Multiple Partial Discharge Sources Discrimination and Localisation within a High Voltage Transformer Winding

Nik Hakimi Nik Ali, P. Rapisarda, P.L. Lewin
17th May 2017
Introduction
Introduction

• In high voltage power transformers, the winding system consists of multiple dielectric media all of which can degrade and subsequently exhibit pre-breakdown behaviour.

• The ability to accurately separate between different PD signals generated from different sources as well as their location is seen as an important function of diagnostic systems.
Measurement System
Figure 1. Experimental arrangement

Table 1. Multiple sources combination

<table>
<thead>
<tr>
<th>Combination</th>
<th>Terminal 1 – Terminal 8</th>
<th>Terminal 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Floating discharge</td>
<td>Surface discharge</td>
</tr>
<tr>
<td>2</td>
<td>Surface discharge</td>
<td>Void discharge</td>
</tr>
<tr>
<td>3</td>
<td>Void discharge</td>
<td>Floating discharge</td>
</tr>
</tbody>
</table>
Signal Analysis
Figure 3. Decomposition results in time (left column) and frequency (right column) domains of a Gaussian signal by using MM signal decomposition method. ((a) Original signal and (b)-(d) Decomposition results for the lengths of flat SE equal to 10, 15 and 20)
Different frequency bands of the measured signal produced from different lengths of SE contain different finite amounts of energy over their specific range.

The use of absolute energy distribution reveal the variation of energy at different measurement points and also at different terminals from different sources.

OPTICS have been used to reveal clusters of pulses that have similar characteristics in terms of their energy distribution.

OPTICS was found suitable for signal separation for its ability to discover clusters of arbitrary shape with different densities in n-dimensional space.
Clustering results
Clustering results

Figure 4. The reachability plot for bushing measurement point

Figure 5. 2D histogram pattern associated with each cluster

(a) Cluster 1

(b) Cluster 2

Figure 6. The reachability plot for neutral measurement point

Figure 7. 2D histogram pattern associated with each cluster

(a) Cluster 1

(b) Cluster 2
Localisation
• In order to estimate the sources location, clusters that are belong to the same PD source from both measurement points need to be paired.

  1. Inspection of the PRPD patterns.
     ▪ Lead to mismatched of the clusters.
     ▪ Need to be manually match by the users.

  2. The time relation between each pulse of each cluster.
     ▪ No mismatched of the clusters.
     ▪ Automatically match the clusters.
Signal cross correlation

Figure 8. Constructed streams; (a) and (b) for clusters from bushing tap point, (c) and (d) for clusters from neutral to earth tap point.

<table>
<thead>
<tr>
<th>Neutral</th>
<th>Cluster 1</th>
<th>Cluster 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bushing</td>
<td>97.63 %</td>
<td>2.37 %</td>
</tr>
<tr>
<td>Cluster 1</td>
<td>2.35 %</td>
<td>86.26 %</td>
</tr>
</tbody>
</table>

Table 2. Stream similarity percentage

• The pairing process is based on which pair of stream gives the highest cross correlation percentage.
• For visualization, PCA was implemented as a dimensional reduction tool to the paired energy data. PCA generates the principle component values of the data, which is representation of the original data in the principle component space.

Figure 9. Clusters plot of source 1 for combination of floating and surface discharges.
Separation distance plots

- In order to precisely determine how much the variation occurs at each terminal along a transformer winding, it may be useful to measure the separation distance between clusters.

Figure 10. Separation distance plots of clusters in 3D for combination of (a) floating and surface discharges (b) surface and void discharges and (c) void and floating discharges.

Figure 11. Separation distance plots of clusters in 20D for combination of (a) floating and surface discharges (b) surface and void discharges and (c) void and floating discharges.
Practically, PD signals can be also injected at bushing core bar and measured at the bushing tap point and neutral to earth connection.

It produced largest separation distance between clusters. Thus, by using the ratio of separation length of the terminal, $D_{\text{terminal}}$, with respect to the bushing core bar separation length, $D_{\text{reference}}$, the location of PD sources along the winding can be estimated.

The ratio, $R_D$ can be calculated by using:

$$R_D = \frac{D_{\text{terminal}}}{D_{\text{reference}}}$$
Conclusion
The operation of a potential future condition monitoring tool that uses pulse waveform information for classification and localization of multiple PD sources within high voltage transformer winding has been proposed.

Cluster plots produced based on a combination of mathematical morphology energy analysis and OPTICS can be used in order to separate multiple PD sources within a transformer winding.

By using the time relation between each pulse of each cluster, a technique that can match source pairs from both measurement points of transformer winding was developed.

The ratio of the length of transformer winding has been used to estimate the location of multiple PD sources within a transformer winding.
The Tony Davies High Voltage Laboratory