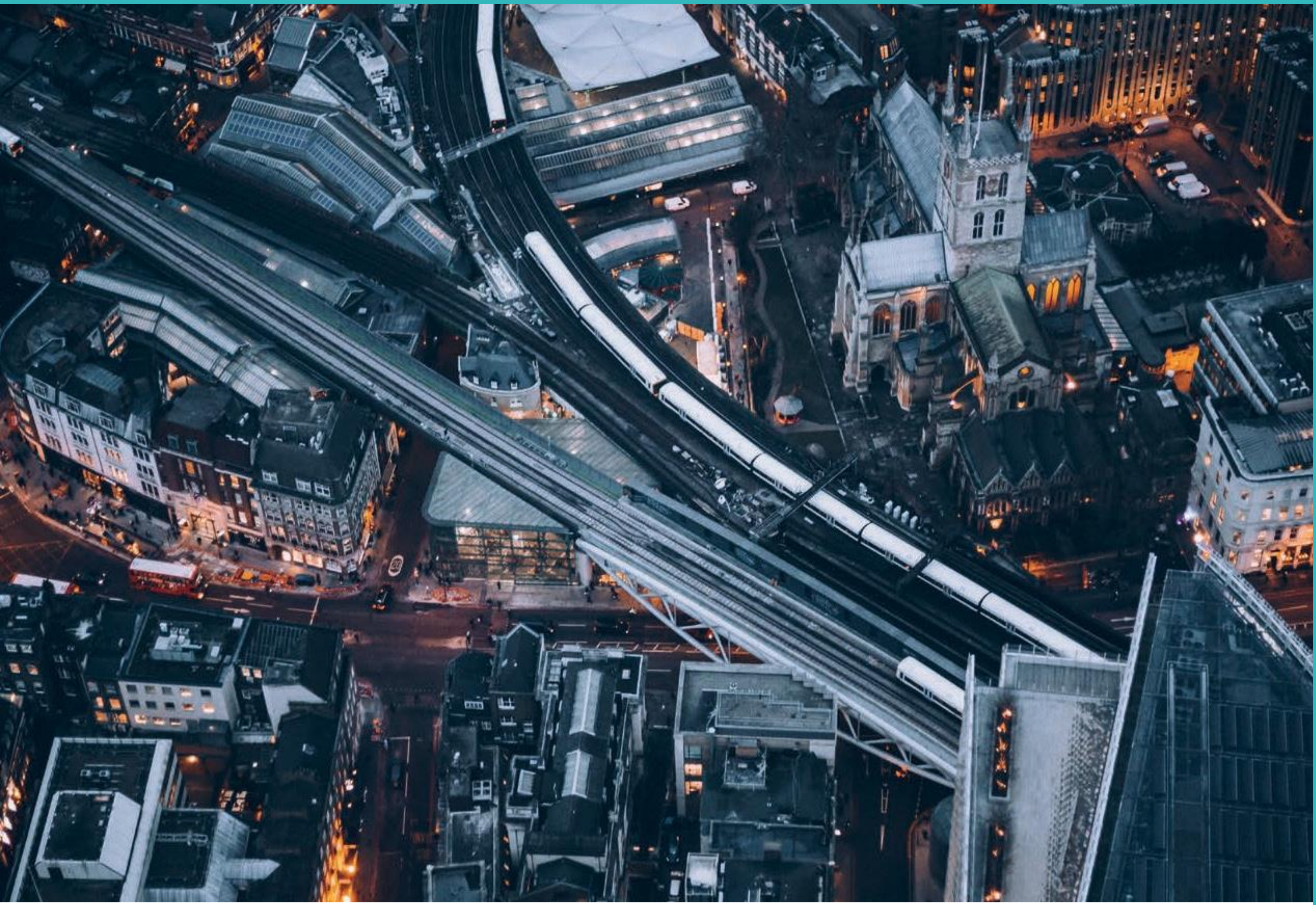
REPORT

LV Pole Top Monitoring Stage 0 Report



technology

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Version History

Date	Version	Author(s)	Notes
27/04/2022	0.1	Mike Lees	Original Draft
02/08/2022	0.2	Mike Lees/ David Roberts	New version for cleaning following several iterations
31/08/2022	0.3	Mike Lees/ David Roberts	Clean draft for Customer Review
14/09/2022	0.4	Mike Lees/ David Roberts	CI & CML figures added to tables in Appendices

Final Approval

Approval	Date	Version	EA Technology Issue Authority
	14/09/2022	0.4	Chris Lowsley

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1. Background and Introduction

Typically, rural (overhead line fed) customers are poorer served than urban (underground cable) customers. With plans for the introduction of proactive fault management on urban underground LV networks, the gap is likely to widen. Customer expectation of more reliable rural and mixed networks is likely to grow, making it increasingly important to improve visibility and management of the LV network, creating a need for better and faster fault location and restoration.

A significant proportion of long duration interruptions to customers' supplies result from faults on the LV network. This results in both a lower income via the IIS incentive, increased operational costs and poorer customer experience than would be the case if these interruptions could be avoided. Mitigating the impact of LV Interruptions requires detection of developing LV faults then localisation of each defect that will develop into a fault, before it produces a supply interruption.

The Foresight Project, undertaken by Northern Powergrid (2017-2021) has developed equipment and methods aimed at finding and fixing LV cable faults, on underground circuits fed from Ground Mounted substations, before they fail. The project has produced a dataset from a fleet of low-cost detectors that is being used to provide health index information for LV underground cable circuits, which are of use in both the areas of Asset Management and Operational Network Management. Asset health is derived from waveform signatures captured by the detectors. Most of the signatures captured are associated with events on the cable networks that 'self-heal' before protection operates (so-called pre-fault events). Once a level of criticality has been reached, additional equipment is then deployed to determine the source of the pre-fault activity and therefore the location of the developing fault. When located, positive proactive action can be taken to ameliorate the impact of unplanned supply interruptions with concomitant improvement in network performance indices and customer satisfaction.

Northern Powergrid (NPg) asked EA Technology (EATL) to scope a project to enable the proactive fault management methods for improving the quality of supply, that have been developed for urban underground networks, to be applied to detection and location of developing faults in network fed from pole mounted equipment. The 1st version proposal produced by EA Technology had eight stages. It aimed to compare installations of a mixture of Guards and VisNet Hubs (both devices were used during the Foresight Project), in order to determine which was the more suitable pole top monitoring device. It also anticipated that there would be a difference between Cable pre-fault breakdown and OHL pre-fault breakdown, hence the pre-fault detection algorithms would need to be modified. Northern Powergrid decided that the scope of this proposal was too wide, so asked EA Technology to produce a proposal with reduced scope, using only one type of device and monitoring the suitability of the existing algorithms for overhead lines. EA Technology proposed a reduced scope project of five stages.

Following a review of the reduced scope proposal, Northern Powergrid asked EA Technology to produce a 3rd version of the proposal. This version was essentially the five stages of the reduced scope (2nd version) proposal followed by a Gate Review of how well the existing algorithms perform for LV overhead line circuits, plus up to three additional stages if these were required. Following a review of this proposal document by Northern Powergrid and discussions with EA Technology, it was agreed that an additional pre-stage was required to plan the project in detail and to assess and select suitable network locations. This was to be followed by a stage gate review meeting at which a Go / No-Go decision for the project would be taken. The program of work in the 4th version of the proposal is:

Stage 0: Detailed project planning, network assessment and selection

Gate: Review possibly revised scope, objectives, project plans and costs. Go / No-Go decision whether to proceed with the project

Stage 1: Integration of Foresight and LV Monitoring functionality in VisNet Hub

Stage 2: Specify, design, build and supply 70 pole mounted monitoring devices, based on the VisNet Hub

Stage 3: Integration of LV OHL condition data from network measurements into a CNAIM model for LV Overhead Line circuits.

