POWER AND ASSET MONITORING STRATEGY TO FACILITATE A SMART NETWORK

Alberto ELENA DE LEONARDO
SP Energy Networks – UK
Aelena@spenergynetworks.co.uk

Ken LENNON
SP Energy Networks – UK
Ken.Lennon@spenergynetworks.co.uk

Andy BEDDOES
SP Energy Networks – UK
Andy.Beddoes@spenergynetworks.co.uk

Malcolm BEBBINGTON
SP Energy Networks – UK
Malcolm.Bebbington2@spenergynetworks.co.uk

ABSTRACT

The purpose of this paper is to describe the deployment strategy followed by SPEN to implement a pseudo-real time monitoring system in strategic locations of the network. This monitoring system directly enables improvements in network performance, and facilitates the transition towards a smart actively managed network in the longer term.

The level of quality of service that customers expect from electricity distribution companies has continuously increased over the last few years. These expectations are fostered by the UK regulatory environment, which incentives Distribution Network Operators (DNOs) to outperform against network performance targets.

Furthermore, a coordinated monitoring system is essential to actively manage a Distribution Network capable of accommodating high levels of embedded generation and low carbon technologies (LCTs). These are key requirements to be met by electricity distribution companies in their transition to Distribution System Operators (DSOs).

INTRODUCTION

SP Energy Networks (SPEN) owns and operates two distribution licence areas: SP Distribution Ltd (SPD) in Central and Southern Scotland, and SP Manweb plc (SPM) in Merseyside, Cheshire and North Wales. The distribution licences cover from LV up to 33kV in SPD and 132kV in SPM.

SPEN owns, operates and maintains over 30,000 electrical substations, 46,000 km of overhead line and 65,000 km of underground cable within the two licence areas. This infrastructure serves circa 3.5 million customers connected to SPEN's network.

Whenever faults or unscheduled interruptions to power supplies occur, customers are inconvenienced and this affects SPEN's performance as a company due to the framework established by the UK regulatory body on Quality of Service Incentives.

The interruption incentive scheme has symmetric annual rewards and penalties depending on each DNO's performance against their targets for the number of customers interrupted per 100 customers (CI) and the number of customers minutes lost (CML).

Consequently, DNOs are looking to improve network performance to outperform against their reward targets

SPEN is committed to its distribution business plan for the regulatory period 2015-2023 to reduce the number of times customers lose power by ~7%, and reduce the average time all customers are without power by ~25%.

The traditional way to address this issue has been to reduce supply restoration times by accelerating the dispatch of field engineers. However, the manual fault location and isolation process remains time consuming.

SPEN has already successfully deployed technology into the network to bring successive improvements to network performance (CI and CML).

SPEN has recognised the need to further invest in the network to improve network reliability and reduce fault restoration times by deploying intelligent technology and alternative operating practices.

Such technology includes Network Controllable Points, Logical Sequential Switching schemes, Fault Passage Indicators and Power Quality Monitors.

This paper sets out the practical use for Power Quality and Asset Monitors by SPEN, and outlines the deployment strategy of the system based on the optimisation of its associated economic, customer and asset management benefits and on future requirements of a smart network that will facilitate transition to a DSO model.

BACKGROUND

In the mid-nineties SPEN began installing Power Quality Monitors (PQMs) into 33kV to 11kV substations from where major customers with sensitive processes were supplied.

In the first instance these customers were silicon wafer fabrication plants where a small voltage dip could cause several millions of pounds worth of lost product. The original recorders were simple and power quality was simply a voltage dip. The concentration of these plants in Scotland was the main driver for SPEN becoming the leader of power quality monitoring in the UK if not Europe.

It was soon established that these monitors could provide hard evidence of a fault on the system as well as visibility of protection clearance times and the propagation of voltage dips across the network. As a result of this knowledge, and the technology was becoming economically available, the monitors were also configured to record the substation currents, which could be obtained without the need for outages.

SPEN's experience then turned to influencing the applications used to analyse the data. Initial expert systems were developed to classify events not only into types but also whether it was upstream or downstream of the monitor. Over time as major sensitive customer numbers reduced and their equipment became more tolerant to system events the use of monitors turned towards the network.

Further enhanced expert systems were developed to determine downstream fault impedance. Impedance mapping techniques were investigated and found to be able to accurately predict a target area for a fault.

Further developments also made the capture of battery current possible and thus the ability to time circuit breaker operation. Again this has been proven to be very effective as every circuit breaker operation is captured rather than an occasional snapshot during periodic maintenance inspections.

APPLICATION

SPEN now utilises an evolved and sophisticated Power Quality and Asset Monitor which is commercially available. This monitor is to be installed in over 700 primary substations (33kV to 11kV) across strategic locations on the network to facilitate improvements in the reliability and availability of the electricity supply.

The monitor provides network power quality information, circuit breaker asset monitoring, substation battery condition information and network impedance to fault data. Future enhancements to the monitor could include partial discharge (PD) and system fault level information.

