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_NGESO062

Project Registration

Project Title

Space Weather Impact for Future Electricity System Resilience (SWIFTER)

Project Reference Number

NIA2_NGESO062

Project Licensee(s)

National Grid Electricity System Operator

Project Start

May 2024

Project Duration

0 years and 9 months

Nominated Project Contact(s)

innovation@nationalgrideso.com

Project Budget

£325,000.00

Summary

This project will deliver a probabilistic space weather impact and mitigation assessment of the current GB electricity system, and of the anticipated electricity system at key milestones in the net zero transition. This will provide an up-to-date assessment of the potential impact of a Reasonable Worst Case Scenario (RWCS) space weather event, and an assessment of ESO's ability to securely operate the system. Space and ground threat, and associated asset vulnerabilities across the electricity network will be analysed. The project will then assess potential mitigations that could be implemented both pre-event and during an event, to inform contingency and response plans developed by electricity industry participants.

Preceding Projects

10060460 - Scenarios for Extreme Events

Nominated Contact Email Address(es)

box.so.innovation@nationalgrid.com

Problem Being Solved

The term 'space weather' describes a series of phenomena originating from the sun, this can cause changes to our atmosphere and environmental conditions in near-Earth space. A broadly 1 in 100-year severe space weather event, would generate several different solar phenomena. Each phenomenon would likely occur several times during a two-week period, with each varying in magnitude, temporal and spatial extent. The RWCS has been developed by the Met Office, corresponding to a 1 in 100-year SSW event.
Space weather impact on electricity systems is a proven challenge, there is evidence of this from across the globe with equipment damage and power outages from Canada, Sweden, South Africa and the U.S. to name a few.
Geomagnetically induced currents (GICs) on a power system can cause half-cycle saturation in transformers, which leads to increases in the reactive power losses, the production of higher harmonics in the current waveform, and negative phase sequence currents on the transmission system. The greatest effects of GICs are normally experienced near the coast, where there is a discontinuity in the

resistivity, and at parts of the transmission network with limited connectivity. Current assessment of the UK grid suggests that loss of power due to safety system trips in urban areas could be recovered in a matter of hours, however in the event of electricity transformers needing to be replaced in remote coastal areas, recovery could take several months, based upon current replacement transformer availability.
Electricity industry understanding of space weather impact on the GB electricity system is based on the Royal Academy of Engineering 2013 report. However, the GB electricity system has changed significantly since 2013 with changes to the electricity network, the type and location of generation sources, the nature of electricity demand and our interconnection to Europe. The understanding of the potential impact of a severe space weather event has not kept up with these changes, which is impacting preparation, mitigation, and response planning for a future severe space weather event across the whole GB electricity sector. There is a need to therefore re-assess the impacts of a severe space weather event for the GB electricity system, taking into consideration system changes over the last decade as well as future developments.

Method(s)

This project will deliver a probabilistic space weather impact and mitigation assessment of the current GB electricity system, and of the anticipated electricity system in 2035 and 2050. This will provide an up-to-date assessment of the potential impact of a RWCS space weather event and an assessment of ESO's ability to securely operate the system at key points during the Net Zero transition.
The project is split into 3 main scope items of work which will be delivered in collaboration between all project partners. Throughout these project scope items, input material and key space weather expertise will be provided by project partners British Geological Survey (BGS) and the Met Office. BGS will also provide running of simulations from impact assessments and potential mitigations to inform overall project analysis.
Scope Item 1: Diagnostics

- Assure a complete understanding of the problem statement and validate this with the stakeholder groups through diagnostic workshops. Workshops to be split into the following topics:
-Space and ground threat.
-Electricity network model and vulnerability assessment including mitigations, including approach to including pre-event and during-event mitigations within these.
-Impact assessment and cost-benefit analysis, including metrics and overall approach.

- Initiate stakeholder engagement and plan for future engagement required throughout the project.
- Confirm and refine the proposed methodology and agree which partner is best placed to deliver each aspect.
- Confirm inclusion of distribution networks within the electricity networks model.
- Identify necessary datasets and pre-existing modelling. It is anticipated that the Electricity Ten Year Statement (ETYS) will be used with some modification derived from FES as appropriate for future scenarios.
- Produce a Project Definition with refined timeframes.

Scope Item 2: Impact assessment

- In coordination with the project partners, complete the modelling and analysis work defined during scope item 1 to assess the impact of a severe space weather event on the GB electricity system.
- Literature review and workshops: asset vulnerabilities, impact assessment.
- Modelling to include: Space threat, electricity networks, ground threat, asset vulnerabilities, impact assessment. Key outputs from this modelling includes:

-Space threat – agreed set of modelled space weather outputs for a RWCS space weather event to be used as the input to the ground threat simulations.
-Electricity networks – models of the network for its current state and projected state in 2035 and 2050 at the agreed level of detail anticipated to be grid supply point.
Ground threat – GIC per node of each of the electricity network models, allowing vulnerability of assets to be assessed.
-Asset vulnerabilities – to include modelling of thermal heating and voltage instabilities.
-Impact assessment – probabilistically calculate impacts based on RWCS outage predictions calculated from above modelling assessments.

