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EXPERIENCE WITH OFFLINE PD-DIAGNOSIS ON MV CABLES – KNOWLEDGE RULES FOR ASSET DECISIONS

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ABSTRACT

The detection, location and evaluation of partial discharges (PD) inside the insulation and the accessories of XLPE and PILC cables offer the possibility of an early diagnosis of cable network failures, however, with the need of a clear differentiation between the insulation systems and the accessories.
In order to be able to carry out an evaluation of the risk factor of PD defects as exactly as possible, the applied voltage for a PD diagnosis should be within the range of the operating frequency, because the typical PD parameters, such as inception and extinction voltage, PD level and PD pattern then correspond to the relevant values under operating conditions.
On the other hand, the electrical stress during the diagnosis measurement should be limited to the extent that no irreversible damage and hence deterioration of the condition of the test objects takes place.
The main difficulty is to evaluate the risc of PD occourences on the reliability of the cable system. If an sufficient amount of PD diagnostic data for the cable components is available statistical methods can be used for determing threshould levels and relevant condition indexes for the asset management.

KEYWORDS

Condition assessment, MV power cables, PD measurement on site

INTRODUCTION

Due to privatisation and regulation of the electricity market the relaibility of distribution networks became more and more importance. Customers minutes lost has to be monitored and the asset management departments are requesting clear indication about the condition of MV cables and their accessories. Since the beginning of the eighties, a large number of XLPE first generation cables have shown the known “water treeing“ and have meanwhile been exchanged or renovated for the most part. It is possible to determine the condition of these cables with the known dielectric diagnosis methods [1-3], which will certainly be necessary for the next 10 years as well.
The much older paper-oil-cables on the contrary are rather inconspicuous regarding their operating performance, even though their predicted lifetime of 40 years has long since been surpassed. As these cables, as every technical insulation, are subject to complex operating stress, ageing and partly forced local damage accumulation have to be reckoned with.

IMPORTANT PARAMETERS FOR PD DIAGNOSIS

The physics and causes for PD defects in XLPE and PILC cable systems is mainly well known and described in detail in several publications. [4 - 8]
From the view of the network owner it is in the first line important to know, if the cable system is operating with permanent PD occurrences under normal service conditions or not.
The second important issue is the behaviour of the insulating system in case of over voltages due to earth faults or switching. In networks with resonance grounding a voltage of 1.7 Uo is applied over some hours to the cables.
If a cable system has during normal operation at Uo continuous PD the question about the risk of these PD is raised.

Basically, three parameters are important for the judgement of the PD behaviour of a cable system.

PD Inception Voltage Ui, PD Extinction Voltage Ue and PD Level . Normally, the maximum impulse charge at Uo is used as a assessment criterion. There are already relatively good experiences in order to evaluate the risk factor for the reliability of operation depending on the location of the PD (cable, joint, terminations), the type of insulation of the cable and the design of the accessories. The occurrence of PD impulses also characterizes the risk coming from a PD source.

IMPROVED TECHNOLOGY FOR PD ONSITE TESTING WITH DAC

About 80 Systems with damped AC technology for medium voltage cables are in use worldwide with excellent experience [6-9]. Due to the resonance principle the PD test is performed by exiting the cable with a voltage shape close to service voltage. The short duration of the exiting voltage is non-destructive which is also very important.
The experience of 6 years field application leads to some improvements in the new generation of the OWTS M-versions (figure 1).

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Besides the hardware optimization for light weight and small size, a new technology for automatically adjustment of the bandwidth of the measurement circuit for optimised signal detection and pd fault location was developed. That means in case of short cables a

Figure 1: PD Offline Test with DAC energizing

high resolution due to bandwidth up to 45 MHz is realised while on long cables the bandwidth adoption leads to higher sensitivity for dispersed signals.

The easy to use automatic calibration mode contains a feature for joint location, which is often helpful to locate unknown joint positions (figure 2).

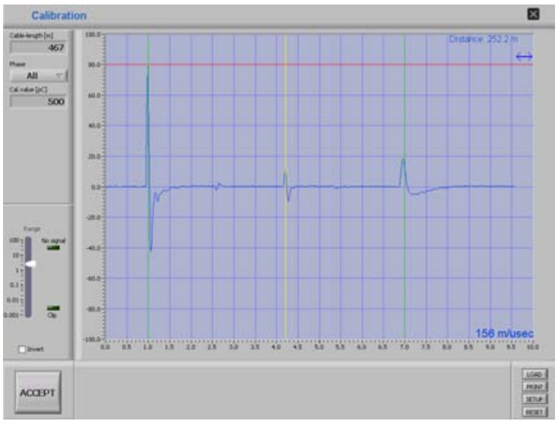

Figure 2: Joint location feature in calibration mode

EXAMPLES OF TYPICAL PD DEFECTS INVESTIGATED WITH OWTS

Typical pattern from PD in an oil filled system (figure 3) can be clearly distinguished from PD in voids, gaps or for example from PD between paper layers in a dry area of PILC cables (figure 4).

