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

Jun 2025

Project Reference Number

NIA2_NGESO079

Project Progress

Project Title

Hydrogen Plant Dynamic Models

Project Reference Number

NIA2_NGESO079

Project Start Date

December 2024

Project Duration

2 years and 1 month

Nominated Project Contact(s)

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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

Objectives

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

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.

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

Background information:
To achieve government's target of low carbon hydrogen production of 10 GW by 2030, this project aims to develop a Hydrogen RMS model in DigSILENT PowerFactory power systems analysis software to assess the integration, operation and the impact to the grid of PEM Hydrogen Power Plant.

Warwick University has been contracted to develop PEM Hydrogen PP RMS model and carry out dynamic simulations under different varying conditions. Also, a Hydrogen laboratory rig is being set up in the universities' premises which will be utilised to compare the RMS model's simulation results against the test results achieved on site.

The project consists of four work packages WP1, WP2, WP3 and WP4. Currently, WP1 is almost completed, and WP3 is partially completed, whereas WP2 and WP4 are on track. The completed tasks under WP1 and WP3 are as follows:

Initial presentation about electrolyser model development – based on the literature review carried out by Warwick University a presentation has been delivered to NESO about electrolysers fundamentals, technology types and operational characteristics. Furthermore, an example of Solid Oxide Electrolysers (SOEC) modelling has been demonstrated with the relevant input and output parameters as well as Heat Exchanger Modelling and Stack Modelling functions were explained. The Proton Exchange Membrane (PEM) electrolyser was finally selected over the Solid Oxide Electrolyser Cell (SOEC) primarily due to its lower operating temperature, faster dynamic response, and greater compatibility with intermittent renewable energy sources.

WP1 – Model development of hydrogen electrolyser

1.1 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.

1.2 Develop Electrolyser Plant Model Including BOP and Control
Construct a model for the entire plant, including auxiliary systems (Balance of Plant - BOP) such as a water supply system, heat exchanger, cooling fan, and power and thermal management to simulate integrated performance.

1.3 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.

Completed work under WP1:

Electrolyser system model has been developed in MATLAB software including the Balance of Plant (BOP) elements such as:

Stack Model – calculates the required input power and flow rate of water
Thermal Model - calculates the temperature of the stack. This model is crucial for understanding the thermal dynamics within the system.
Water Tank Model - calculates the remaining water in the stack. This model helps in managing the water levels within the system.
Water Pump Model - calculates how much water will be transported into the stack, ensuring the system maintains the necessary water flow.
Heat Exchanger - collects heat from the stack and changes it, allowing the calculation of the input temperature into the electrolyser.
Cooling Fan- maintains the stack temperature at the reference level.

The design of the electrolyser system model has been built in block diagrams connected all together with BOP elements. The block diagram design of the electrolyser system is shared in a pdf format with NESO for illustration purposes. At a later stage in the project, the electrolyser plant model will be transferred to PowerFactory software and shared with NESO.

From WP3 Control design of the hydrogen plant (electrolyser and fuel cell plants), 3.1 Electrolyser Plant Control Design control design philosophy is implemented in the electrolyser's system model (MATLAB) providing adequate working flow of the system by optimising the input and output parameters.

After the implementation of the control design to the model dynamic simulation results have been demonstrated to NESO including:
PEM electrolyser stack temperature performance with and without control design implementation
Supply power – Stack temperature correlation
Hydrogen generation –supply power correlation curve

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

No modifications to the planned deliverables, timelines, or cost are planned or required at this stage of the project.

Lessons Learnt for Future Projects

Initial demonstrated simulation results have indicated that the electrolyser stack cannot operate efficiently without adequate controls implementation due to stack overheating challenges. Production of Hydrogen mass is directly related to the power supply rating and is limited due to the stack optimal working temperature. It has been concluded that the stack optimal performance is when the working temperature is between 70 and 80 degrees Celsius.

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

This project is still under delivery, and it is not completed yet. The outcome of the project will be concluded when the PowerFactory RMS model is completed and validated in the wider system network model by NESO. Also, when the reports are shared with NESO by Warwick University, they will provide insights of modelling Hydrogen power plants and a better understanding of the control parameters.

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

Model development of hydrogen fuel cell
Control design for the fuel cell

Dynamic simulation of the fuel cell under varying operation conditions
Model validation using the Laboratory Hydrogen plant rig
Hardware-in-the-Loop (HIL) Testing
Delivery of reports for each WP
Transferring the MATLAB models into PowerFactory