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.

NIA Project Annual Progress Report Document

Date of Submission

Jul 2024

Project Reference Number

NIA2_NGESO032

Project Progress

Project Title

Course-correction Dispatch Instructor

Project Reference Number

NIA2_NGESO032

Project Start Date

February 2023

Project Duration

1 year and 2 months

Nominated Project Contact(s)

Colin Webb

Scope

This project aims to discover, develop, and test a world first course-correction methodology to balance an electricity system. The project will deliver proof-of-concept (PoC) capabilities for course correction dispatch decision support, aiming to release operators of manual tasks and ensure timely decisions are made for economic and reliable operation of the system. The PoC tool will be developed and tested using advanced optimisation techniques and data-driven approaches, including development and implementation of a mathematical model, demonstrating the model performance on selected real-world data examples.

Following successful delivery of the course-correction methodology and PoC, this project will then explore further dispatch support tools covering short-term and long-term energy dispatch, as well as further work to provide explainable solutions within the advice tools developed.

Objectives

- Identify the main components of course correction
- Define a method to select a small set of units for instruction
- Develop a PoC course correction tool and demonstrate the method on selected examples identified
- Define data needs to test the scalability of the course correction method, including scenarios with a larger number of balancing units
- Refine the PoC tool and complete performance tests of the developed course correction methodology

Success Criteria

The following will be considered when assessing whether the project is successful:

1. The project delivers against objectives, timescales and budgets as defined in the proposal
2. PoC tool for dispatch decision-support developed using mathematical models
3. Course correction methodology and scalability successfully demonstrated using real world data examples
4. Clear roadmap for development to achieve an operational tool in the control room, and the development of further tools for short-term and long-term dispatch.

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

National Grid Electricity System Operator ("NGESO") has endeavoured to prepare the published report ("Report") in respect of, Course-correction Dispatch Instructor, NIA2_NGESO032 ("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).

The Report provided is for information only and viewers of the Report should not place any reliance on any of the contents of this Report including (without limitation) any data, recommendations or conclusions and should take all appropriate steps to verify this information before acting upon it and rely on their own information. None of the Publishers nor its affiliated companies make any representations nor give any warranties or undertakings in relation to the content of the Report in relation to the quality, accuracy, completeness or fitness for purpose of such content. To the fullest extent permitted by law, the Publishers shall not be liable howsoever arising (including negligence) in respect of or in relation to any reliance on information contained in the Report

Copyright © National Grid Electricity System Operator 2024

This project will deliver a proof-of-concept decision-support tool to the Electricity National Control Centre (ENCC). Its aim is to relieve control room operators of manual tasks, allowing them to focus on validating results and ensuring timely decisions. While control room decisions encompass operational planning, scheduling and dispatch within a day, the initial focus of the project is on course correction for dispatch decision-support problems.

Phase 1 of this project aims to employ advanced optimisation techniques and data-driven approaches to develop course-correction models for dispatch decision-support problems. This phase involves creating scenarios to test scalability of the developed methods. The development and testing of models will be desktop-based research, consolidating into a single work package spanning 14 months. The work package, designated as WP1, consisting of the following tasks:

Task 1.1 – Identification of the main components of course-correction
Task 1.2 – Determination and development of predictive models for inertia and frequency
Task 1.3 – Implementation of the course-correction tool
Task 1.4 – Credible operational scenarios for testing, including data needs for scalability test of the method
Task 1.5 – Pilot testing of the approach

Following completion of the first phase, this project will then consider scoping the following work packages in more detail for phase 2:

- WP2: Short-term dispatch (within 90mins)
- WP3: Long-term dispatch (90mins – 4hrs)
- WP4: Explanation of optimisation advice tool

Project Progress:

The project is progressing as planned, and significant progress has been made on Tasks 1.1 – 1.3 outlined above. The concept of course correction aims to provide situational awareness to our ENCC and enable informed decision-making instructing balancing mechanism units to maintain demand and generation balance in real-time operation of the system. A high-level architecture diagram for the course correction tool can be see in Figure 1 of the Appendix document. The concept and architecture have been developed in consultation with the ESO project team.

