CONTINUOUS ONLINE MONITORING OF PD ACTIVITY IN THE MEDIUM VOLTAGE DISTRIBUTION NETWORK

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ABSTRACT

Partial discharges (PD) occur as a result of dielectric breakdown in electrical insulation under high voltage stress. They can be caused by the presence of gas pockets or voids in solid insulation / gas bubbles in liquid insulators (internal), insulator surface imperfections / irregularities (superficial) and around an electrode in gas (corona). PD activity, once initiated, causes chemical and physical degradation of insulating material and can lead to catastrophic failure. Early warning of PD activity and localisation is considered essential to ensure the long term reliable operation of high voltage equipment including cables, cable accessories and switchgear.

PD detection in high voltage cable and cable accessories is usually carried out with test objects offline, requiring potentially significant interruption of service. An online detection system is preferable but difficult to calibrate apparent charge magnitudes due to changes in real distribution network loading and topologies. An online PD monitoring system with continuous calibration has been developed to determine the apparent charge magnitudes of PD activity and locations in a section of an in-service distribution network. System components including the online calibration pulse injector, capacitive sensors for high frequency PD pulse detection, and data acquisition, processing and communication components at each monitoring site will be presented. Long term parameter trending data from the ongoing trial in a typical urban distribution network in Spain will also be presented.

INTRODUCTION

Partial Discharge (PD) is localised dielectric breakdown and gives rise to short duration current pulses, typically lasting for only a few nanoseconds (see Figure 1), resulting in emissions throughout the electromagnetic spectrum, including high frequency RF emissions. Commonly used PD detection methods [1] are based on the measurement of the high frequency RF activity, the calculation of the apparent charge, and the relation of this apparent charge to where it occurs in the phase of the power waveform. From the resulting phase resolved PD (PRPD) patterns it is possible to deduce the type of discharge being observed (corona, surface, internal, etc.). An example of a PRPD pattern is shown in Figure 2.

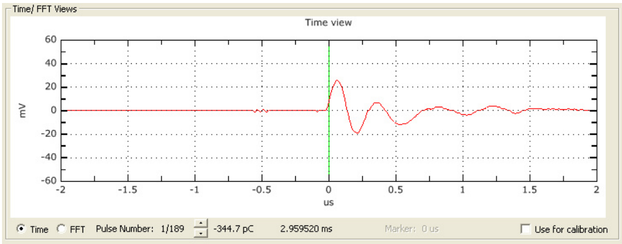

Figure 1 Captured short duration partial discharge signal

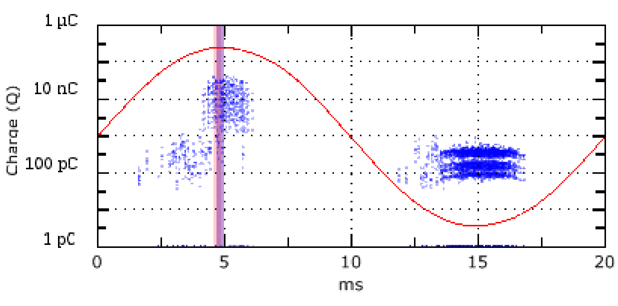

Figure 2 PRPD pattern showing corona and surface discharges in a MV switchgear and cable system energized to 18kV.

The magnitude of the apparent charge of each PD and the frequency of occurrence are important parameters in determining the severity of PD activity [2,3]. However, for asset management and preventative maintenance purposes the trending of these parameters over time [4,5,6] is a key indicator of when assets may fail.

This paper presents continuing observations from a monitoring system installed as part of trials in a typical Spanish urban distribution network [7]

SYSTEM ARCHITECTURE

An overview of the system architecture employed in this trial can be seen in Figure 3 Using in-house developed capacitive coupling units, installed directly into T-junction cable end-plugs within the switchgear enclosure, it is possible to simultaneously capture both high frequency and voltage signals due to the integrated quadripole. This simultaneous measurement allows for PRPD patterns to be easily represented.

