Northern Ireland Electricity Networks

LV ACTIVE NETWORK MANAGEMENT

Innovation Project

September 2020

Contents

1. Background

As electricity customers move towards a low carbon future, it is expected that electrical networks will become increasingly stressed as demand grows with increased reliance on electricity. In particular, Low Voltage *(LV)* networks are expected to become strained as new Low Carbon Technologies *(LCT)*, such as electric vehicles and heat pumps are connected to the network. In addition to this extra demand, increasing amounts of micro-generation, such as solar photovoltaic panels, are expected to be connected to the LV network. Together greater demand levels and a higher penetration of distributed generation *(DG)* can cause thermal, voltage and fault level issues on LV networks. Substantial investment in traditional reinforcement may be required to resolve those issues.

Smart solutions that extend beyond current practice however, can prove to be a less expensive alternative solution to network reinforcement. Smart solutions with the ability to manage LV networks and associated constraints, could defer expensive traditional network reinforcement through better utilisation of existing network capacity.

2. Project Summary

NIE Networks' LV Active Network Management *(ANM)* project will evaluate the ability of ANM to overcome constraints and defer reinforcement requirements through better utilisation of existing networks. LV circuit breakers and switches will be utilised alongside intelligent autonomous control, which will manage the LV network configuration in order to maximise utilisation and mitigate network issues.

ANM can be seen as a form of intelligent network management and at the core of a "smart grid", and among other functions, can be used to manage network constraints or to control network equipment in order to enhance the utilisation of network assets. It can act pre-emptively to prevent network overloads or post-fault in real time to restore the network and customers, with the network monitored as close as possible to real-time, although forecasting and modelling can be used too. There is a minimal requirement for human interaction with an ANM system making decisions, which can be centralised *(more embedded within network control) or decentralised (algorithms are performed within remote devices at the various locations)*.

ANM is mainly driven by the need to connect consumers more quickly and cheaply, to facilitate DG, to manage LCTs and to reduce capital spend. The status of monitoring, communications and computational technology is such that it can now support the deployment of ANM systems.

3. Objectives

The key objectives of NIE Networks' LV ANM project are to:

- Improve utilisation of LV distribution networks through the application of ANM to manage network voltage, power flows and reduce peak power flows.
- Trial a technical solution.
- Evaluate the financial benefits to the Northern Ireland customer.

3.1 Justification

Although learning from Great Britain *(GB)* is relevant to the application of ANM by NIE Networks, additional learning is required to enable NIE Networks to deploy ANM systems in a Business as Usual *(BaU)* manner.

The following points specifically relating to NIE Networks' application of LV ANM need to be addressed:

- Integration of LV ANM operation within NIE Networks' network and existing control systems.
- Evaluation of additional benefits from application of the proposed technology.

3.2 Project Outcomes

It is anticipated that this project will deliver:

- Customer benefits and savings on electricity bills by deferring capital expenditure.
- Scalable innovative learning to enable LV ANM to be applied as BaU.
- Increased visibility of the LV networks.
- Facilitation of greater numbers of LCTs and DG connecting without the need for expensive network reinforcement.

Outside of project objectives, LV ANM systems can reduce the duration of customer interruptions due to systems having the capability to detect transient faults and restore customer supplies, thereby reducing Customer Minutes Lost *(CMLs)*.

4. Project Technique

The proposed LV ANM system is based on similar principles to projects trialled in GB. These are meshing and controlling the LV network remotely and automatically through monitoring key locations and the use of sophisticated control algorithms *(informed by real-time power flow simulations and monitoring)* and automatic control operations. ANM systems are designed to constantly maximise network parameters, such as utilisation, or restoring of the maximum number of customer supplies as quickly as possible following a system fault.

In order to be able to facilitate such an ANM system, it is necessary to have remote control LV devices installed throughout the LV network controlled by the ANM system. To do this, NIE Networks will replace the existing LV fuses in distribution substations with intelligent Remote Control Circuit Breakers *(RCCB)* and links or fuses in link boxes distributed within networks with intelligent Remote Control Switches *(RCS)*. RCCBs and RCS units will communicate with a local Hub, which will in turn communicate with the overarching ANM system.

A potential high-level architecture of an ANM system is shown below in Figure 1. It is assumed that there is one Hub installed at each distribution substation collating and communicating signals from substation RCCBs. Similarly, a Hub is assumed to be installed at each switching point within the network where RCS devices are located. The Hubs may communicate wirelessly with local LV devices and the remote ANM system.