Stage 4: Deployment of data collection devices and project data collection system

Stage 5: Monitor the performance of Algorithms and Apps for 18 months

Gate: Review of how well the existing algorithms perform for LV overhead line circuits. Go / No-Go decision on the following project stages:

Stage 6: Modify the algorithms for Pole Mounted Substation use

Stage 7: Develop training material

Stage 8: Review the learning from the project and produce project closedown report

This report is the output from Stage 0 and is the subject matter to be reviewed at the first Gate review. Its primary purpose is to substantiate the required activities and outputs in the proposed future stages such that a Project Definition Document for the ongoing (larger) project can be prepared with increased clarity and joint understanding for Business sign-on.

1.1 Stage 0 Scope

The scope defined in the proposal document[1] states:

EA Technology will work with Northern Powergrid to review the project objectives; plan the project in fine detail; agree division of responsibilities; and processes for coordination of activities, project progress review, milestone achievement and reporting.

It is anticipated that the planning work will be addressed by two virtual meetings, supported by exchange of information and documents using emails.

Statistical analysis of fault data that is supplied by NPg will be undertaken by EATL. The analysis will be reviewed by NPg. All specific site-related assessments will be undertaken by NPg.

The tasks of this stage are:

[1] Proposal No: EA9744 Version 4.0 LV Pole Top Monitoring

1. Review the project objectives. Expand the objectives into a finer level of detail
    a) Identify questions to be addressed by the project
    b) Identify and plan activities to answer these questions
2. Identify the geographic location of each monitoring installation and the specific environmental and installation challenges of each location
    a) Determine selection criteria
    b) Statistical analysis of faults on circuits fed by Pole Mounted Substations
    c) Produce recommendations for numbers of installations and duration of data collection to produce meaningful project outputs
    d) Produce long list of potential monitoring locations
    e) Identify specific installation challenges e.g.:
        - Cellular reception
        - Safety
        - Mounting arrangements
        - Housings
    f) Produce short list of monitoring locations and site-specific requirements
3. Produce detailed proposed project plan.
4. Agree milestones, division of responsibilities, project progress review and reporting processes.
5. Review and if necessary, revise costs

2. Definition of Stage Zero of the project

2.1 Questions addressed by stage zero of the project

The purpose of stage zero of the project is to define the project in more detail than was possible in the project proposal. A number of issues must be considered to produce a detailed project programme. This section addresses stage zero Task 1a) 'Identify questions to be addressed by the project'.

In this section, the issues to be considered are framed as questions that are addressed in stage zero of the project. There are five main questions. Each of these questions has a number of sub-questions which are intended to guide the level of detail to be considered when answering each question. The questions are:

1. Are the project aims, scope and objectives as defined in the project proposal correct and sufficient?
    1.1. If not, then how should they be modified?
    1.2. What questions are to be addressed by the project? e.g.:
        1.2.1. Should the learning from the project be built into CNAIM?

    1.3. What activities are required to answer these questions?
2. What type of circuits will the equipment monitor?
    2.1. What is a generic description of the network / circuits?
    2.2. What are the possible variants of the network / circuits?
    2.3. What are the possible variants of assets to which the equipment will be attached?
    2.4. What information is required from the monitoring?
    2.5. What measurements would be ideal?
    2.6. Are there practical limitations which means measurement compromises must be made?
3. Which circuits should be monitored?
    3.1. What are the circuit selection criteria?
        3.1.1. What variables are of importance?
    3.2. What specific circuit and installation characteristics increase the attractiveness of specific installations?
    3.3. What specific circuit and installation characteristics reduce the attractiveness of specific installations?
4. Is the existing equipment likely to be suitable for the physical environment?
    4.1. What is a generic description of the physical environment to which the equipment will be exposed?
    4.2. Are there any variants or extremes to this physical environment?
    4.3. What are the specifications of the equipment being considered?
    4.4. Are there any out-of-specification conditions?
    4.5. What is the materiality of these out-of-specification conditions?
5. Is the existing equipment likely to be suitable for the electrical environment?
    5.1. What is a generic description of the electrical environment to which the equipment will be exposed?
    5.2. Are there any variants or extremes to this physical environment?
    5.3. What are the specifications of the equipment being considered?
    5.4. Are there any out-of-specification conditions?
    5.5. What is the materiality of these out-of-specification conditions?

These questions are considered in the following sections of this report.

3. Review of Project Aims, Scope and Objectives

1. Are the project aims, scope and objectives as defined in the project proposal correct and sufficient?
    1.1. If not, then how should they be modified?
    1.2. What questions are to be addressed by the project? E.g.:
        1.2.1. Should the learning from the project be built into CNAIM?
    1.3. What activities are required to answer these questions?

Advantage was taken of available time following a meeting to review progress on a Green Recovery Scheme project[2], to hold a short workshop to review the objectives of the PoleTop Monitoring project. NPg was

[2] The specific Green Recovery Scheme Project between NPg and EATL referred to here, covers the purchase of low cost monitoring to be deployed

represented by Mark Marshall and Rebecca Kelly. EATL was represented by Chris Lowsley, David Roberts and Mike Lees.

A walk-through the proposal stimulated discussions including a reappraisal of the project aims. The outcome of these discussions was that the aim is to determine whether proactive fault management techniques developed and in use for underground LV networks can be adapted for practical application in reducing the impact of faults on customers that are not fed from urban, underground networks. The focus of the project should be to enable the improvement of the Quality of Supply from rural (overhead) and mixed (overhead and underground) networks fed from Pole Mounted Substations instead of the "**detection and location of developing faults in network fed from pole mounted equipment**". A good project output would be enabling customers in rural and semi-rural networks to benefit from proactive fault management methods that are being applied to urban underground networks.

It was believed that networks fed by HV overhead lines are in a more challenging environment (both physical and electrical) than urban LV cables meaning that some further scrutiny of the specifications of the proposed monitoring equipment would be required. It was also considered that Monitoring equipment could be subject to short-term loss of supply from HV Overhead network transient faults suggesting that the project should assess whether short-term loss of supply has a material impact on the quality of LV monitoring by pole mounted devices. Lastly, as it was evidenced during the Foresight Project that HV transients cause detectable perturbations on LV networks, it was recognised that there was an opportunity to investigate the potential of using easy to install LV equipment to identify HV networks insights that could ultimately lead to HV performance improvements.

The workshop produced the following output:

- "Restated Project Purpose" i.e. a succinct description of what the project would achieve, provided it was successful;
- Clarified Project Scope
- Confirmed Project Deliverables

These are recorded in sections 3.1- 3.3 below

3.1 Restated Project Purpose

1. Enabling the proactive fault management methods, for improving the quality of supply that have been developed for urban underground networks, to be applied to rural and mixed networks.

2. Improving the Quality of Supply for rural customers, including vulnerable customers. Rural customers are typically poorer served than urban customers.

3. Assessing the suitability of the equipment in a more challenging environment (both physical and electrical) and adapting where necessary.

4. Providing tools and a solution for applying proactive fault management methods to rural and mixed networks.

3.2 Clarified Project Scope

The project will consider the environmental challenges, both physical and electrical, of rural and mixed LV networks. It will assess the suitability, for this environment, of equipment deployed in the Foresight project and adapt the equipment where necessary.

