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

Mar 2023

Project Reference Number

NIA2_NGET0033

Project Registration

Project Title

DELIVER: Digital-Twin Enabled Innovation for Energy Network Restoration

Project Reference Number

NIA2_NGET0033

Project Licensee(s)

National Grid Electricity Transmission

Project Start

June 2023

Project Duration

2 years and 5 months

Nominated Project Contact(s)

Xiaolin Ding

Project Budget

£586,000.00

Summary

This project will investigate the feasibility of using Digital Twin (DT) technology to support local network restoration plans and the implementation of adaptive protection systems to address challenges associated with high penetration of Inverter Based Generation (IBG) within a power network. Conceptual development will be carried out to model power networks and essential equipment, and build a virtual “twin” system to digitally simulate the live operation. A Real Time Digital Simulator (RTDS) will be deployed with live data fed from Phasor Measurement Units (PMUs) for on-line decision-making and off-line testing/analyses. The project will showcase the use of such a DT system to support the local network restoration plan, in addition to adaptive protection capabilities to eliminate the risks of maloperation.

Third Party Collaborators

Arup

Nominated Contact Email Address(es)

box.NG.ETInnovation@nationalgrid.com

Problem Being Solved

Driven by net zero targets, there have been unprecedented energy transitions taking place in the power industry. Inverter Based Renewable Generation (IBG) sites together with FACTS (Flexible AC Transmission Systems) devices are being deployed and connected to the power network at scale to drive this energy transition. Despite all the positive benefits, it also poses challenges to system operation and network resilience.

The large-scale applications of power electronics devices within a power network may significantly change the circumstances and

best-practices for system restoration in terms of restoration paths, capability as well as facilities and methodology, should a partial or total blackout occur. In addition, the rising challenge of low system inertia and SCL (Short Circuit Level) due to high penetration of IBGs may cause maloperation or mis-operation of Protection and Control (P&C) equipment.

Method(s)

This project will investigate the feasibility of using Digital Twin (DT) methodology to assist network restoration and implement adaptive protection. Conceptual development will be carried out to model essential power network components (both Primary HV plant and secondary P&C equipment) to digitally simulate the live operation of a power network. A Real Time Digital Simulator (RTDS) will be deployed with live data (fed from the Phasor Measurement Units (PMU) and other measurement devices) for both on-line system analyses and off-line equipment testing. Such a DT system will be capable of providing real-time decision-making assistance to network control, or adaptive protection functionality. A demonstrator of such a DT system will be built within a lab environment to showcase the capability of network restoration analyses and adaptive protection and control of the network.

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 = 2

Supplier = 1

Data = 2

Total risk score = 6 Low (L)

Scope

The scope of this project will include 4 work packages (WP)

1 WP1 – Feasibility and Functionality

Work Package 1 (WP1) is to understand and establish the functionality and architectural requirements for the digital twin (DT) system, including

- Survey study to identify appropriate methodologies and best practices to develop and assess the Local Joint Restoration Plan (LJRP).
- Establishment of the key functions for network resilience analyses and control, including real time calculation of SCL/network inertia measurement using PMU data, adaptive protection functionality and on-line decision-making capability for network control/switching.
- Conceptual design of an overall architecture to interface with PMU system data, incorporating LJRP Study tool, Adaptive protection and Hardwire-in-Loop tests.
- Conceptual design of the LJRP analysis tool, capable of performing wide area voltage and reactive management, Ferro-resonance analysis, CB Transient Recovery Voltage (TRV) study as well as assessing Grid Forming capability from IBG, batteries and HVDC interconnectors.
- Conceptual design of adaptive protection functionality with the coordination study capability to assess protection and control functions affected by SCL/Network Inertia.

- Define suitable models (e.g. RMS, Step-RMS and EMT) required for the analytical and control functions with the DT system

2 WP2: RTDS Modelling and Functional Development

Work Package 2 will be focusing on RTDS modelling to fulfil the on-line functions and off-line analyses within the DT system, including

- Develop RTDS primary system models suitable for network restoration analyses, including key network components, conventional and renewable generations as well as HVDC and FACTS devices,
- Develop RTDS secondary system models including protection and control devices and schemes, network automation functions (e.g. DAR, OTS, etc.),
- Build functional block for network restoration study using the RTDS models and the conceptual design from WP1,
- Build functional block for adaptive protection/on-line decision-making using the RTDS models and the conceptual design from WP1,
- Validate the developed RTDS models against the definition/specifications from WP1 or relevant international and industrial standards/reference.

3 WP3 – Lab Demonstrator

Work Package 3 is to demonstrate the feasibility and functionality of the DT system in the Lab environment, showcasing the key functions by

- Building a demonstrator of the digital twin system using the overall architecture from WP1 with the models and functional blocks from WP2. It will include a PMU system, the LJRP study tool, and Adaptive Protection/on-line decision-making aid functions.
- Showcasing the functions for the improvement of restoration plans
  - Test some LJRP routes in a region for complete or partial energisation of a power network
  - Explore the best available options of energisation routes and joining power islands to connect demand.
  - Study of the network during switching exercise for a LJRP scheme, demonstrate capability to identify the risk of the network ability to respond, with mitigations.
- Showcasing the adaptive Protection with setting change functionality and on-line decision-making assistance.

4 WP4 – Final Review and Further Development

- Review the project development and performance of demonstrations, summarise the key outcomes and learnings,
- Identify further development needs (next steps) to form a proposal for a site trial in the GB network, and map out resourcing challenges.
- Produce project final report.
- Disseminate key project outcomes and learnings via workshops and journal /& conference papers.

