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NIA Project Registration and PEA Document

Date of Submission

Jul 2023

Project Reference Number

NIA2_NGET0039

Project Registration

Project Title

Characterisation & Optimisation of Battery Banks in Substations (COBBS)

Project Reference Number

NIA2_NGET0039

Project Licensee(s)

National Grid Electricity Transmission

Project Start

July 2023

Project Duration

2 years and 9 months

Nominated Project Contact(s)

Tinashe E Chikohora

Project Budget

£592,069.00

Summary

Substation battery banks (SBB) in electrical substations participate in black start recovery processes and provide essential back-up power supply for protection, control, telecommunications, and lighting. With stringent limitations on space and increasing requirements for safety and reliability, potential battery sizing optimisation opportunities may be possible to enable reliable, secure, space, time and cost-effective substation energy storage. Battery efficiency with optimal use supports the energy system transition by supporting evolving substation loads requiring appropriate scaling design that avoids costs in either oversizing initial banks or reinstalling entirely new banks. This project considers existing and future battery banks improvements to best practice, better chemistries, and online monitoring techniques with expected benefits in reducing carbon footprint and maintenance costs whilst informing correct & adaptive battery sizing.

Third Party Collaborators

Cardiff University

Nominated Contact Email Address(es)

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Problem Being Solved

Direct Current (DC) low voltage (LV) battery systems (single/dual centralised 110V or 48V and distributed 110V) provide essential power supply for protection, control, telecommunications, and other light current equipment including equipment operation such as circuit breaker tripping. Battery banks also provide a crucial function during the recovery phase of a system outage or black start event, normally designed for a 6 hour 'standby autonomy' in the event of one such mains failure. DC systems are the single most impactful common mode failure of a substation. Loss of DC supply by a random failure event such as ageing depletes protection/tripping/inter-tripping systems reducing network operability and resilience capability.

The type and design of battery banks in NGET's substations differs, currently being sized based on suppliers/manufacturers (EPC

contractors) equipment datasheets and methodology.

Presently, the impulse demand of the battery system during circuit breaker operation is not calculated during the battery sizing assessment as the exact demand for each site according to the circuit breaker numbers and characteristics are not known and a typical demand profile is not understood. As a result, often the battery replacement is oversized, based on the existing capacity and alternatively, it may be undersized if the site has been extended with high voltage plant bays. Undersized battery systems would impact on the substation resilience and further integration of renewable generation during the transition period.

The actual use of these battery banks during their in-service life is not accurately measured or monitored in such way to enable trend analysis. NGET is not fully aware of the disadvantages of the current practice nor the opportunities available for improvements in terms of battery bank overall designs, different type performance and charger sizing. There is need for a benchmarking exercise whilst reviewing current battery bank technical specifications and philosophy (spacing dimensions, optimum size of battery charger etc.).

Method(s)

ata collection surveys and investigations will be conducted at various NGET substation sites. Testing within the high voltage laboratories at Cardiff University will make use of existing generators and recording instrumentation and laboratory general facilities. The current and voltage measurements will require suitable transducer purchases for the specialist condition monitoring. In addition, computerised data acquisition equipment will be purchased. A possible solution to achieve sizing optimisation would be by utilizing tailored duty cycles based on the independently measured load demands of equipment at NGET's substations. Expertise from the university will involve work on electrical testing & measurements, laboratory characterisation and battery technologies.

