellectual property rights that cannot be disclosed in this Report due to their proprietary nature. Should the viewer of this Report ("Viewer") require further details this may be provided on a case by case basis following consultation of all Publishers. In the event such further information is provided each and any Publisher that owns such confidential information or intellectual property rights shall be entitled to request the Viewer enter into terms that govern the sharing of such confidential information and/ or intellectual property rights including where appropriate formal licence terms or confidentiality provisions. Dependent upon the nature of such request the Publishers may be entitled to request a fee from the Viewer in respect of such confidential information or intellectual property rights.

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