NIA Project Registration and PEA Document

Date of Submission: March 2024

*Notes on Completion: Please refer to the NIA Governance Document to assist in the completion of this form. Please use the default font (Calibri font size 10) in your submission. Please ensure all content is contained within the boundaries of the text areas. The full-completed submission should not exceed 10/12 pages in total.*

1. Project Registration

|  |  |  |
| --- | --- | --- |
| Project Title (*This cannot be changed once registered*) |  | Project Reference |
| Neural BB |  | NIA2\_NGESO082 |
| Funding Licensee(s) |  | Project Start Date |
| NG ESO – National Grid ESO |  | June 2024 |
| Nominated Project Contact(s) |  | Project Duration |
| Gopi Yericherla |  | 18 Months |
| Contact Email Address |  | Project Budget |
| box.so.innovation@nationalgrid.com |  | £200,000.00 |

**Project Summary (125 words limit)**

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).

**Benefits Summary (125 words limit)**

* Avoids issues with incompatible black box models.
* A single surrogate model could represent many diverse converters connected to the same substation.
* At present converter manufacturers do not maintain models long-term, so models cease to work as the simulation environment is updated. In contrast the source code for surrogate models is available, so they can simply be re-compiled to work with the latest software.
* Potential for faster execution of studies, as surrogates avoid the “slowest ship in the convoy” effect.
* Potential for simpler, standardised, converter models without software and legal complexities. This would make building EMT grid models much easier.
* Avoidance of “lock-in” with particular EMT modelling software – surrogate models can be re-compiled to work with any new software.

**Lead Sector**

|  |  |
| --- | --- |
| Electricity Distribution | Gas Distribution |
| Electricity Transmission  X | Gas Transmission |

**Other Sectors**

|  |  |
| --- | --- |
| Electricity Distribution  X | Gas Distribution |
| Electricity Transmission | Gas Transmission |

**Primary Research Area** *(Please select just one)*

|  |  |
| --- | --- |
| Net zero and the energy system transition  X | Optimised assets and practices |
| Flexibility and Commercial Evolution | Whole Energy System |
| Consumer Vulnerability | Data and Digitalisation |

**Secondary Research Area** *(Please select up to two)*

|  |  |
| --- | --- |
| Net zero and the energy system transition | Optimised assets and practices |
| Flexibility and Commercial Evolution | Whole Energy System |
| Consumer Vulnerability | Data and Digitalisation  X |

**Development steps**

|  |  |
| --- | --- |
| Technology Readiness Level (TRL) at Start  2 | TRL at Completion  4 |

1. Project Details
   1. Problem(s)

This should outline the Problem(s) which is/are being addressed by the Project. This cannot be changed once registered.

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). 
  1. Method(s)

This section should set out the Method or Methods that will be used in order to provide a Solution to the Problem. The type of Method should be identified where possible, eg technical or commercial.

For RIIO-2 projects, apart from projects involving specific novel commercial arrangement(s), this section should also include a Measurement Quality Statement and Data Quality Statement. [You can find more information here](https://nationalgridplc.sharepoint.com/:w:/s/GRP-INT-UK-ESOInnovation/EUHa8ywhnJ9EmaRDlEXTOGcBR-ixyoa2Nd9onfMs66xdsw?e=fefb74).

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.

* 1. Scope

The scope and objectives of the Project should be clearly defined including the net benefits for consumers (eg financial, environmental, etc). This section should also detail the financial benefits which would directly accrue to the GB Gas Transportation System and/or electricity transmission or distribution.

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.

* 1. Objectives

This cannot be changed once registered.

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.

* 1. Consumer Vulnerability Impact Assessment (RIIO-2 projects only)

Details of the expected effects of the Method(s) and Solution(s) upon consumers in vulnerable situations. This must include an assessment of distributional impacts (technical, financial and wellbeing-related). For RIIO-1 projects please add “Not Applicable”

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.

* 1. Success Criteria

Details of how the Funding Licensee will evaluate whether the Project has been successful. This cannot be changed once registered.

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.

* 1. Project Partners and External Funding

Details of actual or potential Project Partners and external funding support as appropriate.

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.

* 1. Potential for New Learning

Details of what the parties expect to learn and how the learning will be disseminated.

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.

* 1. Scale of Project

The Funding Licensee should justify the scale of the Project – including the scale of the investment relative to the potential benefits. In particular, it should explain why there would be less potential for new learning if the Project were of a smaller scale.

