MANAGEMENT OF SCOTTISH AND SOUTHERN ENERGY'S LOW VOLTAGE DISTRIBUTION CABLE NETWORK USING SMART FUSES WITH ONLINE FAULT DETECTION

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ABSTRACT

This paper presents the strategy employed and the collaborative work and investigations between SSE and Kelvatek in using the 'BIDOYNG' single shot auto-recloser to gather data to understand the nature of low voltage (LV) intermittent faults. This will allow the development of techniques to mitigate LV intermittent fault effects and hence improve the performance of the aging cable network, while simultaneously reducing cable management costs.

INTRODUCTION

Scottish and Southern Energy (SSE), similar to other network operators, has an extensive LV oil impregnated paper insulated cable network. This network consists of buried three phase mains cables with solid tee joints supplying service cables to customers. Services can be single phase or three phase, and are typically terminated inside the customer's premises.

In the United Kingdom the feeder cables typically have multiple single phase services, which can be difficult to access when a fault occurs on them to facilitate fault location.

With existing fault locating techniques, sometimes multiple excavations are required to gain access to the cable to allow the use of traditional fault locating equipment such as TDR. The connected services can be problematic.

The cable assets are aging, and the rate of fault occurrences is increasing. The most frequent faults on SSE LV cables are intermittent in nature.

INCIPIENT FAULT LOCATION

One easily accessible point on these types of network is the LV protection fuse position. Deployment of "BIDOYNG Smart Fuse" single-shot auto-recloser devices on the SSE network to target faulting LV cables helps manage the customer interruptions (CI) and customer minutes lost (CML) by re-energising cables after a cable fault causes the protection fuse to operate. CI and CML figures are key metrics used in UK electricity regulation, OFGEM's Quality of Service Incentives scheme.

Using data collected by BIDOYNG shows that in many instances of fault there is not enough energy passed to

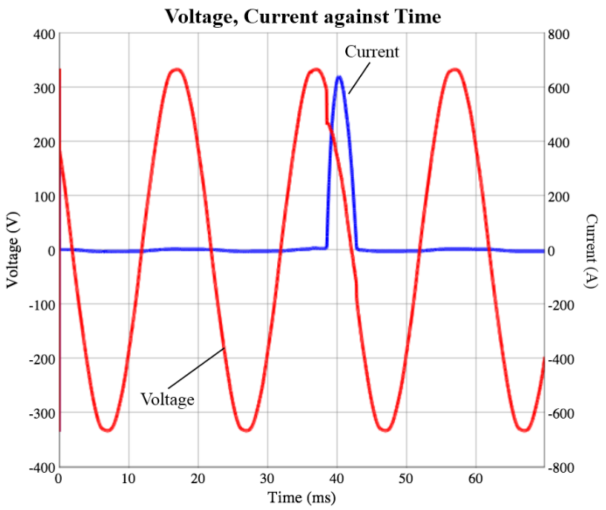

Figure 1 – Voltage is depressed as current rises during an intermittent fault.

cause the protection fuse to operate. Current spikes and voltage dips linked to the intermittent fault activity are easily identified. An example of a voltage and current waveform recorded at the LV fuse position by a BIDOYNG device during a transient event is shown in Figure 1.

Using this type of transient data Kelvatek has developed an algorithm named Single Ended Location of Faults (SELF). The algorithm uses a number voltage and current waveforms from a particular fault as input, and estimates the impedance to the faulted location on the cable. Used in conjunction with the cable parameters, this information leads to locating the fault, which can then be excavated and repaired.

The SELF algorithm was developed by collecting data from tests performed on the Kelvatek test network. This network consists of an 11kV supply from Northern Ireland Electricity's distribution network feeding through fused switches to a 200kVA transformer as well as a 500kVA transformer. Various LV type cables of varying parameters were connected to the transformers via fuse pillars, allowing BIDOYNG devices to be connected at the source end of the cable. Faults were deliberately introduced to the cable, either by switching a conductor between the phases and/or neutral, or by switching in a damaged cable that had been soaked in water. The resulting voltage and current waveforms were recorded by BIDOYNG, and the data was used to develop and refine the algorithm.

