Northern Ireland Electricity Networks

# SMART ASSET MONITORING

## Innovation Project

September 2020

# Contents



# 1. Background

Traditionally distribution networks were designed to be passive with unidirectional power flows i.e. designed to accept bulk power generated on the transmission system and distribute to customers. The recent and forecast growth in distributed generation *(DG)* across the industry presents a challenge to network operators in that distribution networks are expected to be active and accommodate bidirectional power flows.

The high penetration of DG on the Northern Ireland distribution network has resulted in the network becoming increasingly constrained. Significant investment in network upgrade and reinforcement is required to address these network constraints, particularly the congestion issues on the 33 kV network caused mainly by the increase in small scale wind connected to the 11 kV and LV networks. Present regulation means that generators are responsible for network reinforcement costs at the voltage of connection and the voltage level above. Consequently, the cost of 33 kV network reinforcement is not passed onto generation connection applicants connected at LV. The substantial network reinforcement costs required are therefore socialised and borne by the wider customer base. The result of the connection activity is reverse power flows at 33/11 kV primary substations and saturation of sections of the 33 kV network.

Generation that cannot be monitored or controlled by the Transmission System Operator *(TSO) (e.g. a wind farm with a capacity of less than 5 MW)* is categorised as non-dispatchable. The installed capacity of partially/non-dispatchable plant is forecast to exceed the Northern Ireland peak demand by 2024. As a result, in a maximum generation and minimum demand network condition where generated power is higher than local demand, reverse power flows and exceedance of assets' thermal limits is experienced on the 33 kV network, emphasising the need for network reinforcement.

There are a number of innovative technologies, approaches and standards that can be used by NIE Networks to address capacity shortfalls, which have become prevalent as a result of the rapid connection of DG. The industry is however faced with a number of challenges in introducing these into Business as Usual *(BaU)* and replacing decades-old established and reliable practice.

In summary, the problems to be resolved are:

- Exceedance of asset thermal ratings on 33 kV distribution networks as a result of the growth in DG and bidirectional power flows, triggering significant network investment.
- Increased criticality of distribution networks with bidirectional power flows and large volumes of connected generation, making network reliability and security of supply more important.

# 2. Project Summary

Smart Asset Monitoring *(SAM)* will implement an enhanced thermal monitoring system on the 33 kV distribution network through a combination of the use of Real Time Thermal Rating *(RTTR)* of 33 kV overhead lines *(OHLs)* and thermal modelling of 33/11 kV primary transformers. NIE Networks recognise that the SAM project can provide a novel solution to determine more accurately the available network headroom on a real-time basis, enhance utilisation of network assets and reduce capital expenditures, thus ultimately reducing the costs to customers for use of the network.

The intention of the SAM project is to learn from other Great Britain *(GB)* innovation projects and use the most efficient approach to bring the solution into BaU. Adopting this 'fast-follower' philosophy will allow NIE Networks to make full use of the lessons learned on previous trials and effectively develop a solution that meets the requirements for Northern Ireland's 33 kV distribution network.

The SAM project will include a fresh review of technology from recent trials to select the RTTR technologies and thermal modelling techniques for application on the 33 kV distribution network. RTTR solutions will be developed for 33 kV OHLs, based on this technology review, and will be integrated on two or three OHL circuits; and thermal modelling will be applied to thirteen primary transformers on NIE Networks' network.

In addition, operation and planning policies, procedures and required technical and functional specifications will be developed throughout the project and revised at project close in order to support the transition from a network integration project to BaU during RP6. Full knowledge dissemination will be carried out internally within NIE Networks and externally with stakeholders to further support transition and uptake.

# 3. Objectives

The key objectives of the SAM project are to:

- Improve utilisation of 33 kV networks through optimisation of OHL and primary transformer ratings using enhanced thermal visibility.
- Provide learning for future OHL routing and conductor sizing.
- Provide learning and recommendations for the thermal ratings of primary transformers.
- Provide business confidence in the transition into BaU and full business adoption of the SAM system.

## 3.1 Justification

Through the Sustainable Networks Programme during RP4, NIE Networks successfully developed a novel approach to applying dynamic ratings to 110 kV transmission lines. This research highlighted the potential of this approach to reduce network investment requirements. The results of this project demonstrated that dynamic line rating (DLR) worked in conjunction with selective re-conductoring of sheltered sections and identified significant operational changes required before this approach could be integrated into BaU. This includes:

- Dynamic protection;
- Implementation of new software in the control room to forecast ratings and hence network capacity based on weather forecasts;
- Review of relevant standards.