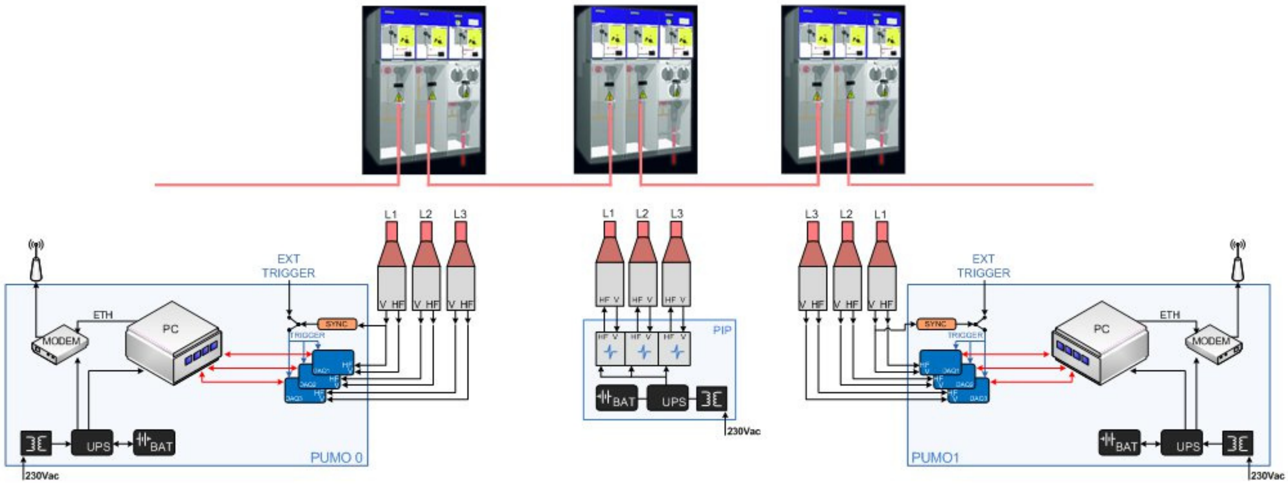

Figure 3 Online PD detection system architecture

In this trial, signal detection is carried out at two points in the same cable section with both the high frequency and voltage signals for each phase being passed to high bandwidth oscilloscopes connected to an industrial computer.

Using customized PC software and with the oscilloscopes sampling at their maximum rate, acquisition of a minimum of 5 power cycles at a sampling interval of 8 nanoseconds is possible. The data processing flow is illustrated in Figure 4

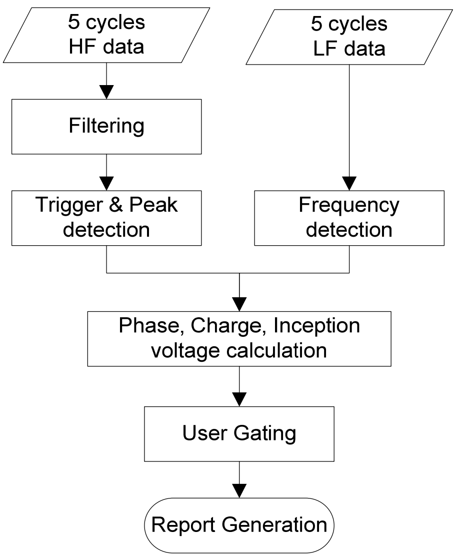

Figure 4 Flow diagram of data processing

High frequency data is initially filtered to remove unwanted low or high frequency noise sources and then processed to obtain the PD pulses and determine the associated discharge parameters (apparent charge, phase with power cycle, inception voltage, trigger time, etc.). Any user noise gating is then applied. Monitor reports are subsequently compiled for transmission over a communications link to a central server.

At a third point in the same cable section as the signal detection, pulses of known magnitude and phase are injected using a calibration system. These reference pulses are injected using the same type of capacitive coupling units used for detection, with two positive and two negative pulses per power cycle (Figure 5 and Figure 6).

