SOME ADVANCES IN PD MONITORING FOR HIGH VOLTAGE CABLES

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Abstract

Some advances have been made recently with detection of the PD activity of medium voltage cables, using an on-line method of detection. This paper illustrates the relationship between the original VLF (very low frequency) power supply results of PD mapping in medium voltage cables, and the newer on-line monitoring methods. The on-line methods offer the possibility of scanning circuits quickly and relatively cheaply to obtain meaningful PD data for older installed cables.

Introduction

The technique of partial discharge mapping has been used on high voltage cables for over ten years in different phases of the development of the method. Since 1987, the method has used a low frequency high voltage power supply to energise the cables, which are isolated from the network for the measurements. These traditional methods can be combined with, and complemented by using PD detection with high frequency current transformers in an on-line method.

Some results are presented from a PD mapping survey carried out by EA Technology over the last ten years. The PD data does correlate with failures and service performance and is clearly dependant on a number of factors including working stress, manufacturing quality, service history and cable type. The newer on-line methods are described, and the benefits resulting from the method are postulated.

PD Measurement methods

Partial discharge measurement and location (mapping) was originally developed for asset management of paper insulated cables. The method operates satisfactorily for polymeric cables, with the proviso that the detection sensitivities required are less in these cases, and better noise immunity will be required. In general, the measurement and location of partial discharge in cables requires a high voltage power supply (PD free) which can apply working voltage (or slightly above) to the cable under test. A VLF supply was used for the off-line measurements, operating at a frequency of .05Hz - 0.50Hz. dependant on the cable lengths for which the method applies. The power supply uses two solid state current controlling stacks. Figure 1 shows the arrangement for locating the partial discharges on the HV cables for both off-line and on-line methods.

In the off-line case, the partial discharges are measured via a high voltage blocking capacitor which is connected to the cable at the point of measurement. A filter and buffer amplifier are used as the detection impedance and a 50Ω coaxial line is taken to the measurement system. The on-line monitoring method uses a current transformer in the earth strap of the cable, with the same detection system. The discharges are then recorded on a digital oscilloscope and transferred under computer control to disc storage

The recorded data is then processed to measure the location of the discharge event and its magnitude (using the area under the current/time curve to calculate the charge). This processed data may then be used to produce the partial discharge map which shows the discharge activity as a function of the cable length. All three phases are plotted on top of each other (where this is appropriate) to allow geographical comparisons of the cable phases.

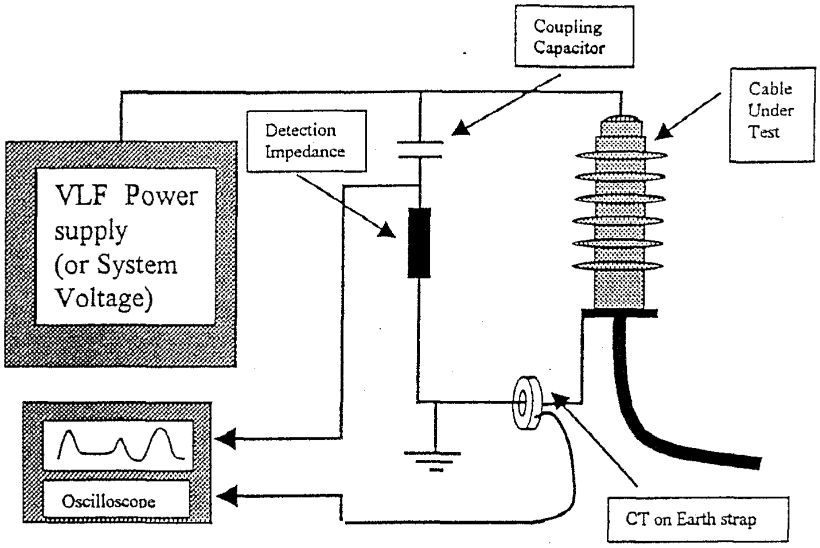


Figure 1 Partial discharge mapping circuit

The method can be used to measure the partial discharge activity on cables from 4m to 2.5km in length, the latter figure arising from the attenuation of the discharge pulses normally associated with paper insulated cables. Longer XLPE cables can be tested. The measurements are normally limited by noise from radiated electromagnetic interference which is variable from site to site. Noise levels between 10pC-500pC are observed with a mean level typically around 100pC.