Further operational trials have since been completed in GB on the back of research findings and NIE Networks believe there is now merit in integrating this approach into BaU. However, in advance of this it is essential for NIE Networks to independently test the integration of the chosen technology within its distribution network. This will ensure that the solution works with NIE Networks' network and its management system before widespread implementation takes place. The successful completion of the integration project will enable SAM to be appropriately integrated into NIE Networks as a BaU solution.

### 3.2 Project Outcomes

It is anticipated that the SAM project will deliver:

- Potential increase in available capacity headroom on the network.
- Potential deferral of network reinforcement investment, reducing customer bills.
- Technical and functional specifications for:
  - > RTTR of 33 kV OHLs; and
  - > Thermal Modelling of 33/11 kV primary transformers.
- Detailed plan for transition into BaU.
- Adoption of SAM on NIE Networks' system if the integration project is successful.

# 4. Project Techniques

The SAM project aims to provide techniques and tools for enhancing thermal visibility on 33 kV OHLs and 33/11 kV primary transformers. Thermal behaviour of network assets depends on loading profiles and environmental parameters such as weather conditions. Based on existing industry standards, weather conditions in the immediate and surrounding areas of network assets are assumed to be constant. The network assets are thermally rated based on these static ratings, which are usually based on pessimistic weather conditions e.g. low wind speed and high ambient temperature.

This approach has been reliably practised by network utilities for a long period; nonetheless studies show that there is potential to enhance the rating of network assets if the real-time thermal ratings are taken into account. Weather conditions vary in time and therefore assets will have a time-varying thermal rating which is usually above their static thermal ratings. For example, at a high wind speed the OHL conductor can dissipate more heat through convection to the surrounding environment. There is also an exploitable correlation between high wind generation *(hence reverse power flows)* and wind cooling on the associated 33kV line.

The dynamic thermal behaviour of network assets is expressed by a heat balance equation which is specific to the types of asset. The technique proposed to model real-time thermal behaviour of 33 kV OHLs is described below:

- An appropriate monitoring system will be deployed to determine the RTTR of each span in an OHL circuit. It is important to calculate the RTTR of each span as each span is exposed to different thermal conditions due to changes in OHL orientation and exposure to different ground terrain and wind shielding conditions. IEC and Cigre standards explain the detailed thermal model of an OHL conductor by considering the conductor's surrounding weather conditions and its real-time loading.
- The field measurement data will be transmitted to a central calculation engine on a real-time basis which evaluates the RTTR of the entire OHL circuit. The real-time data and RTTR forecast algorithm will be used to determine thermal pinch points on the circuit which need upgrade and the uprating of the line.

Transformers are thermally rated based on static ratings, in line with P15, which are also usually based on pessimistic weather conditions. The technique proposed to thermally model 33/11 kV primary transformer is described below:

- Using historic data including Winding Temperature Indicators *(WTIs)*, ambient temperature and transformer loading at a number of NIE Networks' substations, the real time capacity of primary transformers can be determined in both forward and reverse power flow.

It is anticipated that through these techniques, it will be possible to improve the thermal capacity of the assets above the static values outlined in currently practiced industry standards. This will facilitate increased loading of network assets without the need for load-related reinforcement.

# 5. Method

SAM aims to address the aforementioned problems by focusing on lessons learned from previous innovation projects and the transition into BaU. The two core methods being integrated correspond to two work streams: RTTR of 33 kV OHLs; and Thermal Modelling of 33/11 kV primary transformers. Each involving a number of key tasks described below.

## 5.1 RTTR of 33 kV OHLs

The keys tasks of the OHL trial are outlined below:

1. Research & Technology Assessment

   Thorough research into the technologies that will be necessary to implement the SAM project will be carried out. This will include a study of the available off the shelf equipment, including weather stations, asset monitoring equipment, calculation engines, communications equipment and power supplies. Research will provide the pros and cons for each device to guide the selection of the most suitable technologies for the project. It is anticipated that a combination of a weather and temperature based RTTR system will be developed for this project. The monitoring equipment must have high reliability in terms of measuring accuracy and the communication system. This information will feed into the procurement specification.

In addition, a literature review of similar projects with pertinent knowledge and lessons learned will be conducted. Similarities and differences between NIE Networks requirements and other projects will be highlighted early in the process so that the SAM project is as effective as possible. Any possible gaps in the reviewed projects will be identified so that the SAM project can fill these.

2. Site Selection

   The expected locations of the project sites are OHLs expected to be wind loaded with potential thermal constraints within RP7[1]. Surveys of OHLs will identify micro-climate regions, shielded areas and any practical limitations that may influence site selection, which will determine the location of monitoring devices. Line condition studies will ensure that OHLs considered for the integration of RTTR have no damage that an increased dynamic rating could intensify.

   A number of considerations will be made when selecting suitable locations along the OHL route for installation of monitoring equipment including signal strength testing for communications..

