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.

NIA Project Registration and PEA Document

Date of Submission

Aug 2024

Project Reference Number

NIA2_NGESO082

Project Registration

Project Title

Neural BB

Project Reference Number

NIA2_NGESO082

Project Licensee(s)

National Energy System Operator

Project Start

June 2024

Project Duration

1 year and 7 months

Nominated Project Contact(s)

innovation@nationalgrideso.com

Project Budget

£200,000.00

Summary

The project seeks, as a proof of concept, to use machine learning to create a surrogate model from a” black box” model of an AC/DC converter. The black box model and the surrogate are to be of the type used in PSCAD, a type of electromagnetic transient (EMT) simulation software.
The aim is to create a surrogate model that has sufficient accuracy that it can be used by ESO in stability studies.
The surrogate model must be available as source code that can be recompiled so it can work on all future software systems, and it must be able to run at different time steps to ensure compatibility with other converter models (whether surrogate or black box).

Nominated Contact Email Address(es)

box.so.innovation@nationalgrid.com

Problem Being Solved

Manufacturer-provided “black box” representations of converters for EMT simulations create a number of problems for a grid operator attempting to run accurate simulations. These include:

- There may be software incompatibilities between different black box models (e.g. they may require different time steps, different compilers or different runtime environments).
- There is no way simple way to represent locations where there are many different types of converters from many different manufacturers (e.g. embedded generation).
- Converter manufacturers do not maintain their models long-term. This in turn leads to “lock-in” to particular modelling software – and

even to a particular version of the modelling software.

- Some black box models are fast and some are slow. If a study contains just one slow black box model than the entire study is slowed down – the "slowest ship in the convoy" effect.
- Black-box models are complex and bespoke, making it difficult to build EMT grid models. This complexity appears in their technical aspects (e.g. unique dependencies and runtime requirements), their user interface (large and complex, often poorly documented, and different for every product), and their legal requirements (e.g non-disclosure agreements).

Method(s)

The proposed method to finding a solution to the problem involves the following steps:

- Creating a surrogate model that represents a non-black-boxed converter model.
- Building on lessons learned in the previous step, creating a surrogate model that represents a black-boxed converter model (the "proof of concept" step)
- Subject to the proof-of-concept surrogate model passing tests, rolling out the conversion-to-surrogate process to other black-boxed converter models.
- This is a technical method. It does not involve novel commercial arrangements.

The project will be delivered in four work packages:

- WP1 – Literature Search
- WP2 – Train Surrogate of Generic Model & Test in Isolation
- WP3 – Test Surrogate of Generic Model in PSCAD
- WP4 – Train Surrogate of Black Box Model & Test in PSCAD.

Scope

The aim is to create a surrogate model that has sufficient accuracy that it can be used by ESO in stability studies.
In financial terms the largest gains are likely to occur where surrogates allow ESO and/or transmission owners to undertake more accurate EMT studies (e.g. by avoiding compatibility and model-obsolescence issues, or by allowing accurate representation of distributed generation, or by reducing complexity and hence making the creation of more detailed models feasible).
Having more accurate EMT studies will allow margins of safety to be reduced, which should result in substantial financial benefits for consumers.

Objective(s)

The objectives of the project are divided into the following steps:
Demonstrate how machine learning can be used to create a surrogate model that adequately reproduces the behaviour of an open (i.e. non-black-boxed) model when tested in isolation.
Demonstrate how machine learning can be used to create a surrogate model that adequately reproduces the behaviour of a single selected black box model when tested in isolation.
Demonstrate that the surrogate version of the black box model reproduces the behaviour of the original model (to a satisfactory level of accuracy) when it is tested in an actual model of British grid.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

The ESO does not have a direct connection to consumers, and therefore is unable to differentiate the impact on consumers and those in vulnerable situations.

Success Criteria

The project will have been successful if the surrogate version of a black box model can be shown to reproduce the behaviour of the original black box model with adequate accuracy. In this case "adequate" means that grid studies undertaken with the surrogate model will not indicate significantly different grid power flow limits to those undertaken with the original black-box model.

Project Partners and External Funding

No external funding is proposed. The studies will be undertaken by Transmission Excellence ("TX"), who have previously provided

ESO with software and models for EMT grid simulation studies. They will be assisted by machine learning experts at the University of Bristol.

Potential for New Learning

The project has the potential to provide a new and better method for undertaking EMT grid simulations by demonstrating how to convert a particular ("proof of concept") black box model into a surrogate model. Learning will be disseminated via academic paper(s) to be prepared by University of Bristol staff.

