IMPROVING ASSET MANAGEMENT WITH ONLINE PARTIAL DISCHARGE MONITORING OF RING MAIN UNITS AND SECONDARY SUBSTATIONS

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ABSTRACT

Traditional permanently installed Online Partial Discharge (PD) monitoring systems are highly advanced systems, running high resolution data acquisition electronics with processor heavy software analysis to separate PD signals from background noise interference. These systems are cost effective for primary or grid sites, where the cost of a single failure is often much higher than the cost of the monitoring system. In a secondary substation, however, this is not a viable solution technically or financially speaking and alternative asset management solutions must be considered. Unfortunately, there has been a technological void for mid-range monitoring solutions.

However, recent developments in more industrialized and fan-less computers offer the required processing power and technological advancement, enabling the development of PD monitoring systems which can still effectively differentiate PD and background noise and operate in the harsh conditions of a secondary substation. Additionally, powerful microprocessors are being manufactured in a such high volumes, that the price of the units are reaching the level where they can be incorporated into a PD monitoring system which is cost effective for installation over the large asset base of a secondary network whilst ensuring reliable outputs of asset condition. Therefore, offering a solution for condition monitoring of the largest part of a DNO's network which previously went unmonitored.

INTRODUCTION

Online Partial Discharge (PD) testing of new and aging switchgear assets is a well-established condition assessment tool used by asset operators around the world to predict which assets are likely to fail. A range of solutions have been adopted from handheld instruments to permanent monitoring. PD testing has traditionally been focused on switchgear installed in primary or grid substations as opposed to secondary substations due to the potential disruption to network operation should a failure occur.

However, the largest number of substations in any network is made up of secondary substations. London, for example, has 157 primary or grid substations compared to approximately 15,800 secondary substations [1]. These substations are small and inexpensive but still vital to the network. PD testing solutions are difficult to implement at these sites. The resource required for staff to manually test the substations is too great, and permanently installed solutions are traditionally too expensive to implement.

We therefore need to look at a system which can be cost effectively implemented into these sites, which addresses the problems with existing solutions available.

PARTIAL DISCHARGE IN MV ASSETS

PD Theory

Partial Discharge (PD) is an electrical discharge that does not completely bridge the space between two conducting electrodes. Typically, PD occurs in Medium Voltage (MV) Switchgear, assets of 4kV or greater [3]. It can occur in gas filed voids of solid insulation, typically cracks or manufacturing defects in insulating components; in bubbles in liquid insulation, oil filled insulation with air bubbles or across air insulated components, such as contaminated cable terminations and conductors [2].

In defective insulation systems, these low energy Partial Discharges occur regularly, typically in every power cycle, and over time will cause further damage to the already faulty component. After a period of time it is highly likely that this defect will lead to failure of the component and a full breakdown will occur.

Online Partial Discharge Detection

During normal operation of the asset, online PD detection methods can be used to identify the presence of PD activity, and therefore defects, within the equipment.

For MV assets, this typically involves devices which use two types of transducers. For surface tracking, ultrasonic, sometimes airborne acoustic, sensors pick up surface activity provided there is an air path between the defect site and the sensor. For internal PD, capacitive coupled sensors are used to detected Transient Earth Voltage (TEV) signals which propagate from the defect location [4].

Both sensor types are used in conjunction with spot testing equipment and permanent monitoring systems to detect PD whilst the asset is under normal operating loading conditions.

Problems with PD Detection in Distributed Substations

PD activity has a distinct pattern in the power cycle, which enables trained users and permanent systems to correctly classify these signals as coming from a defect. This pattern is directly related to the power cycle. However, electrical noise will also be detected by the transducers, which in some cases can mask the PD. Figure 1 shows multiple power cycles superimposed with real PD and background noise.

