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

NIA_SHET_0056

Project Registration

Project Title

TOTEM (Transmission Owner Tools for EMT Modelling) 3

Project Reference Number

NIA_SHET_0056

Project Licensee(s)

Scottish and Southern Electricity Networks Transmission

Project Start

July 2025

Project Duration

2 years and 3 months

Nominated Project Contact(s)

Brant Wilson

Project Budget

£666,000.00

Summary

Under TOTEM 3, the TOTEM model will be enhanced through three key tasks:

1. **Protection Elements** – Develop UK-standard protection models (e.g., overcurrent, differential, distance) for key equipment, with implementation at substations.
2. **Model Equivalents** – Create tools for static and dynamic network equivalents to simplify studies and improve simulation speed without losing accuracy.
3. **Model Enhancement** – Convert the full GB network from PowerFactory to PSCAD directly, update models to reflect latest developments, and provide a user manual for independent model updates.

The project is a collaboration between NESO and UK Transmission Operators to expand TOTEM's capabilities and usability.

Preceding Projects

NIA_SHET_0032 - TOTEM (Transmission Owner Tools for EMT Modelling)

NIA_SHET_0035 - TOTEM (Transmission Owner Tools for EMT Modelling) Extension

NIA_SHET_0045 - TOTEM (Transmission Owner Tools for EMT Modelling) 2

Third Party Collaborators

Manitoba Hydro International

Nominated Contact Email Address(es)

transmissioninnovation@sse.com

Problem Being Solved

The first TOTEM project enabled the GB Transmission Owners to work together to acquire and validate a new system model that enhances, as well as de-risks the integration of new technologies. TOTEM 2 allowed for enhancements to be made to the tool; ReDispatch Tool Refinement and Simulation Speed Improvement.

This project, TOTEM 3, builds on the previous TOTEM projects by continuing with both fundamental model development and the creation of further support tools.

Method(s)

Under Phase 1 of the TOTEM Project (Transmission Owner Tools for EMT Modelling) with the support of NGET, SPT, and SHE Transmission, a full-scale model of the Great Britain (GB) Transmission System was developed in PSCAD /EMTDC software. At this stage, the GB system network data in PowerFactory format was initially converted to an intermediate data format (.raw and .dyr) before being imported into PSCAD. Additionally, a dispatch (python-based) tool was created to facilitate easy updates to the PSCAD model, enabling representation of different operating conditions and future transmission network scenarios.

Under Phase 2 of the TOTEM Project (TOTEM 2 - NIA_SHET_0045), the network model development approach and the Re-Dispatch Tool were further refined, allowing the direct use of network data from PowerFactory models. A detailed model review was conducted, and changes were implemented to improve the overall simulation speed of the SHE system. In TOTEM 2, these enhancements focused exclusively on the Scottish Grid (including small portion of the network south of the B6 boundary).

Under Phase 3 of the TOTEM project (referred as TOTEM 3), the following tasks have been identified to further advance the GB PSCAD model and expand the potential studies that can be undertaken with this model:

1. Protection Elements

Development of a model library of standard protection elements that can be used to represent protection and relaying actions. The generic models will be developed considering the protection and relaying functionally commonly adopted in the UK. The generic models will have specific features to allow users to implement such features in accordance with UK practice for protection applications.

The protection elements developed will include:

- Overcurrent protection
- Differential protection
- Distance protection (directional or non-directional)
- Out-of-step protection

The protection elements listed above will be applicable to modelling the protection functionality of major equipment such as transformers, generators, motors, busbars, and transmission lines (and cables).

Under this Task, Manitoba Hydro International (MHI) will implement the relays at three selected substations in each operating area (up to nine in total). This implementation and the accompanying documentation will serve as a guide for the engineers of the three entities when implementing protection and relay models in the PSCAD model.

2. Model Equivalent Tool

a. Generate a static multiport network equivalent - A tool to retain a selected area of the GB PSCAD model and to represent the rest of the network as a multiport static Thevanin’s network equivalent.

