NIA Project Annual Progress 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

Jul 2024

Project Reference Number

NIA2_NGESO037

Project Progress

Project Title

Forecasting the Risk of Congestion

Project Reference Number

NIA2_NGESO037

Project Start Date

June 2023

Project Duration

0 years and 7 months

Nominated Project Contact(s)

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Scope

This project will develop new probabilistic forecasts to anticipate the possible spread of values between the day ahead scheduled energy flows and the actual energy flows. The project will first consider development of forecasters for the interconnectors, with the addition of uncertainties from key wind generation units in the final work package. The associated probabilities as well as the correlation between the spread values at different nodes of the grid will also be tracked.

The goal is to predict the risk of congestion on specific branches of the power grid with a probabilistic approach. This will be done by using power flow models to propagate the probabilities of injections and offtakes at different nodes of the grid and applying them into current scenarios on internal lines of the power grid.

Objectives

- Forecast probabilities of deviations between day ahead scheduled flows and actual energy flow for each interconnector connected to the EU
- Critical contingency and critical branch pairs identified for analysis within the project
- Generate a sample of scenarios suitable for analysis of the load flow solver
- Develop a tool tested on a sample of weeks and provide the congestion risk profile for each pair of contingency and critical branches identified
- Interface load flow tool with network topological changes, and generation and demand profiles, ensuring solver can run in timescales suitable for operational use
- Compare results from probabilistic distribution for congestions with existing point forecast, and consider impact on potential operator actions
- Update overall procedure to include uncertainties from key wind generation units

Success Criteria

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

- The project develops a model to predict probabilities of the interconnector physical flow deviations with respect to the day ahead scheduled flows
- Explicit day ahead scenarios for the physical interconnector flows successfully generated and interface with the power flow model is proposed
- Probability distribution reconstructed for the loading of the line for each contingency and each critical branch identified as in scope for the project
- Probabilistic congestion forecast better anticipates historical N-1 congested cases compared to the point forecast
- Project delivers on against objectives, timescales and budgets as defined in the proposal

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

Performance compared to the aims

The project aims to predict the risk of congestion on specific branches of the power grid with a probabilistic approach. Overall, some progress has been made towards this, and the project has created a Forecasting tool that predicts the outputs of interconnector and windfarm units, the flows of which can be compared to actual historic flows. This work is intended to lead to the creation of a prediction of flows on the network lines for the South East region on the GB network, leading to the probabilistic forecast of congestion.
This project was split into two main phases, primarily to enable data requirements for phase 2 to be collated while phase 1 progressed:

Phase 1

WP1 – Development of forecasters for the interconnectors

A supervised learning model to predict the probabilities of the physical flow deviations with respect to the day-ahead scheduled flows. This will focus on the interconnectors between the UK and EU countries with at least 2 years of operating time to give a good size of training data.

WP2 – Generation of scenarios

Generate explicit possible day-ahead scenarios for the physical interconnector flows, filter the produced scenarios, check the correlations, and interface the scenarios with the power grid model.

Phase 2

WP3 – Load flow analysis

Reconstruct the probability distribution for the loading of the line for each contingency and each critical branch within the project scope.

WP4 – Analysis of results and benefits

Analyse the predicted probability distribution for congestions, run the comparison with the outcome from the point forecast and assess the ability of the probabilistic congestion forecast to better anticipate historical N-1 congested cases.

WP5 – Address uncertainties from wind generation

Update the overall procedure leading to the prediction of the congestion risk profile for each contingency and critical branch in scope to include uncertainties from key wind generation units.

Phase 1

Work Package 1

A supervised learning model to predict probabilities of the physical flows with respect to the day-ahead scheduled flows was developed. This focused on the following selection of five interconnectors between GB and EU countries: BritNed, Nemo Link, IFA, IFA2, and ElecLink.
First input features of the model were built through extensive mining of time series data, ensuring alignment with a standard format using UTC timestamps. Following this, a selection of time series were constructed for use as input features for the solution.
In contrast to point forecasting, the models developed in this project are probabilistic. This will enable later work packages to assess

the impact of uncertainties arising from the interconnectors on the congestion throughout the GB network. To model the spread between physical and scheduled flows a tree-based algorithm was used, aggregating the predictions of many individual trees, and resulting in a more robust model. Each tree uses rule-based categorisation that divides all the initial cases of training data into different sets, with the idea to group similar interconnector flow cases together and distinguish distinct cases. Each tree starts with the full training set at the root of the tree.

