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

Aug 2025

Project Reference Number

NIA_SPEN_0116

Project Registration

Project Title

Underground Substation Replacement Phase 2

Project Reference Number

NIA_SPEN_0116

Project Licensee(s)

SP Energy Networks Distribution

Project Start

September 2025

Project Duration

1 year and 7 months

Nominated Project Contact(s)

Ali Kazerooni

Project Budget

£250,000.00

Summary

SPEN is addressing the need to replace 79 legacy underground HV transformers in SPD, originally installed between the 1950s and 1970s and now in poor condition due to decades of exposure to underground environments. With rising demand from EVs and heat pumps, these ageing assets pose increasing reliability and safety risks. In partnership with Kyte Powertech, SPEN will design, prototype, and test a modern underground transformer design with improved durability, reduced size, and innovative, integrated condition monitoring. This solution will overcome the challenges of space constraints in urban areas and avoid the high costs of relocating substations. The project will generate valuable learning for future deployments and support a more resilient, low-carbon electricity network.

Preceding Projects

NIA_SPEN_0061 - Innovative Replacement for Underground Substations

Third Party Collaborators

Kyte Powertech

Nominated Contact Email Address(es)

innovate@spenergynetworks.co.uk

Problem Being Solved

Certain legacy high-voltage (HV) transformers commissioned in SP Distribution (SPD) between the 1950s and 1970s were installed underground or buried. It is forecast that there are 82 of these assets currently in SPD, three of which are covered under load-related

schemes. Due to their underground location, it has not been practical to regularly inspect or maintain these assets. Evidence from projects undertaken during ED1 has shown that these transformers are in extremely poor condition, exhibiting high levels of deterioration and corrosion due to prolonged exposure to soil and moisture.

SP Energy Networks (SPEN) undertook Phase 1 of this project in September 2021. However, despite extensive market engagement, no suitable partner was identified to deliver a replacement for the existing underground transformers which were originally designed 70 years ago.

Through forecast demand analysis, SPEN understands that many of these underground transformers are in areas expected to experience significant increases in demand, driven by the uptake of Electric Vehicles (EVs) and Heat Pumps (HPs). This presents a substantial risk, as allowing increasing levels of demand to pass through assets in such poor condition – with minimal historic maintenance – could lead to serious reliability and safety issues.

Method(s)

Design

The design phase will focus on developing an optimised underground transformer that directly addresses the known failure modes of legacy units. SPEN and Kyte Powertech will assess the excavated transformers – many of which show severe corrosion and deterioration – to inform improvements in material selection, sealing, and structural resilience. Based on the learnings from excavated unit, project aim to develop an enhanced design by exploring some options such as size reduction, and adding health monitoring for the status of the tank and terminations

Testing

Once the concept design is finalised, a prototype unit will be built and subjected to routing and type tests as per SPEN's standards, however, we explore other tests should be considered for this particular application. The aim is to verify that the new transformer meets all relevant performance, safety, and durability standards. The condition monitoring system will also be tested to ensure it can reliably detect early signs of deterioration or failure.

Validation

The final phase will focus on validating the solution's effectiveness and readiness for deployment. This will involve analysing test results, comparing performance against legacy units, and assessing the practicality of installation in real-world urban settings. SPEN will also evaluate the commercial viability of the solution, including cost comparisons with traditional over-ground replacements and potential for wider rollout across the SPD network. Success will be measured not only by technical performance but also by the quality of learning generated and its value to the wider industry.

Scope

The scope of this project is to assess, redesign, and deliver an optimised underground transformer solution that addresses the growing demand pressures in urban areas, particularly where space constraints and ageing infrastructure pose significant risks. By evaluating the mechanical and electrical condition of a recently excavated unit, SPEN aims to extract key learnings to inform a more resilient, efficient, and future-proof design. The objective is to develop a suitable replacement that not only meets current technical specifications but also integrates innovative features such as condition monitoring and improved thermal performance. For consumers, especially those in vulnerable situations, the project delivers tangible benefits – enhanced reliability, reduced risk of outages, and improved safety. Financially, the project reduces long-term maintenance and emergency repair costs, while extending asset life and deferring the need for costly surface-level infrastructure. These efficiencies translate into direct savings for the GB electricity distribution system, supporting a more stable and sustainable network as the UK transitions to low-carbon technologies.