Equipment will be deployed at substations chosen by Northern Powergrid. Feeders will be monitored for 18 months[3].

The project will assess the efficacy for rural OHL and mixed circuits, of the existing pre-fault detection algorithms, also the impedance to fault algorithms and their use for location of defects and faults in rural OHL and mixed circuits. Any gaps and shortfalls of the existing algorithms will be identified.

A gate review will determine whether it is appropriate to modify the algorithms then assess improvements in performance[4].

Draft equipment specifications and network operating procedure documents will be developed.

Learning from the project will be reviewed and a project closedown report will be produced.

Direct monitoring of HV circuits is out of scope of this project. No equipment will be connected to HV circuits. However, it is possible that some events on the HV and higher voltage networks will be detected by monitoring devices connected to the LV networks.

3.3 Confirmed Project Deliverables

Prototype low-cost, pole-mounted sensor devices, which incorporate pre-fault recognition algorithms, that are suitable for deployment in rural and mixed networks.

A strategy and protocol for detection and location of incipient faults on LV rural OHL and mixed circuits.

Knowledge relating to the evolution of rural and mixed network circuit defects into supply interrupting faults using a method which minimises the impact on customers.

Tools and a solution for applying proactive fault management methods to improve the quality of supply of rural and mixed networks.

Draft equipment specifications and network operating procedure documents to enable transfer into business as usual.

A means to improve the level of service that is provided to customers that are fed by rural and mixed networks, including vulnerable customers, that is applicable to all similar GB LV networks.

Subsequent Stage 0 interactions with NPg, considering the practical aspects of an acceptable project delivery, led to further changes to the project scope and deliverables. These are recorded in Sections 3.4 and have been used to shape the detailed project plan in Section 8.

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[3] This was later reduced to 12 months.
[4] Due to accelerated timeframes in the finally proposed project, the stage gate was dropped and a task included to improve the algorithms where shortfalls were identified.

3.4 Questions to be answered by the Project

A series of meetings and discussions between April and August, facilitated by the appointed NPg Project Manager, introduced other Northern Powergrid stakeholder requirements to those refocussed in March 2022 and offered further clarification of the desirable size and shape of a practically deliverable project.

Key amongst the further requirements was the recognition that load monitoring of rural LV networks would play a role in managing the future network performance as rural customers transition to net zero carbon emissions. An emphasis was therefore placed on the integration of load monitoring with pre-fault event capture in the proposed monitoring systems.

Significantly for the go / no-gate gate for the undertaking of the larger project, it was also established within Northern Powergrid that fitting of monitoring equipment to pole mounted substations, both for this project, and for business as usual, was possible, without having to disconnect supplies to connected customers.

The fundamental questions to be answered by the project have been distilled out of the conversations and are listed here:

1. Is it possible to apply / adapt existing proactive fault management algorithms and methods to customers in rural areas fed by LV overhead line and mixed overhead line and cable circuits?
    a. Can existing equipment and systems used in the Foresight project be used to detect, localise and locate pre-fault activity on overhead line and mixed overhead and underground networks?
    b. Do overhead line assets fed from Pole mounted substations provide pre-fault signatures capable of giving predictive insights into impending off-supply events?
    c. How might the systems be used operationally to improve quality of supply for customers fed from pole mounted substations with overhead and mixed overhead and underground LV circuits?
2. What are the functional and practical design requirements for instruments to be used for monitoring overhead and mixed overhead and underground LV networks fed from pole mounted substations?
    a. Can the same equipment used to detect, localise and locate pre-fault events also provide circuit and transformer load monitoring to help manage risks of increased load on these networks during the transition to net zero carbon emissions?
    b. Is it possible to provide additional insights relating to the condition and future reliability of HV overhead line networks from these pole mounted substation LV monitoring systems?
3. Can low-cost detectors / monitors with the required functionality be practically deployed to these networks?
    a. What are the practical requirements for installing, commissioning, operating and decommissioning suitable monitoring systems on pole mounted substations?

Accelerated timescales for the project led to stage relating to the integration of LV Overhead Line condition data into a CNAIM Asset Management Model being taken out of scope for the proposed project.

4. Circuit Types to be Monitored

2. What type of circuits will the equipment monitor?
    2.1. What is a generic description of the network / circuits?
    2.2. What are the possible variants of the network / circuits?
    2.3. What are the possible variants of assets to which the equipment will be attached?
        2.3.1. What are the consequences of those variations on the monitoring equipment
    2.4. What information is required from the monitoring?
    2.5. What measurements would be ideal?

2.1 What is the generic description of network circuits?

The network circuits to be monitored by the project are those that best represent the networks for which solutions to enable the use of proactive fault management methods are sought. The selected circuits for monitoring will therefore be LV circuits fed from Pole Mounted Substations that are either made up of purely LV overhead lines or made up from a combination of LV overhead line and underground cable sections (mixed).

2.2 What are the possible variants of the network / circuits?

The variants are various types and sizes of overhead conductor (typically bare wire or Arial Bundled (insulated) conductor (ABC)) and various types and sizes of underground cables[5]. Fault and Pre-Fault waveforms from LV underground cables are well understood. Those from LV overhead lines are less well understood and are the primary subject for the project investigations.

2.3 What are the possible variants of assets to which the equipment will be attached?

It is intended that the project monitoring equipment is connected to the LV side of Pole Mounted Substations. There are two main construction types of pole mounted substations – those with a single pole construction (for smaller transformers <100kVA) and those with double pole construction (for transformers 100kVA or above). The latter are also referred to as H poles. Substation Transformers may be 3 phase or single phase. Single phase transformers are fed from 2 of the HV phases but deliver a single phase to neutral LV supply.

Each pole mounted substation feeds one or more LV circuits (Feeders) via a fuse or set of fuses mounted lower on the pole than the High Voltage Assets but still above anticlimbing protection (i.e. not accessible from

[5] A more detailed list of the various network types, asset types and topologies considered in the Stage 0 Work is recorded in Appendix I

ground level). As Northern Powergrid fault data and reporting is on a per circuit basis, and to line-up with monitoring on LV underground cables circuits, each phase of each outgoing circuit is to be monitored.

High voltage protection for the substation may be on the same structure or on a separate pole though this variation is not considered material for this project.

2.4 What information is required from the monitoring?

The information required from the monitoring is that which can possibly be used to improve the reliability and quality of supply on the monitored networks:

- Pre-fault waveforms for proactive fault intervention and condition assessment: Voltage and current waveform captures at the same resolution as the data for underground cable networks is required to assess the applicability of the existing LV network insight algorithms.
- Time series load information for network planning and overload mitigation: Knowledge of the time-series rms loading of individual circuits and the feeding transformer is required, to improve network visibility, to reduce risk due to load growth resulting from net-zero customer behaviour shifts.
- Information measured at LV that provides insights as to the operating condition of the High Voltage networks feeding the monitored circuits .

2.5 What measurements would be ideal?

Measurements of voltage and current is required at sufficient resolution to provide waveform information that can be compared with that previously gathered for underground networks. Current measurements are required on each phase of each outgoing feeder. Ideally, but not mandated, is the measurement of the neutral current on each outgoing feeder in addition to the phases.

Other measurements to be considered if practical include magnetic field sensors and weather and temperature data that may, later, inform actual asset temperatures using thermal models with rms values as inputs

2.6 Are there practical limitations which means measurement compromises must be made?

The equipment needs to be low-cost and easy to deploy (e.g. small enough to be able to fit in the available space and not require an outage) to be appropriate for this use case. Safety is paramount. Access to measurements is therefore required at a safe distance from the HV equipment and installation of sensors able to be completed using standard live LV techniques and equipment without interrupting customer supplies. The accelerated timescale of this project requires that suitable off-the-shelf measurement equipment, sensors, connectors and housings are used for the project.

