NEW STUDIES ON PD MEASUREMENTS ON MV CABLE SYSTEMS AT 50HZ AND SINUSOIDAL 0.1HZ (VLF) TEST VOLTAGE

K. RETHMEIER, P. MOHAUPT
BAUR Pruef- und Messtechnik GmbH, Sulz, Austria
k.rethmeier@baur.at

V. BERGMANN, W. KALKNER
Technische Universitaet Berlin, Dep. of HV-Engineering, Berlin, Germany
bergmann@ihs.ee.tu-berlin.de

G. VOIGT
Hochschule Konstanz, Dep. of HV-Engineering, Konstanz, Germany
gvoigt@htwg-konstanz.de

ABSTRACT

Sinusoidal 0.1 Hz VLF test voltage is suitable for cable diagnosis. The diagnostic results are well comparable to measuring data at power frequency.
New studies performed by Technische Universitaet Berlin and Hochschule Konstanz are confirming the good comparability of diagnostic results achieved at sinusoidal 0.1 Hz VLF test voltage compared to 50 Hz and 60 Hz power frequency respectively. Specifically the PD inception voltage (PDIV), the PD level and the phase resolved graphical PD pattern are very similar. This makes VLF test voltage in combination with PD measurements a suitable approach for on-site cable testing.

INTRODUCTION

Since decades the partial discharge (PD) measurement is an important and reliable, non destructive measurement to investigate prospective lifetime and ensure performance of HV apparatus [1-4]. From laboratory the PD routine test is known with a range of PD levels around some pC for cables and accessories. On site, field PD diagnosis however requires different approaches. For medium voltage cable systems the determination of the exact PD level is not the most important issue. Of much more interest is, if there is any PD inception at V_0 or at 1.7 V_0 or not. If there is, this would be harmful in case of a polymer insulated cable or would need further interpretation in case of PILC cables.
In most cases the PD is not located within the cable insulation itself, but in joints and terminations. Therefore it is very important to identify the location of the PD source. PD levels of some 100s of pC or even nC however in accessories may not lead to a failure within years. The remaining lifetime depends on a wide variety of parameters. Lifetime assessment is a complex topic.
Although the power frequency is 50 Hz and 60 Hz respectively, on-site testing is often performed with lower test voltage frequencies as 0.1 Hz VLF test voltage with sinusoidal voltage shape [5,6]. Using VLF test voltage sources leads to benefits in system size and weight and more important to benefits in system costs. Typically it is compared, whether defects result in comparable PD signals at 50/60 Hz and at VLF testing.
In the past several scientific and practical studies concerning the comparability of the diagnostic results had been carried out [7-10]. A general conformance could be stated that critical defects in cable systems are detected with PD measurements at both, 50/60 Hz and VLF. Nevertheless additional new studies had been performed in 2006 by independent departments of high voltage engineering institutes at Technische Universitaet Berlin and Hochschule Konstanz to confirm and to underline these results [11,12]. For these studies modern digital state-of-the-art PD measuring systems have been used to profit from the benefits of new technologies in hard- and software.

PD MEASURING SYSTEMS

The PD measurements have been performed on one hand with the established measuring device ICMsystem (Powerdiagnostix, [13]) as a well known and widespread diagnosis instrument. On the other hand the MPD 540 (mtronix, [14]) was used as a second type of digital pd measuring system. A brief overview on this system is given.

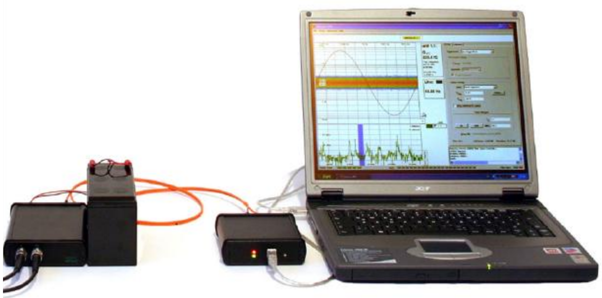


Fig. 1: MPD 540 PD measuring system (PD acquisition unit, power cell, Optic-USB converter, Notebook)

This measurement system consists of one or more acquisition units (fig. 1), an optical interface (fibre optic bus-controller) and a PC including measuring software.

