Energy Networks Innovation Process

Project Close Down Form

Notes on Completion: Please refer to the NIA Governance Document to assist in the completion of this form. Do not use tables

Step 1 - Initial Project Details

Project Title

Solving Intelligent LV – Evaluating Responsive Smart Methods to Increase Total Headroom (SILVERSMITH)

Project Reference

WPD_NIA_068_SILVERSMITH

Project Contact(s)

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Project Start Date

06/22

Project End Date

04/23

Scope (15000 Characters max)

Great Britain is undergoing a transition to renewable and distributed energy. Many energy customers are becoming more involved in the energy system, transitioning from simply being electricity consumers to electricity prosumers. This is being led through the electrification of transport (i.e. electric vehicles) and heating (i.e. heat pumps) along with the continued growth in distributed generation, most commonly solar photovoltaics (PV). Low Carbon Technologies (LCTs) such as Electric Vehicles (EVs) and heat pumps are forecast to witness vast uptake rates over the next few decades. The combined effect of these technologies will have a profound effect on the electricity network. Large numbers of these technologies will be deployed on the Low Voltage (LV) networks, which will place significant additional demand on it, in many cases beyond which the network was designed for. National Grid manage the LV network across our licence areas in the East Midlands, West Midlands, South West, and South Wales, this study aims to help increase our understanding of the challenges and opportunities for new technologies across our LV network.

As National Grid transitions towards the management of an active LV network, this must be achieved in a manner which enables customers to install LCTs at the foreseeable uptake rates. This has to be achieved while minimising costs to consumers resulting from network augmentation but continuing to provide a safe and reliable supply of electricity. Additionally, network management should be fair to all electricity consumers, regardless of whether they own LCTs or not. It is therefore important to maximise value extracted from the existing LV network to minimise network costs arising from network reinforcement.

Past innovation projects have investigated some of these technologies and developed certain use-cases against particular network problems.

- UKPN's 'FUN-LV' investigated how power electronics can enable soft open points,
- Northern Powergrid's 'Customer-Led Network Revolution' investigated on-load tap changers and,
- Electricity North West's 'QUEST' is investigating whole system voltage optimisation.

What we are missing, is an understanding of how widespread these LV issues will become, which mix of novel and Business As Usual (BAU) technologies best addresses them, and an understanding of the functional requirements needing further innovation activity to improve on new or existing practices in light of continued technology development.

Objective (15000 Characters max)

- Understand the issues which are likely to be present on the Low Voltage (LV) network up to 2050. Business As Usual (BAU) activity does not investigate the LV network at this granularity.
- Document the current state-of-the-art LV voltage control options and evaluate which are likely to meet the functional requirements created in this work.
- Develop two design methodologies for selecting whether LV voltage control technologies can offer a benefit over conventional reinforcement strategies.
- Develop an understanding of which network assessment methodology is most suited for modelling issues and forecasting required investment on the LV network.

Success Criteria (15000 Characters max)

The main success criteria of this project were having a detailed understanding of the demographics of LV network constraints at several timescales leading up to a net zero power system, combined with a methodology for identifying the most cost-effective means to address these challenges. The library of project reports documents the approach taken during the project along with detailed results and analysis.

- A detailed literature review is produced that captures all the state-of-the-art LV voltage control technologies available, how they work and which DNO has implemented them.
- Comprehensive network studies are carried out that identify the demographic of LV compliance issues. The outputs from each approach need to explain clearly where network compliance issues will be experienced.
- Each consultant produces a clear methodology, which is clear enough so DNOs can select the best LV voltage control devices based on what likely challenges are forecasted on their network.
- A detailed technology witnessing report is produced that explains whether the up-and-coming technologies can meet the functional requirements determined in the network study.
- A detailed methodology comparison report is produced that explains the strengths and weaknesses of each methodology employed by each consultant. This report clearly explains what method should be used in further analysis.

Step 2 - Performance Outcomes

Performance Compared to Original Project Aims

Details of how the Project is investigating/solving the issue described in the NIA Project Registration Pro-forma. Details of how the Project is performing/performed relative to its aims, objectives and success criteria. (15000 Characters max)

Status of Objectives

Understand the issues which are likely to be present on the Low Voltage (LV) network up to 2050. Business As Usual (BAU) activity does not investigate the LV network at this granularity.
Achieved - Outputs of the SILVERSMITH project highlight the issues which are likely to arise on the LV network. The two network study reports explain these in detail, initially voltage rise issues due to PV uptake causing issues. However, this is quickly overtaken by thermal headroom issues due to increased loading.

