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

Jan 2025

Project Reference Number

NIA2_NGET0068

Project Registration

Project Title

AIDPS: Assessing the Impacts of DC Components from Power Electronic Devices and Geomagnetically Induced Currents

Project Reference Number

NIA2_NGET0068

Project Licensee(s)

National Grid Electricity Transmission

Project Start

April 2025

Project Duration

1 year and 11 months

Nominated Project Contact(s)

Xiaolin Ding

Project Budget

£403,000.00

Summary

This project aims to develop a methodology and Real-Time Digital Simulator (RTDS) system to assess the impact of Power Electronic Devices (PEDs) and Geomagnetically Induced Currents (GICs) on Current Transformers (CTs) and protection and control (P&C) performance in power systems. The focus is on addressing the emerging issue of DC components from the GICs and integration of Inverter-Based Renewables (IBRs) and HVDC and FACTS (Flexible Alternating Current Transmission System) devices. Electromagnetic Transient (EMT) models will be created for various PEDs, and industrial protection relays will be connected to the RTDS to form a Hardware-in-the-Loop (HIL) test platform. The project will evaluate the risks associated with DC components, informing technical specifications and grid code changes to facilitate the energy transition and enhance the integration of renewable energy into the power grid.

Third Party Collaborators

University of Birmingham

Nominated Contact Email Address(es)

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Problem Being Solved

The transition to a low-carbon energy system in Great Britain necessitates the massive integration of Inverter-Based Resources (IBRs) and various Power Electronic Devices (PEDs) into the existing power infrastructure. This integration includes technologies such as High Voltage Direct Current (HVDC) systems, Wind Turbine Generators (WTGs), STATCOMs, and SmartValves. While these PEDs offer significant control capacity and flexibility, they also introduce "DC" components into the alternating current (AC) system. This presents potential risks, particularly concerning the saturation of Current Transformers (CTs), which are critical for the performance of Protection and Control (P&C) systems and the overall stability of the power network.

Additionally, Geomagnetically Induced Currents (GICs) resulting from Geomagnetic Disturbances (GMDs) further exacerbate this issue by introducing a "DC" flux into the magnetizing flux of CTs. This saturation can impair the accuracy and reliability of CTs, leading to compromised P&C performance and increased vulnerability of the power network to faults and instability.

As the energy transition progresses, the challenges posed by the integration of IBRs and PEDs, coupled with the risks associated with GICs, necessitate a comprehensive understanding of their impacts on the power system. Failure to address these issues could hinder the successful implementation of a low-carbon energy system, posing significant risk to grid reliability and safety.

Method(s)

This project aims to develop a methodology and Real-Time Digital Simulator (RTDS) system to assess the impact of Power Electronic Devices (PEDs) and Geomagnetically Induced Currents (GICs) on CTs, (current transformers) and protection and control (P&C) performance in power systems. The focus is on addressing the emerging issue of DC components from massive Inverter-Based Renewables (IBRs) and other devices like HVDC and FACTS.

Electromagnetic Transient (EMT) model with various PEDs, including HVDC systems, Wind Turbine Generators (WTGs), SmartValves, and STATCOMs, and CTs, VTs (voltage transformers) and P&C systems, will be developed within the RTDS. The developed EMT model will accurately reflect their dynamic performance, including generated DC components. Industrial protection relays will be connected to the RTDS to form a Hardware-in-the-Loop (HIL) test platform, allowing us to examine the effects of DC components induced by PEDs and GICs on CTs and protection device performance. This will provide valuable insights into the challenges posed by the integration of PEDs and GICs, ultimately supporting a more reliable and resilient power system.

Data Quality Statement (DQS):

The project will be delivered under the NIA framework in line with OFGEM, ENA and NGGT / NGET internal policy. Data produced as part of this project will be subject to quality assurance to ensure that the information produced with each deliverable is accurate to the best of our knowledge and sources of information are appropriately documented. All deliverables and project outputs will be stored on our internal Sharepoint platform ensuring access control, backup and version management. Relevant project documentation and reports will also be made available on the ENA Smarter Networks Portal and dissemination material will be shared with the relevant stakeholders.

Measurement Quality Statement (MQS):

The methodology used in this project will be subject to the supplier's own quality assurance regime. Quality assurance processes and the source of data, measurement processes and equipment as well as data processing will be clearly documented and verifiable. The measurements, designs and economic assessments will also be clearly documented in the relevant deliverables and final project report and will be made available for review.

