

NIA Project Registration and PEA Document

Date of Submission

Apr 2026

Project Reference Number

NIA_SPEN_0134

Project Registration

Project Title

Model-Free Sub-Transmission Observability for Operating Envelope Capability Assessment

Project Reference Number

NIA_SPEN_0134

Project Licensee(s)

SP Energy Networks Distribution

Project Start

April 2026

Project Duration

1 year and 1 month

Nominated Project Contact(s)

Parham Momeni

Project Budget

£458,000.00

Summary

This project will assess and advance model-free planning techniques by reviewing existing literature and industry practices, evaluating data needs and SPEN's data suitability, and developing a model-free inference method with supporting case studies. It will benchmark model performance, focusing on accuracy, uncertainty quantification, and explainability, and deliver a software demonstrator with a roadmap for future development

Third Party Collaborators

University of Strathclyde

3ideas Solutions

Nominated Contact Email Address(es)

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Problem Being Solved

The rapid adoption of low-carbon technologies is increasing uncertainty at scale across the electricity system, creating new challenges for system planning, primarily in assessing both real-time and future network conditions. While traditional physics-based network modelling remains essential, its effectiveness is increasingly limited by incomplete data, resource-intensive validation processes, and assumptions that may no longer hold under evolving system conditions. Consequently, transmission and distribution system operators are finding it increasingly difficult to define operating envelopes, coordinate flexibility, and make informed investment decisions. In the absence of reliable validation mechanisms, there is also growing difficulty in ensuring that existing network models accurately represent actual system behaviour, particularly at the transmission–distribution interface.

Method(s)

This project will assess and advance model-free planning techniques by reviewing existing literature and industry practices, evaluating data needs and SPEN's data suitability, and developing a model-free inference method with supporting case studies. It will benchmark model performance, focusing on accuracy, uncertainty quantification, and explainability, and deliver a software demonstrator with a roadmap for future development. An extra output from this project will be the enhancement of dnet_go software that converts PowerOn data into connectivity files to be read into NAVI. The enhancement will bring transmission data into the extract, building on the existing HV/EHV extract.

Scope

The project will use model-free methods that leverage machine learning and monitored data to infer network behaviour quickly and at scale, without the need for detailed asset models. These approaches offer a practical way to validate existing models, define operating envelopes, build confidence in planning outcomes, and support more transparent, evidence-based investment decisions. This project will review, develop, and test such techniques, also exploring uncertainty quantification and explainability measures that can enable operational deployment. In doing so, it aims to enhance planning efficiency and support the shift toward more flexible and anticipatory network management.

Objective(s)

- Review and critically assess existing academic literature and industry practice relating to model-free planning techniques, with a focus on their demonstrated benefits and limitations.
- Identify and specify the data requirements for the development of model-free methods, and assess the suitability, coverage, and quality of existing SPEN datasets for this purpose.
- Develop and document a model-free inference methodology and demonstrate its applicability through representative case studies.
- Evaluate the performance of the proposed method by benchmarking model accuracy, and characterise associated uncertainty and explainability measures to support practical usability and decision-making.
- Develop a software demonstrator and define a roadmap for further model development and refinement, including pathways for integration with existing planning platforms.
- Synthesise the project outcomes into a consolidated summary and provide clear recommendations for future research, development, and potential deployment.
- Enhance the existing dnet_go software to extend its PowerOn data extraction capability to include transmission network data, building on the current HV/EHV extract, and enabling the generation of connectivity files compatible with the NAVI platform.

Consumer Vulnerability Impact Assessment

The UK's energy transition, driven by widespread electrification, increases uncertainty in network planning. Model-free simulation techniques enable faster and more accurate planning, improving how uncertainty is managed and reducing the risk of inefficient investment. This supports more timely and targeted network reinforcement, particularly in areas experiencing rapid change or existing network constraints. As a result, consumers in vulnerable situations, such as low-income households, electrically dependent consumers, and those in rural or constrained areas, benefit from improved network reliability and a reduced risk of service disruption.

By reducing planning time and costs and avoiding under- or over-investment, model-free techniques can support more efficient use of network expenditure, helping to limit upward pressure on consumer bills. Improved affordability and reliability of electricity supply also support household wellbeing, reducing exposure to fuel poverty and enhancing access to essential energy services and low-carbon technologies, thereby supporting a more equitable transition to a net zero energy system.

Success Criteria

The new Model free approach being embedded in our planning DT tool.

Project Partners and External Funding

University of Strathclyde - A leading technological university with a strong track record in industry-engaged research and international collaboration. Its Department of Electronic & Electrical Engineering is internationally recognised for research in energy systems, power networks, communications, and intelligent infrastructure, with extensive partnerships across academia, industry, and policymakers.

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Potential for New Learning

This project will generate new, transferable learning on how model-free techniques can be used to enhance sub-transmission observability and directly support operating envelope capability assessments at the transmission-distribution interface. It will also

provide insight into how model-free methods can be applied to improve planning accuracy, target validation efforts, and enhance decision-making under uncertainty.

Specifically, the project will deliver learning in the following areas:

- Understanding when and where model-free approaches are most effective, what data inputs are required, and how they compare to traditional physics-based models.
- How model-free inference techniques can be applied to existing monitored data to estimate network states.
- How to incorporate these methods into existing planning workflows and tools, with a focus on interpretability and planner engagement.
- Quantifying confidence in model outputs and making model-free insights accessible to planning teams.