The research and development conducted to-date have resulted in two key modules of the presented framework: a) predictive models of system inertia and frequency, and (b) the energy requirement estimator. Additionally, an end-to-end demonstrator of the proposed methodology has been successfully created. A snapshot of the demonstrator is presented in Figure 2 of the Appendix document. Our current research and development activities are focused on testing, refining, and enhancing each component of the course correction tool. Given that the tool is created in a modular manner, it provides us with the flexibility to update and revise modules without necessitating changes throughout the overall structure of the tool.

As noted above, the key components developed thus-far are predictive models, in particular frequency predictor, and energy requirement estimator. A high-level description of the two components is provided below. A detailed description will be made available as part of the project deliverable that goes into the details.

The frequency prediction model serves the purpose of anticipating the frequency trajectory of our electricity system for a user-defined horizon. Through a comparative analysis of various parameters, the most suitable predictors for the inertia and imbalance predictive models are identified. These models are trained with historic data, publicly available from the NGESO data portal. The predicted inertia and imbalance for the desired time horizon are then fed into a physics-informed machine learning model for the prediction of the rate of change of frequency (RoCoF). Currently the models provide a point-forecast (a single value for each minute of selected time horizon). However, we plan to extend this methodology to include probabilistic forecast.

The energy requirement component of the model consists of two parts. Firstly, the forecasted frequency at a given time, obtained from the frequency predictor, is used to estimate the automatic dynamic frequency response of the system, which, in turn, updates the previously forecasted system imbalance. Secondly, since there are multiple ways to correct the imbalance and bring the frequency within operational limits, an optimisation problem is defined to calculate the required correction to the energy imbalance, ensuring that the system frequency remains within operational limits. The optimisation problem offers several controls that can be adjusted based on system conditions at a given time, such as weather conditions and expected demand. The energy requirement derived from the course correction methodology can be used as an input to bulk-dispatch optimiser to determine a set of instructions for the balancing units.

Project progress – July 2024

Throughout the project, various predictive models were tested using extensive datasets to achieve two main objectives: identifying the most effective predictive models and building energy requirement methodology that can capture new response products.

One key challenge was assembling a large, representative dataset spanning operational years 2021 and 2022, with minute-level resolution. The dataset includes estimates of system imbalance, a metric developed within this project. Machine learning predictive models are training on the assembled data sets and subsequently validated to predict both inertia and imbalance. A mathematical model informed by the swing equation was developed that is used to translate predictions of system imbalance and inertia to system frequency.

Several machine learning regression models were used for the inertia prediction model, including linear regression, decision trees, support vector regression (SVR), generalized additive model, non-optimised neural network, gaussian process regression (GPR) and an ensemble learner. The most consistent performer was the GPR model, and the other high performer was the SVR model. The GPR hour ahead inertia predictor was used for the inertia inputs in subsequent models for frequency prediction.

For imbalance prediction, it was identified that a past observation of aggregate can be used to predict a future one. Aggregate is calculated as the sum of instantaneous bid and offer volume, whereas imbalance is inferred from the difference between bids and offer accepted. 8 input feature sets and 6 prediction horizons (1,5,10,15,30 and 60 minutes ahead) were investigated to identify the optimal combination of inputs for predicting aggregate at a given horizon. From a comparison of 8 machine learning regression models, a linear regression predictor was found to be the superior performer for imbalance prediction.

Overall, the mathematical model developed can predict system frequency at any time for a given imbalance, however predicting future imbalance values introduces errors which increase with time horizon.

The proof-of-concept tool developed enables users to select a settlement period, a time horizon between 10-30minutes, and set low and high frequency response holdings for categories such as Mandatory Frequency Response (MFR), Dynamic Regulation (DR), Dynamic Moderation (DM) and Dynamic Containment (DC). Within the tool, users can see the expected frequency prediction over a given time horizon, the energy needed to keep the frequency within operational limits, and the updated frequency profile when injecting the energy.

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

Some adjustments within the planned approach were deemed necessary to maximise the impact and value of this project. The changes are summarised as follows:

Probabilistic predictive models.