The PD locations are often to be found in the accessories of the cables. There is comprehensive experience on PILC cables [6-8].

While PD in oil filled joints up to 10 nC are mostly not critical also over a long time, a concentrated PD within the paper insulation Figure 5 could force to a breakdown in a certain time.

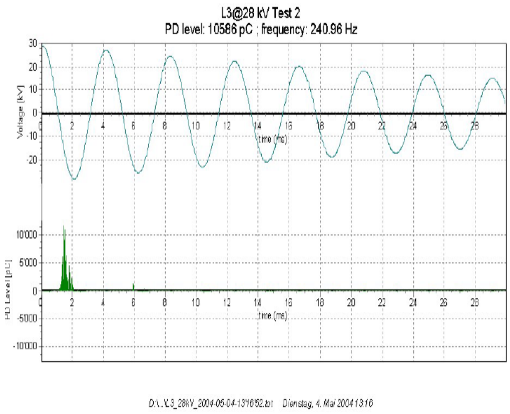

Figure 3: PD pattern in oil filled systems

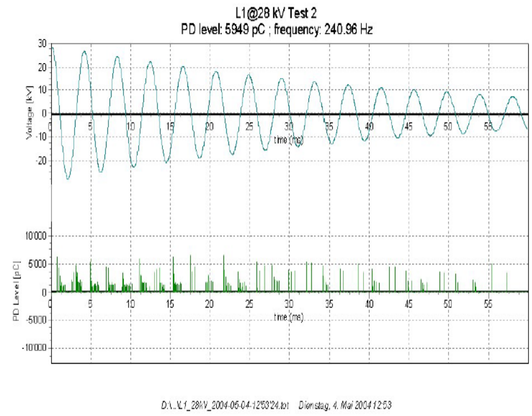

Figure 4: PD between paper layers of dry PILC

On the other hand , a joint in PILC cable can be the cause of brief transient earth faults even with relatively low PD levels. If it is found out during the PD diagnosis that only one joint is PD-affected, it is obvious to replace this joint in order to eliminate the problem, even it has low PD level.

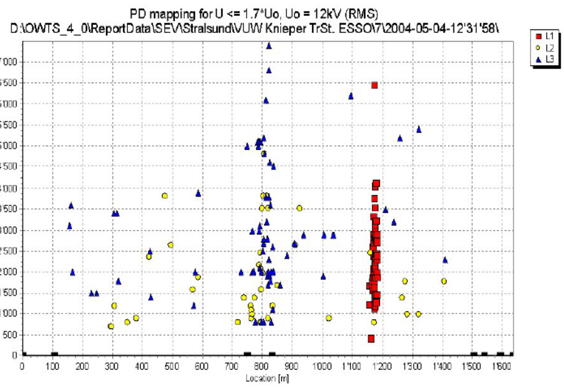

Figure 5: concentrated PD in PILC insulation at 1180 m and in a joint at 820 m

Mappings of PILC cables often show a “Christmas tree-like” distribution of the PD locations (figure 6).

In this case the joint looses its oil filling due to a leakage and the paper insulation nearby the joint is drying out.

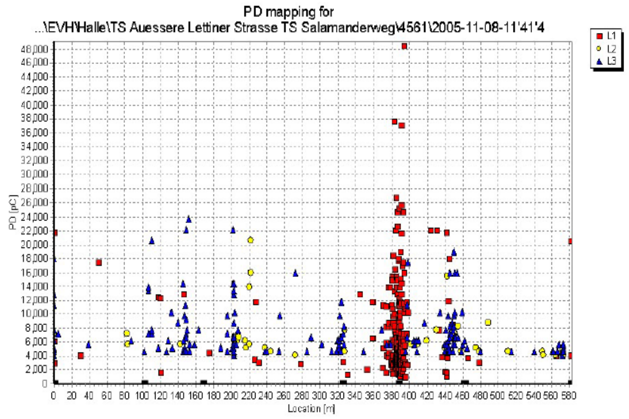

Figure 6: PD in paper insulation nearby a dry joint due to leaking

An other typical situation is mechanical damage of PILC lead sheath due to too strong bending. In this example the PD occurrences where located at a place of a transition joint with about 60 nC at Uo (figure 7). The inspection of the joint shows no mistake in the joint but an extremely deformed lead sheath close to the joint (figure 8)