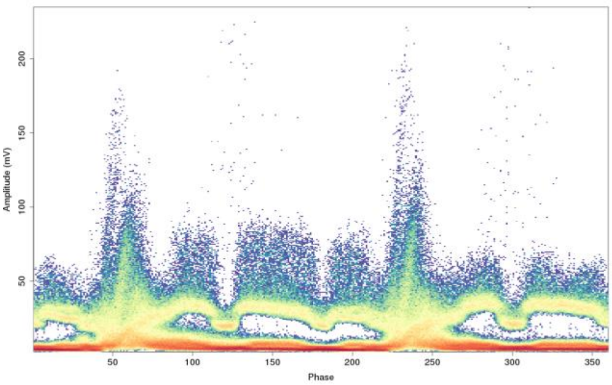

Figure 1: Typical power cycle with PD

It is difficult to differentiate PD from background noise, Figure 2 is the same data, with real PD signals highlighted in black.

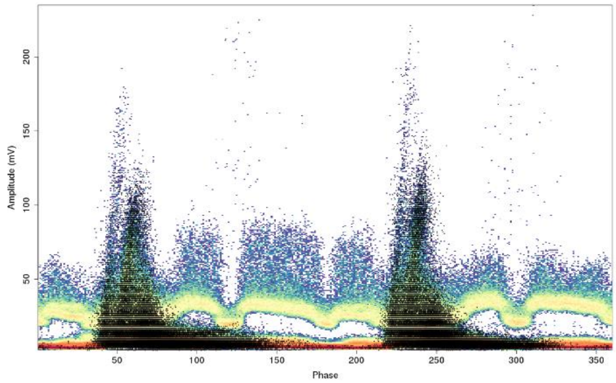

Figure 2: PD highlighted in black

Engineers conducting on site tests with PD instruments must have sufficient training in order to differentiate between PD and background noise. At the other end of the spectrum, permanent monitoring systems must incorporate noise rejection algorithms which automatically distinguish PD from background noise, this is often achieved with high resolutions data acquisition and advanced noise rejection algorithms which process a wealth of data to conclude whether PD is present [5].

It is the application of this noise rejection in a mid-range system that is lacking for distributed MV assets. Those in secondary substations, distribution substations and ring main units, are as prone to defects as those found in primary and grid substations. The distributed assets form the majority of assets in any utility network. London, for example, operates around 16,000 substations. 157 of these are primary or grid sites and over 15,800 are secondary substations [1]. The distributed nature of these assets, and shear volumes, means condition assessment programs to spot test for PD activity would require significant resource allocation, as well as a high skill level if the PD activity is to be detected in high noise environment. This makes spot testing programs for secondary sites too costly, especially considering the fact that PD may not be present all day every day. It is common to see significant PD variations with load. As seen in Figure 3.

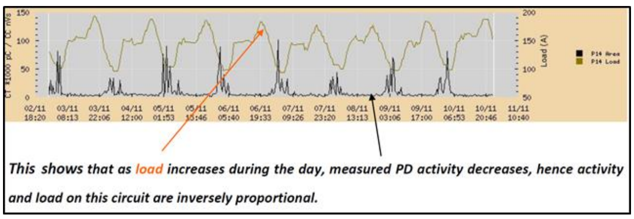

Figure 3: PD and load variation

It is therefore essential that, for most assets, a permanent monitoring solution is available. Innovation must focus on noise detection algorithms that are significantly reliable and robust but within the limitations of affordable hardware and the environmental issues that come with distributed asset networks.

PERMENANT MONITORING EQUIPMENT REQUIREMENTS

As discussed, until recently the limits of processing technology have meant that traditional permanently installed online partial discharge monitoring systems are not viable solutions for secondary substations.

Advancements in microprocessor technology allow us to tailor the noise detection algorithms to make use of particular functions within the microprocessors new capabilities and thus we are able to fill the reliability void in online PD testing technology. Between extensive training to be able to correctly identify PD within the noise signals and the specialist and costly technology required for permanent monitoring systems in primary subs there is this technology gap for reliable monitoring and detection in secondary subs.

