LOW COST CONTINUOUS MONITORING OF PARTIAL DISCHARGE ACTIVITY IN MV SUBSTATIONS

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ABSTRACT

Enemalta, the electricity utility for Malta, has derived considerable benefit from the use of portable Partial Discharge (PD) detection equipment on its MV electricity distribution network.

This paper describes a further development i.e. the application of a permanently or semi-permanently installed PD alarm system. This new technology found immediate application in the detection of intermittent PD activity. The results were corroborated by comparing it to an established PD monitor design.

INTRODUCTION

The state owned utility for Malta, Enemalta, undertakes a broad range of operations including the generation and distribution of electricity. Throughout the years, Enemalta has been instrumental in pioneering the usage of new technology to reach its corporate objectives whilst at the same time offering better products and services.

One such initiative was the adoption of best practice in condition assessment of substations with a particular emphasis on insulation condition and the detection of partial discharge at MV. Starting in 2005 Enemalta has invested heavily in portable partial discharge detection and location equipment. This investment has paid substantial dividends in improved reliability and safety of personnel visiting substations.

PORTABLE VS. MONITORS

At transmission voltages, the importance of continuous monitoring of Partial Discharge (PD) activity in switchgear and other assets has long been recognised [1]. The consequence of asset failure within a transmission network, in terms of customer interruptions and customer minutes lost, can be high. Transmission assets also have a high capital cost, therefore the addition of continuous PD monitoring can be of great value with a relatively small addition to the overall capital cost.

At MV, the viability equation changes. Here assets are of lower relative value and the consequences of a failure of a single asset in terms customer minutes lost is generally lower.

Portable instruments, therefore, tend to prevail as their cost can be amortised over the whole network of assets.

For Enemalta’s MV network, it was natural therefore to start with portable instruments. Simple to use UltraTEV Detectors were initially issued to each district office and one to the maintenance section. Later numbers were increased so that each technical officer within the maintenance section had access to an UltraTEV Detector. These devices were primarily issued for staff safety in entering substations or operating switches. They detect PD activity using ultrasound and Transient Earth Voltage (TEV) [2] indicating dangerous levels of PD with a red light. Any red light detected would be investigated further by more sophisticated instruments and experienced staff based locally. The use of the instruments was later expanded to cover asset condition assessment. There are striking parallels between Enemalta’s use of these type of portable PD detectors with the previously reported [3] application in ESB, Ireland.

Since the acquisition of portable PD detection and location equipment and through the application of a scheduled programme of surveys, Enemalta has detected discharges in 34 cable terminations (mostly heat shrinkable type), 18 switchgear busbar accessories and 11 Ring Main Unit switch or circuit breaker related faults.

All these showed a high activity of partial discharge and therefore immediate action was taken to repair or replace the defective components. Had these faults not been detected then Enemalta customers would have experienced power cuts and in some instances insulation breakdown would have led to catastrophic failure of the substation with wider consequences. Figure 1 shows the quantity of PD activities located in various switchgear compartments.
For the majority of Enemalta substations, the use of portable instruments has proven to be a cost effective way forward. However, some assets were considered to be critical because:

1) their continued reliability was key to the stability of a large section of the Enemalta network supplying substantial numbers of customers with importance to Malta’s economy i.e. tourist and industrial areas;

2) they are known troublesome assets with a history of problems but were currently not shortlisted for replacement;

3) where intensive but intermittent PD activity had already been detected with portable instruments and a measure of the activity over time was required.

It was for these reasons that Enemalta decided to install a continuous partial discharge alarm system into its substation at Msierah Distribution Centre, New Hospital Distribution Centre and later at Marsa South Distribution Centre. The chosen system was an UltraTEV Alarm.

The installation of this equipment supported with the PD Locator and the Ultrasonic equipment provided further information about the state of the switchgear where the UltraTEV Alarm was installed. Where previously a snapshot of readings was taken through a scheduled programme, now these substations were being monitored continuously and intermittent partial discharges were detected. Although these results raised concern to the maintenance engineers, they were in a position to further investigate and plan an outage on the affected switchgear before any partial discharge became continuous or, worse still, the equipment failed.

Indeed, through use of the UltraTEV Alarm, the maintenance engineers managed to locate and repair or replace some defective components such as an 11kV Voltage Transformer, an 11kV circuit breaker, a 33kV single core cable and 11kV busbar.