5. Monitoring Site Selection Criteria

3. Which circuits should be monitored?
    3.1. What are the circuit selection criteria?
    3.2. What variables are of importance?
        3.2.1. What specific circuit and installation characteristics increase the attractiveness of specific installations?
    3.3. What specific circuit and installation characteristics reduce the attractiveness of specific installations?

Part 2 of the Scope of this Stage 0 Project (Section 1.1.) was to identify the geographic locations of monitoring installations and specific environmental and installation challenges. This was to be done using statistical analysis to determine a 'long list' of potential candidate sites from which a 'short list' of intended sites would be created using further criteria generated by the Stage 0 project team (NPg and EATL). The selection criteria would aim to provide the maximum chance of obtaining sufficient data to meet the project objectives whilst recognising the requirement for efficiency (deliverability) in the main project execution.

The long list was generated by analysis of the fault history of LV circuits fed by pole mounted substations, to identify those circuits that have experienced faults in recent history, and which were of a type of interest to the Polesight Project. This approach was borrowed from the Foresight Project where it was proved that underground LV network circuits with recent fault history, unless they have been recently replaced, were likely to have further faults and therefore much more likely than a more random sample to generate useful data for the project. Details of the analysis can be found in Section 6.

5.1 Selection criteria

Timeframes and resource available to the project would not allow every possible variation of pole mounted substations and the circuits supplied from them to be included within the trial. The variations/variables of importance between the targeted rural networks and previously monitored urban networks, and those between various types of pole mounted substations, were therefore determined and their relevance discussed. The outcomes from these discussions shaped the final selection criteria for the candidate monitoring sites for the main project.

The following Variables of Importance were identified at an NPg / EATL meeting on 23rd March 2022:

- **Different environmental conditions** (physical and electrical) between Pole Mounted substation and Ground mounted substations
    - The standards for monitoring on pole mounted substations are likely to be different to those for ground mounted substations.
    - HV Overhead Line (fuse protection) will allow loss of single HV phases causing abnormal voltages on the secondary (monitoring side) that may affect monitoring function and insights. Pole mounted substations fed by HV overhead lines are to be targeted to explore these differences

- Different designs of pole mounted substations will have different installation challenges. A variety of different substations will be included as far as is practical. A general installation method will be established. The short list will be oversubscribed allowing sites found to present challenges to the agreed method to be noted but bypassed with other alternatives available
- A variety of circuit components and conductor types (e.g. Bare wire, Aerial Bundled Conductors) may present different signatures of developing faults.
    - Many circuits will be hybrid i.e. they will consist of various sections of different conductor, including underground cable sections. As far as is possible, monitoring should include samples of all types.
    - It is impractical to target pure circuit types and hybrid circuits are typical. Hybrid circuit types will not be specifically targeted but will not be excluded.
- Potentially different load characteristics than for urban networks. Different load types on rural networks, coupled with lower fault levels that reduce fault current yet exaggerate the voltage disturbance during current changes may affect the ability of the existing algorithms to distinguish between load/ generation and fault events

Following the meeting in March 2022, a number of options for project delivery were identified by EATL to help develop the final selection criteria for the installation sites. These options were discussed during an NPg / EATL Teams meeting on 27th July 2022 with the outcomes as noted below.

1) To explore the practicality of fitting low-cost equipment to the population of pole mounted substations, a number of PM substation types should be targeted

Outcome: Suitable Single pole and H Pole sites will be sought. Predominantly three phase transformers as these have the most extensive LV networks but also a few single-phase transformers. To avoid outages, selected sites must be capable of voltage connections using Insulation Piercing Connectors. Any HV-side voltage can be considered (20kV or 11kV are equally valid)

Discussion:

- The type of fuse-holder (rotary or slot in) is immaterial as they will not be modified during installation
- LV cabling (connected to and from the fuses) is required to be suitable for the connection of IPC connectors – Phase and Neutral IPCs will be required. The phase connectors are to be installed downstream of the fuses on one of the circuits
- The primary target will be 3 phase transformers. Also seek to trial a few single-phase transformers
- No specific effort will be made to select transformers with the max expected number of fused circuits
- No specific project task is required to trial installations in controlled environment at the training school

2) To gain insights relevant to creating a condition-based measurement and predicting time to failure.

Outcome: Selection of suitable sites for installation of pole mounted monitors will consider only circuits that have had a previous fault history. No specific effort is required to identify purely overhead lines as long as there are some overhead line sections of whatever type on the LV circuits being fed. No specific effort is required to target multiple sites within the same protection zone to aid with HV event insights. Selected sites will include industrial and domestic customers.

Discussion:

- Faults and pre-faults will be sought on:
  - All overhead circuit (ABC)
  - All Overhead Circuit (Open Wire)
  - All overhead Circuits (mixed ABC and Open Wire)
  - Mixed overhead and underground circuits
    - Expect transient faults related to cable boxes and transitions
- Select some circuits with domestic load and others with more industrial (farming / pumps) to learn about non-fault event detection categorisation and rejection
- No specific effort will be made to select circuits that do not have previous fault history as control
- Circuits are to be monitored for sufficiently long to get statistically defendable 'first-look'
- No specific effort will be made to ensure that more than one device is connected in every protection zone to support HV fault or voltage change insights
- It is considered probable that some of the 6000 Guard devices that are to be installed in ground mounted substations as part of a separate NPg monitoring initiative will be monitoring LV circuits with overhead line sections. Where this is recognised and practical to do so, this data can be added into that gathered from the pole mounted monitors proposed in the Polesight project

3) To determine whether transformer size has an impact on detection settings and location and relative assessment of circuit health

Outcome: As a minimum, 200KVA and 100kVA transformers will be included in the site selection. To allow inclusion of the other criteria regarding structure type and single-phase transformers every effort will be made to include a selection of those in the short list of selected sites

4) To determine the effectiveness of the detection and location algorithms

Outcome: Circuits will be targeted that have a known fault record or suspect assets deemed likely to give fault evidence during monitoring period. Enough circuits should be targeted to ensure a steady supply of relevant data.

Discussion:

The analysis of historical faults on circuits supplied by pole mounted substations (see section 6) should adequately target circuits. The number of circuits to be monitored by pole mounted equipment will be constrained by the available project timescales and installation resource. Additional data on overhead line sections, particularly for the mixed circuit type (overhead line and cable), may become available by including data from the existing 700 installed Guards the scheduled 6000 Guard installations (some of which may be monitoring circuits with overhead line sections) in this project.

5) Is load monitoring material to this project?

Outcome: Selection Criteria should allow for a variety of different loads to be monitored. As transformer loading is not currently known, selection of potentially overloaded transformers will not form part of the selection criteria.

Discussion:

- Load increase is felt to be a risk to the future reliability and performance of the network. Visibility of the load should therefore be added to the functional requirements for the monitoring systems to be deployed/trialled on the project.
- Transformer and circuit load should be monitored
    - Transformer load can be calculated by adding the circuit loads
- As loading on candidate pole mounted transformers is unknown, it cannot form part of the selection criteria
- Both monitors being considered for the trial are capable of load monitoring
    - The Guard returns spot measurements of RMS load at 15-minute intervals.
    - The VisNet returns half hour average load every 10 minutes in the standard monitoring App
- Compare simple RMS spot measurements (Guard) versus on-board computation of average values (VisNet) for sufficiency for the use case
- Monitor for 4 seasons

6) To determine the suitableness of standard equipment and allow a general specification for an effective device to be drawn up

Outcome: Visnet Hub and Guard monitors will be deployed on separate sites, including Single Pole and H Pole sites. VisNets should be prioritised to sites with more than 2 LV circuits. Selection criteria for the substation sites remains unchanged by this requirement.

