NIA Project Annual Progress Report Document

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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

Jul 2024

Project Reference Number

NIA2_NGESO027

Project Progress

Project Title

Carbon Intensity Modelling

Project Reference Number

NIA2_NGESO027

Project Start Date

January 2023

Project Duration

1 year and 0 months

Nominated Project Contact(s)

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Scope

This project for carbon intensity modelling will:

- Explore how to accurately model carbon output of carbon plant in different operational modes
- Use a combination of traditional statistical techniques and cutting-edge machine learning methods to increase accuracy beyond current peak efficiency assumption
- Build upon internal capability with external domain experts.
- If successful, provide recommendations for future development of carbon intensity tool into Carbon Intensity of Balancing Actions and Virtual Energy Systems (VES).

Objectives

- Identify key missing data items that will have the most impact on our understanding of the carbon intensity of gas/coal/biomass generation.
- Improve the carbon intensity modelling of CCGT/OCGT/Coal/Biomass plants in different states by creating models for when they are operating outside of peak efficiency, and by better understanding the relative efficiencies of BMUs where data is available.
- Develop a PoC tool to optimise the dispatch of the plants on the grid with respect to the carbon intensity of the energy produced (e.g. by generating a carbon merit order, providing recommendations for dispatch which factor in predicted upcoming BM requirements as well as peak / partial load efficiency of available BMUs, or other methods yet to be determined).

Success Criteria

The project will be deemed a success if:

- It delivers against objectives, timescales and budgets as defined in the proposal.
- WP1 models deliver higher accuracy when compared against actual gas usage (as provided by Major Power Producers (MPP) survey or the Gas System Operator if available) than the current fixed value being used.
- A PoC tool is developed for optimising dispatch based on carbon intensity as well as system requirements.

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 Carbon Intensity Modelling, NIA2_NGESO027 ("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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Background information: The carbon intensity of fossil fuel plants depends on how they are running, whether they are starting up from cold or operating at less than full capacity. Currently a single value is used in the overall calculation of the carbon intensity of the grid. With the rise of renewables, increasingly the fossil fuel plants no longer run at a steady state, which means this single value is increasing less accurate. In addition, the NGESO has no sight of what the impact of both carbon intensity and cost would be if the grid was optimised based on carbon intensity rather than cost.
This project will improve the understanding on modelling of the carbon emitted by power plants in their different states and then use that to explore the optimisation of the grid based on carbon intensity.
Currently, National Grid ESO publish half-hourly information on the carbon intensity of the GB electricity system. This data is important in tracking the progress towards de-carbonising the electricity system. The Hartree Centre has been partnered to improve the existing models for a couple of fossil fuel powered plants by refining the models that doesn't use a static value but more accurately reflects real world usage and emissions of these plants.

Problem statement: The single value for the carbon intensity of each type of fossil fuel plant is increasingly inaccurate. This prevents the accurate understanding of the carbon impact of optimisation and balancing actions. In addition, the NGESO would like to understand what the impact on cost and carbon emissions would be of optimising the grid based on carbon intensity rather than cost.
Progress against stated project plan
The project has built models of the carbon intensity of gas, coal and biomass plants using features generated from half hourly operation of the plants. These include when the plants were on, off and whether they were operating at constant power output or if they were going through a period of ramp up or ramp down of energy production. The length of time a plant had been off has been used to identify warm and cold starts from the data.
Data on the fuel used for groups of power plants on a monthly basis has been sourced and this is the target variable used for the modelling. This is then translated into a carbon intensity for the electricity generated by these groups of plants within a month and compared against the figures currently in use.
The second work package has delivered against the plan of building a conceptual tool that optimizes the operation of the grid by both carbon intensity and cost. This tool uses an approach that combines reinforcement learning with evolutionary strategies. This is still at an early TRL level so is operating on a simplified version of the power grid, and importantly assumes central dispatch as a simplifying measure. However, this simplified version based on a sample of historic data shows the range of potential options given cost/carbon trade-offs.

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

No modifications have been made to the deliverables or cost so far during the project but the duration has been extended due to staff availability.

Lessons Learnt for Future Projects

The key lesson learnt from the first half of this project is that the currently publicly available data (monthly and grouped by power plants), limit the modelling techniques available for understanding the performance of the power plants. This would be improved by collecting this data at more regular intervals, for example daily or weekly, or for single plants.

The secondary lesson from the first work package is that we see model performance that suggests with the additional data we would be able to have a sufficient level of performance to model power plant performance at half hourly level. This would give the National Grid ESO the opportunity to review the decisions made controlling the grid based on their impact on carbon intensity – for example balancing services.

Key lessons learnt from work package 1:

- Currently available data (monthly and grouped by power plants) limit the modelling techniques that can be used, and the results that can be driven.
- The results with the limited data show improved accuracy on the current approach and also start to segment the performance of the different types of CCGT plants and the different types of operation. This shows there is the opportunity to extend the work with additional data.
- The calculation of carbon intensity across gas, coal and biomass in general is not standardized and future work should review this.

Key lessons learnt from work package 2:

- Having an accurate CO2 intensity model for every generator in the network has a big impact on the allocation optimization. However, building such models requires data on individual generators which is not available in the public domain.
- Current model has a straight-forward energy demand forecast — the project assumes the control room has a perfect demand forecast 16 hours ahead. Improving this forecast model through collaborations with the NG-ESO demand forecast team can enhance the allocation model and optimization.

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 delivery of the project is almost complete. Data used for the project was sourced from the National Grid ESO open data portal. Data on fuel consumed by power plants was requested from the DUKES team in the Department for business, energy and industrial strategy.
The initial work package, to build models improving on the carbon intensity of a power plant compared to the current single value, has built initial models for gas, coal, and biomass, and compared them to the single values for carbon intensity currently used. These models show reasonable initial performance given the small amount of available data and are being refined to ensure best performance and to reduce the risk of overfitting. The models are built using features generated from the half hourly running of the power plants. Various iterations and combinations of the features are used as inputs, including considering interactions and nonlinear terms. Due to the low data volumes and a focus on explainability, the modelling approach being used is linear regression and only a small number of features are used in the final models to reduce the risk of overfitting. This has been concluded and delivered.
Making use of publicly available data and the CO2 intensity analysis in the first work package, the second work package has created a simplified model of the grid, the generators, and the allocation problem. It then optimizes dispatch decisions based on this simplified model. The optimization method used is Deep Reinforcement Learning with Evolutionary Strategy finetuning. The work package has successfully developed a proof-of-concept tool that can produce central dispatch allocation plans that are optimized based on both carbon intensity and cost. The tool can also provide estimates for the environmental benefits and financial costs of such plans.

The project is currently in final report writing with work package 3.

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:

- Jupyter notebook or equivalent to build and test preferred models (delivered)
- Report on models built in wp1 and their performance (delivered)
- Report analysing the methodology used to create the control mechanism and corresponding Jupyter notebook demonstrating the control method developed (delivered)

- Report providing overview of work completed, potential impact and limitations (in progress)