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

Jul 2025

Project Reference Number

NIA2_NGET0095

Project Registration

Project Title

Transformer ReStart (TReS)

Project Reference Number

NIA2_NGET0095

Project Licensee(s)

National Grid Electricity Transmission

Project Start

November 2025

Project Duration

1 year and 1 month

Nominated Project Contact(s)

Xin Wang

Project Budget

£264,000.00

Summary

Energising large power transformers during the early stages of Electricity System Restoration (ESR), when the network is weak and fragmented into isolated Power Islands, is challenging and leads to a variety of technical issues. With new ESR standards and increasing use of inverter-based resources, there is an urgent need for innovative tools to assess critical configurations, guide operational decisions, and identify necessary investments, while addressing modelling challenges in the EMT domain. Through this project, National Grid Electricity Transmission (NGET) will collaborate with Electric Power Research Institute (EPRI) to carry out fundamental research to identify the critical configurations for transformer energisation on the GB network during ESR, assess associated risks, define acceptable operational limits, and evaluate which configurations can be managed through operational measures.

Third Party Collaborators

EPRI

Nominated Contact Email Address(es)

box.NG.ETInnovation@nationalgrid.com

Problem Being Solved

Electricity is the lifeblood of modern society, powering homes, businesses, and critical national infrastructure. When widespread outages occur due to natural disasters, cyberattacks, or asset failure from human error, having robust restoration plans is crucial to minimise disruption and ensure public safety. The power industry worldwide faces significant challenges in adapting existing plans, developing and implementing new restoration plans due to the ongoing transition towards renewable energy sources and the decommissioning of conventional power stations.

Unlike conventional synchronous generators, inverter-based resources (IBR) have different operational characteristics and withstand capabilities, offering various advantages but also introducing limitations during the restoration process. The use of IBR in the early

stages of restoration will act to alter the power system dynamics, requiring new methods and procedures to ensure successful system restart. To address these challenges, rigorous review and testing of restoration plans are crucial to verify the capability of new technologies to work in tandem with existing conventional synchronous generators, to facilitate system restoration and ensure the stability of restored power islands.
In GB, the Electricity System Restoration Standards (ESRS) will come into force in 2026, introducing clear targets for the System Operator and Transmission Owners to achieve.
Along with the energisation of long complex circuits and the recovery of large block loads, the energisation of large transformers is one of the most challenging tasks during the early stages of restoration, which has the potential to collapse the island either by tripping the generation or inflicting damage to critical assets on the restoration path.
Given the critical importance of ESR speed, overly cautious operational measures may lead to insufficient restoration time. Therefore, an innovative solution is required that can:

- Assist network operators and designers in identifying when a specific configuration is crucial for transformer energisation.
- Aid in pinpointing effective operational measures and establishing criteria for their application.
- Help determine when investments are necessary and identify the most effective investments.

Method(s)

Comprehensive review and testing provide certainty that restoration plans will work effectively when needed. It allows for the identification of potential issues, refinement of procedures, and validation of new strategies tailored to high-IBR penetration scenarios. By conducting a thorough assessment and simulations, power system operators can gain confidence in their ability to restore power safely and efficiently. The proposed method includes:

- Model Development: Creation of positive sequence and electromagnetic transient (EMT) models for selected restoration paths, incorporating detailed transformer and system configurations, including cables, synchronous generators, and inverter-based resources (IBRs).
- Scenario Definition: Identify credible ESR configurations through consultation with NGET's control centre, NESO restoration teams, and DNO planners.
- Simulation & Risk Assessment: Conduct time-domain and frequency-domain simulations to assess transient overvoltages (TOVs), voltage dips, negative sequence levels, and protection stability.
- Mitigation Testing: Demonstrate and evaluate mitigation methods such as point-on-wave switching, pre-insertion resistors, and soft energisation. Special cases that failed the success criteria will be selected for further analysis to highlight the effectiveness of mitigation methods.
- Parametric Studies: Assess sensitivity to equipment characteristics and network topology to identify boundary conditions for safe operation.

Data Quality Statement (DQS):
The project will be delivered under the NIA framework in line with OFGEM, ENA and NGGT / NGET internal policy. Data produced as part of this project will be subject to quality assurance to ensure that the information produced with each deliverable is accurate to the best of our knowledge and sources of information are appropriately documented. All deliverables and project outputs will be stored on our internal sharepoint platform ensuring access control, backup and version management. Relevant project documentation and reports will also be made available on the ENA Smarter Networks Portal and dissemination material will be shared with the relevant stakeholders.