Discussion:

- Trial Guards and VisNets on separate sites (unlikely there is space for dual deployment)
- Compare the practicality of deployment on similar substation designs
- Observe the impact of higher functionality of VisNet Hub versus additional cost, size, power requirements
- Record installation issues and things that went well and ensure that photographic evidence and witnessed documentation is harvested

7) Ensuring the project is deliverable

Outcome: Sites will be selected in the smallest achievable geographic area that satisfies the other selection criteria, to minimise the number of linesmen teams required. Since installation will be by two-person teams with a ladder making access on foot, accessibility should not be an issue. If communication or suitability for installation without outage or other issues are identified at a shortlisted site which exclude the site from the project, then installation at such sites will be aborted. The selection criteria will be used to over-allocate the candidate sites to allow for this possibility. Installation will continue in ranking order until all equipment has been installed. The monitoring period is determined by the end date of the project which is 31st March 2024.

Discussion:

- Target a few geographical areas with a range of different designs to ensure efficient deployment and knowledgeable and engaged NPg personnel.
- Select the number of sites that is sufficiently low for the monitoring to be efficiently rolled out and decommissioned at the end of the project without undue impact on other NPg initiatives
- Make sure the PMT is accessible during the monitoring period (easements, crops, vehicular access, customer permissions)
- Make sure the networks are not targeted for refurb or planned work
- Make sure communication infrastructure is sufficiently robust to ensure data remote data collection over the monitoring period
- Note but avoid designs that create engineering difficulties that might compromise existing assets or customer supplies or become a liability.
    - Designs for these to be separately considered should the main project deliver positive benefits
    - Over-allocate PM substations in an area to have fallback sites if prime candidate unsuitable
- Determine methods whereby equipment can be installed, commissioned, inspected decommissioned and uninstalled with circuits live and customer supplies unaffected
- Select a monitoring period sufficiently short for the project to maintain momentum and deliver the necessary learning

8) If the work to determine HV insights from low-cost monitoring is deemed important

Outcome: During site selection it will be determined whether sites fall within the same HV protection zone. Preferably, but not exhaustively, sites will be identified in more than one HV protection zone to extend the reach of the project in detecting separate HV events.

Discussion:

- Select circuits with likelihood of HV fault data
- Select circuits with generation connected
- Select circuits that are likely to vary in fault level – some on spurs and others on main line closer to primary substations
- Monitor several substations on the same circuit for comparative analysis

The eventual selection criteria decided to be implemented to select the candidate sites were:

For the Long List

- Substations that had LV circuits with at least one LV OH line fault record between 2016 and 2021 and at least one fault record in 2021/22 (see section 6)

For the Short List

- Substations that have relatively high number of LV OH line fault record in 2021/22, preferably with multiple faults in between 2016 and 2021 faults.
- Only Pole mounted substations fed by HV overhead lines
  - Ground mounted subs rejected (some GM subs with LV overhead circuits expected to be monitored by 6000 Guards)
- Mixture of transformer sizes. Mainly 100kVA and 200kVA as these have most extensive LV networks. No smaller than 50kVA.
- Mixture of single pole and H pole substation but mostly H Pole – reflecting larger transformers
- Mostly 3 phase substations but some single phase
- All in same geographic area for convenience of fitter training/ management/ project efficiency
- Any HV Voltage – likely to be the same for a particular geographic area
- Mostly on separate HV feeders (to increase chances of HV faults being encountered)
- Preference for substations which are easily accessible (by roads etc)
- Substations to be selected in areas with decent GSM signal coverage for data backhaul
- Substations with LV circuits that have significant overhead line sections
  - Substations with only LV cable circuits rejected
- A selection of substations with an expected predominance of domestic load and some with an expected predominance of Industrial Load

A practical number of substations for monitoring (in one particular area) was deemed to be 20.

30 substations were identified for the short list, overallocated to enable installation crews to abort impractical sites in favour of others nearby for efficient monitoring system roll out.

A short list of 30 substations was created using the selection criteria applied to an area of Northern Powergrid's network in Northumberland. This short list is included in Appendix II.

6. Monitoring Site Selection

6.1 Long list of potential monitoring locations

6.1.1 Selecting OHL faults from fault records

Fault records from circuits fed by Pole Mounted Substations were analysed to extract relevant fault statistics. LV Fault Data from 2016 to 2021 which was provided by NPg was pivoted to show the number of incidents per substation (plus CML and CI) in each reg year and the total across 2016-21, then filtered .to show only Ofgem Category = "Overhead Lines - Asset Repair / Replacement" plus Ofgem Category = "Overhead"

This list was sorted by number of incidents high to low and the first 200 substations selected.

Subsequently fault data for 2021/22 was provided by NPg This data was treated in the same way to produce another list of 200 substations. The lists were compared and a further 19 substations that did not have faults in 2016/21 were identified.

The list was reviewed by NPg and a significant number of substations identified in this way are ground mounted. Whilst the list might be useful for targeting some of the 6000 Guards, it is not useful for selecting sites for pole-mounted installations.

6.1.2 Comparing Fault records with support-mounted substation records

NPg provided data, extracted from GIS records, of all network sites. This data was filtered to select only pole mounted secondary sites. In order to join the site data with the fault data, it was necessary to transform the site_name into the same format as the text in the S/S Key field of the Fault data.

A set of records of faults recorded for LV circuits fed by pole mounted secondary substations was then created by an inner join of the two data sets using the S/S Key field of the Fault data and the transformed site_name of the pole mounted secondary sites as the key field. The resulting dataset was pivoted to show the total number of incidents per substation across 2016-21 and sorted by number of incidents high to low. The number of incidents recorded for these substations in 2020/21 was subsequently added to the dataset.

The number of faults and number of pole mounted substations were counted for each town_name field and ranked by Substation count and Fault count in the period 2016/21and the Substation count and fault count in 2021/22. The variation between the two periods was explored for substations in York, which had the highest number of substations and faults. The variation in ranking between the two periods is greater for the fault count than for the number of substations, which might be expected. Therefore it is probably better for substation selection to choose substations that have relatively high numbers of faults in 2021/22, which also have relatively high numbers of faults in 2016/21, rather than the other way around.

The fault records in reg year 2021/22 for the top two substations in York by the Fault Count in 2021/22 were examined. Both of these substations are good candidates for monitoring. In the first case, there is a mixture of Non-Damage and Damage faults. In the second case, there is a sequence of Non-Damage faults. In both cases there are non-damage faults without a final damage fault.

This is the recommended methodology to identify suitable substations in a chosen area. A long list of 200 potential monitoring sites, ranked by the number of faults experienced in 2021/22, is shown in Appendix III.

6.2 Specific installation challenges of each location on the long list

Cellular reception

This will be assessed at high level for short list selection by looking at geographical area signal strength maps from cellular communications providers. Later, this will be re-assessed by the installation team before installation at each of the pre-selected sites. If the reception is unacceptable then installation will be aborted and the installation team shall move to the next installation site on the list.

Safety

Mounting arrangements

Housings

These three installation challenges were initially assessed by Peter Sanderson at a meeting with Francis Shillitoe (NPg Project Manager for Polesight Stage 0 Project) at Kepier training school on 25/7/22.