The types of switchgear installed at these substations are as follows:

<table>
<thead>
<tr>
<th>Substation</th>
<th>Voltage</th>
<th>Type</th>
<th>Manufacturer</th>
<th>Year</th>
<th>Insulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Msierah DC</td>
<td>11kV</td>
<td>VMXC</td>
<td>GEC ALSTHOM</td>
<td>1995</td>
<td>Air insulated busbar</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cast Resin bushings</td>
</tr>
<tr>
<td>New Hospital DC</td>
<td>33kV</td>
<td>HMXS</td>
<td>GEC ALSTHOM</td>
<td>1995</td>
<td>Air insulated busbar</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cast Resin bushings</td>
</tr>
<tr>
<td>Marsa South DC</td>
<td>11kV</td>
<td>SAFESIX</td>
<td>ABB</td>
<td>1992</td>
<td>Air insulated busbar</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cast Resin bushings</td>
</tr>
</tbody>
</table>

PD Activity in a Heat Shrinkable 11kV Termination

UltraTEV Alarm system installation
DESCRIPTION OF THE SYSTEM

The system consists of a series of nodes magnetically attached to each switchgear panel in a substation. On the back of the node is the TEV sensor. In addition, each node can be equipped with ultrasonic detection via a magnetically clamped microphone on a flexible stalk. The nodes are daisy chained together with a single wire carrying both signals and power. Each node is capable of recording a Current TEV Alarm and a Current Ultrasonic Alarm. The nodes will show when an alarm has occurred at some point previously via a separate Historic TEV Alarm and Historic Ultrasonic Alarm. The nodes apply a time constant to help prevent spurious noise tripping a Historic Alarm. The Alarm States are communicated back to Hub unit using the single wire bus. The Hub unit also provides power to the Nodes.

The Hub unit provides a contact closure to indicate either a Historic TEV or Ultrasonic alarm. This contact closure can be used to trigger a local visual or audible alarm. Alternatively, the contact closure can be fed into a SCADA system, where this available. A third option, and the one selected by Enemalta, is to monitor the system for Alarms using GPRS/iHost system. This enables the Alarm state to be monitored by a web browser. This is a convenient solution for Enemalta and, additionally, allows EA Technology to easily view the results as part of its support for Enemalta.

RESULTS OF INSTALLATION

Almost immediately after installation of the UltraTEV Alarm, the Msierah substation was indicating abnormal PD activity. These initial results seemed to indicate intermittent PD activity but there was a lingering doubt. UltraTEV Alarm was new design and maybe something was not right, a previously undiscovered error in design or aberration of software. It required verification.

To do this EA Technology, supplied and installed in parallel a PD Monitor. The PD Monitor is a 12 channel TEV only monitor with advanced data collection and analysis. It records its data to a local FLASH memory card. Rather than just simple alarms states, it gives great detail on any PD activity and, by the use of precedence between probes [2]; it can assist in the location of TEV activity in the substation. It is an established design with loyal following from engineers but considerably more expensive option than the somewhat simpler UltraTEV Alarm.

A comparison of the results, over the same time period, of the UltraTEV Alarm and PD Monitor is shown in Figures 2, 3 and 4.

- Figure 2 shows the PD Activity (Short Term Severity) as recorded on Channel 6 of the PD Monitor.
- Figure 3 shows the PD Activity (Short Term Severity) as recorded on Channel 11 of the PD Monitor.
- Figure 4 shows the UltraTEV Alarm state (either OFF or ON).

Short Term Severity (STS) is a useful short hand employed by the PD Monitor for expressing PD activity over time. It is defined as:

$$STS = |TEV| \times P$$

where

- $|TEV|$ is TEV magnitude in mV
- $P$ is the number of TEV pulses per mains cycle
CONCLUSION

The comparative results showed a very good correlation between the UltraTEV Alarm and the PD Monitor. This gave Enemalta confidence in their new UltraTEV Alarm equipment. The switchgear continues to be monitored by the UltraTEV Alarm with further investigations ordered using portable PD detection equipment on any alarm raised. Faulty components are replaced as soon as a full outage is possible.

The two UltraTEV Alarm systems have now picked up critical partial discharge activity in both internal and external components including cast resin bushes and voltage transformers. All were spotted before they could develop into faults which could lead to failures. The UltraTEV Alarm had proven itself to be a cost effective method of monitoring for MV assets.

Enemalta are now proposing moving the equipment from use on primary substations (largely 33kV to 11kV) to use on their numerous secondary substations (11kV to 400V).

REFERENCES

