Date of Submission
July 2019

Project Closedown Report Document

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Project Title	Project Reference
Automated Loop Restoration	NIA_SSEPD_0009

Funding Licensee(s)	Project Start Date	Project Duration
Scottish Hydro Electric Power Distribution	June 2015	40 Months

Nominated Project Contact(s)	Year
SSEN NIA Programme Delivery Manager –Joe McNeil	2019

Scope

Two sections of 11kV overhead line networks have been chosen which share a common switching point and this is normally kept open to separate the line sections. These two sections will be combined into an overall scheme with 8 sections by installing 7 pole mounted circuit breakers (CBs).

These 11kV circuits on the Kintyre Peninsula are supplied from sub stations at Campbeltown and Ballure. Data on supply interruptions is available and has been analysed for the 8-year period 2007 to 2015 to establish a base line. The 7 pole mounted CBs will be installed with one placed at the common normally open point and 3 CBs on each line. The CBs will be fitted with a low-cost communications option using mobile telephone technology. The operation of the scheme will not be dependent upon this communications technology, but it will be used to provide information on the status of the scheme and occasional monitoring of network power flows. It is expected that installation on site will be completed for the start of winter 2015/16. We will then monitor the faults on the line for a three-year period to the end of 2018. In early 2019 we will analyse the effectiveness of the scheme.

If the scheme effectively improves the network performance by reducing CIs and CHLs then it will be left in place as a business as usual deployment.

Objective(s)

- Achieve an effective reduction in CIs and CHLs over the three-year trial period by 50% when compared to the base line figures for the 8 years from 2007 to 2015.
- No network fault to affect 100% of customers on the feeder during the trial period
- Demonstrate that it is feasible to restore supplies to 50% of customers on the overhead line from Ballure substation towards Campbeltown, following a fault on the single 33kV circuit to Ballure substation.

Success Criteria

Determine the impact on network performance delivered by the automated loop restoration methodology on the trial network sections.

Performance Compared to the Original Project Aims, Objectives and Success Criteria

1. **Achieve an effective reduction in CIs and CHLs over the three-year trial period by 50% when compared to the base line figures for the 8 years from 2007 to 2015.**

The entire system of seven pole mounted CBs has not been fully deployed. Initially, there were delays in installation partly due to difficulties in integration of communications with the new technology as well as the lengthy timescales of consolidation activities around particular working policies which were necessary for the trial project. After installation of three units, some significant learning associated with the main technology under trial arose from another project on the Isle of Wight. To investigate the learning from the Isle of Wight and understand its impact on this project, further delays ensued. In the meantime, SSEN commenced deploying a SCADA based system of automated restoration which works with conventional hardware and the existing Distribution Management System (DMS). That approach delivers the same benefits as the project under trial and therefore superseded this project's method. The units installed have now been decommissioned and the project terminated prematurely. This objective was therefore not fully met.

2. **No network fault to affect 100% of customers on the feeder during the trial period.**

As stated in the foregoing section, the full system has not been installed. The objective has not been met.

3. **Demonstrate that it is feasible to restore supplies to 50% of customers on the overhead line from Ballure substation towards Campbeltown, following a fault on the single 33kV circuit to Ballure substation.**

Same as above, the objective has not been met.

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

Required Modifications to the Planned Approach During the Course of the Project

As the trial project progressed, SSEN adopted a new proven system of automated restoration which made use of existing systems, thus negating the intended project trial. It was therefore decided to remove the three pole mounted CBs which have been installed, subject to availability of outages, from the overhead line and return the network to normal. Decommissioning has been completed and the project has now been terminated.

The Network Licensee should state any changes to its planned methodology and describe why the planned approach proved to be inappropriate.

Lessons Learnt for Future Projects

Time must be invested at the start of a project to specifically address the different architecture systems, this will ensure easier integration into the existing internal control systems. This should be done before the delivery of the items of plant in question, if practicable.

Developing communications between the Distribution Management System (DMS) and the field devices, requires a specific skill set and time to get the scheme to a stage where it could be installed. Do not underestimate the importance of communications development, ensure resource and programme for this specific activity.

While the communications were eventually made to work, they used a system which was lightly loaded at the time of testing and first installations. Subsequently, as more pole mounted Circuit Breakers were connected higher data rates started to cause congestion issues which became a major challenge to resolve. The learning from this is to ensure communication calculations take account of the final number of units and also explore the possibility of system extensions to allow suitable mitigations measures are developed.

Introducing new equipment often requires unfamiliar tools, new techniques and processes, to ensure integration into existing working patterns, it's essential to speak to the primary stakeholders, build a picture of what is currently done and undertake gap analysis. This will help identify the areas that need to be addressed and enable planning to take place as supporting information may be required or demonstrations of equipment. The earlier your start to prepare for business as usual the more information that can be accumulated to support the transition.

Recommendations on how the learning from the Project could be exploited further. This may include recommendations on what form of trialling will be required to move the Method to the next TRL. The Network Licensee should also state if the Project discovered significant problems with the trialled Methods. The Network Licensee should comment on the likelihood that the Method will be deployed on a large scale in future. The Network Licensee should discuss the effectiveness of any Research, Development or Demonstration undertaken.

The Outcomes of the Project

The most significant learning outcomes up to the time of termination pertained to new paradigms of automation which have the potential to create greater network resilience in the future.

