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

Dec 2024

Project Reference Number

NIA2_NGESO079

Project Registration

Project Title

Hydrogen Plant Dynamic Models

Project Reference Number

NIA2_NGESO079

Project Licensee(s)

National Energy System Operator

Project Start

December 2024

Project Duration

2 years and 1 month

Nominated Project Contact(s)

innovation@nationalenergyso.com

Project Budget

£440,000.00

Summary

This project aims to develop a dynamic model for polymer electrolyte membrane (PEM) hydrogen plants within DIgSILENT PowerFactory software, addressing a critical need for the UK's power system planning, stability analysis, and operational studies. As the UK government targets 10 GW of low-carbon hydrogen production by 2030, understanding the integration and interaction of hydrogen technologies with the grid becomes imperative. The project will focus on modelling electrolyser and fuel cell plants, analysing their scalability, and developing control systems for grid integration. Through Root Mean Square (RMS) and Electromagnetic Transients (EMT) simulations, the project will investigate hydrogen plants' impact on grid stability, facilitating a smoother transition to low-carbon hydrogen production. This project aligns with the UK's net-zero ambitions, enhancing energy security, decarbonisation, and supporting the broader strategy for a zero-carbon energy system transition.

Nominated Contact Email Address(es)

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Problem Being Solved

The integration of hydrogen technology into the GB's grid is a key step towards achieving the government's target of 10 GW of low-carbon hydrogen production by 2030. However, specific challenges need to be addressed to ensure successful integration:

Lack of specific detailed hydrogen plant models in PowerFactory: While PowerFactory is a sophisticated analytical tool for power system analysis, there is currently a notable absence of detailed, dynamic models for hydrogen plants within the software. This

gap hinders the accurate analysis of hydrogen plant interactions with the grid.
Understanding grid stability with hydrogen integration: The integration of hydrogen plants, particularly when synchronised with variable renewable energy sources, presents complexities in managing grid stability. There is a need for models that can accurately predict the behaviour of hydrogen plants as demand responders, generators, or energy storage systems.
Control systems and scalability: The novel nature of hydrogen technologies within the energy grid poses questions about their control systems' design for optimal operation and their scalability. Effective models are needed to explore these aspects within PowerFactory for accurate representation and integration into the grid.
Comprehensive analytical capabilities: Although PowerFactory provides a robust platform for power system analysis, the specific modelling of hydrogen plants and their dynamic interactions with other grid elements remains underdeveloped. Enhancing PowerFactory with models that can simulate these interactions is crucial for maintaining system stability and operational efficiency as the number of hydrogen projects increases.

Addressing these challenges is essential for facilitating the smooth integration of hydrogen energy into the GB's energy system, ensuring grid stability, and aligning with the national strategy for a zero-carbon transition and energy security.

Method(s)

This project will aim to develop a suitable hydrogen plant model in DIgSILENT PowerFactory for the GB power system planning, operation, stability and studies. The project will identify how a hydrogen plant interacts with the inverter-based resource penetrated grid. In carrying out this work, the project will aim to develop a clear understanding of the response and interactions which the hydrogen plant will have with the rest of the grid. This in turn, should lead to improvements in planning the integration of hydrogen plant effectively into the energy system and decision-making, which may be beneficial for the transition to a low-carbon economy.
The project will deliver 4 key Work Packages (WPs) which are detailed below:

WP1 – Model development of hydrogen electrolyser (5 months)

- Develop Electrolyser Stack Model

Create a mathematical or computational model of electrolyser stacks to accurately capture physical and chemical processes like electrolysis, heat transfer, and fluid dynamics.

- Develop Electrolyser Plant Model Including BOP

Construct a model for the entire plant, including auxiliary systems (Balance of Plant - BOP) such as water purification, gas handling, cooling, and power management to simulate integrated performance.

- Dynamic Simulation Under Varying Conditions. Use the model to simulate plant response to changes in input conditions like electricity supply fluctuations, hydrogen demand, or operational parameters to assess flexibility, efficiency, and identify potential issues.

WP2 – Model development of hydrogen fuel cell (4 months)

- Develop the fuel cell stack model

Create a detailed simulation of individual fuel cell stacks, focusing on electrochemical processes like hydrogen oxidation and electricity generation, considering temperature, pressure, and material properties.

- Develop the fuel cell plant model including BOP

Build a model integrating fuel cell stacks with systems like air compressors, hydrogen supply, and electrical interfaces to simulate overall performance and operational constraints.

- Dynamic simulation of the fuel cell plant under varying operating conditions

Use the model to simulate plant behaviour under different conditions, testing responses to changes in hydrogen supply, electricity demand, and other variables.

- Model validation using real-world Fuel Cell Systems

Compare model predictions with real-world data from operational systems to validate accuracy and reliability.

WP3 – Control design of the hydrogen plant (electrolyser and fuel cell plants) (3 months)

- Electrolyser Plant Control Design

Developing a control system to optimise the electrolyser plant's efficiency and safety by managing input power, water supply, operating pressure, temperature, and hydrogen production demand fluctuations.