Initially, the project plan aimed to provide point estimates for predictions. However, after discussions with the ESO project team, it was recognized that given uncertainty within various input parameters, the probabilistic predictions along with error estimations and confidence interval would provide much more value than a point estimation. This feature will be included in the project, and we intend to extend our predictive models to incorporate this.

Enhanced focus on testing and validation.

To instill confidence in the system operator regarding the accuracy of energy requirement identified by the course corrector, extensive testing, and validation of a large set of data exemplars are crucial. As noted above, some capability has been developed on reading and creating data exemplars from the ESO open-source data portal that we plan to expand to conduct rigorous testing of our developed models and provide estimate of errors.

Identification of a small set of instructable units.

Initially, the project plan included the objective of identifying a small set of instructible units. The idea was to create instructions as quickly as possible for course correction. However, based on the discussions, this objective has been deprioritised in favour of the above two and on creating a robust reliable energy requirement that can be used as an input to the bulk dispatch.

To enable time to fully complete the final project analysis, the final deliverables were extended out beyond the original timeline. These are currently under final review and will be published upon project closure.

Lessons Learnt for Future Projects

The work within the project has resulted in the development of several scripts used to process and generate input data for the testing and validation of our predictive models. The project will further enhance and refine the scripts, creating a robust mechanism for automated testing and validation. These exemplars generated as part of this project will be particularly valuable for research and innovation projects focused on ancillary services of reserve, response and inertia, as well as the second phase of the project, which focuses on long-term dispatch and scheduling.

One of the deliverables from this project is energy requirement for a given time horizon, which is closely linked to the bulk dispatch optimizer of Open Balancing Platform within the Balancing Programme project. The energy requirement serves as an input to the bulk-dispatch optimization, which is currently manually drawn. This project will close the loop by providing the means to automate determination of energy requirement.

While this project successfully developed an end-to-end course correction tool, several areas need further work and discovery:
Rich and Broader Datasets. We need richer and broader datasets for better development, training, and testing of predictive and machine learning models. In this project, we had to create a large dataset using available open-source tools, which took time away from developing and testing sophisticated machine learning models.
Close collaboration with the system end users. The demonstrator serves two important purposes. The first is to demonstrate the idea and the modelling capability developed during the project. Secondly, it provides means to elicit feedback from the end-users which would be immensely useful to enhance existing modelling capability, quantifying operational benefit, as well as building additional capabilities.
Enhanced modelling and validation of response levels. We lack data on how response is being used at a finer resolution. During the project, we discussed approach to estimate this data, however, due to time limitations this is something which we have not investigated.
Combining this with the Bulk Dispatch Optimisation (BDO). A key input from course correction is the energy requirement which can be fed into the BDO. There are several aspects within the BDO that can be captured within the Course Correction, for example the headroom and footroom available, notice periods etc. This is an aspect which will be worth exploring as a future work.

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 key outcomes included:

- Calculated and validated minute-by-minute BM instruction data for 2021 and 2022
- Using minutely BM instructions and estimating contribution from frequency response and demand damping, pre-BM correction system imbalance was estimated at minute resolutions before corrective actions for the years 2021 and 2022.
- Post-correction imbalance is the running imbalance that is seen as changes in system frequency. Using estimated inertia at minute resolution and historic frequency data, post-correction imbalance was calculated.
- Developed mathematical model capable of recreating system frequency using quantified imbalances.
- Conducted a thorough testing and validation process to identify machine learning predictive models that are effective for predicting inertia and system imbalance.
- Built a proof-of-concept demonstrator for testing and further development.

Data Access

Details on how network 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 www.nationalgrideso.com/innovation.

National Grid Electricity System Operator already publishes much of the data arising from our NIC/NIA projects at www.smarternetworks.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

The following outcomes are expected to be delivered by this project:

- Open-source tool, codes, data and tool documentation.
- An internal report summarising the course-correction method.
- A report on performance testing of course-correction and insights to enhance performance
- Final project report describing the methodology, scalability results and refinements/enhancement made to the approach. The report would also present plans for the second phase of the project.

The reports will be uploaded to the Smarter Networks Portal.