- Establish a standard methodology for describing and recording asset vulnerabilities.
- Develop a report detailing the impact of a RWCS space weather event on the GB electricity system, including individual impact

assessments and asset vulnerabilities.

Scope Item 3: Mitigations

- Complete the stakeholder engagement activities required to identify the pre-event and during-event mitigation options for the GB electricity system, and agree how these will be incorporated within the phase 2 impact assessment models.
- The main mitigations expected to be assessed are pre-event asset hardening, and forecasting capabilities.
- Completed the required modelling activities.
- Complete cost-benefit analysis for the identified mitigation options.

Throughout the project, engagement with specialists and a wide stakeholder group will be required to refine, enhance, and guide the methodology developed for this safety critical study.
In the diagnostics stage, three workshops will be held to focus on agreeing the problem statement, modelling requirements and modelling methodology. The three workshops will cover space weather, electricity networks and impact assessment. These topics will allow engagement to be targeted with key interested stakeholders on the areas which are most aligned with their expertise.
In the impact assessment and mitigations stages, three further workshops will be facilitated to confirm the detailed methodology, assumptions, and input data for modelling asset vulnerabilities, impact assessments and mitigations. These will build on the earlier diagnostics workshops to confirm the detailed approach, data and assumptions required for the models.

In line with the ENA's ENIP document, the risk rating is scored Low:
TRL steps = 2 (3 TRL steps)
Cost = 1 (<£500k)
Suppliers = 2 (3 supplier)
Data assumptions = 1
Total = 6 (low)

Scope

SWIFTER will deliver an up-to-date assessment to understand the current electricity system's resilience to a SSW event and how this resilience may change in the future as the system continues to change during the Net Zero transition. The project will assess the potential impact of a RWCS SSW event, and an assessment of ESO's ability to securely operate the system now and at key points during the Net Zero transition including:

- The space threat from a RWCS space weather event and how this translates to the ground threat experienced by the electricity grid assets.
- Vulnerability assessments for current transmission, generation and interconnection assets subjected to these ground threats, and for the projected system assets in 2035 and 2050.
- The likelihood, extent and duration of any power outages predicted to occur as a result.
- The direct and indirect impacts to society of those power outages.
- The effectiveness of the mitigation options which could reduce the likelihood or duration of power outages.
- Cost benefit analyses of those mitigations to inform future decision making by the ESO and the wider GB electricity industry.

Objective(s)

- Identify necessary datasets required for modelling and analysis, and any pre-existing relevant modelling, to refine proposed methodologies.
- Carry out stakeholder engagement throughout the project, including relevant workshops for each project stage.
- Complete modelling and analysis work to assess the impact of a severe-space weather event on the GB electricity system.
- Establish a standard methodology for describing and recording asset vulnerabilities.
- Identify and agree mitigations for pre-event and during-event, and update models as required to reflect these.
- Complete cost benefit analyses for identified mitigation options, ranked according to their cost effectiveness.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

This project has been assessed as having a neutral impact on customers in vulnerable situations because it is a transmission project.

Success Criteria

Overall, industry should be able to use results of the project to make informed decisions regarding future changes to preparedness and response plans, including investment in mitigations. Success criteria includes the following:

- All workshops completed as planned, including relevant industry stakeholders. Workshop outputs clearly documented in relevant project reports.
- Necessary industry datasets identified and shared with relevant project partners to enable modelling and analysis.
- Modelling of impact assessment and agreed mitigations completed and methodologies documented.
- Cost benefit analysis for mitigations delivered.

Project Partners and External Funding

This project will be completed with 3 project partners in addition to ESO:

- Frazer-Nash are the main delivery partner, providing simulation and modelling expertise. They will be supported by internationally recognised experts in space weather bringing further direct experience of modelling space weather events, and the resulting infrastructure and socioeconomic effects.
- Met Office Space Weather Operations Centre will provide key space weather expertise.
- British Geological Survey (BGS) will provide space weather and geological modelling expertise.

No external funding to be provided.

Potential for New Learning

The diagnostics workshop at the start of the project will form a foundation for new learnings to be realised from the project. These will focus on confirming understanding of space weather and the interactions with the electricity system, including space and ground threat, electricity network model and vulnerability assessment, and impact assessment and associated cost benefit analysis. To date, RWCS assessments for a severe space weather event have been on the transmission network. This project will consider whether distribution networks are likely to be impacted by an event, and if so, how they should be included within modelling.
The impact assessment will assess the overall impact of a severe space weather event on the GB electricity system, establishing a standard methodology for describing and recording asset vulnerabilities. The cost-benefit analysis completed as part of the mitigations phase will inform future decision making by the ESO and the wider GB electricity industry regarding RWCS space weather events. In addition to this, the methodology for including mitigation within assessment modelling will also be confirmed.