The outputs will be documented and shared in a form that can be readily applied by other stakeholders. These insights will help inform broader planning strategies for model validation, data-driven planning, and regulatory submissions under anticipatory investment frameworks.

Scale of Project

The Model-Free Sub-Transmission Observability for Operating Envelope Capability Assessment project is a low-TRL research initiative led by SP Energy Networks (SPEN) in collaboration with the University of Strathclyde (UoS). It addresses the increasing uncertainty across distribution and transmission networks driven by the rapid adoption of low-carbon technologies. Traditional, physics-based network models are becoming harder to validate and maintain as network conditions evolve and data gaps persist. To tackle this, the project will investigate model-free, data-driven methods that use machine learning and network monitoring data to infer system behaviour without detailed asset models. These techniques aim to improve network visibility, validate existing models, quantify uncertainty and support more informed, evidence-based investment and operational decisions. By developing and testing these approaches, the project seeks to enhance planning efficiency and enable a more flexible, anticipatory approach to network management in the transition to net zero.

Technology Readiness at Start

TRL3 Proof of Concept

Technology Readiness at End

TRL5 Pilot Scale

Geographical Area

The Project will take place within SPEN's licensed distribution network areas, including SP Distribution and SP Manweb regions, using data, case studies, and operational contexts relevant to those licence areas.

Revenue Allowed for the RIIO Settlement

0

Indicative Total NIA Project Expenditure

£458,000

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:

The UK's energy transition, driven by widespread electrification, introduces greater variability and uncertainty into the construction of network models. Model-free simulation techniques enable faster, scalable, and more accurate planning, helping planners respond quickly to emerging challenges. This improves the management of uncertainty, reduces the risk of under- or over-investment, and supports equitable access to reliable, low-carbon energy. By cutting planning time and costs, planners can better prioritise investment, particularly for areas and consumers most in need.

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

Costs are expected to be avoided in:

- Avoided over-investment
- Cost of inaction
- Efficient use of monitoring data

These are expected to give benefits with a NPV of £9.6m over the next 10 years. A CBA has been produced to calculate this.

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

Model-free data-driven techniques are highly replicable across GB, as they are applicable to a wide range of electricity distribution network archetypes. They could be applied to a significant proportion of a network operators licence area, potentially covering 70–90% of network nodes where monitored data is available. These approaches are scalable and adaptable, allowing deployment across multiple sites and regions with minimal modification, subject to local network characteristics and data availability.

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

The costs of rolling out model-free techniques across GB will depend on network size, complexity and the availability of existing data and infrastructure. Core cost components include: initial setup and integration, staff training, data collection and management, and computational resources for modelling and analysis.

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

This project will generate new, transferable learning on how model-free techniques can be used to enhance sub-transmission observability and directly support operating envelope capability assessments at the T-D interface. It will also provide insight into how model-free methods can be applied to improve planning accuracy, target validation efforts, and enhance decision-making under uncertainty.

Specifically, the project will deliver learning in the following areas:

- Understanding when and where model-free approaches are most effective, what data inputs are required, and how they compare to traditional physics-based models.
- How model-free inference techniques can be applied to existing monitored data to estimate network states.
- How to incorporate these methods into existing planning workflows and tools, with a focus on interpretability and planner engagement.
- Quantifying confidence in model outputs and making model-free insights accessible to planning teams.

The outputs will be documented and shared in a form that can be readily applied by other stakeholders. These insights will help inform broader planning strategies for model validation, data-driven planning, and regulatory submissions under anticipatory investment frameworks.

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.

This project does not duplicate any existing or completed innovation projects within the electricity sector in GB. It is distinct in its use of

model-free, inference methods leveraging smart meter and substation data to establish operating envelopes and validate network planning models at scale.

No other project has combined these specific techniques with uncertainty quantification and explainability measures, nor demonstrated their compatibility with existing planning tools in GB. This approach represents a novel methodology rather than a repeat of existing technology or model-driven approaches.

This project explores a fundamentally different method and aims to deliver new, practical learning to support wider deployment across GB networks. Therefore, it avoids unnecessary duplication and complements existing innovation efforts by filling a gap in data-driven validation and planning.

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

This project is innovative as it applies model-free inference and validation techniques, drawn from data science to network planning, a domain that has historically relied on established practices and traditional physics-based modelling approaches. While these techniques are used in other sectors, they remain untested in a whole system context in GB for supporting planning decisions under uncertainty. The approach represents a novel use of existing monitored data to estimate network behaviour without requiring full network models.

Relevant Foreground IPR

N/A

Data Access Details

The SP Energy Networks Data sharing policy can be found [here](#).

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

SPEN cannot pursue this work as business as usual as it involves both the development of new analytical methodologies and the exploration of novel planning workflows that require dedicated engagement with planning teams and prototyping, none of which are part of existing delivery processes. Moreover, the commercial and regulatory justification for model-free validation as a formal component of investment planning has yet to be established, adding further strategic risk. Support from the NIA is therefore essential to de-risk the concept, demonstrate value, and build internal and sector-wide confidence. The project provides a controlled environment in which to develop, test and refine this approach before considering broader operational rollout.

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 business case is currently unproven. Key uncertainties remain regarding the accuracy and usability of model-free techniques across transmission-distribution interfaces, and how planners can interpret and trust outputs in planning environments. There is also a technical and operational risk in integrating these tools with existing planning systems and ensuring they deliver usable insights. These risks mean that, while the potential benefits are significant, further research and testing is required before widespread adoption is viable.

This project has been approved by a senior member of staff

Yes