Pulse-closing technology: This project worked with hardware which uses the concept of pulse-closing. This is a new way of reclosing on overhead lines which reduces the impact of fault current flow upstream of circuits. Fault current creates thermal and mechanical stress on all circuit components through which it flows. This has the effect of reducing the life of plant and equipment such as transformers. It is therefore critical to remove fault current from the system as quickly as possible. In overhead line operation, most faults are of a transient nature. Therefore, an auto-reclose scheme is used on a feeder to restore the circuit after a predetermined delay to clear the fault. The most upstream auto-recloser, which may be a circuit breaker, is set with a higher number of operations than similar downstream switchgear. This enables discrimination whereby such downstream switchgear items lock out only for faults in their sections and the rest of the circuitry is restored up to their location. Depending on scheme design and the number of sections on the circuit, it can take several shots of recloses before the faulty section is disconnected from supply.

In conventional reclosing, every time a reclose takes place, the whole magnitude of the fault current is impressed on the system. The stress associated with this level of fault current shortens the life of equipment. In addition, the voltage sags that take place during the recloses can cause a bad experience for the customers on nearby feeders. There is also significant potential for safety hazards associated with re-ignition of arcs on grounded conductors. With pulse closing, following initial fault interruption, only a low energy current pulse is injected into the line. This is done to determine if the fault has not yet cleared before re-supplying current at full energy to the fault. Pulse-closing is achieved by a very fast close-open sequence of the switchgear contacts. The closing of contacts is performed at the point on the voltage wave at which the lowest possible energy current can be provided but with enough magnitude to allow measurement and analysis of the existence of the fault.

Communication-free automation: The major challenge with most automation schemes is the reliance on communications for successful operation. For instance, another SSEN project on the Isle of Wight tested the viability of an automation scheme with similar power hardware but relying on real time communication between the items of switchgear. The method involved creation of a virtual team of devices that could autonomously reconfigure the network via exchange of status information. One of the lessons from the project was that such schemes are very difficult to implement especially in areas where distances and topological constraints can affect signal strength. Where such difficulty is encountered, the cost of providing reliable communication infrastructure makes that automation approach unviable. If communication difficulties are envisaged, the automated loop restoration approach trialled in this project would be recommended as the scheme can operate for its primary function without the need for communication between devices or between each device and central control.

Loop reconnection is an automated system for the reconnection of un-faulted sections of circuits which are part of a network run as an open ring from a single source, or a physically interconnected network from two separate sources. In the latter case, electrically, the network consists of two separate radial feeders with a normally open point that can be used to tie the two. If interconnection via a normally open point is not provided, each of the radial feeders will have a reclosing source circuit breaker coordinated with downstream reclosers so that the nearest upstream recloser to a permanent fault will stay open after its reclose sequence is complete. However, in such an implementation, all downstream customers will suffer the interruption for the entire duration of the outage unless if other localized approaches of temporary restoration are provided. For greater network resilience and to fully take advantage of the benefits of loop restoration, circuit interconnection is provided via normally open points. The next section reviews how a simple scheme would work for the primary purpose of loop restoration, without reliance on communication.

Each item of recloser on the ring network is equipped with loss-of-voltage sensing on both sides of the primary contacts. In addition, each has pulse-closing to enable the network onto which it closes to be tested for the existence of a fault before full reclose. Without any communication, the loss-of-voltage timer settings on each of the normally closed reclosers on either of the loops of the ring are coordinated with the operation of the normally open point recloser which is set to close after a longer time delay upon loss of volts on one side. The closure of the normally open point provides volts to the reclosers on the loop with the faulty section which enables them to reclose, initially pulse-closing each time, in sequence until all upstream un-faulted sections have been restored and the faulty one isolated for intervention. If the faulted section is between two reclosers, a similar sequence of events will take place between the source circuit breaker and the downstream reclosers until the two reclosers nearest to the fault have locked out to isolate the fault from both sources.

The foregoing logic is reliant only on the performance of the integral voltage sensing hardware without the need for communication to be exchanged between different network components. However, in practical implementation, communications may be available at the source substation to capture fault data and at the switchgear item locations to provide status information which is vital to prompt deployment of repair teams to the faulty section. The autonomous operation free of communications enables this method to be deployed in hard to reach areas or simply where running the network in depletion due to communication loss would be unacceptable.

The learning outcomes above could potentially help in the formulation of automation and protection strategies for network licensees depending on the specific circumstances encountered on their networks.

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

Data Access Details

No network or consumption data was gathered during the project. Data sharing requests can be made in accordance with SSEN Network Innovation Competition (NIC) and Network Innovation Allowance (NIA) Data Sharing Procedure, further details may be obtained via emailing - future.networks@sse.com

A description of how any network or consumption data (anonymised where necessary) gathered in the course of the Project can be requested by interested parties. This requirement may be met by including a link to the publicly available data sharing policy.

Foreground IPR

No foreground IPR has been generated by this project

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

Planned Implementation

There is no plan to implement the outcomes of this project. The project was terminated when another approach to automation via the Supervisory Control and Data Acquisition (SCADA) got rolled out in SSEN. The automation logic of the alternative method was premised on DMS control and took advantage of communications, fault passage indication equipment and switchgear already installed on the network thereby providing a greater opportunity for a quicker rollout.

Other Comments

N/A

Standards Documents (Electricity projects only)

N/A