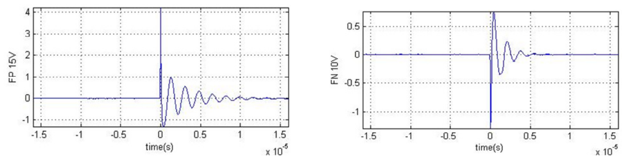

Figure 5 Positive and negative injected reference pulses

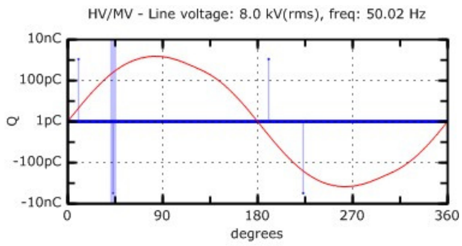

Figure 6 Charge pulse positions in phase resolved PD diagram

As the phase and charge characteristics of the injected pulses are well known, they are easily distinguishable from noise and PD events. These pulses are used for synchronization purposes as well as providing the constant reference to the acquisition units albeit that changes occur in network loads or topology.

As previously indicated, the compiled monitor reports are sent to a central server at a rate of one per minute from each of the detection points on the monitored cable section. Using timing information from the units for any PD pulses that are detected, a time of flight difference calculation can be used to determine locations [8]. Charge/Phase, PD count and location data from each monitored line is stored for later trending analysis.

RESULTS

The results presented in this section come from a short cable section (350m) of an 11kV urban distribution network, consisting of 3 single phase XLPE insulated aluminium cables. The section contains several cable joints, short cable runs and a substation between data acquisition points. It is also noted that in close proximity to one acquisition point is a transition from XLPE to PILC cables.

The trending data presented shows some predictable behaviour of the monitored parameters related with variations in the system line voltage. Some atypical behaviour was also observed close to the start of the monitoring period.

PD event count variation with line voltage

Figure 7 shows increasing and decreasing PD event counts related with the corresponding occasional changes in line voltage. The voltage reading here is the phase to neutral RMS voltage of an 11 kV urban distribution cable network.

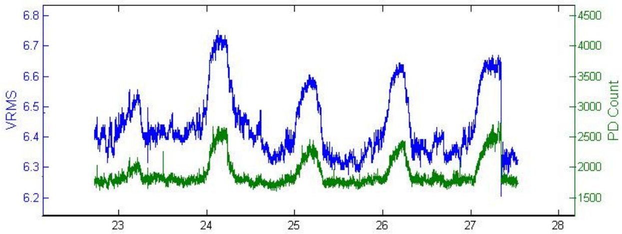

Figure 7 Relation between line voltage and PD event count over a period of approximately 5 days

PD maximum apparent charge variation with line voltage

In Figure 8 several observations can be made illustrating the usefulness of trending:

- Line voltage data exhibits some interesting maximum and minimum variations during a several hour period each on two consecutive days at the midpoint of this sample.
- The charge scale factor, calculated using the fixed calibrator reference, exhibits both a daily cycle and an underlying inverse proportionality to the line voltage.
- The scaled maximum PD charge is proportional to the line voltage over the observation period.

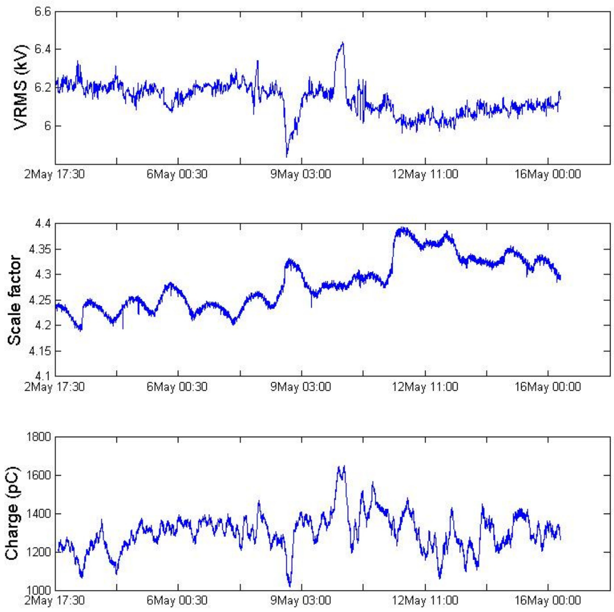

Figure 8 Trending of line voltage, charge scaling factor and apparent charge over two week period.

Trending increase in activity

A sudden increase in PD event count and maximum apparent charge that was not related to line voltage was observed within the first two months of the trial indicating a real increase in PD activity on one phase and in one detection point. Although it has been detected it remains at a low frequency and only visible at one detection point so believed to lie outside the monitored section and potentially in the PILC section close by.