Measurement Quality Statement (MQS):
The methodology used in this project will be subject to our supplier's own quality assurance regime. Quality assurance processes and the source of data, measurement processes and equipment as well as data processing will be clearly documented and verifiable. The measurements, designs and economic assessments will also be clearly documented in the relevant deliverables and final project report and will be made available for review.

In line with the ENA's ENIP document, the risk rating is scored Low (6).
TRL Steps = 2 (3 TRL steps)
Cost = 1 (~£264k)
Suppliers = 1 (1 Supplier)
Data Assumption = 2 (Assumptions known but will be defined within the project)

Scope

This project focuses on assessing and mitigating the risks associated with transformer energisation during Electricity System Restoration (ESR), particularly under weak system conditions and high inverter-based resource (IBR) penetration.
The project will focus on the GB electricity transmission system, particularly in England and Wales. It will:

- Develop detailed EMT and phasor models of restoration paths to simulate energisation events.
- Assess transformer energisation risks during restoration.
- Develop a risk map and mitigation guidelines.
- Provide technoeconomic assessments of mitigation options.
- Deliver EMT modelling guidelines for restoration studies.

Deliverables:

- Developed model, model description, and guidance for modelling.
- Technical report with risk maps and mitigation strategies.
- Simulation analysis and testing report.
- Disseminate key results of the project and learnings via final dissemination workshop.

Objective(s)

The primary objectives of this project are to:

1) Identify and mitigate transformer energisation risks during network restoration.

- Identify high-risk transformer energisation configurations during system restoration across representative GB network scenarios.
- Quantify technical risks such as transient overvoltages (TOVs), voltage dips, and negative phase sequences using detailed EMT and phasor-domain simulations
- Create a transformer energisation risk map to rank scenarios based on severity and likelihood, supporting operational decision-making.

2) Provide tools and insights to improve restoration planning and execution.

- Develop and validate mitigation strategies (e.g. point-on-wave switching, pre-insertion resistors, soft energisation) to reduce energisation risk.
- Produce modelling guidelines for ESR studies, including best practices for EMT modelling of transformers, lines, and IBRs.

These outcomes will support TOs and NESO in compliance with ESR standards by 2026, enabling safe, reliable, and low-carbon system restoration.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

An assessment of distributional impacts (technical, financial and wellbeing related) for this project has been carried out using a bespoke assessment tool, which assesses the project as having a positive, negative or neutral effect on consumers in vulnerable situations. To help inform the assessment, this tool considers the categories of consumers identified in the Priority Services Register.

This project has been assessed as having an overall positive impact on consumers in vulnerable situations. The assessment has identified that this project will look to (please select/delete as appropriate) reduce the costs for households, improve the exchange of information between networks and customers while reducing the amount of disruptions to them in the home. Other considerations including the projects impact on supply, immediate health and safety in the home have been made in carrying out this assessment.

Success Criteria

The success of the project will be evaluated against the following criteria:

- Development of detailed EMT and phasor-domain models for representative GB restoration configurations involving large transformer energisation.
- Completion of simulation studies quantifying the technical risks associated with energising transformers under weak network conditions.
- Production of a risk map ranking transformer energisation scenarios based on severity and likelihood.
- Demonstration of effective mitigation methods through simulation and technical analysis.
- Delivery of practical modelling guidelines for future ESR assessments.
- Dissemination of results through technical reports, stakeholder engagement, and publications.
- Effective dissemination of the project’s key findings and learnings through a workshop at the end of the project and related publications.

Project Partners and External Funding

EPRI are project supplier.

Potential for New Learning

This project will quantify transformer energisation risks during Electricity System Restoration using detailed EMT simulations—an area currently lacking empirical insight under high IBR conditions. It identifies critical thresholds and failure mechanisms that affect restoration success. By assessing and comparing mitigation strategies, this project provides recommendations for operational practice and investment. In addition, it develops practical EMT modelling guidance, which will support future restoration studies across GB and ensure consistency in approach.
The key findings will be shared with other Transmission Owners and the System Operator through regular project meetings, workshops, technical documentation, and/or publications.

Scale of Project

The scale of this project has been carefully designed to capture the diversity of transformer energisation scenarios that could arise across the GB transmission network during Electricity System Restoration.
By including a representative range of network configurations, the project ensures the analysis is both technically robust and broadly applicable.
Reducing the project scope would risk overlooking critical edge cases, limiting the value of the risk map, weakening the modelling guidelines, and reducing confidence in the proposed mitigation strategies.
The project scale is justified by the potential benefits—improved restoration readiness, avoidance of costly asset damage, and compliance with ESR 2026 standards—making it proportionate to the expected operational and financial impact.