Scale of Project

The project is of the minimum scale necessary to provide a proof of concept, as it will only be aiming to create a surrogate for one single black-box model. If this proof-of-concept project is successful then a larger scale roll-out, creating surrogates for many black box models, could follow.

Technology Readiness at Start

TRL2 Invention and Research

Technology Readiness at End

TRL4 Bench Scale Research

Geographical Area

The ideas being developed by this project are not bound to any particular geographical area. Notwithstanding this, the EMT stability studies that aim to validate the proof-of-concept surrogate converter model are likely to focus solely on the South East Coast area for simplicity. The South East Coast was selected as it is particularly complex, and has known "converter stability" issues.

Revenue Allowed for the RIIO Settlement

None

Indicative Total NIA Project Expenditure

£200,000

Project Eligibility Assessment Part 1

There are slightly differing requirements for RIIO-1 and RIIO-2 NIA projects. This is noted in each case, with the requirement numbers listed for both where they differ (shown as RIIO-2 / RIIO-1).

Requirement 1

Facilitate the energy system transition and/or benefit consumers in vulnerable situations (Please complete sections 3.1.1 and 3.1.2 for RIIO-2 projects only)

Please answer **at least one** of the following:

How the Project has the potential to facilitate the energy system transition:

The energy transition involves the replacement of fossil fuelled power generation with renewable sources, especially wind and solar. It also involves increased use of battery energy storage and HVDC transmission. The application of wind, solar, batteries and HVDC technologies all involve the replacement of synchronous machines with power electronic (transistor-based) converters. These converters are controlled by software, and so the behaviour of the grid cannot be simulated without simulating the control software. The project aims to develop a better mechanism to simulate the control software, leading to the numerous benefits described elsewhere in this document, and hence facilitating the energy transition.

How the Project has potential to benefit consumer in vulnerable situations:

n/a

Requirement 2 / 2b

Has the potential to deliver net benefits to consumers

Project must have the potential to deliver a Solution that delivers a net benefit to consumers of the Gas Transporter and/or Electricity Transmission or Electricity Distribution licensee, as the context requires. This could include delivering a Solution at a lower cost than the most efficient Method currently in use on the GB Gas Transportation System, the Gas Transporter's and/or Electricity Transmission or Electricity Distribution licensee's network, or wider benefits, such as social or environmental.

Please provide an estimate of the saving if the Problem is solved (RIIO-1 projects only)

n/a

Please provide a calculation of the expected benefits the Solution

If the project is successful and the concept is fully rolled out then the largest financial benefits are likely to occur where surrogates allow more accurate EMT studies to be undertaken (e.g. by avoiding compatibility issues, or by allowing accurate representation of distributed generation, or by reducing complexity and hence making the creation of more detailed models feasible).
Having more accurate EMT studies will allow margins of safety to be reduced, which should result in substantial financial benefits for consumers. For instance, studies of the stability constraints in South East Coast found that every MW of extra stability margin would increase curtailment cost by £66k pa, or the cost of adding sync comps by £26k pa. If using a more accurate model to reduce margins of safety gave just 1% more capacity on this single boundary it would equate to a saving of £0.9-2.3m pa. In reality potential savings are likely to be much larger, and across many system boundaries, especially since converter-stability limited boundaries can be expected to become much more common as wind/solar/batteries/HVDC become increasingly dominant sources of energy. For instance, a 5% gain across five converter-stability-limited boundaries of similar size to the South East Coast would be worth (more than £0.9m * 5 * 5, which is roughly £20-60m pa. In capitalised terms this would be over £300m.

Please provide an estimate of how replicable the Method is across GB

As noted above, the intention is to undertake validation tests using EMT grid models of the entire grid, with the surrogate converter model under test being located in the South East Coast part of the grid. Given that this area is particularly challenging in terms of interactions between converters, it is likely that if it passes the test in this part of the grid then the approach should be replicable across all parts of the GB grid.

Please provide an outline of the costs of rolling out the Method across GB.

In principle, any technique developed and demonstrated during the project can be applied to any black box model and used to create a

surrogate model. It is difficult at this stage to estimate exactly how much effort should be required to create each surrogate model, but it should be possible to automate the process. A low-end estimate of the cost, therefore, would be £5k per converter design times 100 converter designs and special sites with unique mixes of different converters (e.g. embedded solar and wind). This would give a total of £500k. In addition to this, work on the automation of the process might have a one-off cost of £200k. This would give an overall low-end cost of £700k.
There is a risk that, even if this proof-of-concept is successful, so many black box models prove difficult or impossible to reproduce as surrogates that the concept as a whole cannot be rolled out. The expected post-project TRL of 4 also suggests that this risk is not negligible.
In the longer term, converter manufacturers could be required to undertake the conversion and testing process themselves, and to submit a suitably tested surrogate model to ESO instead of (or as well as) a black box model. This would substantially reduce ongoing costs for ESO.