However, there are also considerations that must be applied to any developments in technology to fulfil this technology void.

Industrialisation

Most primary substations or grid sites are often fitted with environmental control systems, which ensure the environment remains at a condition which maximises the life of the switchgear and auxiliary systems. In distributed substations, this is not the case, and therefore these assets regularly see high temperatures, low temperatures and varying humidity. The sites also have a long maintenance period, meaning the site can become contaminated with dirt, grime, sand etc.

A permanent monitoring system designed for distributed substations must be designed to operate normally in industrialised environments.

Most permanent monitoring systems operating in primary sites are PC based systems, with moving components such as fans requiring regular maintenance. With distributed assets, monitoring systems must be robust, with a low maintenance requirement to reduce engineer site visits. With large number of systems installed, this would be as resource draining as spot testing for PD.

Communication

Partial Discharge monitoring systems installed in primary sites collect a large amount of data for processing, and save a large amount of data for analysis by condition monitoring teams. This requires robust communication systems such as ADSL, Fibre or 3G/4G technology. In distributed assets, this type of communication is not available, and expensive to install if needed. Communication is also a common weak point in any system.

A monitoring system designed for distributed assets must include the capability to communicate with existing technology or have a robust alternative. In many urban networks, substations are fitted with Remote Terminal Units (RTU's) which accept inputs from other devices. The main aim of a PD monitoring system is to alert the condition monitoring engineers of the existence of PD which can then be addressed, this information can be communicated in the form of an alarm via the RTU. If no RTU exists, very robust communication such as GSM or SMS would be desirable.

Noise Rejection

By far the greatest challenge in large scale PD Monitoring system deployment is ensuring the system outputs reliable results. Just a small percentage of false positives from the systems would result in a heavy resource drain.

We continue with the London example to demonstrate this. If 25% of the distributed assets are monitored with a new generation of permanent monitoring systems, there would be 3950 in service. Of these 3950 monitors, if there were 10% false positives per year, then investigation or maintenance could be carried out the condition monitoring team would have to visit 395 substations per year to investigated the presence of PD, a very resource heavy task.

Effective noise rejection and accurate alarms are needed to ensure false positives do not occur and site visits are made to investigate real network problems, not false alarms. The potential of new technology now allows for a high accuracy rate with improvements to the algorithms that make efficient use of the microprocessors capabilities while working within its limitations.

ONLINE PD MONITORING OF DISTRIBUTED ASSETS

Our key requirements have been investigated, these are summarised in Table 1.

Requirement	Description
PD Test Solution	Permanent PD monitoring system
System Type	Industrialised, no moving parts
Communication	Integration with existing comms protocol or simple robust communication
Results	Accurate results, effective noise rejection

Table 1: PD Monitoring requirements

The high-resolution data processing which PC based systems offer is required to effectively differentiate between PD and background noise. The innovation in recent years of powerful microprocessors, driven in part by more portable and higher powered handheld devices, has enabled the development of equipment that can be used to process significant data. This can be applied to PD activity in high noise environments and ensure that the output of a distributed monitoring system can give condition monitoring teams accurate alarms and reliable PD detection, which could previously not be done at such a low cost.

These types of systems are also able to operate in harsher conditions which are found in secondary substations and distributed assets, to operate at higher temperatures and recover safely from power failure, without the vulnerability of moving parts and thus high maintenance requirements.

Figure 4: IPEC PD Alarm - secondary substation Online PD Monitoring System

CONCLUSIONS

Traditionally, Online PD Monitoring has been focused on large primary or grid substations which DNO's operate. For PD Monitoring systems to operate in the much larger network of distributed substation, they need to meet a very strict criterion of efficiency, reliability and accuracy. Advancements in highly efficient, low cost microprocessor based systems mean innovative solutions can be developed making both a robust and reliable monitoring system which provides utility companies with viable Online PD Monitoring for large networks of distributed assets.

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