Scale of Project

This project will be delivered over 9-months with 4 core project partners. Throughout the project, further engagement with specialists and a wider industry stakeholder group will be required to refine, enhance, and guide the methodology developed for this safety critical study.

Technology Readiness at Start

TRL3 Proof of Concept

Technology Readiness at End

TRL6 Large Scale

Geographical Area

This project has as geographical scope which covers Great Britain’s electricity system.

Revenue Allowed for the RIIO Settlement

None

Indicative Total NIA Project Expenditure

£325,000

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:

This project will enable the whole electricity sector to understand the potential impact of a severe space weather event (SSWE) and associated system and asset vulnerabilities. It will enable strengthening of the system and mitigation of risks associated with an event where possible, ensuring robust contingency, response and recovery plans are embedded within all organisations across the industry. The project will deliver a probabilistic space weather impact and mitigation assessment of the current GB electricity system, and of the anticipated electricity system in 2035 and 2050.

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

The understanding of the potential impact of a severe space weather event has not kept up with the changes in the electricity system since 2013. This is impacting preparation, mitigation, and response planning for a future severe space weather event across the whole GB electricity sector. There is a need to re-assess the impacts of a sever space weather event taking into consideration system changes as well as future developments.
A complete cost-benefit analysis for the identified mitigation options for a severe space weather event will be delivered as part of this innovation project.

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

This project will enable the whole GB electricity sector to understand the potential impact of a severe space weather event and the associated asset vulnerabilities. It will enable strengthening of the system and mitigate the risks associate with an event where possible, while ensuring robust contingency, response and recovery plans are embedded within organisations across the electricity industry. The project will primarily focus on the transmission network across GB, however will also consider the impact of a RWCS severe space weather event on distribution networks and generators.

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

The project will consider the whole of the GB electricity system, and a complete cost-benefit analysis for identified mitigation options will be delivered as part of the project. This will capture the wider societal benefits of the mitigations as the impact assessment considers a range of direct and indirect impacts. The cost-benefit analysis will output a list of mitigation scenarios ranked according to their cost effectiveness.

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

Engagement across Networks is a key dependency of this project, and stakeholder engagement activities are planned throughout including with transmission and distribution network licenses. The overall project will be considering the impact and associated mitigations of a severe space weather event across the GB network, and so learnings will be relevant for all Network licenses and will be disseminated as appropriate.

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.

The Electricity Task Group (ETG) are updating joint industry response plans for a severe space weather event based on the 2013 space weather impact report published by the Royal Academy of Engineering "Extreme space weather: impacts on engineered systems and infrastructure". The ETG have been involved in the wider scoping of SWIFTER, as this will provide a more up to date and forward-looking assessment of the impacts of a severe space weather event on the GB electricity system. In parallel to this work, DESNZ are developing the UK Government Severe Space Weather Preparedness Strategy across all industries, for which SWIFTER results will be able to feed into if the project is successful and timings align.
The SIF project Scenario for Extreme Events is investigating "black swan" events and creating a methodology to quantify the impact of these events as the energy system evolves. The modelling will use emerging datasets on infrastructure resilience, and weather and

climate patterns collated by academia and the Met Office. The project does not currently consider a severe space weather event within its scope, but the results of SWIFTER may be relevant as both projects progress in parallel.

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

There is a need to re-assess the impact of a severe space weather event based on the RWCS for the electricity sector, considering significant system changes over the last decade and future developments as we progress to net zero system operation. This project will include new technologies within the electricity system and look beyond what has been studied to date regarding space weather impacts on the GB electricity system.
The project will build on modelling methodologies from industry subject matter experts, updating and improving existing models whilst also developing new modelling tools for asset vulnerabilities, impact assessments and suggested mitigations. Defence and mitigations strategies will consider innovative new approaches, including pre-event and during-event strategies for a severe space weather event.

Relevant Foreground IPR

- Diagnostics early insights report
- Diagnostics report
- Impact assessment report
- Mitigations report

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:

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

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

This work requires key industry expertise around space weather and associated modelling, the ESO will be undertaking this project on behalf of the industry and so the work does not form part of expected BAU activities.

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

This project requires industry collaboration around the impacts of space weather and associated modelling required to assess these impacts. With the support of NIA funding the latest methodologies can be incorporated into modelling by relevant industry experts and wider stakeholders. Potential impacts across the system may include transmission, distribution, and generators, highlighting the need for this project to be led at system operator level. Mitigations should consider new ways of thinking which are suitable for an evolving electricity system, and through using NIA will enable results and learnings to be shared and disseminated more widely across the sector.

This project has been approved by a senior member of staff

☑ Yes