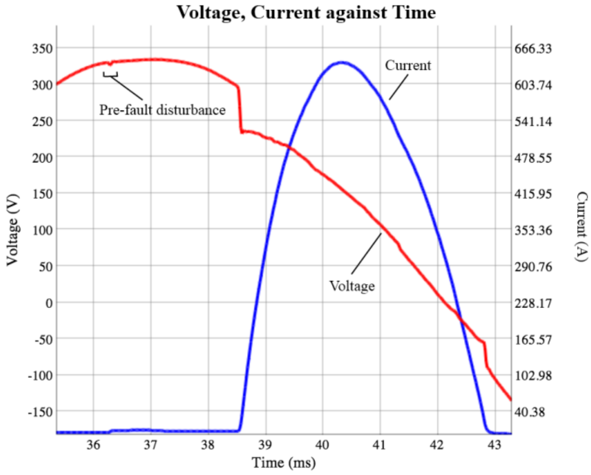

Figure 2 – Pre-fault disturbance is pronounced when zooming closer.

After development and verification of the algorithm, SELF was supplied to a number of distribution network operators (DNO's), including SSE, to test on real networks. The results have been very successful, and will be collated and published by Kelvatek later in 2013.

SSE uses BIDOYNG Smart Fuse to reduce CI and CML figures by both auto-reclosing after a fault, and also by reducing the time taken to locate and repair faults on the network. This has led to large savings, both financially and in time spent searching for and resourcing faults.

Previous work at both SSE and Kelvatek suggests that there is voltage and current activity relating to the fault at times when large fault currents are not flowing. By detecting and recording this activity over a period of time for a particular cable asset, it is proposed that a 'health index' of the cable under scrutiny may be derived. This data is very valuable, as it can be used by SSE to manage and prioritise their resources in their cable replacement programmes.

Records of actual fault currents and associated voltage, as shown in figure 1, can be used with the SELF algorithm to determine the sections of cable that are causing problems. This will avoid having to replace whole cables, meaning reliability can be restored by replacing small sections of cable. At present the health of a LV cable is determined by fault history (the number of permanent faults and fuse replacements it has had.)

The waveform of figure 1 is typical of intermittent type faults, and can be split into two clear sections, non-faulting and faulting. The 51.2 kHz sampling rate of the BIDOYNG allows us to zoom in and analyse the waveform in greater detail. Of particular interest is the non-faulting section from 36.25 ms to 36.4 ms, a voltage disturbance related to the fault (figure 2). The methodical way in which this disturbance data was detected was designed to reduce interference from noise created by loads on a typical LV network. By utilising the test network, we have been able to attach faulted sections of

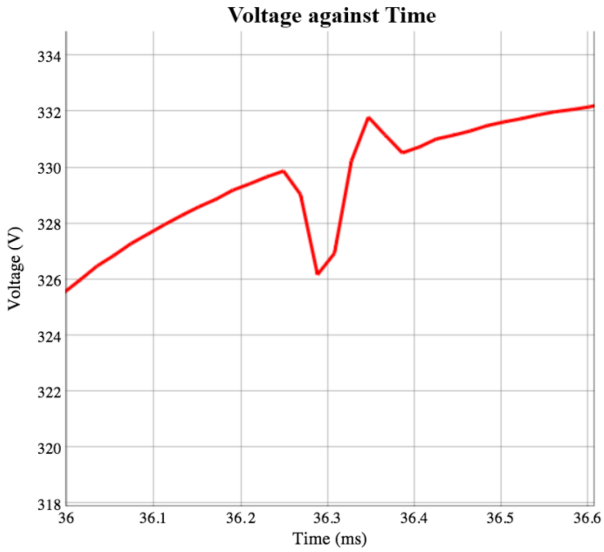

Figure 3 – A closer inspection of the pre-fault disturbance shows dip followed by overshoot on recovery.

PILC or CONSAC type cable to an LV distribution network that has no customer loads attached to it.

Figure 3 shows the voltage disturbance detected using this method.

FURTHER WORK

Work is being carried out to further characterise these disturbances using high bandwidth monitoring to allow detection and recording of these small voltage disturbances using BIDOYNG on real networks with noisy customer loads attached. Implementation of the triggering and recording system will be in the form of a firmware upgrade and this will be disseminated to devices already installed in SSE's LV network remotely through a Gateway GPRS connection.

SUMMARY

SSE LV distribution network has many thousands of kilometres of paper insulated LV cables with a particularly high fault rate on the CONSAC types installed between 1970 into the 1990's. When applying this equipment and techniques it will enable SSE to gather data on our LV cables to further understand fault activity on the network.

This has two major advantages for SSE and will provide a step change in how we manage the LV network.

1. This technology will enable SSE to be provided with data that will and allow a statistical analysis to yield a health index for the asset management and capital replacement of LV cable.

2. It will also enable us to effectively identify LV cable faults and in turn will help us to potentially outperform our customer standards and those set by our regulator.