Risk Assessment:
TRL Change = 1
Cost = 1
Supplier = 1
Data = 2
Total risk score = 5 Low (L)

Scope

WP1 – Detailed Modelling of PEDs in RTDS

This work package focuses on building detailed RTDS models of key Power Electronic Devices (PEDs), including FACTS devices (such as SmartValves and STATCOMs), HVDC systems, and Type 4 wind turbines. Additionally, detailed models of Current Transformers (CTs) and Voltage Transformers (VTs) will be developed. All devices will be represented in the RTDS to closely reflect practical implementations in the GB transmission network.

WP2 – Power System Modelling in RTDS and Impact Assessment of DC Components from PEDs

WP2 aims to build a complex power system in the RTDS that includes PEDs (e.g., FACTS, HVDC, Type 4 wind turbines) and secondary systems, particularly CTs. This will assess the impact of DC components from PEDs on the performance of CTs and VTs, as well as the associated effects on the protection system. Key tasks include:

- Building a complex power system with PEDs in the RTDS as a benchmark test system.
- Assessing the risk of saturation of CTs and VTs due to induced DC components from PEDs.
- Configuring and connecting industrial protection relays with the RTDS according to National Grid's predefined relay setting guidance.
- Investigating the impact of PEDs and their DC components on protection performance.

WP3 – GICs Modelling in RTDS and Impact Assessment of DC Components from GICs

WP3 focuses on simulating GICs in the RTDS and establishing a benchmark test system to assess their impacts on CTs, VTs, and the associated protection system. Key tasks include:

- Modelling GICs in the RTDS and establishing a benchmark test system for GICs.
- Investigating the performance of CTs, VTs, and industrial protection relays against various levels of GICs.
- Understanding the tolerance of CTs and VTs to GICs and identifying potential risks to the network.

WP4 – Impact Assessment of Complex Power Systems with DC components from both PEDs and GICs

WP4 – Impact Assessment of Complex Power Systems with DC Components from Both PEDs and GICs WP4 aims to assess the overall impacts of DC components from both PEDs and GICs on the performance of CTs, VTs, and the associated protection system in the RTDS. Key tasks include:

- Investigating the impacts of DC components from PEDs and GICs on the performance of CTs, VTs, and the protection system.
- Analysing the complex nonlinear dynamics and oscillations potentially triggered by DC components.
- Identifying potential risks of CT saturation and improper operation of protection devices.
- Exploring effective methods and strategies to mitigate any potential risks posed by PEDs and GICs.
- Recommending necessary changes to technical specifications and Grid Codes where applicable.

WP5 – Final Report and Further Development

- Identifying further development needs.
- Producing a final project report detailing the development of RTDS modelling, impact assessments on the performance of CTs, VTs, and protection systems, key outcomes, learnings, recommendations, and future work.
- Disseminating key project outcomes and learnings through workshops and journal/conference papers.

Objective(s)

This project aims to develop a methodology and study tools to assess the impact of PEDs and GICs on protection & control performance within a power system, particularly addressing the emerging DC component issue.

The objectives are:

- To build complex power system models that accurately represent the dynamic behaviours of PEDs and GICs in RTDS.
- To understand the impacts of DC components from PEDs and GICs on the performance of Current Transformers (CTs) and their effects on protection systems.
- To identify potential risks associated with the emerging challenges posed by DC components from both PEDs and GICs, and to provide recommendations for mitigation measures, as well as necessary changes to technical specifications and codes where appropriate.
- To disseminate key findings and learnings through workshops and journal/conference papers.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

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 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 an overall positive impact on consumers in vulnerable situations. The assessment has identified that the project will look to identify potential risks posed by DC components from PEDs and GICs, and thus mitigation measures can be taken to ensure the safe operation of the network, which will reduce costs for households, including consumers in vulnerable situations.

Success Criteria

The success criteria of this project are as follows:

- Build complex power system models that accurately represent the dynamic behaviours of PEDs and GICs in RTDS
- Understand the impacts of the DC components posed from PEDs and GICs on the performance of CTs and protection systems via detailed assessments in RTDS
- Successfully identify potential risks of the DC components from PEDs and GICs on the protection system, and to provide recommendations to mitigate these risks, as well as necessary changes to technical specifications and codes where appropriate
- Effectively disseminate the project's key findings and learnings via workshop and publications.

Project Partners and External Funding

N/A

Potential for New Learning

The project will develop complex power systems with detailed representations of PEDs and GICs in RTDS. It focuses on assessing the impacts of DC components from PEDs and GICs on the performance of the CTs and VTs and associated power system protection. The project will help to understand the maximum DC component that existing CTs and protection systems can tolerate. The key findings will be shared with other Transmission Owners and the System Operator through workshops, technical documentation, and/or publications.