- Fuel Cell Plant Control Design

Creating a control system to ensure the fuel cell plant's stability and efficiency by managing hydrogen input, air supply, temperature control, and generation demand.

- Hardware-in-the-Loop (HIL) Testing

Testing the control systems for both plants using HIL simulation with an Opal RT simulator and separate microcontroller unit, ensuring real-time performance and reliability under various conditions.

WP4- EMT simulation and Hydrogen Plant integration into the renewable-based power system model (12 months)

- Develop/adapt the renewable-based power system model

Create a renewable-focused power system model aligned with the UK energy roadmap for 2030 onwards.

- Integrate the hydrogen plant into the power system model

Incorporate hydrogen electrolyser and fuel cell models into the renewable power system model to study synchronisation with renewable energy sources.

- Interaction studies of hydrogen plants with the grid

Analyse the impact and interaction of hydrogen plants on grid stability, response time, and energy flow.

In line with the ENA's ENIP document, the risk rating is scored Low.

TRL Steps = 1 (2 TRL Steps)
Cost = 1 (£424k)
Suppliers = 1 (1 supplier)
Data Assumptions = 2 (Medium)
Total = 5 (Low)

Scope

The project aims to build a dynamic model of polymer electrolyte membrane (PEM) hydrogen plants (i.e., electrolyser and fuel cell plants) and their control systems, analyse their stability and interactions within the electrical grid via both RMS and EMT simulations. The model will be built in PowerFactory software to better prepare for future hydrogen plant connections, ensuring grid stability GB. The outcomes will be used to understand the impact of these plants on the grid and aid in planning and managing the transition to low carbon hydrogen production. The project fits within the broader strategy for zero carbon transition, whole energy system, constraint management, and system stability.

The work packages outlined above provide an overview of the scope for this project however, the following elements are excluded from the scope and will be funded through BAU:

- Operability for real-time operations
- EMT model delivered to NESO

Objective(s)

The project has the following five main objectives through 4 linked work packages:

1. To carry out an Industrial assessment and review of emerging hydrogen technologies
2. To build dynamic PowerFactory models for electrolyser and fuel cell hydrogen plants, ensuring accurate representation of their operational behaviour for integration into the UK's electrical grid
3. To investigate the scalability of the hydrogen models
4. To develop control systems for the hydrogen plants and their grid integration
5. To study the interactions of the hydrogen plants with renewable-based power system via both RMS and EMT simulations

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

This project has been assessed as having a neutral impact on customers in vulnerable situations, as the project will focus on investing the impact of hydrogen plants on grid stability to support a smoother transition to low-carbon hydrogen production, which will support the move toward greener energy and help make the energy system more efficient.

Success Criteria

The project is considered successful when the below are delivered and ready to use by NESO:

- The detailed model of fuel cell plant is built in PowerFactory.
- The detailed model of electrolyser plant is built in PowerFactory.
- The control system of the hydrogen plants is developed.
- RMS and EMT simulations of hydrogen plants are established.

Project Partners and External Funding

University of Warwick have been appointed to carry out the four work programs specified in Section 2.2, over a period of 24 months. No external funding.

Potential for New Learning

The lessons learnt from our ongoing EPSRC hydrogen project will be used to facilitate our understanding of the tools required and any adjustments needed to model the hydrogen plant for the GB power system. The success of this NIA project contributes to enhancing the knowledge and capabilities for better understanding the role of hydrogen in energy system, their impacts and utilisations for balancing mechanisms, ancillary services and planning, as well as influencing the direction for future R&D activities at NESO, the energy sector and academic community.

It is expected that the learnings from this project will also support the GB whole system operability strategy.
The learnings from this project will be captured as part of the regulatory reporting process for the ENA Smarter Networks Portal, and the model will be shared internally with teams within NESO to ensure access is not restricted or learnings are not limited to PowerFactory users only.

Scale of Project

The project spans 24 months. The project consists of development a DigSilent PowerFactory RMS model and validation of the computer model behaviour against the physical Hydrogen power plant setup in the laboratory of Warwick University, demonstration of RMS and EMT simulation results in a report as per the grid code requirements and carry out related studies with the relevant NESO and wider network teams.

Technology Readiness at Start

TRL3 Proof of Concept

Technology Readiness at End

TRL5 Pilot Scale

Geographical Area

The project is based upon the GB NESO area of operations.