Document the current state-of-the-art LV voltage control options and evaluate which are likely to meet the functional requirements created in this work.
Achieved - The Literature Review has captured the state-of-the-art technologies which are available for LV voltage management. This showcases the results of our stakeholder engagement and Request for Information.

Develop two design methodologies for selecting whether LV voltage control technologies can offer a benefit over conventional reinforcement strategies.
Partially achieved – change in scope - Network modelling was performed using two separate methodologies. This led to two separate Network Study reports, and two separate evaluations of how novel solutions can be applied to manage network compliance issues. However, it was decided during the project that the Design Methodology should be a single document using aspects of each design methodology.

Develop an understanding of which network assessment methodology is most suited for modelling issues and forecasting required investment in the LV network.
Achieved - This has been completed during the project.

Status of Success Criteria

A detailed literature review is produced that captures the state-of-the-art LV voltage control technologies available, explains how they work, and shares which DNO has implemented them.
Achieved - A detailed literature review document has been produced which explains the state-of-the-art and showcases the responses from our Request for Information.

Comprehensive network studies are carried out that identify the demographic of LV compliance issues. The outputs from each approach need to explain ~~clearly where~~clearly where network compliance issues will be experienced.
Achieved - Two detailed reports explain the methodology and results from network modelling.
The demographic of network issues at future study periods has been presented in graphic means.

Each consultant produces a methodology that is enough so DNOs can select the best LV voltage control devices based on what likely challenges are forecasted on their network.
Partially achieved – change in scope - The separate methodology aspect of the project was minimised during delivery. Although modelling was completed using two separate methods (parametric model and power flow model), the results were combined into a single methodology.
Section 6 explains the reasoning, in essence, it was deemed more useful to narrow the scope of the PowerFactory modelling to understand how each novel technology operates.

A detailed technology witnessing report is produced that explains whether the up-and-coming technologies can meet the functional requirements determined in the network study.
Achieved - Ongoing engagement with suppliers was key to the success of this project.
Following the initial responses to the Request for Information, follow-up interviews were made with each supplier to better understand the ability of their device to meet network needs.
Subsequent analysis in the Functional Requirement phase evaluated the suitability of each technology in dealing with the expected compliance issues, and the Technology Witnessing report explains in detail whether specific devices were selected. If they were not, it also explains why not.

A detailed methodology comparison report is produced that explains the strengths and weaknesses of each methodology employed. This report clearly explains what method should be used in further analysis.
Achieved - A comparison between each methodology has been made in the Closedown Report.

Required Modifications to the Planned Project Approach

The Network Licensee should state any changes to its planned methodology and describe why the planned approach proved to be inappropriate. Please confirm if no changes were required. (15000 Characters max)

Change of supplier

Initially, the project was scoped to achieve a comprehensive analysis of the network using two separate, but parallel approaches. One depth-based analysis using PowerFactory and Connect LV, and one breadth-based approach using the Transform Tool. However, during the start of the project, a key supplier became unexpectedly unavailable, which resulted in a change of delivery team. As per our project governance, we instigated actions from our risk and issue control framework to contain the impact. This change meant that the PowerFactory-based approach, which was to be delivered by a separate consultant, was delivered by EA Technology Ltd. Despite the change, the mitigation measures put in place to contain the impact resulted in a very limited effect on the project.

Revised scope for D2.1b: Functional Requirements (PowerFactory)

The scope of work for the Phase 2 deliverable 'D2.1b: Functional Requirements (PowerFactory)' was tailored to suit the project during delivery. Initially, the report was designed to be performed in parallel to the 'D2.1a: Functional Requirements (Transform)' report and offered a contrasting methodology. However, during the course of the project, two factors influenced a change in approach from this. The altered report focused more on investigating the impact of each novel technology on the Distribution Network, investigating its performance in managing the LV network and highlighting any significant issues which arise.

The first factor which influenced this change was the output of the Network Study. During work on 'D1.1b: Network Study (PowerFactory)' it was found that the severity of network compliance issues was relatively limited. This shows the importance of being able to model clusters of LCT uptake being unevenly distributed, as the uptake is not evenly spread across feeders. Another reason for the relatively small number of compliance issues was because the cables selected for study were at relatively high capacity. Their low impedance meant that voltage issues were less likely, and could accommodate higher loading. This, however, is not representative of our entire network.