This is an expansion/update of tools and techniques developed under TOTEM 1. Updated tools, scripts and technical documentation are the deliverables for this task. The user will be able to generate updated network equivalents to represent different operating scenarios and study horizons ‘automatically’ for each study through the scripts. The outputs of this task are less novel than those of the dynamic equivalent (below), as most of the work carried out will be based on existing knowledge.

b. Generate a dynamic equivalent - A tool to retain selected area of the GB PSCAD model and to represent the rest of the network as a single (or multiple) radial dynamic equivalent. The main objective of this approach is to capture the impact that the external network will have on the dynamic response as seen near the point of interest for a particular study. A successful derivation of a network dynamic equivalent will potentially enable to limit the extent of the study area that has to be represented in explicit detail in PSCAD. In

addition, a significant benefit will be fast simulations without compromising dynamic response accuracy.

This task is different from the static network equivalent task above. The proposed equivalent will be a dynamic representation of the external network. There is no known dynamic equivalent derivation technique that can be applied to practical networks. There has been effort in the past, but no meaningful progress has been made. Thus, this task will have a significant research and development component. One advantage the TOTEM 3 team have is practical knowledge of power systems, accessibility to data and the vast experience on important features to be captured in a dynamic equivalent. MHI will deliver any scripts or tools that may be developed under this task.

3. TOTEM Model Enhancement

During Phase 2 of the TOTEM project, the feasibility of a direct approach for converting PowerFactory data to PSCAD was explored. Building on these findings, TOTEM 2 focused on applying this direct method to the Scottish Grid region. Under the new task, the entire GB network will be converted directly from PowerFactory to PSCAD without relying on an intermediate third-party format.

MHI will develop a comprehensive strategy for this conversion and update the existing TOTEM models (Years 1, 5, and 10) to align with the ETYS (Electricity Ten Year Statement) year agreed at contract award. This update will incorporate the most recent network developments, including those identified in the Network Options Assessment (NOA) refresh and Accelerated Strategic Transmission Investment (ASTI) projects. MHI will then undertake three sub-tasks to enhance the TOTEM Model.

4. Model Conversion User Manual

MHI will develop a comprehensive process and convert the full GB model directly from PowerFactory software to PSCAD. MHI will document the conversion process and deliver a detailed guide as well as the tools that are required for the user to convert the desired network model from Power Factory to PSCAD. The full set of tools and the comprehensive user manual will enable a user to develop/update the TOTEM model independently.

This project will be based on working with the National Energy System Operator (NESO) and other transmission network operators to implement additional functionality and changes to the latest TOTEM model developed as part of TOTEM 2 to improve functionality.

This project involves incremental enhancements of the TOTEM tool, which remains an innovative tool being developed by the UK Transmission Operators (SSEN-T, SPEN and NGET) and NESO.

Scope

Project Overview

The project is led by SSEN-T with MHI, SPEN, NGET, and NESO, focused on power system modelling, protection, and network equivalencing with MHI (third-party collaborator) carrying out the below scope.

Task 1 – Protection Elements

- Scope: Develop a Protection Elements Library and implement it at 9 substations
- Estimated Duration: 8 months
- Milestones:
- Library design complete: Month 3
- Pilot implementation: Months 5–8
- Acceptance Criteria: UK standards compliance, validated pilot results

Task 2 – Network Equivalencing

- Scope:
- 2.1: Update static multiport network equivalents
- 2.2: R&D on dynamic network equivalents
- Estimated Duration: 15 months
- Milestones:
- Static equivalent: Month 10
- Dynamic R&D report: Month 15
- Acceptance Criteria: Validated equivalence with full GB model, comprehensive R&D documentation

Task 3 – GB Model Conversion

- Scope: Convert ETYS GB models (Years 1/5/10) from PowerFactory, integrate monitoring, and deliver conversion tools
- Estimated Duration: 11 months
- Milestones:
- Initial conversion: Month 5
- Tools/scripts: Months 8–10
- Monitoring integration: Month 11
- Acceptance Criteria: Verified model alignment, tested tools, and monitoring

Task 4 – User Guide

- Scope: Create a comprehensive user guide for model conversion
- Estimated Duration: 1 month
- Milestone: Month 1
- Acceptance Criteria: Reviewed and approved guide

Objective(s)

This project focuses on enhancing the TOTEM tool with innovative features, including:

- Alignment with ETYS 1-, 5-, and 10-year models to match Power Factory models
- A model library for standard protection and relaying elements
- Tools for static and dynamic model equivalence

Each component involves research, development, or demonstration. The dynamic equivalence tool and user guide, in particular, represent a novel area with no existing practical methods, requiring significant R&D effort.

A key project outcome is the creation of a dynamic network equivalent—a novel representation of external networks. Since no practical derivation method currently exists, this task will drive substantial research and generate new insights for future transmission network modelling.