These installation challenges will be reassessed during the project in NPg workshops involving Standards, Safety and Smart Grid to provide technical requirements.

6.3 Short list of monitoring locations and site-specific requirements

The short list will be prepared by filtering the long list using the selection criteria decided in Section 5. The short list will be overallocated allowing site teams to assess the site conditions at close range and, if there are practical difficulties, to abort the installation in favour of the next one on the list. The short list selected is recorded in Appendix II.

7. Suitability of Existing Equipment

4. Is the existing equipment likely to be suitable for the physical environment?
    - 4.1. What is a generic description of the physical environment to which the equipment will be exposed?
    - 4.2. Are there any variants or extremes to this physical environment?
    - 4.3. What are the specifications of the equipment being considered?
    - 4.4. Are there any out-of-specification conditions?
    - 4.5. What is the materiality of these out-of-specification conditions?

A detailed review of the requirements for equipment to provide LV Monitoring for Pole Mounted Substations is proposed in the main project. Here, a short review was carried out to consider whether the existing EA Technology LV monitoring equipment (VisNet Hub and Guard) would be suitable as a prototype Pole Mounted Substation LV Monitoring system for the purposes of the trial.

The pole mounted substation installation represents an unsheltered outdoor environment. The equipment will be mounted at height, above anti-climbing guards. Physical and weather protection will be required.

From the brief review of NPg's 'Technical Specification for Secondary Distribution Substation Monitoring Systems' Document NPS/007/021 , the following information regarding pole mounted equipment was found (paraphrased here rather than quoted):

- In addition to the general requirements for indoor substation monitoring equipment of -25 to +55 degrees C and relative humidity between 0-90% non-condensing, that designed for outdoor installation is required to have the additional environmental features:
    - Be protected against ingress to BS EN 60529 IP44D or better
    - Be demonstrated to be stable against UV light in accordance with BS ISO 4582
    - Be immune to polluted coastal locations as evidenced by tests to ISO 9227, 7253, 4628, 10289
- In addition to this, when mounting on electricity poles above 3.65m, the equipment is required to have the additional feature below:
    - Be protected against ingress to BS EN 60529 IP45 or better

To ensure additional protection against the environment and to make it less obvious to vandals, NPg standards and safety specialists recommended the prototype Polesight monitor (VisNet or Guard) should be mounted in a separate box/cabinet before installing on the Pole Mounted substation, behind the Fuses and secured to the pole with coach bolts. A suitable box/cabinet is therefore to be sought in the final design with the above requirements in mind[6].

The existing equipment leads have not been tested for UV stability. There is, however, evidence from installations of the voltage and current leads outdoor (in a pole mounted installation) in Australia that the insulation of the Rogowski coils and voltage leads were not adversely affected by 9 months in operation in the extreme UV of that country. It was therefore considered that the risk from UV exposure to the leads in the UK, for short term, prototype installation, was low. Pending more detailed investigations in the design part of Workstream 1 of the main project, the equipment in this format (boxed with leads connected, using suitable connectors, to existing conductors on the pole mounted structure) was deemed suitable to be put forward for the trial.

8. Detailed proposed project plan.

This section serves two purposes. Firstly (as the title suggests) as the repository for the suggested project plan for the ongoing Polesight Project; indicating tasks, costs and timescales. And secondly, as the major part of the format and words for a Project Proposal to be sent to Northern Powergrid. Alongside a Project Definition Document (business case) prepared by the NPg Stage 0 Project Manager, the Project Proposal will act as the input to the Stage Gate process that will decide whether to proceed with the Polesight Project or not.

Section 3.4 defined three questions to be answered by the project. The project has thus been set out into three separate workstreams, each of which addresses one of the questions. The three workstreams are:

- Pole Mounted Device Design and Development
- Pole Mounted Device Installation and Operation
- Pre-fault Data Analysis and Actionable Insights

8.1 Project Background and Purpose

Following the Stage 0 reviews of the proposed Polesight Project, the main purpose remains to determine whether proactive fault management techniques developed, and in use for underground LV networks, can be adapted for practical application in reducing the impact of faults on customers fed from Overhead Line networks. In pursuing this purpose, LV monitoring will be installed at selected pole mounted substations. The monitoring will prioritise LV overhead circuits and mixed overhead and underground circuits fed by Pole Mounted substations over pure underground circuits.

[6] Note that both VisNet and Guard meet the additional IP45 requirement without the additional enclosure. Also note that, on the standard devices, status LEDs are lit during normal service and without an additional enclosure, this makes them particularly visible on a pole structure at night

At the request of other stakeholders within Northern Powergrid, the Polesight Project will also take a fuller look at the opportunities and practicalities of also providing load monitoring and other data that could provide other potentially valuable network performance insights from the same installed systems.

The project aligns with Northern Powergrid's innovation strategy as part of their continued commitment to find ways to deliver improvements and best value to their customers via the deployment of a more intelligent and flexible smart grid. Faster localisation and restoration of faults, plus detecting and locating developing LV faults before they result in supply interruptions, both within overhead line conductors/fittings and associated underground cable systems, would significantly improve quality of supply of customers that are reliant on these networks. It would ensure that rural customers are inclusively able to benefit from proactive fault management methods currently envisaged for their urban neighbours.

The project will build on the Foresight learning and will provide Northern Powergrid with an insight of what is possible with respect to being able to pro-actively manage these networks and reduce the number of unplanned interruptions whilst increasing the Quality of Supply to customers. It will also improve understanding of indicative pre-fault behaviour relating to pole mounted substations, their outgoing circuits and the development of management options for LV rural overhead line and mixed networks.

Some of the Guards already installed in Ground Mounted (GM) substations (plus a proportion of those from the 6000 additional guards expected to be rolled out during 2023) will be monitoring LV circuits with overhead line sections. Data from installed GM substation Guards which experienced overhead line faults during the monitoring period of the project will be harvested and analysed for supporting evidence of predictive insights.

Rural LV networks are large but connected customer numbers are small and access to equipment and measuring points is limited. They have had little monitoring to-date and no condition information relating to potential faults. If monitoring is to be introduced, a single piece of monitoring equipment providing multiple monitoring duties makes the most sense. The project will consider the environmental challenges, both physical and electrical, of rural and mixed networks. It will assess the suitability of equipment deployed in the Foresight project in this environment and use this assessment to design the prototype project monitoring systems. Near the end of the project, using learning from the practical application of the devices and the information they provide, suggested updates to Northern Powergrid's Monitoring Specifications and, where appropriate, installation instructions for pole mounted substation monitoring will be drafted. Equipment will be deployed at substations chosen by Northern Powergrid.

8.2 Workstream 1: Pole Mounted Device Design and Development

Scope: To assess the suitability of, and if necessary modify, Guard and VisNet Devices so that they are capable of being installed outdoors at a pole mounted substation.

This workstream aims to answer the question:

What are the functional and practical design requirements for instruments to be used for monitoring overhead and mixed overhead and underground LV networks fed from pole mounted substations?

- Can the same equipment used to detect, localise and locate pre-fault events also provide circuit and transformer load monitoring to help manage risks of increased load on these networks during the transition to net zero carbon emissions?

- Is it possible to provide additional insights relating to the condition and future reliability of HV overhead line networks from these pole mounted substation LV monitoring systems?

8.2.1 Workstream 1: EATL Scope of Work

WS1: Specify, design, build and supply 20 pole mounted monitoring systems, based on the VisNet Hub and the Guard, report on the performance of the equipment and update Technical Specifications

It is proposed to provide equal numbers of two alternative pole mounted monitoring devices, one based on the VisNet device and the other based on the Guard device.