ANM system decisions relating to network optimisation and fault management may be made locally in a distributed control architecture or centrally in a centralised architecture. Furthermore, specific features of the ANM system operation may be controlled by separate architectures, such as network optimisation being centralised while network fault management being decentralised, managed locally and reporting back network status.

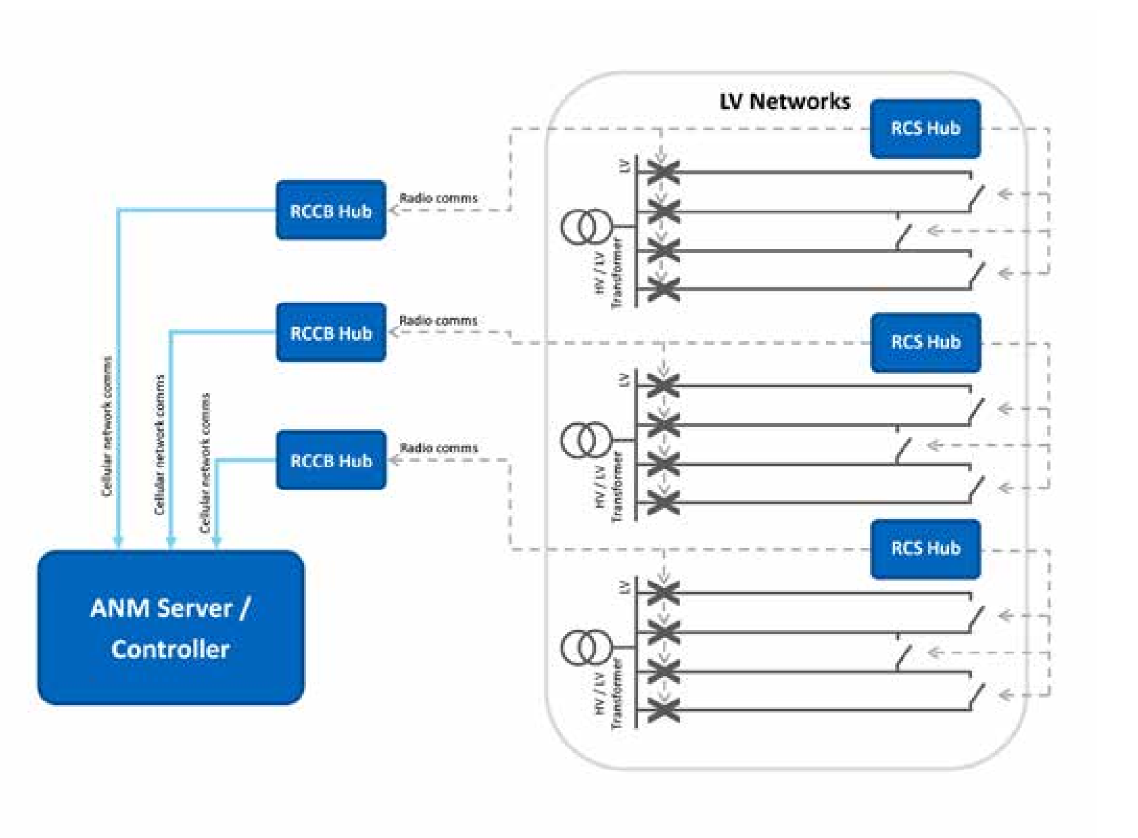

Figure 1: LV ANM scheme

The algorithms and the control decisions performed in the ANM controller will result in instructions communicated back to the LV devices via the same channels. This process of informing the ANM system and then transmitting its decisions back is depicted in Figure 2 over.