Scope

1. Literature survey:
Carry out a wider literature survey of DC battery usage in LV systems within transmission substations. Reviewing published literature and examining practice of battery usage on electrical networks in the UK and beyond will reveal any important aspects of battery bank practice that are worth noting going forward.
2. Survey of battery usage on NGET network:
Carry out survey of LV equipment connected to substation 110V & 48V DC systems which mainly feeds control and protection equipment through the use of substation batteries on the grid. Work with National Grid engineers to survey and develop an inventory of types of batteries and their typical use on NGET grid network. The survey will also include existing practice for charge/discharge and control of the battery banks. Any available measurement data will be collected and analysed.
3. Development of sensors & transducers:
Develop or purchase and install suitable measurement sensors and transducers to monitor DC loads and battery charge/discharge profiles on both centralised and distributed dc systems. Emphasis will be on measurement of current and voltage under both steady state and transient operating conditions. This is a core design, test and calibrate task within the project for both short- and long-term measurements and determination of battery utilisation profiles. It is expected that multiple measurements will be developed and deployed to allow measurement at the battery input/output as well as the direct feed from the alternating current (AC) system and the consumption at the DC energised LV equipment.
4. Deployment of online condition monitoring:
Develop an online condition monitoring system and computerised data acquisition and analysis to obtain short to long-term load profiles and parameters of DC equipment for all LV types of DC equipment tied to the system. It is expected to use the measurement equipment developed in sensors & transducers task above.
5. Explore optimisation of battery usage:
Using the characterisation findings above from condition monitoring measurements (transient & steady state standing load), explore the suitability of current Institute of Electrical and Electronics Engineers (IEEE) sizing methodology used by suppliers, and assess possibility of battery sizing optimization.
6. Application of existing standards for DC standby systems:
Survey existing practices used by National Grid in relation to DC standby systems as well as any related standards e.g., International Electrotechnical Commission (IEC) & IEEE standards connected to stationary applications.
7. Feasibility of new battery chemistries:
Exploiting the new knowledge gained from the current battery usage profiles, explore use of battery chemistries not yet used by National Grid and assess any potential advantages and disadvantages for substation standby applications. This should consider whole life value parameters (installation and maintenance requirements, decommissioning) as well as performance aspects.
8. Standard and industry practice revision:
With the findings of this work, explore revision of maintenance standards where applicable.

Objective(s)

The project objectives can be summarised as to:

- Understand current battery banks world best practise through a wide literature survey including a survey of battery usage on NGET network
- Monitor direct current loads and battery discharge profiles on both centralised and distributed systems to measure current and voltage performance under different steady state or transient operating conditions
- Acquire short-term and long-term load profiles through online condition monitoring and computerised data acquisition

- Consider standard battery sizing methodologies and possibilities for optimisation
- Review existing standards for DC standby systems
- Investigate and recommend use of new of battery chemistries not yet used by National Grid and assess any potential benefits
- Review applicable maintenance standards and industry practise
- Support the energy transition and deliver net benefit through innovation in low voltage direct current systems.

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, least cost decision making, transmission capability and operability that will ultimately reduce exposure costs for households.

Success Criteria

This project is deemed as successful if the objectives stated in 2.4 are achieved timeously. The project will allow NGET to survey the various uses and types of batteries with focus on developing new measurements techniques which will allow determination of the long-term charge or discharge parameters of the battery usage under steady state and transient conditions. Such usage trend understanding will help optimise the use of battery banks on the network and allow exploring new options of battery types and their usage. Furthermore, employing new battery designs with non-conventional high energy density chemistries will offer numerous advantages in reduced footprint, high power, low maintenance also coming with an active battery management system (BMS), allowing both new and old battery cells to operate in parallel.

Project Partners and External Funding

N/A

Potential for New Learning

The potential new learnings from this project are:

- Nomination of new or emerging high energy density battery alternatives with different better performing chemistries
- Identification new testing and measurement techniques to optimise battery bank condition monitoring
- Revision of maintenance standards where applicable
- Creation of new standards to fully deploy new battery chemistries.

The learning will be disseminated through the publication of project progress and closedown reports on the ENA portal. Various workshops and dissemination events would also be planned.

Scale of Project

The initiative of the project is to benchmark NGET's usage of battery systems with best practises in electricity networks across the UK and beyond. A subset of NGET's strategic substations will have monitoring systems installed to understand loading profiles and parameters of operational equipment and thus inform optimisation opportunities before full deployment. This project is planned to take approximately 2 years 9 months to allow for the market surveys, laboratory tests and analysis.

Technology Readiness at Start

TRL3 Proof of Concept

Technology Readiness at End

TRL5 Pilot Scale

Geographical Area

The work will be undertaken at Cardiff University's laboratories and data collection surveys will be conducted at any of the various NGET substations including Deeside Centre for Innovation.

Revenue Allowed for the RIIO Settlement

N/A

Indicative Total NIA Project Expenditure

£562,059

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:

Research into alternative, more environmentally friendly (alternative materials used) and recyclable battery technology for use in substation standby direct current (DC) supplies contributes to the energy transition rather than remaining on course with using traditional lead technology indefinitely. Also, alternative technology may also provide different chemical characteristics that enhance substation battery performance.