Both devices have similar electrical and physical environmental specifications. They are both able to detect capture and return waveforms though the triggering strategies differ slightly. They are both able to provide the data required for EA Technology's location services though the VisNet location service is more mature and automated services are already available.

The advantages of the VisNet Hub include:

- Larger size. Can monitor up to 24 separate currents (in 6 sets of 4) and 3 voltages;
- Specific functions (Apps) can be individually updated and new apps can be developed for specific additional functions. It is designed to be more flexible and have fewer constraints when updating software and algorithms than other LV monitoring devices, including EA Technology's Guard.
    - Apps for Pre-Fault Event Waveform Capture and for Load Monitoring already exist. Both run concurrently
- Load Monitoring reports 30-minute average RMS Currents and Voltages as well as Real and Reactive Power. Reporting frequency for the Load information is configurable. In the standard arrangement values are returned every 10 minutes.
- Default triggering on current.
- Mature systems for alarms and alerts

In contrast, the advantages of the Guard include:

- Smaller size than the VisNet Hub
    - 8 individual currents and 3 voltages can be monitored.
- Simple design specifically tailored for quick installation
- Simple spot measurements of rms currents and voltages returned every 15 minutes

Default triggering includes triggering on Voltage Disturbances. Following consultation with Northern Powergrid safety and standards specialists in stage zero of the project, each monitoring device[7] will be pre-mounted in a box/ enclosure. The box/enclosure is to be suitable for installation on a pole by screwing two coach bolts into the pole. The tasks of this stage are:

[7] Although both the Visnet Hub and Guard devices satisfy the IP ratings of the NPg NPS (ref), NPg standard engineers believe that additional protection makes sense to provide additional environmental and physical protection as well as reducing the risk of third party damage to the equipment.

Task 1: Review specifications and functionality of the proposed monitoring equipment (Visnet Hub device and the Guard device, plus ancillary equipment, including Rogowski coils, voltage connections, leads etc.) against relevant NPg specifications, including specifications for pole mounted equipment and monitoring.

Task 2: Confirm that the specification and functionality of the proposed monitoring equipment is suitable for the purposes of the project. Identify and record any modifications or additions that would be required to the proposed monitoring equipment to achieve conformance for BaU.

Task 3: Select equipment housing(s) and connections for the monitoring equipment, suitable for mounting on a wooden pole OHL support.

Task 4: Supply 10 Visnet Hub devices and 10 Guard devices and sensors. The devices fitted in a box, which is suitable for installation on a pole by screwing two coach bolts into the pole.

Task 5: Provide quarterly comparative reports on the performance of the equipment for provision of load monitoring on rural LV networks

Task 6: Provide quarterly comparative reports on the merits of using Pole mounted substation LV monitoring to provide actionable insights on HV Network events and operating conditions

Task 7: Use feedback from workstream 2 and 3 to confirm the requirements for, and produce a draft technical specification for, future pole mounted substation LV monitoring equipment based on learning. Suggested draft wording covering pole mounted installations will added to the NPg Technical Specification for Secondary Substation Monitoring Systems

8.3 Workstream 2: Pole Mounted Device Installation and Operation

This workstream aims to answer the question:

Can low-cost detectors/ monitors with the required functionality be practically deployed to these networks?

- What are the practical requirements for installing, commissioning, operating and decommissioning suitable monitoring systems on pole mounted substations?

8.3.1 Workstream 2 EATL Scope of Work

WS2: Deployment of data collection devices and project data collection system

This price includes the provision of 12 months Data Communications and Hosting Services by EA Technology. Data backhaul will use EA Technology SIM cards. Data will be hosted on EA Technology's S360 database and use existing User Interfaces to access the data for the purposes of the research, and generation and recording of learning.

Northern Powergrid will install and commission the pole mounted monitoring devices.

The tasks of this stage are:

Task 1: Set up data collection infrastructure, data warehouse and analysis system

Task 2: Data backhaul, Hosting and system support services for 12 months

Task 3: Support NPg in drafting installation/ operation and decommissioning instructions and training material for the pole mounted monitoring systems

Task 4: Support NPg by delivering orientation training on various supplied systems (e.g. Set-up. Commissioning. UIs) to NPg staff from the installation area (at NPg local offices/ depot)

Task 5: Attend early installation to record learning & update the instructions/ training material accordingly

Task 6: Monthly report on the numbers and locations of successfully commissioned devices and any exceptions and issues and learning related to the installation, ongoing operation and decommissioning of the monitoring systems.

Task 7: Attend decommissioning site to record learning & update the instructions/ training material accordingly

Task 8: Assess the durability and reliability of installed equipment at the end of the monitoring period and identify improvements where necessary.

Task 9: Support NPg in producing draft amendments to standards (NPS) documentation for installation of Pole Mounted Substation Monitoring Equipment

8.4 Workstream 3: Pre-Fault Data Analysis and Actionable Insights

This workstream aims to answer the question:

Is it possible to apply/ adapt existing proactive fault management algorithms and methods to customers in rural areas fed by LV overhead line and mixed overhead line and cable circuits?

- Can existing equipment and systems used in the Foresight project be used to detect, localise and locate pre-fault activity on overhead line and mixed overhead and underground networks?
- Do overhead line assets fed from Pole mounted substations provide pre-fault signatures capable of giving predictive insights into impending off-supply events?
- How might the systems be used operationally to improve quality of supply for customers fed from pole mounted substations with overhead and mixed overhead and underground LV circuits?

8.4.1 Workstream 3 EATL Scope of Work

WS3: Monitor the performance of Algorithms and Apps

The performance of existing pre-fault detection algorithms and fault prediction algorithms, which have been developed in the Foresight project, will be assessed for their suitability and applicability to LV OHL. Changes to the algorithms and additions of categorisations will be drafted where shortfalls are identified. The tasks of this stage are:

Task 1: Production of a Monthly short report during the monitoring period on the numbers and locations (substation / feeder) of successfully detected pre-faults, other events (such as Load events) and any learning accrued.

Task 2: Tracking and tracing of 25 possible sources of selected transient events including tracking developing faults to actual fault status. We may track more than one event from some devices and track no events from others.

Task 3: Supplement the data from Pole Mounted installations with data from Guard Devices in Ground Mounted Substations that are monitoring networks with LV overhead line faults

Task 4: Correlation of pre-fault event parameters with time to fault using the method developed in the Foresight project.

Task 5: Comparison of location information from the monitoring systems with the location of faults that are reported to EA Technology by NPg.

Task 6: Assessing the efficacy of the existing pre-fault detection and impedance to fault algorithms and their use for location in OHL circuits including identifying any gaps and shortfalls of the existing algorithms.

Task 7: Draft changes to existing event categorisations and algorithms where gaps and shortfalls are identified

Task 8: Assessing the efficacy of existing proactive responses for underground cable networks for use on overhead and mixed networks fed from overhead lines

Task 9: Production of two technical summary reports, one sharing the first-pass insights report 6 months into the monitoring period and a final report at 11 months recording the final outcomes. Each report will cover:

- An assessment of the effectiveness of existing equipment and systems, used in the Foresight project, for the detection, localisation and location of pre-fault activity on overhead line and mixed overhead and underground networks
- An assessment of the effectiveness of predictive insights into the impending off-supplies derived from pre-fault signatures measured on overhead line assets fed from Pole mounted substations and from data from Guards in Ground Mounted Substations that are monitoring circuits with LV overhead line sections

8.5 Project Management and Dissemination

To ensure the smooth running of the project, a Project Manager will be appointed to manage the EATL activities. The Project Manager's duties will include the timely and regular provision of management material relating to project progress, risks issues and technical queries and invoicing.