Figures 9 and 10 show the latest PRPD diagram and repetition map from that phase showing a typical internal void PD pattern. The evolution of the PD activity over time for just the pulses within the internal void cluster is also shown in Figures 11 and 12.

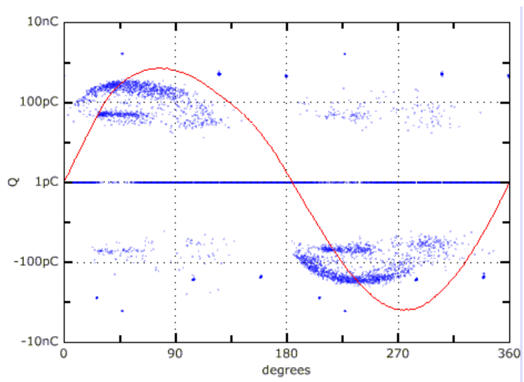

Figure 9 Bi-polar PRPD pattern of observed defect

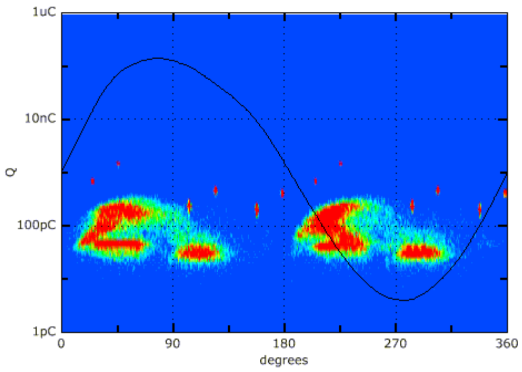

Figure 10 Uni-polar repetition map of observed defect

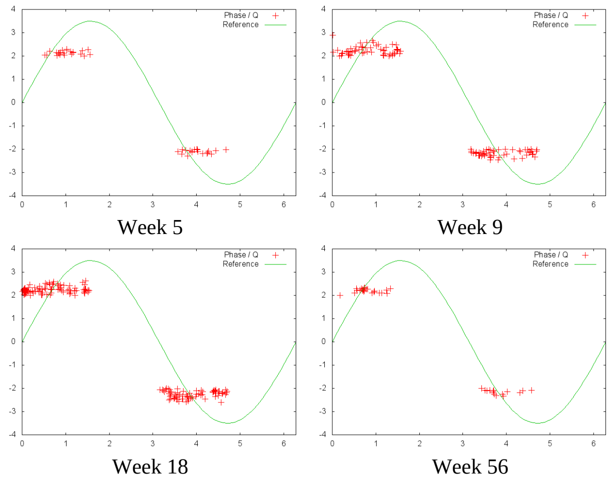

Figure 11 Evolution of PRPD plots of defect cluster.

An initial rapid increase has been followed by a steady slow decline in activity. To date this cable section has not failed but is being actively monitored.

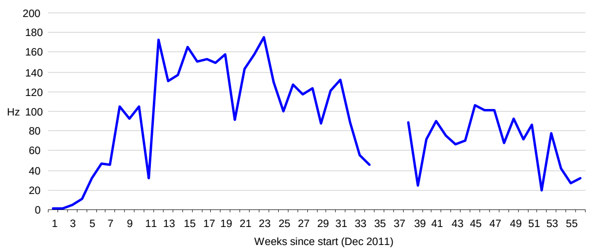

Figure 12 Evolution of PD pulse frequency of defect cluster since detection.

CONCLUSIONS

Failures in high voltage installations are disruptive and can be dangerous and costly to repair. Continuous partial discharge monitoring of in service installations and their components provides a means to observe and prevent these failures. This continuous monitoring offers advantages over periodic offline testing of installations.

The early and ongoing results observed from trending data have shown:

- Good detection capabilities of in-house developed equipment for monitoring 'real world' networks
- Use of injected fixed reference pulses for system synchronisation and automatic adjustment of PD charge readings accounting for changes in network loads and configurations.
- Predictability of variations in PD activity and parameters related to line voltage variations.
- Use of trending data to observe long term changes in PD activity.

Work in this trial is ongoing and monitoring will continue on this and other cable sections to identify key parameters required for failure prediction.

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