Objective(s)

The objectives of the project include:

1. Design and develop a replacement for the existing underground transformers.
2. Test and validate the new underground transformers as per SPEN's standards.
3. Integrate conditional monitoring to the new transformers.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

The proposed underground substation and transformer design is expected to deliver benefits to consumers in vulnerable situations by addressing both current and future risks associated with ageing infrastructure in high-demand urban areas. Technically, the solution

enhances network resilience and reduces the likelihood of faults or outages, which is critical for vulnerable consumers who may depend on uninterrupted power for health, mobility, or communication needs. Financially, by avoiding costly emergency repairs and unplanned outages, the project helps stabilise long-term network costs, reducing the risk of sudden bill increases that disproportionately affect low-income households. From a wellbeing perspective, the assurance of a safer, more reliable electricity supply in densely populated areas – where vulnerable consumers are often concentrated – provides peace of mind and supports a more equitable energy transition. The solution also avoids the disruption and displacement often associated with surface-level infrastructure upgrades, ensuring that improvements are delivered with minimal impact on local community.

Success Criteria

Key success criteria will include:

- Development of a viable underground transformer design that addresses the known failure modes of legacy units, with improved resilience to underground environmental conditions such as moisture and corrosion.
- Successful build and testing of a prototype unit, demonstrating that the new design can meet performance, safety, and durability requirements under simulated operational conditions.
- Evidence of reduced installation complexity and footprint, through optimised transformer sizing and reduced excavation requirements – critical for deployment in space-constrained city centre locations.
- Integration of a novel condition monitoring solution, providing real-time visibility of asset health and enabling proactive maintenance strategies for underground installations.
- Cost-benefit insights comparing the new solution to traditional over-ground replacements, particularly in terms of lifecycle cost, installation feasibility, and long-term reliability.

Project Partners and External Funding

Kyte Powertech

Potential for New Learning

Through this project, SPEN and Kyte Powertech aim to generate critical learning around the design, performance, and long-term viability of underground high-voltage (HV) transformers in modern urban networks.

Key areas of learning will include:

Design optimisation: By analysing the condition of excavated legacy units, the project will identify failure modes and deterioration patterns. These insights will directly inform the development of a new underground transformer design with improved resilience, longer expected lifetime, and reduced susceptibility to corrosion and moisture ingress.
Size and installation efficiency: The project will explore opportunities to reduce the physical footprint of the new transformer design. A smaller unit will minimise excavation requirements, reduce disruption during installation, and enable deployment in space-constrained urban environments.
Condition monitoring innovation: A novel approach to monitoring and managing the condition and performance of the new units will be developed. This will provide real-time visibility of asset health in underground conditions – something not currently possible with legacy assets.
Prototype testing and validation: A prototype unit will be built and tested to validate the concept design, installation methodology, and monitoring systems prior to full deployment.
Dissemination of learning will be a key focus throughout the project. SPEN will share findings through:

Industry forums and working groups, including ENA-led initiatives, to ensure alignment with wider network innovation efforts.
Technical reports and case studies, made available to other DNOs and stakeholders to support replication and inform future investment decisions.
Knowledge-sharing workshops with manufacturers, engineering consultancies, and academic partners to encourage cross-sector collaboration.
Regulatory reporting through established ED2 mechanisms, ensuring transparency and accountability in the delivery of innovation benefits.

Scale of Project

The scale of the project will be to design, test and validate a prototype underground transformer as per SPEN's requirements and standards.

Technology Readiness at Start

Technology Readiness at End

TRL4 Bench Scale Research

TRL8 Active Commissioning

Geographical Area

SP Distribution licence area

Revenue Allowed for the RIIO Settlement

N/A

Indicative Total NIA Project Expenditure

£250,000

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:

Through detailed demand forecasting, SPEN has identified that many underground transformers are situated in areas projected to see sharp increases in electricity demand – primarily due to the growing adoption of Electric Vehicles (EVs) and Heat Pumps (HPs). These same areas often include densely populated urban centre.

The current condition of these legacy assets, coupled with limited historic maintenance, poses a serious risk to network reliability and safety

By developing a new underground substation and transformer design, SPEN is proactively addressing these risks. This innovative approach not only ensures a more resilient and future-proof network but also directly supports the energy system transition by:

- Reducing the likelihood of unplanned outages in high-demand urban areas.
- Improving safety and reliability of supply in locations where vulnerable populations are concentrated.
- Avoiding the need for disruptive and space-intensive surface infrastructure, which can be particularly challenging in constrained city environments.