At the end of the project a Final Report will be drawn up in a format suitable for onward dissemination of the learning generated. Provision has also been made for end-of-project dissemination material and support .

8.5.1 Project Management and Dissemination EATL Scope of Work

The tasks of this stage are:

Task 1: Project Management of the EATL scope of the Polesight Project.

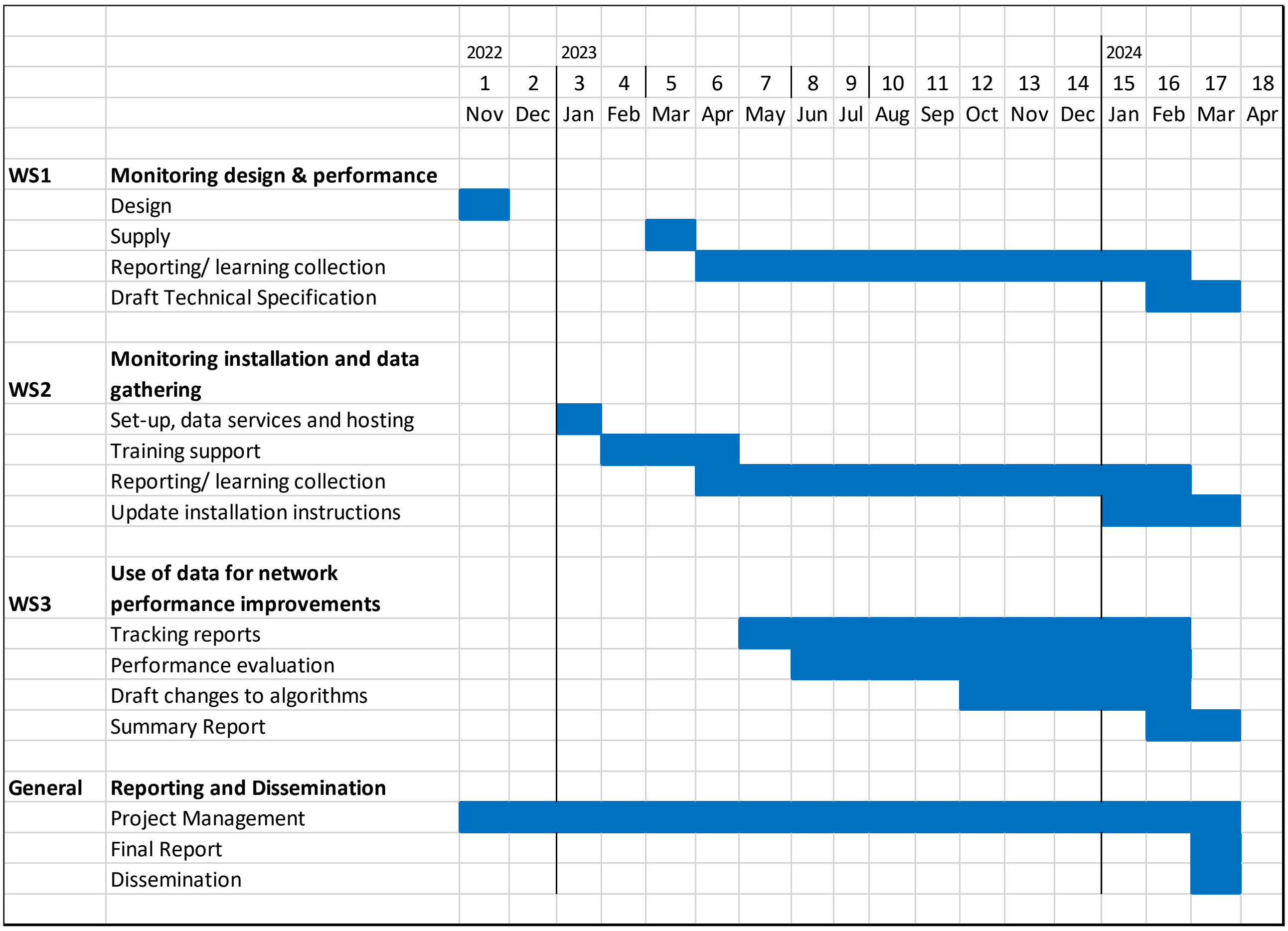
Task 2: Provision of a Final Report summarising the outcomes and learning from the Project in a way that is suitable for onward dissemination

Task 3. Support (including provision of additional materials – expected to be a Powerpoint Slide presentation) for Northern Powergrid in two dissemination events at the end of the project. The expectation is that there will be one internal and one external event to interested parties.

8.6 Project Timeline Summary

The anticipated start date of the main Polesight Project, pending approval, is November 2022

The anticipated end date is 31st March 2024



Appendix I Target Asset Types and Configurations

Topology is radial, can be either branched or un-branched

1. HV Networks can be Two Phase or 3 Phase.
    a. Substations fed from Two Phase Overhead Lines have single phase LV circuits
    b. Substations fed from Three Phase Overhead Lines have 3 phase LV circuits
2. LV Circuits feeding several houses can be 3 phase or single phase
3. LV Circuits can have Separate Neutral and Earth or Combined Neutral and Earth construction
4. LV Circuits can be ABC, Open conductor, underground cable or mixed
5. Pole Mounted Transformers can be connected to HV Main Lines or spur lines with different protection behaviours
    a. HV Overhead networks may have automatic recloser technology on main line
    b. HV Overhead lines may have smart fuses designed to coordinate with HV Reclosers
    c. HV Overhead lines protected by fuses may operate after a fault with one or more HV phases missing giving rise to sustained and unusual LV voltages
6. HV Overhead lines may be 6.6kV, 11kV or 20kV
7. Long overhead lines may have voltage regulation along the line

Pole mounted Transformers can be three phase or single phase

1. A fuse operation on a single phase supply will cause monitor to lose power
    a. Need for separate power supply – wind gen/ solar?
    b. Will location information be affected?
2. How many current line will need monitoring (max)?
    a. What should be done with other leads?
3. Pole mounted transformers can vary in size (e.g. 25kVA to 200kVA)
    a. Does transformer size affect operation?
4. Pole mounted substations may have one or more low voltage circuits that needs monitoring
    a. Do 3 phase circuit neutrals need monitoring?
    b. Do single phase neutrals need monitoring
    c. What is the max number of current sensors that would be needed for PMT monitoring
5. Circuits that need monitoring may be single phase or three phase
    a. Maximum number of current sensors required
    b. Need to measure neutral on 3 phase and/or single phase
6. Circuit fuse sizes will vary
    a. Fast fuse operation – could affect cable Risk category
7. Circuit fuse holders will vary in design
    a. Do fuseholders offer opportunity for voltage connections
    b. Is this (safe distance) a good place for the current sensors
8. Some circuits may be sub fused at a location away from the pole mounted transformer
    a. Remote fuse detection function?
9. Materials used for Transformer to Fuse leads may vary
    a. Voltage connection method for one deign may not work for another
    b. Is live connection of equipment possible
10. PMT layout will vary – single pole and H pole designs

    a. Distances between voltage connections and current connections
11. PMT may have monitoring equipment mounted already (e.g. Max Demand Indicators)
    a. Does this present an opportunity to piggy back Polesight Monitors
    b. Will this restrict the space available for monitors

Appendix II Short List of Substations in Northumberland Area

Appendix III Long List of potential monitoring sites

Safer, Stronger, Smarter Networks

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