Revenue Allowed for the RIIO Settlement

None

Indicative Total NIA Project Expenditure

£440,000

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:

The project has the potential to facilitate the energy system transition in several ways:

- **Enabling Increased Hydrogen Integration:** By creating accurate hydrogen plant models for PowerFactory, this project allows the NESO to understand how these plants will behave when connected to the grid. This knowledge is crucial for facilitating the safe and efficient integration of large-scale hydrogen production (10GW by 2030) into the GB's energy mix, which is a key goal of the government's energy security roadmap.
- **Optimising Use of Renewable Energy:** Hydrogen plants can store excess renewable energy generated during peak periods and then use it to produce electricity when renewable sources are unavailable. The project's models will help NESO understand how to optimise this process, allowing for greater use of renewable energy sources and potentially reducing reliance on fossil fuels.
- **Improved Grid Stability and Management:** Understanding how hydrogen plants interact with the grid is essential for maintaining stability. This project's models will allow NESO to assess the impact of hydrogen plants on factors like grid frequency and voltage control. This knowledge can be used to develop control strategies for hydrogen plants, enabling them to provide grid balancing services and contribute to a more stable and efficient energy system.
- **Informs Decision Making and Planning:** The project's outcomes will provide valuable insights for the NESO and energy sector on the technical aspects of hydrogen integration. This can inform future decisions about hydrogen plant deployment, grid infrastructure upgrades, and overall energy system planning to support the transition to low-carbon energy.

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

Not applicable, as this is a research project.

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

The method developed in this project has high replicability across GB for the following reasons:

- **Standardisation on PowerFactory:** The project utilises PowerFactory, a widely used software platform in the power systems industry within GB. This means the core modelling techniques and functionalities developed for hydrogen plants would be directly transferable to other projects and GB regions using the same software.
- **Focus on Generic PEM Technology:** The project focuses on PEM technology, which is a commercially available type of hydrogen plant. The models developed for PEM plants would be applicable across GB as this technology is expected to be among the common choices for future hydrogen integrations.
- **Scalable Model Design:** The core functionalities of the models can be adapted to different sizes and capacities of hydrogen

plants, making them relevant across various GB regions with diverse power needs.

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

We do not expect any direct costs of rolling out the method across GB. Our main focus lies in facilitating widespread adoption and knowledge sharing. To achieve this, we plan to engage with various network licensees throughout the project by hosting workshops. These workshops will serve the purpose of ensuring a common understanding of the developed models and how to utilise them effectively for grid integration.

Additionally, the project's final deliverables, encompassing reports and the hydrogen plant models, will be shared across the interested industry participants in a format to be agreed at a later stage. This approach allows stakeholders to easily access and leverage the project's outputs for further analysis, planning, and grid optimisation. By prioritising knowledge dissemination and access to project deliverables, the project aims to minimise any barriers or costs associated with replicating the method across GB. This fosters collaboration and encourages widespread adoption of the hydrogen plant modelling approach for successful grid integration.

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

This project's hydrogen plant models could offer a valuable key for Network Licensees, including National Grid Gas Transmission and NESO, to unlock smoother hydrogen integration. These models should provide crucial insights for planning large-scale hydrogen production facilities, ensuring efficient grid operation as hydrogen becomes more prominent. Furthermore, the project intends to equip licensees with the knowledge to optimise network management for hydrogen plants, leading to a more robust electricity system. The learnings should also contribute to shaping future regulations for safe and efficient hydrogen integration, paving the way for a clean energy future with seamless hydrogen adoption within their networks.

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.

While other projects might explore hydrogen integration or the use of PowerFactory for grid modelling, this project will focus on developing detailed hydrogen plants within PowerFactory equipped with their control strategies. This addresses a gap in existing knowledge and complements, rather than duplicates, efforts in related areas. A key project outcome is the creation of CIM models and sharing the developed methodology. This allows other projects and stakeholders to leverage our learnings without duplicating the modelling effort. NESO will actively collaborate and share information with relevant stakeholders to avoid redundancy

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 tackles the challenge of modelling hydrogen plants within PowerFactory. Existing grid integration models may not fully capture the nuances of hydrogen plants, and this project carves out a new approach specifically tailored to this technology.
Secondly, the project prioritises the development of scalable models. We recognise the need for models adaptable to the varying sizes and capacities of hydrogen plants across GB regions.
Finally, this project goes beyond simply developing the models. It also develops control systems for the hydrogen plants from the device level to the system level control.

Relevant Foreground IPR

- RMS model of a detailed Hydrogen power plant including both the electrolyser and fuel cell elements
- WP 1 Report – Literature review and model description for electrolyser
- WP 2 Report – Literature review and model description for fuel cell
- WP 3 Report - Literature review and controller design description
- WP 4 report – Description of the simulations both for RMS and EMT in a renewable-based system model

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’. NESO 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@nationalenergyso.com

Details on the terms on which such data will be made available by NESO 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

Due to the nature of the project and that it is researching potential future impacts to the grid based largely on assumptions, this does not fall into current business as usual (BAU).

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 involves the design, modelling and implementation of hydrogen plants in PowerFactory software for use in GB power system that could be expanded to the whole grid. Running the project under the NIA scheme allows NESO to disseminate the learnings from the project to the energy sector and GB network licensees.

In addition, as the TRL of the overall framework is relatively low, the NIA funding is more suitable for exploring the project's potential and increasing the TRL before transferring into BAU activities.

This project has been approved by a senior member of staff

☑ Yes