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, with an estimated cost of £250,000, encompasses the design, testing, and validation of a new underground transformer intended to replace SPEN's existing units. The long-term value lies in demonstrating that the new transformer can serve as a direct replacement. Once proven successful, this innovation will enable significant cost savings for the network operator by eliminating the need for land acquisition, extensive civil works, and other expenses typically associated with constructing new ground-mounted substations. This solution is especially advantageous in urban or space-constrained environments where traditional ground mounted substations are not feasible.

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

This project can be replicated across any network which uses underground substations or may want to install underground substations in places with space constraints.

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

1. Capital Costs

Transformer Unit Development & Manufacturing
Custom underground transformer units (per unit cost)
Bulk manufacturing discounts for scale
Installation Costs
Excavation and trenching
Cable laying and connections
Safety and environmental compliance
2. Civil Engineering & Site Preparation

Reduced compared to ground-mounted substations, but still includes:
Access roads (if needed)
Drainage and waterproofing
Structural reinforcement for underground vaults
3. Design & Validation

Engineering design for various site conditions
Prototyping and testing
Certification and regulatory approvals
4. Project Management & Labour

Skilled labour for installation
Project oversight and coordination
Training for maintenance teams
5. Operational & Maintenance Costs

Monitoring systems
Maintenance access provisions
Spare parts and servicing
6. Decommissioning of Existing Infrastructure

Removal of old ground-mounted substations
Recycling and disposal costs
7. Contingency & Risk Allowance

Typically 10–20% of total project cost

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 learnings from this project can be used by other network operators when replacing obsolete equipment. The learnings can be used to develop new underground substations in city centres and built-up areas where space is a constraint. This will provide a more sustainable and future-proof solution for replacing legacy assets in constrained urban environments.

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.

SP Energy Networks (SPEN) undertook Phase 1 of this project in September 2021. However, despite extensive market engagement, no suitable partner was identified to deliver a replacement for the existing underground transformers which was originally designed 70 years ago.

After another round of market research, SPEN will be working with Kyte Powertech to develop an underground transformer that can be a replacement for the legacy transformers. The design of new underground transformers will be improved compared to the old transformers and will be based on the learnings from the excavated units to achieve longer expected lifetime and reduce risk of deterioration in underground conditions.

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

Through this project, SPEN will collaborate with Kyte Powertech to develop an underground transformer as a potential replacement for legacy units. The new design will incorporate improvements informed by insights gained from excavated transformers, with the aim of extending asset life and mitigating deterioration risks in underground environments. Transformer size is also expected to be optimised, resulting in more compact units and reduced excavation requirements.

In parallel, the project will explore the integration of a novel approach to monitoring and managing the condition and performance of the transformer. This will help provide greater visibility of asset health in the challenging environmental conditions in which these units operate.

Relevant Foreground IPR

As IPR is developed we will include details in the annual progress reporting.

Data Access Details

Access to this data must be requested by contacting SPInnovation@spenergynetworks.co.uk. Please provide the following information in your request:

- Affiliation, position and contact details of requesting party
- Relevant project and type of data required
- Reasons for requesting this data and evidence that this data will be used in the interest of the UK network electricity customers
- How data will be shared internally and externally by the requesting party

Any data request deemed unsuitable for sharing will be highlighted to the appropriate requesting party. After receiving the request we will provide the estimated date for completing the data provision based on other requests and our team workload at that time. All requested data remains the property of SP Energy Networks.

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

SPEN is not funding this project as a BAU activity as this new underground transformer has not been tested in the network. With the current level of risk associated with the project, the business is not willing to use BAU allowance to fund the 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

Reallocating funds from a CV bucket originally earmarked for transformer replacements to support the development of a new underground substation introduces a significant financial risk. If the new substation design carries a high likelihood of failure or underperformance, the investment may not yield the intended benefits. Consequently, the diverted funds would no longer be available to support business-as-usual transformer replacement activities, potentially impacting the reliability and continuity of essential infrastructure upgrades.

This project has been approved by a senior member of staff

☑ Yes