Results

The database of results contains over 400 circuits at service voltages between 6.6kV and 33kV..

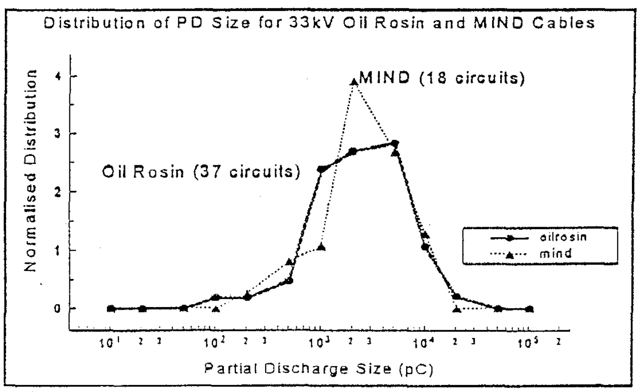


Figure 2 Distribution of maximum PD for Oil Rosin and MIND cables

Figure 2 shows the normalised magnitude distributions for 33kV Oil rosin and MIND cables (Mass Impregnated Non Draining). The distributions are normalised because the number of measurements is not the same for the different types of cable. The PD magnitude scale is pseudo logarithmic with the scale going from 10pC to 100 000pC. The distributions are remarkably similar. There may be a slight tendency for the oil rosin cables to exhibit larger discharge than the MIND cables. The oil rosin cables tend to be older than the MIND cables. Generally, oil rosin cables have been installed in the UK up to 1970, and MIND cables from then onwards.

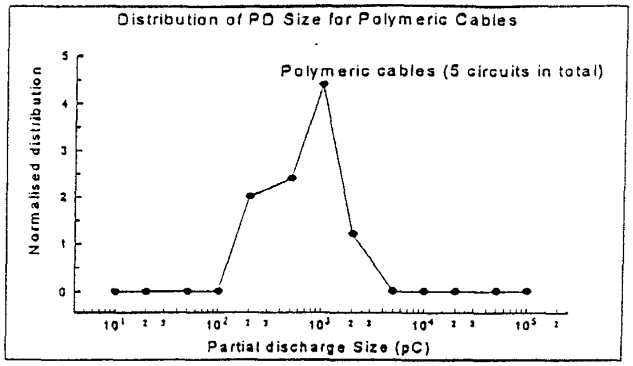
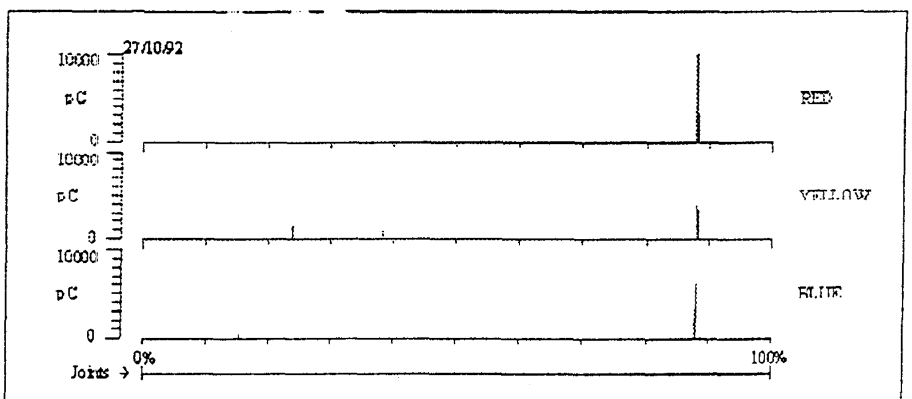


Figure 3 Distribution of Maximum PD for polymeric cables

Figure 3 shows the maximum distributions for XLPE cables. This distribution is surprising, as all XLPE cables manufactured in the UK are tested to be discharge free. (actually less than 10pC at 1.5 or 2.0 times working voltage The explanation is that the discharge events arise from accessories, and not the cables themselves. This will have implications for the cable network.