- **Power quality information** - DNOs have an obligation to maintain electrical power quality within statutory and recommended limits. Monitors record the characteristics of the supply. Voltage magnitude, current and power levels are measured along with harmonic and flicker information necessary to ensure compliance with UK regulations on voltage distortion [2] and voltage fluctuation [3]. Alarms are announced if values exceed user defined limits. Power quality information is also sequentially trended to provide full yearly reports. These reports provide valuable data for the DNO long term development statement, helping existing and future users of the network assess connection opportunities.

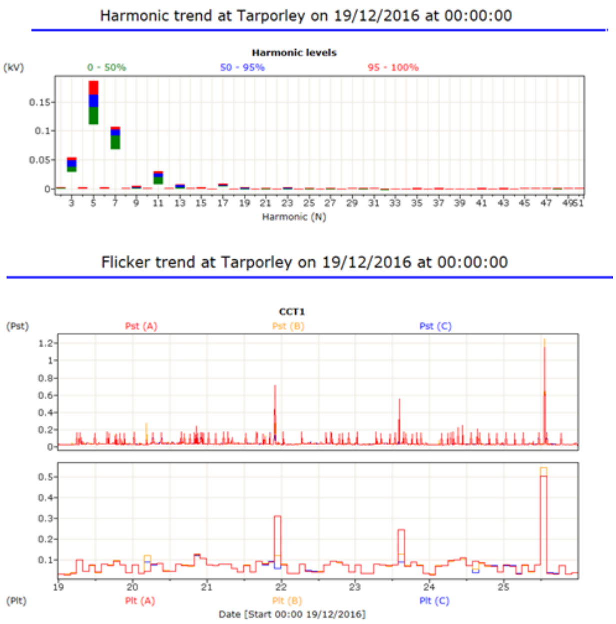

Figure 1 – Harmonic and flicker trend

- **Circuit breaker asset monitoring** - Speed of operation of circuit breakers is a fundamental characteristic of this network asset. Slow fault clearances, caused by slow operating circuit breakers, are a source of danger and detrimental to network security. Economical trip circuit monitoring of all on-site circuit breakers is achieved by insertion of a Hall Effect probe into the main battery trip circuit. Trip current characteristics, collated during fault or remote control trip conditions are measured and reported back to the main data management system. Alarms are generated if the tripping time extends normal tripping limits. Circuit breaker auxiliary contacts identify the circuit breaker associated with the trip current. Trending this information over time also helps prioritise circuit breaker maintenance schedules.

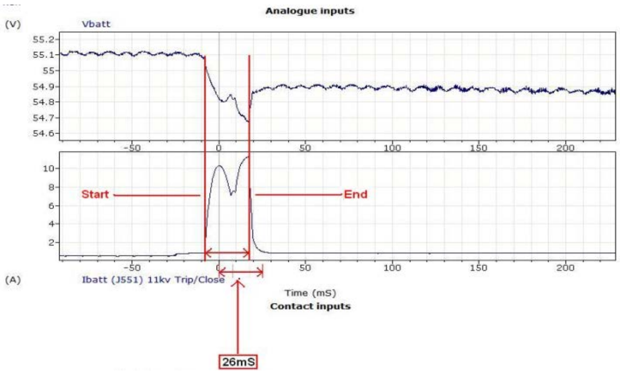

Figure 2 – Circuit breaker contact change

- **Substation battery condition** - The Hall Effect probe used to provide circuit breaker asset monitoring also provides battery condition impedance information. The Power Quality and Asset Monitor is powered from the substation battery and utilises this voltage together with the Hall Effect probe DC tripping current to calculate the battery impedance during trip and close operations. An alarm is raised if the battery impedance increases beyond a defined limit.

- **Network impedance to fault data** - The monitor incorporates an algorithm for predicting overhead network phase to phase distance to fault. Data is extracted from voltage dip and fault current power quality information. The data provides field engineers with an effective network fault search area which is usually accurate to within a few spans of HV overhead line. Future additions include phase to earth fault prediction.

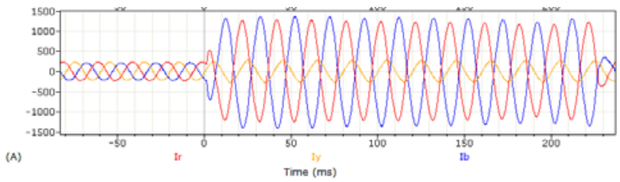

Figure 3 – Downstream 'red' phase to 'blue' phase fault

- **Partial discharge** - A multi-bay UHF partial discharge sensor system is available to detect increasing levels of PD activity which may lead to a fault. The PD sensors are linked together and the data is recorded and reported by the Power Quality and Asset Monitor. The sensors use multiple frequency bands and can discriminate between surface and internal discharges.

- **Fault level monitoring** - In co-operation with a leading manufacturer of power quality measurement equipment, SPEN continues to progress development of a fault level monitor. It is envisaged this monitor will become integral to SPEN's monitoring strategy and enhance network design and performance management.

A third party server and associated management tool provides the link between Power Quality and Asset Monitors and users of the system. The strategy includes the development of server and associated management tool within SPEN.