Some compliance issues were experienced in the later years, under the more aggressive uptake scenarios however the majority of the networks in the three case studies remained largely unaffected by the increased LCT uptake. It was proposed that this was likely due to the sites having high-capacity LV mains cables already installed, which with their relatively low impedance could cater for the additional current at peak demand without a significant impact on voltage. Rather than artificially breaking the network to test how to fix it, or alter the models to change conductor type, it was proposed that subsequent power flow studies should investigate the impact of each novel solution.

The second factor which influenced our decision to focus specifically on the novel technologies was the suitability of the PowerFactory software in identifying the needs of the network on a macro scale. The project did not have the resources or budget to perform power flow studies at the scale required to obtain a macro view of the network's functional requirements. In fact, due to incomplete LV network records, constructing and testing the three relatively simple case studies took significantly longer than initially expected. It would be wise to say that any future work to construct power flow models for large parts of the LV network should be cautious in their time budgeting.

Due to the comparative ease in conducting macro-scale analysis using Transform, and acknowledging that the strength of PowerFactory lies more in the detail, the scope of 'D2.1b: Functional Requirements (PowerFactory)' was revised to focus on evaluating each of the technologies which were the focus of the Request for Information.

Lessons Learnt for Future Projects

Describe how the project (methodology, stakeholder engagement etc.) changed, or provided opportunities, from your expectation at the start of the project and therefore could be useful for a future project. In addition, please discuss the effectiveness of the research development or demonstration undertaken. (15000 Characters max)

State-of-the-art LV Voltage Control devices

- As part of the literature review, a range of solutions have been considered that have the potential to provide either additional voltage or thermal capacity to the network. These solutions range from retrofit devices, physical network interventions, market solutions (encouraging consumer engagement) and policy solutions.
- The Literature Review documents the operating parameters of different LV voltage control devices.

Modelling LCT uptake using Distribution Future Energy Scenarios (DFES)

- Currently, no commercial heat pump profile exists. Within this project, this limited the insights and results obtained for LV feeders, which had more commercial customers connected.
- It was recommended that an understanding of commercial heat pump profile(s) should be developed such that the effect of commercial heat pumps can be included in future network modelling.

Power flow models

- During the PowerFactory network modelling, several delays were caused by a lack of model convergence. LV network studies are not currently performed as a business-as-usual activity, as such the electrical diagrams are often incomplete or missing detail. Where information was missing, approximations and assumptions were made, which often caused a lack of convergence until improvements were made incrementally.
- In future work, it is recommended to err on the side of caution when planning detailed network modelling using LV records. It is also recommended that to improve this process, systematic improvements to the LV records should be made.
- The networks modelled in the PowerFactory work at the project's outset were limited in their ability to evaluate novel solutions. D1.1 showed that very few issues were expected to arise looking out to 2050. When it came to assessing the functional requirements of the novel options, solutions were limited to improving areas of the network that didn't experience significant issues. In particular, remote switching/meshing was only possible to be modelled on one area of the urban model.
- One of the main objectives was to understand how often LCT loads would require certain proactive measures to be taken on the LV network. For instance, we wanted to understand how increased LCT loading and export at different times throughout the day may require multiple interventions throughout the day to manage the voltage. By only investigating three scenarios, we were not able to accurately model the impact of this across the network and understand where this may be needed at scale.