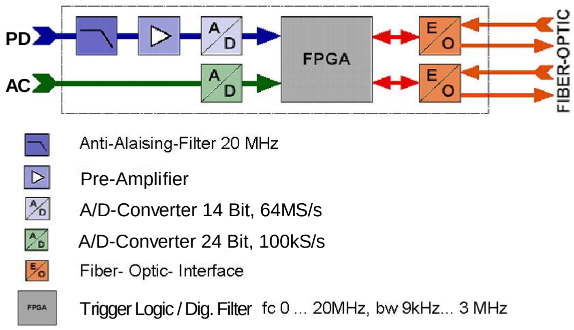


Fig. 2: Block diagram of an acquisition unit of MPD 540

The PD signals are filtered, amplified and digitized. Having an amplitude quantization of 14 bit and a sampling rate of 64 MS/s, the time accuracy of detection of a PD signal is at about 2 ns. The quasi-integration is realized by a digital band-pass filter. The centre frequency for the digital filter can be chosen in a frequency range from DC up to 20 MHz, the bandwidth between 9 kHz and 3 MHz, respectively. Hence an optimal frequency band can be chosen to avoid disturbances and to reach a high SNR even under noisy conditions on site. Furthermore, the test voltage signal is digitized in acquisition unit to document the test voltage during the PD measurement (see fig. 2).

TEST VOLTAGE SOURCE

The sinusoidal VLF test voltage with 0.1 Hz frequency was generated with a commercial mobile VLF generator (VLF28, BAUR) and an experimental VLF voltage source designed for test voltage levels up to aprox. 400kV$_{eff}$ alternatively. This generator has a very low noise level, so sensitive PD measurements could be performed.
Reference PD measurements were performed with 50 Hz test voltage frequency.

TEST SAMPLES

For basic measurements well known structures and geometries (tip on potential, tip on ground, Toepler discharges) were considered. As a next step MV cable and cable accessories were prepared with artificial defects. One termination of a short cable test sample was removed in order to force heavy discharges. In another test series an impurity was implemented under the stress cone of one cable termination to create a void (see fig. 3).

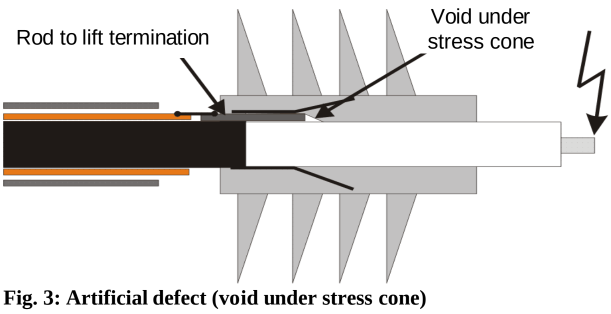


Fig. 3: Artificial defect (void under stress cone)

To simulate an irregularity or damage a small part of the outer semicon layer was removed, as shown in fig. 4.

Fig. 4: Artificial defect (damage of semicon layer)

Due to the ongoing outsourcing process many accessories are mounted on site by subcontractors nowadays. This sometimes goes ahead with a loss of know how and quality awareness. Therefore several test accessories are mounted wittingly in an incorrect way. For instance, fig. 5 shows a part of a joint with improper measures leading to partial discharges.

Fig. 5: Incorrect mounted joint

RESULTS

All PD measurements have been performed at sinusoidal 0.1 Hz VLF test voltage and 50 Hz power frequency, respectively.

PD Inception Voltage

For all test samples and test series the PD inception voltage was noted. Figure 6 shows the results for artificial PD defects.

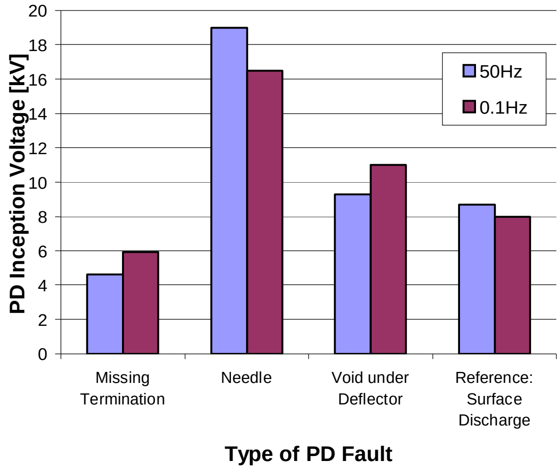


Fig. 6: PDIV of artificial defects

In all observed test series the PD inception voltage was well comparable for 0.1 Hz VLF test voltage and for 50 Hz power frequency.

Also the misassembled joints showed a similar PD behavior concerning the PD inception voltage (see fig. 7).

