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.

NIA Project Annual Progress Report Document

Date of Submission

Jul 2025

Project Reference Number

NIA2_NGESO062

Project Progress

Project Title

Space Weather Impact for Future Electricity System Resilience (SWIFTER)

Project Reference Number

NIA2_NGESO062

Funding Licensee(s)

NESO - National Energy System Operator

Project Start Date

June 2024

Project Duration

1 year and 1 month

Nominated Project Contact(s)

Innovation@neso.energy

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.

Objectives

- 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.

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.

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

National Energy System Operator ("NESO") has endeavoured to prepare the published report ("Report") in respect of Space Weather Impact for Future Electricity System Resilience (SWIFTER) , NIA2_NGESO062 ("Project") in a manner which is, as far as possible, objective, using information collected and compiled by NESO and its Project partners ("Publishers"). Any intellectual property rights developed in the course of the Project and used in the Report shall be owned by the Publishers (as agreed between NESO and the Project partners).

The Report provided is for information only and viewers of the Report should not place any reliance on any of the contents of this Report including (without limitation) any data, recommendations or conclusions and should take all appropriate steps to verify this information before acting upon it and rely on their own information. None of the Publishers nor its affiliated companies make any representations nor give any warranties or undertakings in relation to the content of the Report in relation to the quality, accuracy, completeness or fitness for purpose of such content. To the fullest extent permitted by law, the Publishers shall not be liable howsoever arising (including negligence) in respect of or in relation to any reliance on information contained in the Report

The vulnerability report was delivered in May 2025. The report collates the work performed to date in assessing the GB electricity network's vulnerability to a RWCS space weather event. The report provides an update on the analysis of vulnerability to the three main failure mechanisms: thermal heating, voltage instability and harmonics.

British Geological Survey(BGS) developed a model which calculates Geomagnetically induced currents (GIC) across the GB transmission network for 1-in-200 year and 1-in-500-year events. For this project, a 1-in-200-year event was assumed to be the RWCS. The outputs from the BGS model were used to calculate effective GIC for each transformer. The effective GIC calculations allowed us to assess transformer vulnerability to thermal heating and calculate reactive power losses across the network.

The thermal heating failure vulnerability was analysed using a detailed temperature response model and identified transformers to be at high risk of failure during a RWCS. Increasing the event intensity to a 1-in-500-year event, puts additional transformers at high risk of thermal heating failure.

The BGS model does not currently include the distribution networks across the GB electricity network. In Scotland, the 132 kV network is considered part of the transmission network, whereas this is not the case in England and Wales. By turning the Scottish 132 kV network off in the BGS model, we simulated the potential impact of including the distribution network in the model. It was found that those transformers with several 132 kV network connections could experience large increases in GIC of up to 200% when the 132 kV network is connected. Turning the 132 kV network off did not put more transformers over the 75 A threshold that would put them at risk of thermal failure in our model.

Adding in the 132 kV distribution network for England and Wales could help identify additional transformers that are at risk of thermal heating under a RWCS. Significant effort would be required to model the entire 132 kV distribution network and this is not within the scope of this project. However, future projects may find it worthwhile to simulate distribution connections for those transformers that are already modelled to have high GICs as well as those known to have multiple connections to the 132 kV network.

The thermal response of transformers was based on available data for a limited number of transformers. To more accurately represent the vulnerability of at-risk transformers, Finite Element Analysis could be used to simulate specific transformer temperature response to GIC. The accuracy of the model outputs could be further improved by capturing actual earthing resistances of transformers in the BGS model calculating GIC rather than using a blanket 0.5 Ω assumption.

The reactive power loss at each feeder on the network was calculated for input to voltage instability models. Peak reactive power loss was 44.9 MVAr at Fort Augustus 33kV substation. This level of reactive power loss does not cause immediate concern, but we are awaiting the findings from voltage models and will update this report once completed.

The modelling steps, tools and screening criteria required to enable a model of harmonics have been identified. The effort required and capability available to perform this analysis however is not currently clear. The harmonics model is beyond the current scope of the project.

Following the vulnerability assessment, the remainder of the project will focus on the impact assessment for a RWCS. Findings from the vulnerability assessment indicate that outages would be unlikely in a RWCS. Transformers vulnerable to thermal heating are all located at interbus sites, which would more likely constrain the network rather than see customers disconnected. Power flow modelling would be needed to confirm the risk of outages. Impact assessment will instead focus on costs of lost transformers and costs of network constraints following failures. Mitigations will be evaluated against these quantified impacts. Support is needed from project partners to ensure mitigations are thoroughly evaluated. One mitigation that can be immediately actioned is assessing whether disconnecting the three transformers most at risk from thermal heating would reduce the risk of thermal heating failure during a RWCS across the network. This would require BGS to rerun their model; the thermal heating impacts would then be reassessed.

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

The project was extended to cover additional transformer and voltage instability modelling. The uplift associated with this change cost £76,793.

Lessons Learnt for Future Projects

A small number of transformers are likely to be vulnerable to thermal heating failure under a reasonable worst-case scenario. Vulnerability depends on local geology, earthing resistances, extent and number of connections and capacity and type of transformers. The most recent model shows three transformers being at risk of failure (exceeding temperatures of 200 °C for their structural elements) under a 1-in-200-year event. The model could be improved by capturing the 132 kV network in England for vulnerable substations, capturing better earthing resistance data, including generator and interconnector owned transformers and further validation against measured geomagnetically induced current data. Finite element analysis of the most vulnerable transformers would help to confirm the anticipated temperature response and thermal heating failure likelihood.

The project is awaiting the findings of modelling the vulnerability to voltage instability. Modelling vulnerability to harmonics is technically challenging, and further work is required to determine capability and availability of data to perform this work (outside the scope of the current project).

There is a large stakeholder community interested in space weather and its impact on the electricity grid. Multiple stakeholders across different organisations have unfortunately slowed the pace of the project. This is especially true of the modelling, with different elements of the models owned by BGS, Frazer-Nash and NESO.

External guidance, particularly that published by EPRI, has been hugely valuable to the project. Much of that guidance is only available behind a paywall, however.

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

The SWIFTER team delivered the Impact Assessment report in April 2025 which provided an update to the vulnerability analysis for thermal heating, voltage instability, and harmonic failure. Work is ongoing to address NESO and other stakeholder comments.

The results of the modelling have identified transformers at increased risk of damage from severe space weather events. This will update our understanding of transformer failure risk. The voltage instability assessment results have been shared with NESO and are currently being checked on the power system model for possible impacts.

Results are currently being reviewed by industry stakeholders. The next steps of the project is to deliver the mitigations report and impact assessment, followed by Final report in June.

The output from the project will provide guidance for NESO contingency plan during severe space weather events. It will also help other industry participants to understand space weather risk and plan mitigations.

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 NESO can be found in our publicly available "Data sharing policy related to NIA projects (and formerly NIC)" and [Innovation | National Energy System Operator](#).

National Energy System Operator already publishes much of the data arising from our 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

The following outcomes are expected to be delivered by this project:

- Vulnerability Assessment – thermal heating model, reactive power, voltage instability, harmonics literature review (delivered)
- Impact Assessment Report – result of the modelling and expected impacts of the reasonable worst case on the electricity network
- Mitigations – additional modelling following possible mitigating actions
- Final Report