The demographic of network issues

- Feeder types dominated by commercial customers are forecast to witness primarily voltage rise constraints. This is due to the ~~uptake~~uptake of PV.
- Transformer load-related constraints are consistently the most significant issue across all licence areas.
- In 2028, on average across all National Grid's licence areas approximately 6% of feeders require intervention for thermal constraints under net import (approximately 4.5% transformer and 1.5% cable), and 2% of feeders require intervention for voltage rise constraints.
- By 2040, thermal constraints will affect 40% of feeders. 27% Transformer, 13% thermal. This increases to 60% by 2050.
- While commonly a single network constraint is encountered, it is also common that multiple types of network constraints are encountered at the same time. When multiple network constraints are encountered, these are sometimes on distinct feeders, but regularly also on the same feeder. A common example would be thermal transformer and thermal cable constraints being witnessed simultaneously on a feeder.
- The network results showed that the Dense Urban network is more likely to experience breaches in thermal capacity significantly before statutory voltage limits are breached. This may mean that solutions which may become necessary for the Dense Urban network will favour those which can reduce circuit loading, particularly during the winter evening peak periods. Flexibility may be a strong solution in Dense Urban networks, which are estimated to require around 1.0 kW of demand turn-down per customer.
- In the Urban Network, higher levels of PV generation and longer feeders, when compared to the Dense Urban network, show that statutory upper voltage limits (+10%) could begin to be breached from 2033. It was also found that thermal loading begins to become overloaded during the winter peak from 2033 (Leading the Way) and 2040 (Best View) at which point some intervention would be necessary. For the Urban Network, interventions which reduce the thermal loading during the winter whilst also improving voltage management in the summer will be necessary.
- For the Rural Network, some customers will experience high voltages breaching the upper statutory voltage limits during peak PV export from 2040 onwards. Although circuit loadings remain well below their 100% rating the total loading on the supply transformer will begin to be exceeded for the highest LCT uptake scenarios (Leading the Way). In some situations, circuit loading remains within thermal limits but in Rural networks, voltage issues may begin to occur at different points along the feeder.

Performance of Novel LV Voltage Control Devices

- To use a STATCOM successfully, remote monitoring of the network is needed. This is to feed into an algorithm which triggers when the STATCOM needs to be operated. Failing to do so would increase losses and consumer capacity.
- Ideally, a STATCOM would only resolve voltage issues during the middle of the day when the voltage rise is the highest due to PV. At other times of the day, it was found to consume too much of the network's capacity due to the additional reactive power flow.
- Harmonic filtering and phase balancing offer benefits which primarily apply to the transformer and the HV network upstream of the connection point. On the LV network, harmonic currents will still exist as the active injection to cancel the harmonics will only benefit the network upstream of the filter.

Most commonly used technologies
The novel solutions most commonly deployed across National Grid's LV network and therefore offering value over business-as-usual solutions are:

- Network data monitoring
- Active network management (dynamic control of the network by controlling, for example, normally open points)
- Active transformer cooling
- Real-Time Thermal Ratings for HV/LV Transformers
- If the ENA140 Consultation which is considering whether to widen voltage tolerances is passed, manual tapping to increase headroom could be accommodated on networks where previously it would not be deployable due to voltages dropping below the statutory voltage minimum limit.

Sensitivity studies

- Similar solutions are selected to be deployed across all four of National Grid's electricity distribution licence areas. The proportion of solution deployment is sensitive to the LCT uptake rates on each licence's area feeder set. Any solutions deployed should be based on the network constraint type and extent of constraint witnessed on the specific feeder.
- The number and types of distinct solutions required across National's Grid network are independent of the scenario. Regardless of the actual LCT uptake rate, distinct solutions will be utilised for particular feeders due to the variability in the clustering of LCT deployments. Network Operators do not need to be concerned about the uptake rate of LCT across the system, instead, they should focus on the constraint type and extent caused by LCTs on each feeder.

Consideration of flexibility

- The use of domestic flexibility (technology agnostic) was considered as part of the Selection Methodology. The average amount of flexibility per feeder and per customer on that feeder was calculated to i) defer the initial reinforcement by 5 years, and ii) remove the need for the second wave of reinforcement. Based on these studies, to defer network reinforcement for 5 years from the time of the first network constraint, a change in demand at system peak of between 0.7kW and 2.1kW per customer is required depending upon the network archetype.
- The cost and duration of this flexibility was beyond the scope of this work, but is being considered in our NIC project EQUINOX which this learning has supported.
- As further trials investigating domestic flexibility are conducted, more accurate information will be available to estimate the amount of demand side response available to shift demand away from peak times, and the expected cost which DSOs would be willing to pay.

Opportunity for future innovation

- It was estimated that solutions offering cable headroom increased between 15% and 100%, for less than £50,000, would have significant value. Where a network experiences a cable headroom requirement of between 15% and 50% headroom uplift, Transform would pick network meshing. However, for practical reasons, it is unlikely that retrofitting classic Network Meshing would be achievable at scale which leaves a significant opportunity. In cases where network meshing is not possible, the next logical solution is splitting the feeder at a totex cost of £53,880. Therefore, solutions that can release greater than 15% thermal cable capacity with less cost and technical challenge than that of permanent network meshing would offer significant value.
- Innovative technologies that could offer between 20% and 80% thermal transformer capacity at less than approximately £16,000 per feeder (for feeders supplied by GMTs) or £7,500 per feeder (for feeders supplied by PMTs) would provide significant value to the network operator. Innovation activity could investigate solutions able to fill this gap. Appendix 2 provides details of each network archetype including the average number of feeders per archetype, which varies between 1 and 5.
- The available solution set has a gap between cheaper minor improvements and costly major improvements. Where solutions offering minor improvements don't address the network issues, we are forced to deploy far more costly solutions. Intermediate solutions would offer significant savings.