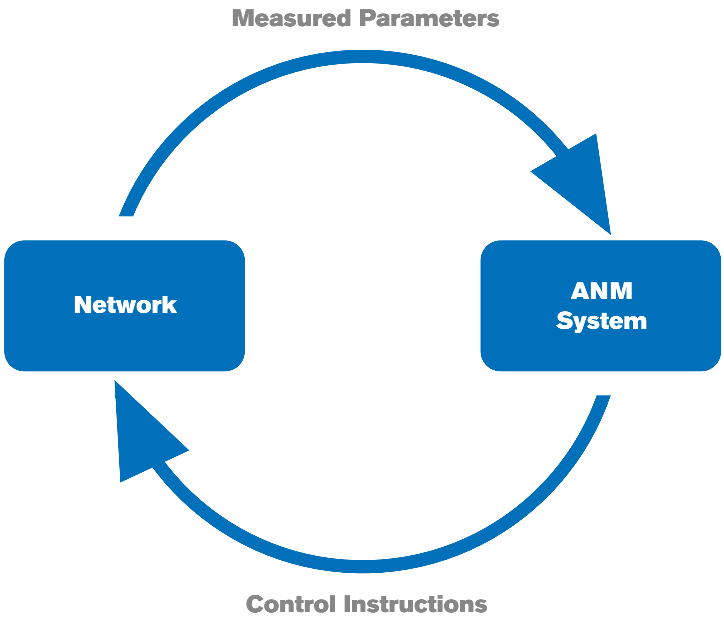

Figure 2: ANM system cycle

A standalone server may host the proposed ANM system, with external users being able to connect; for example, NIE Networks' control engineers shall be allowed to remotely access it in order to monitor the system, create alerts and issue instructions. Alternatively, the ANM could be hosted within NIE Networks' existing Network Management System *(NMS)*. A standalone server may be simpler and less expensive, although it may not offer the same level of future flexibility as when integrated within NMS. The advantages and disadvantages of the alternatives will be considered as part of the initial system architecture design.

5. Method

The proposed LV ANM project aims to address the identified challenges by focusing on lessons learnt from previous innovation projects and their transition into BaU. This will be carried out through a number of key tasks detailed below.

5.1 Technology Assessment

A desktop assessment of the available off the shelf ANM systems, including the equipment and communication systems, will be performed informing NIE Networks of the technologies available and suitable for the LV ANM project. The technology assessment will include a detailed description of equipment including operational philosophy, dimensions, fault recognition process specifically looking at safety, protection, maintenance etc. The advantages and disadvantages for each will support the development of a recommendation on the most suitable technologies for the project and the research information will feed into the development of a procurement specification.

The technology assessment will ensure that technologies are suitable for the purposes of ANM monitoring and control. The requirements may be split into system requirements and user requirements:

- At the heart of the ANM system requirements lay the remote control LV devices. Key features include local and remote operation, measuring capabilities, automation etc., these will be specified and reflect the functionality of the devices used in other projects.
- User requirements include those necessary for users to interact with the ANM system to operate and maintain the network or design new connections.

Consideration of the safety case and public risk with LV ANM devices with reclosing functionality will also be given, including consideration of the risks of auto-reclosing on LV cables, with a review of NIE Networks' safety policies and reclosing procedures to inform a safety case.

In addition to research of the technologies and the various system elements that are necessary to implement the LV ANM system, a literature review of similar projects with pertinent knowledge and lessons learned shall also be carried out; similar projects in GB include ENWL's Smart Street and UKPN's FUN-LV projects. Similarities, differences and possible gaps with these projects shall be identified early in the process so that the research is as effective as possible.

5.2 Site Selection

NIE Networks will complete the site selection and it is anticipated that the ANM system will be trialled at four sites subject to onsite conditions. The site selection will be undertaken through a series of steps:

- Initial screening, which will exclude substations not suitable for a trial, for example those that are being refurbished or that have been already scheduled to participate in other trials.
- Classification of substations according to certain criteria, such as location, load level and class, generation levels, utilisation levels, LCTs etc.
- System studies that will identify the types of constraints that the substations are or will face in future. Sites with existing or forecast constraints in the near future would be more suitable for the trial.
- Final selection of the most suitable sites for the project trial.

Site selection can also consider aspects, such as site acceptance of trial equipment, minimum disturbance of the public or consumers, existing substation equipment, scalability of results etc. It is envisaged that this task will require both desktop assessments and site visits.

Considering the interconnection of two LV networks, the site selection should ensure load profiles of the network are complementary so that a beneficial "partnering" of the two networks can be achieved. This means that substations with different load profiles will be considered, so that some level of diversification will be maintained upon interconnection.

5.3 Modelling and Simulations

Upon identification of sites from the site selection task, models will be built in network simulation packages and studies performed as a desktop exercise. These simulations will be conducted iteratively and shall commence when the preliminary work on site selection has provided suitable initial suggestions. To carry out detailed modelling, extensive monitoring at LV to understand network loading will be performed.

The simulations of the selected trial sites will be created in detail including any new devices and their capabilities. These models will be used in order to make comparisons between the different network configurations and modes of operation. More specifically, models corresponding to the trial modes shall be created and scenarios simulated:

1. A model that reflects the current radial configuration of the trial networks.
2. A model with permanent LV interconnections.
3. A model that has the developed control algorithm of the ANM integrated into it, so that it provides the dynamic network reconfiguration control.