Scale of Project

This project aims to develop a methodology and study tools to assess the impact of PEDs and GICs in a power system, with a particular focus on investigating the emerging DC component from these sources on CTs and protection performance. Initially, the project will create individual component models of PEDs and GICs within the RTDS, followed by the development of complex power system models that include CTs and relays. The project will then concentrate on investigating the impacts of PEDs and GICs on CTs and power system protection. All phases of the project are strategically linked and designed to achieve the defined objectives. Therefore, the scale of the project is intentionally set to be comprehensive, as a smaller project would limit the potential for new learning and insights.

Technology Readiness at Start

TRL3 Proof of Concept

Technology Readiness at End

TRL4 Bench Scale Research

Geographical Area

The project will be a combination of computer-based studies and lab-testing. The project will be carried out at the innovation supplier’s facilities in the UK.

Revenue Allowed for the RIIO Settlement

N/A

Indicative Total NIA Project Expenditure

£362,700

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:

This innovation project facilitates the energy transition by providing a fundamental understanding of the impacts of DC components introduced by Power Electronic Devices (PEDs) and Geomagnetically Induced Currents (GICs) on future networks. By developing a methodology to assess these impacts on current transformers (CTs) saturation and protection performance, the project identifies potential risks in the performance of the CTs and the existing protection systems. This assessment will determine how much DC component can be tolerated by these systems, ensuring their reliability as we integrate more renewable energy sources. Furthermore, the findings will inform the development of Technical Specifications and necessary changes to the Grid Code where applicable. Overall, this project facilitates the energy transition and enhances the reliable integration of PED-based renewable energy into the power grid.

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

This innovation project will provide a fundamental understanding of the impacts of DC components introduced by PEDs and GICs on future networks. By developing a methodology to assess these impacts on CTs saturation and protection performance, the project will help identify potential risks in the performance of the CT and the existing P&C systems. This assessment will determine how much DC component can be tolerated by these systems, ensuring their reliability as we integrate more renewable energy sources. Furthermore, the findings will inform the development of Technical Specifications and necessary changes to the Grid Code, regulating DC components within AC systems where applicable.

The project is R&D focused with relatively low TRL level, hence no detail CBA assessment is conducted.

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

The research outcomes and the developed methodology are of generic nature and would be applicable to all electricity network Licensees across GB.

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

The project is concluding at a relatively low Technology Readiness Level (TRL) and will not result in a Business as Usual (BAU) implementation. As such, no rollout plan is currently scheduled.

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

The key findings of the projects will be shared with other Network Licenses (Transmission Owners and Operator) via workshops, technical documentation and/or publications. The key learnings and methods developed in the projects would be equally appliable to relevant network licensees.

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.

No similar innovation projects have been identified to build RTDS model to assess the impacts of PEDs and GICs on the performance of CTs and power system protection. There is seen to be no duplication or overlapping with any previous projects.

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 innovation of this project lies in the development of PEDs and GICs models and methods in assessing their impacts on the performance of CTs and power system protection. The project will provide an in-depth understanding of the effects of DC components from PEDs and GICs on future systems, helping to minimize risks and enhance network resilience. Notably, no similar developments have been undertaken before.

Relevant Foreground IPR

The expected Foreground IPR from this project includes the complex power system built with detailed model of HVDC, FACTS and type 4 wind turbines, GICs and CTs VTs in RTDS, the methodology to assess the impacts of the DC components from PEDs and GICs, and the study results.
The Foreground IPR also includes technical reports developed for the projects and any publications associated. The findings will be recorded in written technical reports along with recommendations for future work.

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 several ways:

- A request for information via the Smarter Networks Portal at https://smarter.energynetworks.org, to contact select a project and click 'Contact Lead Network'. National Grid 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 https://www.nationalgrid.com/uk/electricity-transmission/innovation
- Via our managed mailbox box.NG.ETInnovation@nationalgrid.com

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

This project is currently in the research stage and focuses on developing models and methodologies to assess the impact of PEDs and GICs on the performance of CTs and protection. No similar developments have been carried out or implemented in the transmission network. This initiative is not a business-as-usual activity, and there are considerable risks associated with the project. Additionally, there is no guarantee that the development of the model and methodology will be successful.

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 significant technical and commercial risks during its development. The proposed methodology requires thorough verification, and the potential for failure is considerable. Therefore, it can only be undertaken with the support of the NIA.

This project has been approved by a senior member of staff

☑ Yes