Recommended technology developments

- Of the available technologies, active transformer cooling was widely selected and recommended for a trial by the late 2020s.
- By the early 2030s, trial Real-Time Thermal Ratings for HV/LV Transformers across a sample of National Grid's pole-mounted transformers are forecast to become thermally constrained. Trials should focus on how to install equipment necessary for RTTR on PMTs and on quantifying the benefit of RTTR on thermal PMT capacity.
- By the mid-2030s trial active network management across a section of National Grid's LV network and quantify the thermal and voltage headroom release achieved.
- Trial new use cases of network data monitoring. This includes real time flexibility forecasting, real time thermal ratings, and temporary ratings to increase the utilisation of existing assets.

Outcomes of the Project

When available, comprehensive details of the Project's outcomes are to be reported. Where quantitative data is available to describe these outcomes it should be included in the report. Wherever possible, the performance improvement attributable to the Project should be described. If the TRL of the Method has changed as a result of the Project this should be reported. The Network Licensee should highlight any opportunities for future Projects to develop learning further. (15000 Characters max)

The outcomes of the project are as follows:

- A detailed literature review which documents the state-of-the-art technologies which are being developed by suppliers.
- A breadth-based Network Study which uses the economic model Transform to estimate the demographic of future network constraints witnessed on the LV network from now up until 2050. Different DFES scenarios consider the impact of the LCT uptake rate on network constraints.
- A depth-based Network Study using DIgSILENT's PowerFactory software to evaluate three case study networks. After connecting LCTs according to the three DFES scenarios, analysis was performed in study years: 2028, 2033, 2040, and 2050.
- A report detailing the Functional Requirements expected to be needed by each archetype was produced. This details the range of BAU technologies which would be used today, and also where novel technologies are used in place of BAU approaches, detailing the financial savings which could be possible.
- A power-flow-based study evaluated each of the novel technologies considered in our project. This study evaluated the relative strengths and weaknesses of the technologies.
- A comprehensive LV Voltage Control Selection Methodology was produced, which clearly explained the types of technologies that should be considered for addressing network compliance issues in different case studies. It also highlighted the scale of customer flexibility which would be required to defer and avoid BAU reinforcement.
- A summary report, that gives an overview of how each technology is applied to our network in the study, and reasons why some of the novel technologies were not selected.
- The information contained within the SILVERSMITH reports provides benefit to our customers, by allowing us to direct our innovation to the most critical parts of our network requirements. It focuses the effort for future innovation, and provides a stimulus for supply chain engagement.

All reports can be found on the SILVERSMITH project page: https://www.nationalgrid.co.uk/innovation/projects/solving-intelligent-lv-evaluating-responsive-smart-management-to-increase-total-headroom-silversmith

Step 3 - Outputs And Implementation

Data Access Level

A description of how any network or consumption data (anonymised where necessary) gathered in the course of the Project can be requested by interested parties. Please include a link to the publicly available data policy. (15000 Characters max)

All reports and supporting work are published on the National Grid – SILVERSMITH project page. Additional data can be requested by contacting us directly.
NGED data can be requested via the National Grid Connected Data Portal (https://connecteddata.nationalgrid.co.uk/).
(/http://www.nationalgrid.co.uk/innovation/contact-us-and-more)

Foreground IPR

A description of any foreground IPR that have been developed by the project and how this will be owned. (15000 Characters max)

New foreground IPR has been created in the project reports. These are published and freely available on the NGED Innovation website.

Planned Implementation

Please describe the next steps to implement this innovation project. What policies and standards need to be updated or created as part of this implementation. (15000 Characters max)

This project is a piece of research which will direct our innovation efforts towards the areas that have the greatest impact on maintaining a secure and cost-effective network.

Other Comments

N/A

Standards Documents

Identify any industry standards that may require updating due to the outcomes or understanding developed from this innovation project. If no standards will need to be updated, please state - not applicable

N/A