3. Material Procurement

   The technical and functional specification for the RTTR OHL system including monitoring equipment, calculation engine, visualisation software, data systems, interfaces, power supply and communication systems will be developed.

   The specification will support the competitive tender in the procurement process from which suitable manufacturers will be procured following the tender process.

4. Calculation Methodology

   A RTTR calculation methodology based on monitored data will be developed based on IEC and Cigre techniques.

5. Installation

   The installation and commissioning methodology will be developed with particular consideration of the trialling technique and associated equipment.  Communication through all systems including NIE Networks' NMS and data centre will be established.

6. Analysis of Results

   The results for this trial will be monitored  on a monthly basis for the duration of the trial. The trial is expected to begin in 2021 and last for at least one to two years to experience all types of weather conditions.

   Analysis of gathered data will be undertaken to:

   - Calculate the capacity headroom released from OHLs on the network through the use of RTTR technology, and assess the extent to which proposed network reinforcement can be deferred.

[1] Regulatory Price Review Period starting in April 2024

- Demonstrate improved utilisation of assets.
- Carry out a system reliability assessment.
- Identify and implement modifications that are required to improve accuracy of the RTTR system, e.g. consider whether weather measurement systems are in optimal locations.

When the trial is complete, NIE Networks will conduct detailed assessment of the deferral of CAPEX and impact on losses, existing construction practices, maintenance costs and asset lifespan *(OHL conductor, insulators and all other assets relating to overhead circuits)*. This will feed into the cost benefit analysis *(CBA)* for the roll out to business as usual across the 33kV overhead network.

## 5.2. Thermal Modelling of 33/11 kV Primary Transformers

The technique for thermal modelling of primary transformers involves measuring key parameters of the transformer to deduce the asset's real time thermal rating. The system will measure the following parameters to calculate this rating:

- Ambient temperature
- Transformer temperature *(WTIs)*
- Transformer load
- Tap position

NIE Networks do not intend on installing an active real time thermal rating system for primary transformers; instead the project aim is to understand the thermal rating of the transformer using historic data, determine the reverse power capability and determine if the current design assumptions can be modified.

The key tasks are outlined below:

1. Site Selection

   There are a number of different considerations to be made when selecting suitable sites for thermal modelling. This task will identify primary transformers that encompass a diverse range of transformer ratings, ages and manufacturers; however primary transformers due for replacement during the project will be discounted.

   Condition assessments of transformers will be undertaken to differentiate the condition of the assets and sites are likely to be selected to represent a range of exposed rural and enclosed indoor primary substations to assess the performance of thermal modelling under differing environmental conditions.

   The majority of the parameters mentioned in Section 5.2.1 are already available to NIE Networks' PI Historian system through SCADA. Currently NIE Networks has access to WTIs at 21 primary substations and further sites which are going into reverse power flow will be identified and WTIs installed at these.

2. Calculation Methodology

   Current and historic weather data available online will be used to determine the environmental temperature at the time of measurement. This weather information and the data collected through PI Historian will be passed through a calculation engine to determine the enhanced thermal rating of the transformer. The algorithm to determine the enhanced thermal rating using all the parameters set out above will be developed.

3. Analysis of Results

   NIE Networks expect to have WTIs fitted and available to PI Historian in line with the installation of the RTTR system on the overhead circuits. Therefore, there will be at least 1 year of data available to analyse. Analysis will be carried out monthly and conclusions included in end of year reports.

   Analysis of gathered data will be undertaken to:

   - Calculate the headroom capacity released from the primary transformer in both forward and reverse power flow and assess the extent to which transformer reinforcements can be deferred.
   - Demonstrate improved utilisation of primary transformers.
   - Determine the impact on losses and transformer lifespan and maintenance cycle.
   - Complete a cost benefit analysis of implementing an enhanced thermal rating system for a single deployment and the roll out to business as usual across all primary transformers.
   - Determine the relationship between transformer age, make, size and the increased headroom from enhanced thermal ratings. The algorithm will require modification in line with the findings.

## 5.3 Transition to Business as Usual

Provided the trial is successful and the CBAs positive for both RTTR of 33kV OHLs and enhanced thermal ratings of primary transformers, NIE Networks will roll out into BaU. This will include training and support of staff and updating policies and specifications. In addition, NIE Networks will carry out dissemination of project learning.

The final step to transition to BaU comprises of:

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 for planning and operation of RTTR of 33 kV OHLs and thermal modelling primary transformers.
3. Determine the ownership of RTTR and thermal modelling within NIE Networks and provide NIE Networks' staff with appropriate and sufficient training and support.

# 6. Project Timeline

| Q2 2019 | Q2 2021 | Q4 2023 |
|---|---|---|
| START DATE | TRIAL START | EXPECTED COMPLETION |