Quite a number of cables have failed subsequent to the cable map being made. A major objective of the work, is to relate PD activity to service life. In many cases, very little data has been collected from the circuit following failure, unless the engineer involved has either sent a report back to EA Technology, or other records exist. Hence it may well be that many circuits in the study have failed, but these are simply unknown

The output from the PD mapping system is a graph of the discharge activity as a function of cable length. The following diagrams illustrate the output.



	RED	YELLOW	BLUE
Inception voltage (kV rms):	-	-	-
Number of cable events:	90	88	90
Max cable discharge (pC):	12397	3744	6058
Ave. cable discharge (pC):	4463	2262	3401
Max term. discharge (pC):	0	0	0

Termination end effects:	3%
Cable length:	736m
Cable return time:	9us
Cable type:	2sqin Cu 11kV BELTED

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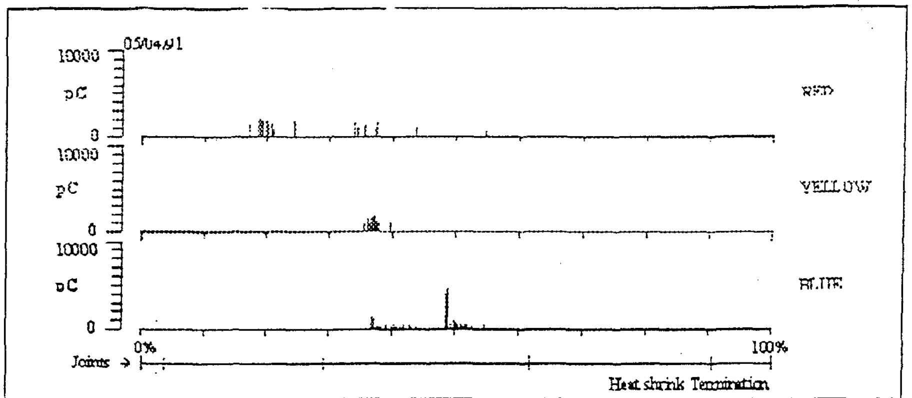
Figure 4 PD map for a 11kV MIND cable with installation damage

Figure 5 shows an oil rosin 33kV cable which failed at two positions, 184m (failed Aug. 1993) and at 134m (failed Nov. 1993) from the near end. No data is available from the fault examinations, but are known to be internal failures of the insulation.



	RED	YELLOW	BLUE
Inception voltage (kV rms):	12.0	12.5	15.3
Number of cable events:	116	70	151
Max. cable discharge (pC):	2249	1800	4476
Ave. cable discharge (pC):	1226	1139	1689
Max term. discharge (pC):	0	0	0

Termination end effects:	3%
Cable length:	339.01 m
Cable return time:	4.62μs
Cable type:	250IN OIL ROSIN 33kV PILC

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Figure 5 33kV oil rosin cable, failed in service.

The partial discharge detection and location can be carried out using on-line methods. The most convenient method is to use a high frequency current transformer on the earth strap or around the whole cable at the section of the cable with the earth removed. With a split core CT, many results can be taken in a relatively short time. This allows magnitude data as well as location data to be collected simply and cheaply. In a utility, the classification of the cable circuits into a priority for any replacement programmes, has large implications for cost and reliability. This method can give easy and inexpensive PD data on cable circuits. Incidentally, this actually also applies to switchgear PD data, with detection sensitivities which compare well with other non intrusive methods, and generally with improved noise immunity.