The root mean squared error (RMSE), bias and variance were used to assess the performance of the models. Based on a 4-month testing period, the models for all the interconnectors showed clear benefits compared to using the scheduled flow as a proxy for physical flow. This performance improvement was largest for BritNed and Nemo link, with an average improvement of 14% and 11.5% respectively. For others, the performance improvement in terms of RMSE is between 2.5% and 7.5%.

All interconnectors demonstrated satisfactory performance regarding bias and variance, with IFA showing the highest bias. Overall, in conjunction with a notable reduction in variance, the developed forecasting model accurately capture the uncertainties stemming from the interconnectors.

Work Package 2

While per-interconnector forecasts were seen to perform very well, having a model to predict percentiles for the spread between physical flows and scheduled flows is not sufficient to handle the uncertainties in the loading of transmission lines. Explicit values for physical flows on the interconnectors needed to be generated which can be used as input to steady-state power flow analysis. This work package generated a sample of scenarios for the physical flows that ensured the spread between physical and scheduled flows were distributed according to the AI models from WP1. Each scenario specified the predicted physical flow for each of the five interconnectors.

A scenario-based multi-target model was constructed to consolidate the per-interconnector models into a 5-dimensional target model to keep track of correlation across different interconnectors. To assess the loading on critical lines at a given time unit, a power flow analysis needs to be applied on definite scenarios for the flow values on all the interconnectors in scope. As a result, a set of 5-D scenarios were constructed explicitly where the value of the flows for the five interconnectors in scope is specified in each scenario. To preserve the entanglement of flow deviations across interconnectors, the procedure included first re-expressing the prediction from the tree-based model as a distribution of weighted historical events. Following this, for each predicted time unit, the historical weight sequences for different interconnectors was combined into a consolidated historical weight sequence. Finally the multi-interconnector historical weights were used to predict the 5-D distribution of flow values for all interconnectors.

This work package concluded that it is possible to build scenarios for the physical flows using a procedure that keeps track of the correlations across interconnectors and preserves the accuracy of the single-target model developed in WP1. Although the number of scenarios is large, it can be reduced by assuming a finite resolution in the flow values.

Phase 2

The phase 2 work packages have not been completed in numerical order, e.g. both work package 3 and 5 were started during the same period in April 2024, with WP 5 being completed by June 2024 and WP 3 completed in July 2024.

Work Package 3

Work package 3 has the objective of developing and configuring the load flow analysis for the specific use-case at hand. For the project, it was decided to focus on the SE corner of the GB network. Moreover, the tool is able to handle boundary flows (as opposed to individual line flows). A clear focus was put on boundary SC2 and SC3.

After the completion of this work package, the tool is able to construct the probability distribution of the loading of a specific boundary, given some contingencies. Based on these distributions, a performance assessment can be made in work package 4, comparing the predicted distribution to the realised flow data.

This work package has recently been completed, with some additional assumptions/limitations compared to the initial project plan:

The load flow was executed in DC (as opposed to AC). This decision was taken by the limiting scenario information on the (realised/historical) reactive power profiles for all elements in scope of this project.

The realised/historical (active) power profiles were mapped to the generators/loads within the network based on GSP ID and BMU ID (and not on individual network models for each time stamp). This could introduce some issues to balance the grid during the load flow analysis (as some inconsistent mappings were found) that in turn could impact the flow on the boundaries.

A small comparison between the DC and AC results will be carried out to give some insights in the size of any inaccuracies that may result from this assumption.

The above-mentioned points imply that congestion profiles cannot be seen as “realistic”. However, being consistent on these assumptions during the performance assessment phase (and for both the realised/historical information as for the forecasted data), the impact on the final conclusions and benefits of the tool are deemed limited. The advantage by taking these assumptions was to minimise the delay in the final deliverables of the project.

Among the stochastic nodes included in the load flow analysis, the nodes connected to three wind generation parks have also been considered. To predict the power probability distributions for these nodes, historical weather data as well as historical power profiles spanning over the previous years have been used to train AI algorithms, with the objective of predicting the historical power values.

This work package is considered as completed.

Work Package 4

Analysis of results and benefits is currently ongoing. The idea is to compare the D-1 forecasted congestions profiles with the actual (realised) boundary flows to identify if the tool can better anticipate congestions. This will be evaluated with the same metrics that were used for the probabilistic congestions for the HVDC interconnectors: bias and variance. Other insights will also be investigated, such as “Does congestion coincide typically with the peak load?”.

Work Package 5

The initial forecasting models for the HVDC interconnectors were extended to include three main wind farms so that the tool also considers uncertainties for wind generation (when predicting the congestion levels).