STRATEGY

SPEN has prioritised the deployment of Power Quality and Asset Monitors in the areas of the network with the longest overhead circuits, and in the primary substations presenting the types of circuit breakers with the lowest levels of reliability.

In the meshed sections of the network these criteria have been combined with the target of getting sufficient and strategic power quality data from every interconnected group to further enable and help facilitate the integration of a DSO model within SPEN based on a 'Cell' concept in an 'Active' or 'Smart' network.

Figure 4 – Power Quality and Asset Monitor in SPEN primary substation

The concept and philosophy of an 'Active' or 'Smart' network is nothing new, with key elements required to establish an 'Active' network discussed over a decade ago [1] with the authors proposing the evolution of Distribution Networks around a 'Cell' concept.

In summary, the "Cell" concept is based on local monitoring, communications and control. The idea is that 'Cells' take cognisance of the various monitored and communicated values and parameters. The immediate benefit of this approach is that it does not have a significant impact on the topology of a power network, with interconnected networks (like that within SPEN) perhaps being a more suitable candidate for the 'Cell' network philosophy.

The inherent interconnectivity helps provide a platform from which to select and apply suitable 'network responses' as a result of local 'system issues'. Furthermore, this is perhaps considered a natural evolution of today's network to meet the demands of future networks and customers. The 'Cell' concept within the SPEN interconnected / meshed network is illustrated in Figure 5.

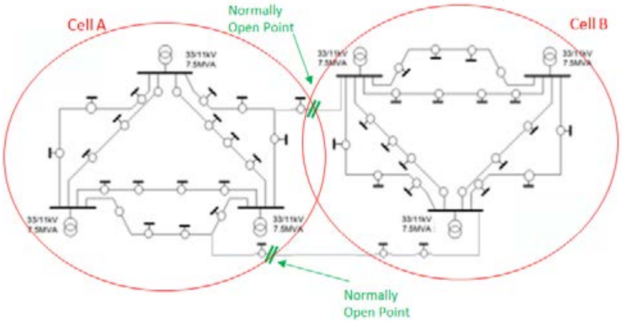

Figure 5 – 'Cell' concept in SPEN meshed Distribution Network

In considering the above, one of the key elements is the application and integration of simple, effective and reliable monitoring of the various parameters within the respective 'Cells'. As an enabler to this SPEN is to deploy and utilise some 700 Power Quality and Asset Monitors as the functionality, embedded intelligence, processing capabilities and communication protocols they provide lend themselves to this application ideally.

The location of the Power Quality and Asset Monitors within the topology of the network is a key consideration in the deployment of the monitors within the 'Cell' structure, since the data they then provide for that and the surrounding network can be strategically used, or the data provided to infer states within other network areas / locations.

With all this data available, a key element in the 'Cell' concept is the processing and analysis protocol of the data since it is important to understand exactly:

- What data is required;
- Once acquired, what data can be ignored;
- What is the 'priority' of the data.

This protocol and philosophy is important, otherwise there is a risk of too much data handling and monitoring of unnecessary parameters, with only a small proportion of the data actually being of any use / benefit. Just because it is possible to monitor lots of factors / parameters using Power Quality and Asset Monitors, it does not mean that the data needs to be communicated. One of the most effective ways is to apply a 'monitor by exception' protocol with key strategic rules applied enabling key strategic data to be collected and considered, rather than all data which takes time to process with a large percentage being superfluous.

As part of the analysis of the data, SPEN is also looking at the various applications available to analyse the data in the most effective manner possible. One of the key elements of this is that the systems are commercially available and easily integrated with the existing systems within the SPEN Distribution Network.

CONCLUSIONS

SPEN has improved the network performance for events that have happened in the primary substations where the Power Quality and Asset Monitors have been installed.

The monitoring of strategic data, such as circuit breaker performance, substation battery condition, fault impedance, partial discharge activity and fault level monitoring, is considered to help facilitate the integration of a DSO model within SPEN which is based on a 'Cell' concept in an 'Active' or 'Smart' network.

The use of commercially available monitors and simple integration into SPEN's data systems is considered a key enabler in helping to achieve a robust and adaptive Distribution Network which envelops the 'Cell' network concept.

The interconnected philosophy of the SPEN Distribution Network is a natural enabler to the "Cell" concept and natural evolution of SPEN current Distribution Network to meet the demands of future networks and customers, providing measurable benefits for connected customers which cannot be realised within other Network Operators. This is considered possible due to the unique way in which the commercially available systems are integrated with the existing systems within the SPEN *'DSO Model Ready'* Distribution Network.

REFERENCES

[1] A. Beddoes, 2003, "active networks for the accommodation of dispersed generation", *17th CIRED conference*, session 4, paper 51.

[2] Engineering Recommendation G5/4-1, Planning levels for harmonic voltage distortion and the connection of non-linear equipment to Transmission Systems and Distribution Networks in the United Kingdom, 2005.

[3] Engineering Recommendation P28, Planning limits for voltage fluctuations caused by industrial, commercial and domestic equipment in the United Kingdom, 1989.

[4] *SP Energy Networks 2015-2023 Business Plan*, 2014.