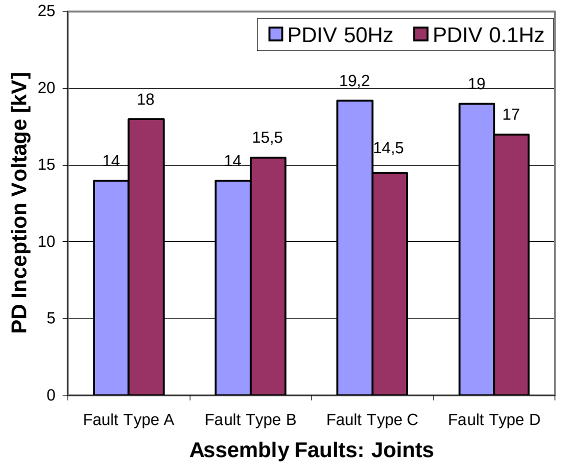
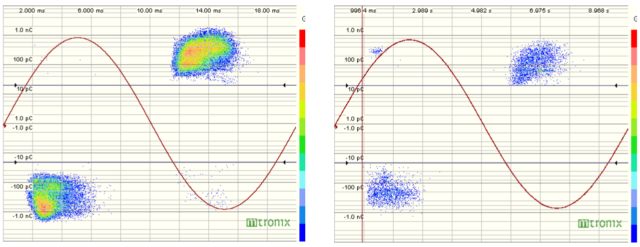


Fig. 7: PDIV of assembly faults

It can be stated that the PD inception voltage levels at 0.1 Hz VLF are in the same order of magnitude with less then 30% deviation compared to 50 Hz power frequency. In some cases the PD inception voltage level was even lower for VLF as for 50 Hz power frequency (faults Type C and D).

Phase Resolved Partial Discharge (PRPD) Pattern

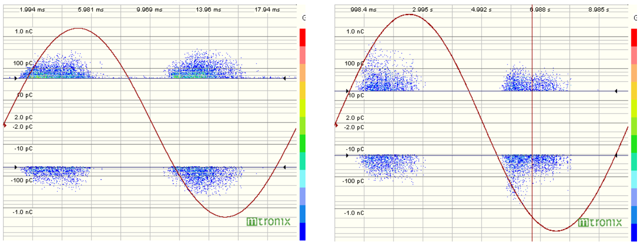
For further statistical analyses PD pattern were recorded. Due to significant clusters PRPD pattern are an important tool to estimate the type of the PD defect or even its position in the cable system [15]. Therefore it is important to proof the similarity of these typical cluster formations, too.
Figure 8 shows the PRPD pattern of a Toepler surface discharge for 50 Hz and 0.1 Hz.



50 Hz **0.1 Hz**

Fig. 8: PRPD Toepler

The PD clusters are nearly identical in shape and phase position related to the test voltage. Therefore the diagnostic result based on these clusters will be identical, too.
Figure 9 shows the PRPD pattern of an artificial defect within the cable termination (void below stress cone).



50 Hz **0.1 Hz**

Fig. 9: PRPD, void

Four significant clusters can be seen in both diagrams, symmetrically to the zero-line within the rising positive edge and the trailing negative edge. An identification of the PD fault can be done successfully for 0.1H Hz VLF as well as 50 Hz.

ON-SITE APPLICATION

Doing PD measurements on medium voltage cable systems on site the main focus is the localization of the PD fault in order to replace joints or cable sections. Therefore an automatic statistic PD pulse acquisition with TDR failure estimation has to be started. Figure 10 shows a location graph of a 6.6kV XLPE cable system with aprox. 1200 m length.

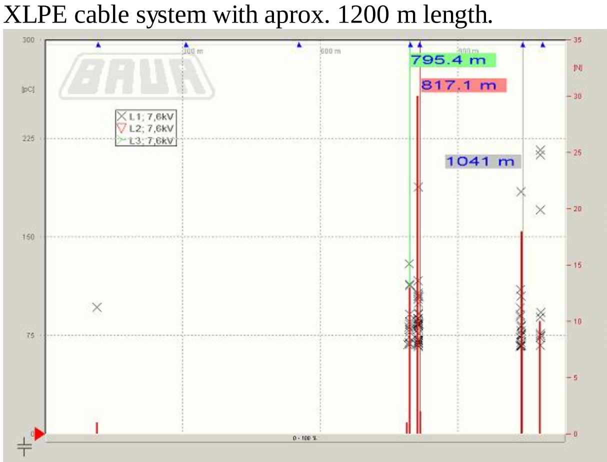


Fig. 10: localization of PD defects, automatic analyses (software screenshot)

The red columns indicate the position of defective joints that should be observed in detail. PD activity inside joints can lead to material degradation (see fig. 11) and finally to the breakdown of the whole cable system.