This work package extended the tool by also forecasting the wind generation for three wind farms: Greater Gabbard, London Array and East Anglia One. The results show that the models achieve satisfactory performance with three of the considered wind farms and there is a little bias in the probabilistic predictions, which is a crucial element for the subsequent scenario generation process.
This work package is considered as completed.

Progress against objectives:

The following objectives have been partly met with some limitations due to incomplete data and some questions that require further clarification:
Forecast probabilities of deviations between day ahead scheduled flows and actual energy flow for each interconnector connected to the EU: This work has been delivered in Phase 1.
Generate a sample of scenarios suitable for analysis of the load flow solver: This work has been recently completed in Phase 2, as part of work package 3. The intention is to use those generated scenarios with a DC load flow analysis (given some data limitations).
Develop a tool tested on a sample of weeks and provide the congestion risk profile for each pair of contingency and critical branches identified: The tool that has been created in Phase 1 resides on N-SIDE’s systems, there is currently no apparent mechanism for the ESO to utilise it to test it (e.g. via an online platform to access the system remotely). N-SIDE will still compare the predictions of the tool with the actual (realised) flow data and provide the ESO with the underlying data for those tests.
Extend the analysis to include the uncertainties from key wind generation units.
The following objectives require further work to demonstrate how they can be / have been met:
Identifying the critical contingencies for analysis within the project
Interface load flow tool with network topological changes, and generation and demand profiles, ensuring the proof of concept solver can run in timescales that might be suitable for possible future development into operational use. Note, development of the tool for operational use does not fall within the scope of this project.
Compare results from probabilistic distribution for congestions with existing point forecast, and consider impact on potential operator actions

Progress against success criteria:

The project has so far delivered against the following Success Criteria
The project develops a model to predict probabilities of the interconnector physical flow deviations with respect to the day ahead scheduled flows: This has been completed in Phase 1.
Explicit day ahead scenarios for the physical interconnector flows successfully generated and interface with the power flow model is proposed: This work is ongoing in Phase 2.
The following success criteria require further work to demonstrate how they can be / have been achieved:
Probability distribution reconstructed for the boundary flow for certain contingencies identified as in scope for the project
Probabilistic congestion forecast better anticipates historical N-1 congested cases compared to the point forecast

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

In September 2023, a detailed plan of the second phase has been produced by N-SIDE and presented as follows:
Work Package 1: Development of forecasters for the interconnectors
The project focused on five interconnectors (only those connecting to the SE corner): BritNed, Nemo Link, IFA, IFA2, and ElecLink.

Work Package 3: Load flow analysis

Reconstruct the probability distribution for the loading of the line for each contingency and each critical branch in scope.
Instead of focusing on individual line loadings, it was decided to look into system boundaries to be closer to operational conditions.

Work Package 4: Analysis of results and benefits

Predicted probability distribution analysis for congestions,
Comparison with point forecast
Assessment on the ability to better anticipate historical N-1 congested cases

Work Package 5: Address uncertainties from wind generation

Procedure update to include uncertainties from key wind generation units in prediction of the congestion risk profile for each critical branch and contingency
All the above items were planned for completion along with a final detailed report as Work Package VI delivering the results in January

2024.
There have been delays in progressing Phase 2 of the project, because a network model for the South East of the GB network was required by N-SIDE. The model information was subject to ESO internal data sharing controls which delayed the continuation of the project.
The project resumed in January 2024, once N-SIDE was able to acquire some of the model data necessary to perform the work. They have highlighted some information missing and some outstanding questions which places limitations on the outputs of their work.
A revised plan has since been submitted which is very similar in outputs as the original presented in September 2023 and the final report is now expected by October 2024.
All variations to the project have been captured in the agreed change control form.

Lessons Learnt for Future Projects

The primary lessons learnt from this project has been around the data requirements. Although there are network models available in the public domain, these have several limitations depending on what the required needs for the model are. For the purposes of this project, they were not representative of the current GB electricity network. A reduced model was generated for the purposes of this project, with commercial and confidential network data removed where feasible. For the remaining confidential data, the relevant Transmission Owner was approached for approval to share the network model with this data remaining. For future projects that may require a similar data set, lessons from this project can be utilised to streamline the data sharing process.

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

- Supervised learning model to predict interconnector flows
- Generation of scenarios for interconnector flows
- Correlation and filtering of scenarios
- Load flow analysis
- Analysis of results and benefits for probability analysis for congestions, compared to point forecasts - ongoing
- Model update to include uncertainties from key wind generation units

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

Final report documenting the methodologies, the application to the GB electricity grid, and the analysis of the results will be made available on the smarter networks portal at the end of the project.