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.

* 1. Geographical Area

Details of where the Project will take place. If the Project is a collaboration, the Funding Licensee area(s) in which the Project will take place should be identified.

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.

* 1. Revenue allowed for in the current RIIO settlement

An indication of the funding provided to the network licensee within the current RIIO settlement that is likely to be surplus to requirements as a result of the Project.

None

* 1. Indicative Total NIA Project Expenditure

An indication of the total Allowable NIA Expenditure that the Funding Licensee expects to reclaim for the whole of the Project (RIIO1).

An indication of the Total NIA Expenditure that the Funding Licensee expects to reclaim for the whole of the Project (RIIO2).

£200,000

1. Project Eligibility Assessment

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).

* 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:

* + 1. 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.

* + 1. How the Project has potential to benefit consumer in vulnerable situations:

Not applicable

* 1. 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.

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

Not applicable – RIIO-2 project

* + 1. Please provide a calculation of the expected benefits the Solution

This is for Development or Demonstration Projects, not required for Research Projects. It should be (Base Cost – Method Cost, Against Agreed Baseline) and include a description of the recipients of the benefits.

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.

* + 1. Please provide an estimate of how replicable the Method is across GB

This must be in terms of the number of sites, the sort of site the Method could be applied to, or the percentage of the Network Licensees system where it could be rolled-out.

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.

* + 1. 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.

* 1. Requirement 3 / 1 – involve Research, Development or Demonstration
     1. RIIO-1 Projects

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 systems and 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 GB electricity transmission or distribution systems |  |
| A specific novel commercial arrangement |  |

* + 1. RIIO-2 Projects

A RIIO-2 Project must involve the Research, Development or Demonstration of at least one of the following:

|  |  |
| --- | --- |
| 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 | X |
| 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 |  |

* 1. Requirement 4 / 2a – develop new learning

A Project must develop new learning that can be applied by Gas Transporter and/or Electricity Transmission or Electricity Distribution licensees. For RIIO-1 Network Licensees may wish to address challenges specific to their network.

Please answer one of the following:

* + 1. Please explain how the learning that will be generated could be used by relevant Network Licenses

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.

* + 1. Or, please describe what specific challenge identified in the Network Licensee’s innovation strategy is being addressed by the Project (RIIO-1 only)

* + 1. Is the default intellectual Property Rights (IPR) position being applied?

This cannot be changed once registered.

|  |  |
| --- | --- |
| Yes  X | No |

If “no”, the following questions must be answered:

* + - 1. Demonstrate how the learning from the Project can be successfully disseminated to Network Licensees and other interested parties:

n/a

* + - 1. Describe how any potential constraints or costs caused, or resulting from, the imposed IPR arrangements:

n/a

* + - 1. Justify why the proposed IPR arrangements provide value for money for customers:

n/a

* 1. Requirement 5 / 2c – be innovative

A Project must be innovative (ie not a business as usual activity) and have an unproven business case entailing a degree of risk warranting a limited Research, Development or Demonstration Project to demonstrate its effectiveness. This could include Projects which are untested at scale, or in relation to which there are risks, which might prevent the widespread deployment of the equipment, technology or methodology.

* + 1. Why is the project innovative?

RIIO-1 projects must include description of why they have 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).

* + 1. Why is the Network Licensee not funding the Project as part of its business as 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.

* + 1. Why can the Project can only be undertaken with the support of NIA?

This must include a description of 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.

* 1. Requirement 6 / 2d – 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.

* + 1. 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.

* + 1. If applicable, justify why you are undertaking a Project similar to those being carried out by any other Network Licensees.

Not applicable

**Relevant Foreground IPR**   
*Please provide a list of the relevant foreground IPR that will be generated in the course of the project e.g. reports, models, tools etc.*

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** *(standard ESO response - please do not edit)*

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:

1. 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.
2. Via our Innovation website at <https://www.nationalgrideso.com/future-energy/innovation>
3. Via our managed mailbox [innovation@nationalgrideso.com](mailto: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>.

1. PEA approval

The senior person (RIIO-1) or senior network manager (RIIO-2) responsible for implementing RIIO-2 NIA Projects must approve the PEA. It must then be published on the Project Registration page of the Smarter Networks Portal.

|  |  |
| --- | --- |
| **Please confirm this project has been approved by a senior member of staff** |  |