Objective(s)

The project will carry out the conceptual development of a Digital-Twin system for power network restoration and adaptive protection, and deliver a demonstrator to showcase the feasibility of using of such a DT system:

- as a study tool to support the implementation of the new electricity system restoration standards (ESR),
- to perform on-line analysis of the system restoration plans,
- to support on-line decision-making of protection setting changes (open loop application),
- for adaptive protection function to on-line change setting groups or block protection relays (closed loop application).

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, 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 an overall positive impact on consumers in vulnerable situations. The assessment has identified that this project will look to enhance network resilience, transmission capability and operability which will reduce the costs for households.

Success Criteria

The delivery of the following items will be used to evaluate the success of this project:

- Identification of the methodology and best practice for network restoration analyses and control with conceptual design of the LJRP analysis and adaptive protection functions

- Design of overall architecture Design for the DT based network restoration system including the function of LJRP Study, adaptive protection and HIL (Hardware in loop) test functionality.
- Establishment of RTDS models required for functional blocks for network restoration study and adaptive protection.
- Building a demonstrator of a Digital Twin system in Lab environment to showcase key functions for the restoration plan study and adaptive protection.
- Recommendations on further development of the DT based system for network restoration, with a proposal for a site trial in the GB network, disseminate key project outcomes and learnings via workshops and journal /& conference papers.

Project Partners and External Funding

N/A

Potential for New Learning

The project will conduct conceptual design of the digital twin system and establish functionality and architectural requirements of such a system to support network restoration analysis and adaptive protections. A Real Time Digital Simulator (RTDS) will be developed with live data fed from Phasor Measurement Units (PMUs) to support on-line decision-making and off-line testing/analyses. The project will help to understand the feasibility and functionality of the proposed DT system in the Lab environment for network restoration and adaptive protection and highlight further steps needed to lead to a site trial.

The key findings of the projects will be shared with other Transmission Owners and the System Operator via workshops, technical documentation and/or publications.

Scale of Project

This project aims to establish a methodology of a Digital Twin (DT) based system to support network restoration plans and adaptive protection as well as on-line decision-making. To achieve the challenging objectives set out in Section 2.4, it is necessary to deliver the project in 4 staggered development phases. The first phase involves a feasibility study and conceptual design for the overall architecture and the key functionality, establishing functional and technical requirements including the models required for the network analysis and real-time simulations; The second phase will focus on the development of essential models and functions within a RTDS to simulate the operation of a power network and key components so that a “digital twin” of a power network can be “created”; At the 3rd phase, a demonstrator of such a DT system will be built within a lab environment, fed with “live data” from the Phasor Measurement Units (PMU) to showcase the capability of network restoration analyses and adaptive protection and control of the network; The final phase of the project will be directed towards development for real applications, incorporating all the key project outcomes and learnings to form a proposal/recommendations for a site trial in the GB network.

All phases are strategically linked and designed to deliver the defined objectives. Therefore, the scale of the project is as specified, since there would be inadequate potential for new learning with a less ambitious and smaller project.

Technology Readiness at Start

TRL3 Proof of Concept

Technology Readiness at End

TRL5 Pilot Scale

Geographical Area

The project will be a combination of computer-based studies and lab-demonstration. The project will be carried out at the innovation provider’s facilities.

Revenue Allowed for the RIIO Settlement

N/A

Indicative Total NIA Project Expenditure

£527,400

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 project supports the energy transition in a way that will enhance the resilience and operability of the network, reducing the restoration time should a blackout occur. The conceptual DT system development will be able to support real-time decision-making for network restoration, and also enable future adaptive protection systems to prevent mal-operation of the protection devices when risks are detected. All these will help to facilitate the energy transition by maximising the availability of the network to transmit renewable electricity from generation sites to demand centres.

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

The project aims to investigate the feasibility of using Digital Twin (DT) methodology to assist network restoration and implement adaptive protection. The project will design a virtual twin system to digitally simulate the live operation of a power network with essential power network components representations. The conceptually designed DT system will enable the capability of "playing ahead of game" and providing real-time decision-make assistance to the network control for network restoration and adaptively changing protection settings. The benefits are calculated based on improved efficiency of network restoration from the completion of the project till the end of 2044/45. Based on our cost benefit analysis, the estimated benefit in a NPV value can reach around £146m if the project is successful.

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 to develop the conceptual design of a digital twin system to assist the network restoration plan and analysis. If the project is successful, the methods can be further developed to roll out across GB. The estimated cost will be reviewed at the completion of the project.

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 found to use or develop a DT based methodology to assist the network restoration and adaptive 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 is related to the use of a Digital Twin methodology for implementation of the new electricity system restoration standards (ESR) and adaptive protection, which will potentially enhance network resilience and operability and improve the efficiency of network restoration. No similar developments have been done before. The DT based system could be used to develop the Local Joint Restoration Plan (LJRP), which has not been attempted previously.

Relevant Foreground IPR

No Background IPR will be required. The expected Foreground IPR from this project includes the overall architecture and conceptual design for the DT based network restoration system including the function of LJRP Study, adaptive protection and HIL (Hardware in loop) test functionality, RTDS models for functional study, the development of a demonstrator of a Digital Twin system of network restoration study and adaptive protection in a lab system. 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 further steps to be taken to bring the knowledge into Business as Usual activities.

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:

- 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 starts from the research stage and initially involves the feasibility and conceptual design of a DT based system for network resilience and on-line P&C functions. No such similar developments have been carried out and implemented in the transmission network. This is not a business-as-usual activity and there is considerable risk associated with the development of an innovative architecture and functionality. There is no guarantee the development of the overall system architecture and conceptual design of the functionalities 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 contains high technical and commercial risk in developing a DT based system for network restoration and on-line adaptive protection and control functions. The proposed methodology and design need to be verified and the risk of failure is high. Therefore, it can only be undertaken with the support of NIA.

This project has been approved by a senior member of staff

☑ Yes