By using appropriately sized systems and smaller battery cells, it becomes possible to design a recovery system with greater redundancy and longer backup time. This, in turn enhances the system's reliability and support energy system transition (net zero) effort.

To accommodate the anticipated growth in energy demands, it will be necessary to install additional switching and station equipment, which in turn will necessitate the installation of new station batteries. However, if space for expansion is limited, the proposed new technologies and methods proposed can be employed to overcome this constraint.

Improving battery performance will improve overall resilience of the substation DC system which is key to the operational performance of the substation more-so during strenuous conditions. New technology may result in smaller footprint, less maintenance burden, and eradicate expensive gas monitoring systems. DC supplies are used for essential protection and control systems. This facilitates the connection of renewable generation at NGET substations which will also be implemented at downstream substations to deliver net benefit to consumers.

How the Project has potential to benefit consumer in vulnerable situations:

The DC system must stand alone and supply power in the event of loss of site AC supplies. The project's potential benefits render the new battery technologies particularly attractive for deployment in specialized applications such as in isolated communities, where operations are hampered by high installation, transportation, and maintenance costs. These batteries also become highly competitive when their small footprints obviate the need to install expensive additional structures such as "Ready-to-Move" (RTM) trailers in particularly cramped substations

Battery management system (BMS) will actively manage the batteries, thereby permitting both new and old battery cells to operate in tandem within a single string. This will enable National Grid to scale the power needs to suit evolving substation loads over time instead of either oversizing initial banks or reinstalling entirely new banks once loads increase beyond design capacity.

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

NGET's capital & operational budget shows that £54m investment is expected over 10 years around LVAC systems, with approximately 600 battery replacements in RIIO-T2/3. The assumption for the benefit estimation is that this project would harvest 5%

savings of the planned investment. The innovative case is envisaged to result in £20,000 footprint savings per each new substation. This yields potential savings/NPV benefits over the next 10 years of approximately £3.240m.

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

The outcomes of this project will be informed from the wider networks across the UK and can be adopted as substation battery banks best practise.

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

The estimated costs of rolling out the method across GB will be reviewed during project delivery after the research effort has progressed.

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 project outputs will enable NGET and any other transmission or distribution network operators to be aware and benchmark against leading substation back-up technologies, new battery chemistries and management/monitoring techniques.

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.

The project is coming to add on and expose alternative green opportunities in substation back-up supplies and practice and we're not aware of other networks having undertaken this project.

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

Understanding the working regime of batteries through condition monitoring will help improve battery application and lifecycle in future.

The project will allow to tailor power needs to suit evolving substation loads over time instead of either oversizing initial banks or reinstalling entirely new banks once loads increase beyond design capacity.

Furthermore, newly introduced high energy density batteries offer numerous practical advantages to their conventional lead-acid and nickel-cadmium counterparts. For example, they have a reduced footprint when compared to vented lead acid (VLA) batteries and can be quickly and safely installed by personnel without specialized training or expertise. They are also claimed to have long operational lifetimes, require virtually no maintenance, remain functional even after prolonged periods of storage in an uncharged state and are unlike VLA batteries which begin to calcify after 4-6 months.

Technical guidelines that specify station sizing standards for certain battery chemistries (such as lithium/sodium nickel) have not yet been published. However, this project aims to help develop them.

Finally, the green impact and the recycling practice analysis of batteries will be core component of the solution.

Relevant Foreground IPR

All IPR is governed by the "National Grid Standard RIIO-2 Contracting Position – JOINT IP OWNERSHIP" that sets out National Grid's standard approach to Network Innovation Allowance (NIA) funded projects under the RIIO-2 framework. The Foreground IPR shall be owned jointly between the Parties in equal shares.

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 part of it's business and usual activities

The proposed solution is innovative in nature, with a component level of risk that is unsuitable to Business as Usual (BaU) implementation straightaway and thus BaU is not the appropriate funding mechanism for this project.

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 settles in to get support of NIA, in a fully controlled environment where there is no risk of causing network disruptions/outages while surveys and investigations could also be safely developed. Therefore, NIA, rather than BaU, is the appropriate funding mechanism for this project.

This project has been approved by a senior member of staff

Yes