Consumer Vulnerability Impact Assessment

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 a neutral impact, meaning that it does not have any effect on customers in vulnerable situations. This is because it is a Transmission project.

Success Criteria

That all stages of the project are met to time, cost and quality with the learnings easily disseminated between TO's and NESO. Realising the potential for future technologies to be applied to the network which will allow for smarter management of the Transmission Network.

Project Partners and External Funding

- SSEN-T (Scottish and Southern Electricity Networks – Transmission)
- SPEN (Scottish Power Energy Networks)
- NGET (National Grid Electricity Transmission)
- NESO (National Energy System Operator)
- MHI (Manitoba Hydro International Ltd)

Potential for New Learning

This project will detail the ability for TO's to successfully adopt new technology on their systems, working collaboratively to achieve success across the major system operators in the UK. This will allow for faster and more efficient deployment of technology on the system by the use of accurate modelling.

This project will further develop TOTEM to be one of the most advanced network modelling tools globally, incorporating interconnectors

and radial connections within our model. This learning can provide a dynamic learning equivalent – a representation of the external network which can be modified within the model. As stated before, this has not been done anywhere else in the world and therefore completion of this project will require a significant research and development component, producing learnings for the TO's going forward. Learnings from the project will be disseminated via internal and external stakeholder events which will be conducted during the project. The learnings will also be shared within the annual project report and at relevant dissemination events such as the Energy Networks Annual Conference.

Scale of Project

As this is an evolution of an existing project, the continuation allows for the further modelling of network scenarios, allowing for the making of smarter decisions on the network. By increasing the scale from TOTEM 2 it will allow the network operators to more accurately anticipate and deliver new technology which could significantly benefit consumers / GB energy landscape.

If conducted at a smaller scale the project would be much less innovative, as detailed in section 2.8 the use of this model will be a first of its kind. As the third stage in the TOTEM project programme it also shows the continued desire for an evolution to address the aforementioned problem of de-risking, integrating and deploying new technology on the network.

With the confidential nature of the data being shared with TOTEM 3 – additional security checks were required which has extended the project duration.

Technology Readiness at Start

TRL2 Invention and Research

Technology Readiness at End

TRL6 Large Scale

Geographical Area

The networks involved in this project cover all of Scotland and parts of England and Wales – allowing the evolution of modelling interconnections across most of the UK.

Revenue Allowed for the RIIO Settlement

No allowance has been made for this type of development within the RIIO-T2 settlement. No savings are expected during project implementation; future savings may be possible depending on the outcomes of the project and future adoption of the created model(s).

Indicative Total NIA Project Expenditure

• Total: £666,000
o £380k SPEN - £100k contribution to cover MHI cost + £230k of other spend (internal and equipment)
o £36k NESO - £30k contribution to cover MHI cost + £6k internal
o £120k SSEN-T - £100k contribution to cover MHI cost + £20k to cover internal spend
o £130k NGET - £100k contribution to cover MHI cost + £30k to cover internal spend
• £330,000 total for third party supplier MHI work (as included within TO / NESO costs)

Project Eligibility Assessment Part 1

Requirement 1

Facilitate the energy system transition and/or benefit consumers in vulnerable situations

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

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

By allowing for a more accurate model of the UK energy system, including interconnectors, network operators will have the ability to deploy more technology aimed at accelerating the delivery of NetZero and aid the energy system 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

N/A

Please provide a calculation and/or description of the expected benefits of the solution

- For the estimation of benefits in this project, a risk- benefit analysis was adopted as the most appropriate method instead of a standard CBA. The main benefits of this innovation focus around the reduction of risk probability of a range of disruptive events which differ in their level of severity.
- The benefit of this project is estimated based on the potential systematic risk reduction and working hours reduction expected from using this tool. Additionally, by using this tool could also reduce probability of advance asset replacement by minimising oscillation events.
- A risk benefit analysis conducted in estimating the benefits of this project which resulted in £1.5m in 2018 real prices. However, due to the risk associated with this project, we accounted for the consequences of using this tool and applied the probability of failure at 30%, which resulted in a more conservative benefit value of £1m.
- The project has a BCR of £16, which means for £1 project spending, it returns £16 (£1+£15) in lifetime cost benefits. Annualised ROI: 6.2%. This is on top of the potential benefits estimated for TOTEM inclusive project.