Technology Readiness at Start

TRL3 Proof of Concept

Technology Readiness at End

TRL6 Large Scale

Geographical Area

This project will be carried out on computers and software (desktop exercise).

Revenue Allowed for the RIIO Settlement

N/A

Indicative Total NIA Project Expenditure

£237,600

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:

As the grid moves toward inverter-based resources (IBRs), traditional restoration methods face new technical challenges. This project supports the transition by developing tools to assess transformer energisation risks in weak, IBR-dominated networks. It enables safer and faster restoration and helps align ESR practices with 2026 standards, ensuring system resilience in a low-carbon future.

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

This project has been assessed as having a positive impact on consumers in vulnerable situations. By improving the speed, safety, and reliability of ESR, the project reduces the duration of power outages. Faster restoration helps protect the well-being of vulnerable consumers who have limited access to resources without electricity. In addition, by reducing the risk of asset failure and unplanned disruptions, the project contributes to a more resilient and secure energy system, supporting equitable access to electricity during system emergencies.

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

N/A as low TRL research project

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

The results of the project can be applied to all comparable situations, enabling all Transmission Owners to shape policies and guide investment choices. Additionally, when evaluating a new network configuration, the same methodology can be employed for the assessment. The produced network models, technical reports, and modelling guidance will empower all Transmission Owners and the System Operator to evaluate any new configuration. Also, DNOs can follow the same approach developed in this project to study the energisation of their own transformers.

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

The estimated costs of rolling out the method across GB will be reviewed during project delivery after the research effort has progressed.

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 learning from this project will provide Network Licensees with practical tools and insights to support ESR in a variety of network conditions. The project outputs can be used to inform restoration planning and operational procedures across different regions, support compliance with the 2026 ESR standards, guide investment decisions, and standardise the practices for ESR studies. These outputs will enable Transmission Owners and the System Operator to enhance system resilience, reduce restoration risk, and ensure decision-making during future restoration events.

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.

All the previous innovation projects published in ENA were reviewed. ESR inrush simulations may have been sporadically performed in the past for individual potential ESR providers, but never for the UK grid as a whole. In addition, none of them have looked into the uncertainty associated with the transformer energisation without adopting a case-by-case method, especially for the grid with high IBR penetration. In summary, no similar innovative projects have been identified, and there is no duplication with any previous projects.

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 project addresses the uncertainty associated with the transformer energisation by identifying the conditions that could pose risks when energising transformers, considering the typical and probable network configurations in E&W network. This eliminates the need for running studies on a case-by-case basis, which may not be feasible to identify during the planning stage due to the unpredictability of the timing and location of the transformers that will be energised in the early stages of the ESR. Furthermore, the produced risk map and mitigation analysis will provide a guidance for operational staff who are unable to perform any analysis within the operational timescale.
Additionally, it examines transformer energisation from inverter-based resource (IBR) during the ESR, an area of research that is continually evolving.

Relevant Foreground IPR

The following foreground IPR will be generated:

- Models for representative GB restoration configurations involving large transformer energisation.
- Risk maps associated with ranking transformer energisation scenarios based on severity and likelihood.
- Analysis and results of mitigation methods.
- Modelling guidelines and technical documentation

All outputs will be made available in line with the default IPR arrangements, ensuring accessibility to other Network Licensees and stakeholders.
No EPRI background intellectual property is expected to be used in connection with this project. In the event that any EPRI background intellectual property becomes necessary for the performance of this project or the use of project results, EPRI agrees to provide a license to such intellectual property at a fair and reasonable rate under terms and conditions to be negotiated in good faith between the parties.

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 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.nationalgrid.com/uk/electricity-transmission/innovation
- Via our managed mailbox box.NG.ETInnovation@nationalgrid.com

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

The proposed solution is innovative in nature. The modelling and analysis activities carry technical and methodological uncertainty, with no immediate guaranteed outcomes or commercial return. The research-led nature of the work makes it unsuitable for funding through BAU mechanisms.

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 project settles in to get support of NIA, in a fully controlled environment where there is no risk of causing network disruptions/outages while surveys and investigations could also be safely developed. Therefore, NIA is the appropriate funding mechanism for this project.

This project has been approved by a senior member of staff

☑ Yes