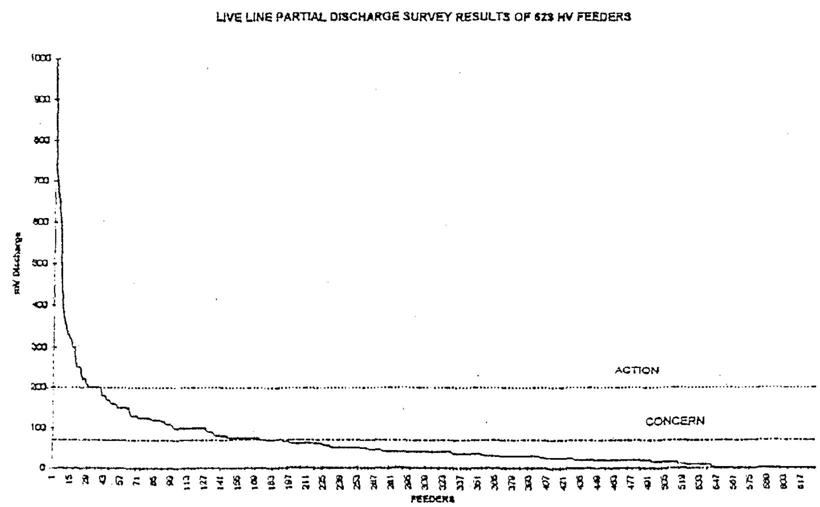

Figure 6 Survey of 629 11kV Feeders using on-line PD data

Figure 6 shows the results for a survey of 629 MV feeders. The magnitude of data is measured in mV at the output of a high frequency split core CT. The method shows the advantage of prioritising circuits so that more expensive diagnostics can be targeted on those circuits more at risk from PD related failures

Conclusion

The paper has outlined the method of PD mapping The work has shown good correlation between the PD activity and service performance.[5] This is particularly true for the failures occurring following testing. However remaining life of cables is not always accurately predicted. A summary of the findings are:-

- The PD method works well for HV paper insulated cables, and shows good correlation with service conditions. Large PD activities are associated with poor service performance, and circuits with no service failures, and no cable deterioration, show very small activity.
- The PD levels do not give a time to failure of a cable system yet. This may be improved in the future, when PD levels throughout the cable life may be measured.
- The positions of PD activity in HV cables correlates well with failures, mechanical damage, and joint problems.
- Some failures have occurred in cables which have shown no PD at the sites of failures. However for operational reasons no examinations of these failures have been made to correlate with the PD data.
- Measurements on polymeric cables have no PD activity within the cables. However, accessories do show PD activity. No correlation with failures yet made.
- There seems to be no 'safe' limit for paper insulated cables. It is difficult to measure PD levels correctly, but failures in paper insulated cables have been associated with PD levels as low as 1100pC. A 'safe' limit for paper insulated cables will probably be less than this.
- On-line PD methods can provide excellent diagnostics for use on networks, with very large cost/benefit ratio. Some aspects of off-line techniques are complementary to the on-line methods.

References

1 Mackinlay R.R. "Managing an ageing underground high voltage cable network", Power Engineering Journal November 1990

2 Robinson G. "Ageing characteristics of paper insulated power cables" Power engineering Journal, March 1990

3 Robinson G. "The interperetation of discharges in paper insulated cables" ECRC Report R2393 december 1989

4 Robinson G. "Prediction of life of paper insulated cables: using low frequency voltage ramps to initiate characteristic discharges" EA Technology report No 3606, September 1995

5 Hetzel, E. and Mackinlay R.R. "Diagnostic field testing of paper insulated lead covered MV cable" Jicable, Fourth International Conference on Insulated Power Cables, Versailles, June 1995

Acknowledgements

The Authors would like to thank EA Technology and London Electricity for their help and kind permission in publishing this work.