Requirement 3 / 1

Involve Research, Development or Demonstration

A RIIO-1 NIA Project must have the potential to have a Direct Impact on a Network Licensee's network or the operations of the System Operator and involve the Research, Development, or Demonstration of at least one of the following (please tick which applies):

☐ A specific piece of new (i.e. unproven in GB, or where a method has been trialled outside GB the Network Licensee must justify repeating it as part of a project) equipment (including control and communications system software).

☐ A specific novel arrangement or application of existing licensee equipment (including control and/or communications systems and/or software)

☐ A specific novel operational practice directly related to the operation of the Network Licensees system

☐ A specific novel commercial arrangement

RIIO-2 Projects

☐ A specific piece of new equipment (including monitoring, control and communications systems and software)

☑ A specific piece of new technology (including analysis and modelling systems or software), in relation to which the Method is unproven

☐ A new methodology (including the identification of specific new procedures or techniques used to identify, select, process, and analyse information)

☐ A specific novel arrangement or application of existing gas transportation, electricity transmission or electricity distribution equipment, technology or methodology

☐ A specific novel operational practice directly related to the operation of the GB Gas Transportation System, electricity transmission or electricity distribution

☐ A specific novel commercial arrangement

Specific Requirements 4 / 2a

Please explain how the learning that will be generated could be used by the relevant Network Licensees

The project aims to show how a surrogate model can be created that can replace a black box model in a PSCAD study without unacceptable loss of accuracy. For this learning to be used by ESO and other network licensees, the technique would need to be rolled out so that it covers most (or even all) of the black box models currently in use. This is likely to require a further research project to develop the software that would automate the black-box-to-surrogate conversion process.

Or, please describe what specific challenge identified in the Network Licensee's innovation strategy that is being addressed by the project (RIIO-1 only)

n/a

Is the default IPR position being applied?

☑ Yes

Project Eligibility Assessment Part 2

Not lead to unnecessary duplication

A Project must not lead to unnecessary duplication of any other Project, including but not limited to IFI, LCNF, NIA, NIC or SIF projects already registered, being carried out or completed.

Please demonstrate below that no unnecessary duplication will occur as a result of the Project.

Not aware of any other work (whether funded by the GB transmission industry, or by any other source) that is proposing to use machine learning to create surrogate models of EMT converter models.

If applicable, justify why you are undertaking a Project similar to those being carried out by any other Network Licensees.

n/a

Additional Governance And Document Upload

Please identify why the project is innovative and has not been tried before

The use of machine learning to train surrogates of EMT models of AC/DC converters (as found in HVDC, wind, solar, battery, etc) has not previously been demonstrated GB or elsewhere.
(Work applying machine learning to RMS - as opposed to EMT - stability studies has been undertaken elsewhere, with successful results reported. This provides some mitigation for the innovation risk).

Relevant Foreground IPR

Deliverables are reports and three “proof of concept” surrogate models (the first two would run only in isolation and would represent an “open” and a “black-boxed” converter model respectively; the third would run in PSCAD and would represent the black-boxed model).

Data Access Details

Data for this project and all other projects funded under the Network Innovation Allowance (NIA), Network Innovation Competition (NIC) or the new Strategic Innovation Fund (SIF) can be found or requested in a number of ways:
A request for information via the Smarter Networks Portal at https://smarter.energynetworks.org, to contact select a project and click ‘Contact Lead Network’. National Grid ESO already publishes much of the data arising from our innovation projects here so you may wish to check this website before making an application.
Via our Innovation website at https://www.nationalgrideso.com/future-energy/innovation
Via our managed mailbox innovation@nationalgrideso.com
Details on the terms on which such data will be made available by National Grid ESO can be found in our publicly available “Data sharing policy relating to NIC/NIA projects” at https://www.nationalgrideso.com/document/168191/download.

Please identify why the Network Licensees will not fund the project as apart of it's business and usual activities

The concept is at a low level of maturity (TRL 2) and therefore has high risks, making it inappropriate for ESO to pursue it as part of business as usual.

Please identify why the project can only be undertaken with the support of the NIA, including reference to the specific risks(e.g. commercial, technical, operational or regulatory) associated with the project

The concept is at a very low level of maturity (TRL 2) and therefore has high risks, making commercial funding difficult. Furthermore the expected benefits involve replacing black box models with surrogate models for which ESO (and other network licensees) will have the source code, preventing “lock in”. This is a benefit for ESO and the consumer, but it also makes it difficult for any enterprise to profit from the innovation.

This project has been approved by a senior member of staff

☑ Yes