Summary of Benefits:

The outputs from TOTEM 3 innovation project will allow TO's to effectively maintain an accurate model which will establish the correct reinforcements to maintain a safe and secure transmission network. This should prevent the need for costly future reinforcements similar to the example below.

- At the time of construction of the Hunterston – Kintyre subsea cables, a harmonic filter was not installed as the model at the time didn't have all the information it has now. If today's model was used then a harmonic filter would have been installed for a maximum of £5M as it would have been designed into the substation and the required land acquired. Instead, a harmonic filter is now being retrospectively installed at a cost of approximately £18.5M as the substation needs to be extended to accommodate the harmonic filter equipment.
- There is also a resource time reduction associated with the outcome of TOTEM 3: using the tool to create equivalent models will save approximately 2 hours each time an equivalent model is created. As a representative example, considering the creation of 8 equivalent models per month and also updating the TOTEM model using the tools manual developed during an output of TOTEM 3 will save approximately 1.5 hours each time. Per month: 8 models created (2 hours saved each time) and 4 TOTEM model updates (1.5 hours saved each time) = 22 hours saved, the equivalent to 3 working days saved for one engineer. The saving here is approximately £909 per month (based on 23/24 prices) or £10,908 per year.
- The probability of failure for TOTEM 2 deployment is expected to reduce by 10% (from 30% to 20%) due to the TOTEM 3 efficiencies planned to be introduced. This reduces the overall project risk to 21.2%.

- Finally, the potential benefits expected from mitigation of major, minor and localised events and their associated assumptions remains the same as in TOTEM 2.

The estimated benefit value of TOTEM 3, based on the above example, is £11.6M (discounted, 2018 real prices) for SSEN-T and similar savings expected by the other TO's. Accounting for risk, the risk adjusted value is estimated then to £9.2M (discounted, 2018 real prices). This is an indicative figure based on the Hunterston – Kintyre example only.

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

This project involves multiple network operators, showcasing the applicability of the project across the GB energy network.

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

As all GB TO's are involved in TOTEM 3 the method will be rolled out during the project.

Requirement 3 / 1

Involve Research, Development or Demonstration

Projects 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

Involve Research, Development or Demonstration - Please select all that apply

☐ 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

As the project has all GB TO's as partners, learning during the project will be directly and consistently disseminated between the licensees.

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. Networks must explicitly mention similar projects that they have considered and how these differ.

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

The project is first of its kind, and although a continuation of previous TOTEM projects – there is a clear scope to add interconnectors and radial circuits to the modelling capability which has not been completed as part of the previous projects:

NIA_SHET_0032 TOTEM (SSEN-T, SPEN and NGET, and NESO)

NIA_SHET_0035 TOTEM Extension (SSEN-T, SPEN and NGET, and NESO)

NIA_SHET_0045 TOTEM 2 (SSEN-T)

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 additional capability that will be achieved through this project supports an incremental innovation approach to the development of this tool to ensure its effectiveness can be maximised. The TOTEM tool remains an innovative tool being developed by the GB Transmission Operators (SSEN-T, SPEN and NGET) and NESO as a novel approach to system modelling of the GB Transmission System.

Relevant Foreground IPR

No new Foreground IPR will be generated as part of the project, background IPR – each TO has provided details of their network.

Data Access Details

For information on how to request data gathered in the course of this project, see Strategic Innovation Fund (SIF) and Network Innovation Allowance (NIA) Data Sharing Procedure at https://www.ssen-transmission.co.uk/about-us/innovation/.

Additionally, data from this project and all other projects funded under the Network Innovation Allowance (NIA), Network Innovation Competition (NIC) or the Strategic Innovation Fund (SIF) can be found or requested in the ways listed below:

- Via the Smarter Networks Portal at: https://smarter.energynetworks.org. To contact select a project and click ‘Contact Lead Network’. SSEN Transmission 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: Innovation - SSEN Transmission (ssen-transmission.co.uk)
- Via our managed mailbox: transmissioninnovation@sse.com

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

As this type of project has never been conducted it falls within the remit of NIA / RIIO-2 activities and thus warrants exploration and allows for collaboration between the network partners. There are business risks associated with implementing a solution making it unlikely to secure general funding.

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 can only be undertaken with the support of NIA due to the overall costs and timescales required. There is also commercial risk that the project may not deliver the expected benefits. NIA is the best mechanism to fund development projects such as this.

This project has been approved by a senior member of staff

☑ Yes