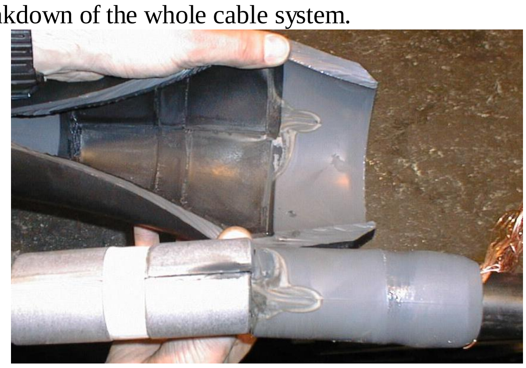


Fig. 11: PD activity due to improper bending of joint

CONCLUSION

On-site PD measurement as a tool to diagnose medium voltage cables can improve the reliability and extend the lifetime of the whole cable system [16,17]. Therefore light weighted and small sized VLF test systems are available to perform PD measurements with sinusoidal 0.1 Hz VLF test voltage. It has been shown in independent up-to-date studies accomplished at German universities in 2006 that diagnostic results of 0.1 Hz test voltage frequency are well comparable to service conditions with 50 Hz power frequency. PD inception voltages as well as PRPD pattern are similar so results of diagnostic measurements are well transferable.
Due to good experience on the MV cable sector the use of sinusoidal VLF test voltage will be extended even to HV and EHV cable systems. First studies showing promising results have been published [18].

REFERENCES

[1] A. Borlinghaus: „Kabeldiagnose mit 0.1 Hz Sinusspannung – Erfahrungsbericht der RWE Energie AG“ RWE Energie AG, 1999

[2] van Schijk, Steenis, van Dam, Grotenhuis, van Riet, Verhoeven: Condition based maintenance on MV cable circuits as part of asset management, CIRED, Amsterdam, 2001

[3] K.Weck: Zustandsorientierte Instandhaltung von Mittelspannungsnetzen, FGH-Forschungsreport 2002

[4] Smit: Trends in PD-diagnostics for Asset Management of Aging HV Infrastructures, -14th International Symposium on High Voltage Engineering, Bejing/P.R.China, 25-29th August 2005

[5] Muhr, Sumereder, Woschitz: The use of the 0.1 Hz cable testing method as substitution to 50 Hz measurement and the application for PD measuring and cable fault location, 12 th International Symposium on High Voltage Engineering (ISH), Bangalore, IND, 2001

[6] S. C. MOH, 2003, "Very low Frequency Testing – Its Effectiveness in Detecting Hidden Defects in Cables", CIRED 03, Barcelona, Session 1, Paper 84

[7] R. Plath, W. Kalkner, I. Krage: „Vergleich von Diagnosesystemen zur Beurteilung des Alterungszustandes PE/VPE-isolierter Mittelspannungskabel“ Elektrizitätswirtschaft, Jg 96

[8] K. Rethmeier, W. Kalkner: „Untersuchungsbericht: Vor-Ort-TE-Messungen an Mittelspannungskabelstrecken sowie Laboruntersuchungen an aufgenommenen teilentladungsbehafteten Muffen“, Investigation report TU Berlin, Institut für Hochspannungstechnik, 2000

[9] Voigt, Mohaupt: Partial Discharge Measurements on Service Aged Medium Voltage Cables at Different Frequencies, Jicable 03, Paris, F, 2003

[10] Pepper, Rethmeier, Kalkner: PD-Testing of Service Aged Joints in XLPE-insulated Medium Voltage Cables at Test Voltages with Variable Shape and Frequency, 13th Int. Symposium on High Voltage Engineering, Delft, The Netherlands, 2003

[11] Kalkner, Rethmeier, Bergmann: Untersuchungen zur Eignung von VLF-Prüfspannung zur Spannungsprüfung und zur diagnostischen TE-Messung an VPE-isolierten 110-kV-Kabelanlagen, Investigation Report, 2006, Technische Universitaet Berlin, Dep. of HV-Engineering, Berlin, Germany

[12] Voigt: Teilentladungsmessungen An Mittelspannungskabeln und Garnituren bei 50 Hz und 0,1 Hz, Investigation Report, 2006, Hochschule Konstanz, Dep. of HV- Engineering, Konstanz, Germany

[13] Power Diagnostix Systems GmbH: PD Measuring Device ICMsystem, Product Brief, Aachen, Germany, 2004

[14] mtronix: Advanced PD Analysis System MPD 540, Product Brief and Technical Specification, Berlin, Germany, 2004

[15] D. Pepper, W. Kalkner: PD-Pattern of Defects in XLPE Cable Insulation at Different Test Voltage Shapes, 11th International Symposium on High Voltage Engineering (ISH), London, England, 1999

[16] Mohaupt, Reimann, Rethmeier: Practical Aspects and Experience of On Site Diagnosis on MV Cables, 16th Conference of the Electric Power Supply Industry, 2006, Mumbai, India

[17] Rethmeier, Reimann: Experience of On Site Diagnosis on MV Cables, MNC-CIRED, Asia Pacific Conference on T&D Asset Management, 2006, Malaysia

[18] Rethmeier: VLF for Diagnosis on High Voltage Cable Systems CIGRE Session 2006 - Paris, France, Spontaneous Contribution B1-2-7