Simulations of the trial circuits or of a representative under the three scenarios will be studied to evaluate the theoretical performance against certain parameters, e.g. capacity released, voltages, losses etc.

5.4 Material Procurement

Technical and functional specification for the LV ANM equipment and any required software, data and communication systems or interfaces will be developed. This specification will be used for competitive tender in the procurement process.

Contingency plans will be developed for returning to conventional operation in the event that the LV ANM is not operational and failsafe mechanisms established to prevent unintended back feeds to higher voltage levels during fault conditions. Strategic spares will also be procured for the replacement of a faulty unit.

5.5 Installation

Development, installation and testing of the LV devices, the control and the communications systems will be carried out by NIE Networks. Factory Acceptance Tests *(FATs)* shall be conducted to test the new equipment in conditions that resemble those where the equipment will be installed. Site Acceptance Tests *(SATs)* shall be conducted and it should be confirmed that system performance meets functionality requirements and technical specifications when deployed on site.

5.6 ANM Operation

The parameters which will be utilised by the ANM system to control the network will be decided upon. Parameters, such as voltage levels, network utilisation, losses etc., will be prioritised according to their significance in system operation and network limitations. Tolerance levels around all these parameters, their necessity and the time of application shall be considered, these may be defined according to network performance standards, statutory obligations, and licence obligations. Fault levels, reverse power flows, power quality, reliability and supply related metrics *(e.g. Customer Interruptions and Minutes Lost)* may also be included.

These parameters will determine the inputs to the ANM system and also the monitoring required at specific network locations. Voltage and current are considered to be essential for control algorithm function, while monitoring of other system metrics may be included too. The manner in which the identified inputs will be used by the control algorithm will be a process similar to a flow chart, where an order for decisions to be made in a logical manner is defined.

Alongside the monitored inputs from the network, the different network topologies and control strategies will be included in the decision making. The decisions on control actions shall be flexible so that unnecessary operations of the ANM devices are avoided, for example, excessive operation of the RCCBs and RCSs.

5.7 Trial

Live LV ANM system trials will be run in order to test, observe and analyse ANM system operation. Transition from radial to interconnected configurations, and vice versa, will be tested and ANM system reaction to actual or simulated system faults and onerous operational conditions shall be assessed. Although the trial methodology will be developed as part of the project delivery, it is anticipated that the trial examines periods with existing radial configuration, periods with full ANM control and possibly fully interconnected networks in order to compare network operation. The trial will also help ascertain that the systems in place were designed and implemented correctly.

The trial shall persist for sufficient time to provide useful learning, a minimum period of 12 months capturing all seasons and variations in load and output from DG. Results of the trial will be analysed and reported, with benefits that arise and areas for improvement identified and documented.

A testing schedule for the trial to ensure all possible outcomes are tested, in line with standards and safety regulations, will be developed prior to the trial commencing. The testing schedule will include provision for maintenance to assess the requirements in terms of outage planning for maintenance and repairs.

5.8 Analysis of Results

The results for this trial will be monitored continuously by NIE Networks which will last for a minimum period of 12 months. Following network simulations, the results can be analysed and compared in order to estimate the theoretical expectations of the trials and results may also be used to revise and improve the control algorithm or even to refine or alter the site selection.

Following trial completion, a detailed assessment on the impact of LV ANM on network utilisation, power quality, losses, CMLs, existing assets and fault level will feed into the cost benefit analysis (CBA) which will be conducted. The CBA will be completed for a single deployment of LV ANM and for the roll out into BaU across the LV network in subsequent regulatory periods.

5.9 Customer Experience

A survey of all customers affected prior to and on completion of the trial will be completed. This survey will support understanding the impact of LV ANM on quality of supply. All findings from the customer surveys will be included in the end of year and close down reports.

5.10 Transition to Business as Usual

On the basis of a successful trial and a favourable CBA for deploying LV ANM systems on LV networks, NIE Networks will progress LV ANM into BaU. This will include training and support of staff and updating policies, procedures and specifications.

This step comprises of three key tasks:

1. Making a fully justified business case in order to demonstrate the benefits of the project and the knowledge that stemmed from it.
2. Preparing the necessary documentation that will cover planning and operational policies and procedures and the specifications of the ANM system and its architecture.

6. Project Timeline

Q4 2018
START DATE

Q4 2020
TRIAL START

Q4 2022
EXPECTED COMPLETION