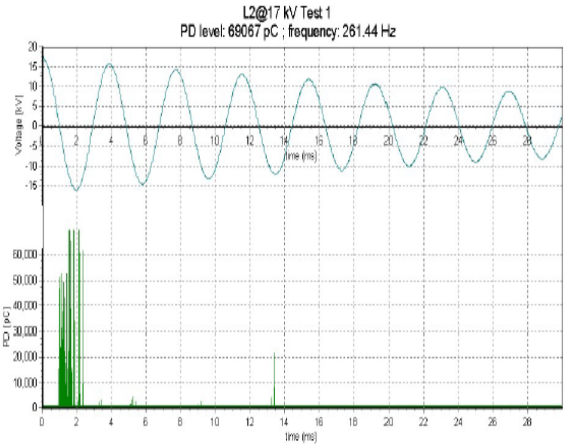

Figure 7: 60 nC in heavily damaged PILC see fig. 8

Figure 8: Mechanical damage due to strong bending causes PD in PILC insulation

While in PILC scattered PD locations in the paper insulation are quite normal and not dangerous (figure 5 and 6) in XLPE cables in the insulation normally no PD is to be observed. In XLPE cables PD faults are mainly caused by bad workmanship at joints and terminations. In figure 9 It can clearly be seen that in the set of joints at 200 m in conductor 1 and at 360 m in conductors 2 and 3, PD with high intensity very often occur. This test object is a 20 kV XLPE cable system with poorly mounted heat-shrink joints. Remarkably these extremely bad mounted joints with very high PD levels did not lead to a failure of the joints until 5 to 6 years of operation (figure 10).
In the last 5 years lots of similar assembly defects were detected and located by OWTS technology.

Because of the stochastic of the physics of PD in any case a statistical evaluation of the PD signals is absolutely necessary for a significant statement about the type and location of PD sources! Interpretations based on just a few assumed PD signals can lead to wrong decisions with very high subsequent costs. After all, the network operator must make a sound decision about the replacement or not of the affected accessories or cable sections based on the PD diagnosis.

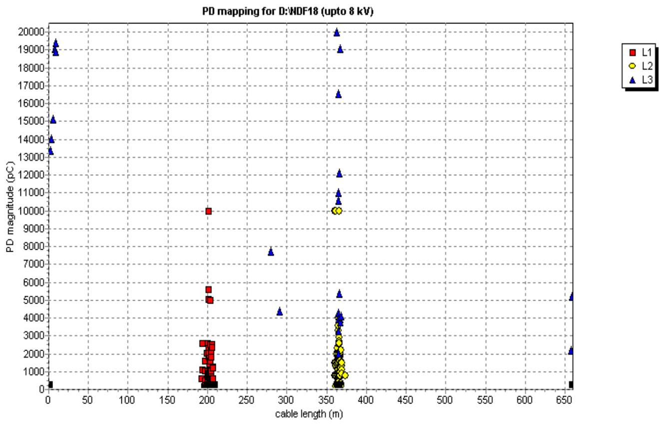

Figure 9: PD locations in bad mounted heat shrink joints of XLPE cable

Figure 10: Gap between field stress tube and insulation tube due to incomplete shrinking

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Moreover, several diagnostics such as measurement of partial discharges, dielectric losses or dielectric response may provide relevant information about insulation degradation. Applying diagnostics related to degradation processes in MV and HV components these diagnostic data can also be analyzed to make an assessment about relevant changes in the condition of the high voltage components of that population.

As a result, based on sufficient diagnostic data, experiences and statistical analyses the diagnostic information could be used to index the actual insulation status of a HV component [9-11].

Using statistical distribution fitting norm values can be generated in accordance with an estimated probability distribution function (PDF).

This also introduces a confidence interval around the calculated norm. This confidence interval represents the maximum error expected at this norm. Figure 11 shows an example of PDF with indication of typical confidence interval is set at 95%.

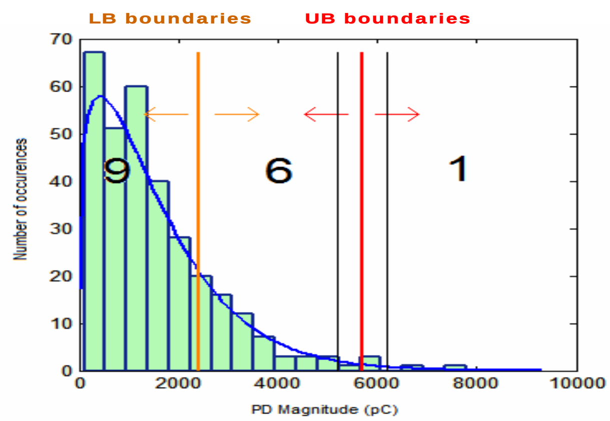

Figure 11: Diagnostic data analysis. Based on statistical boundaries condition indexes can be determined to support asset management decisions

To adopt the boundaries definition to the practical situation of insulation degradation and condition indexing experimental support is important to validate the above described approach .

After a linkage has been confirmed between statistical boundaries on the one hand and the physical processes on the other hand, the norm values for diagnostic data can be used for condition indexing. As a result, excellent decision support can be obtained for maintenance and operation planning (figure 12).

CONCLUSIONS

For the control and maintenance of the reliability of medium voltage cable networks, the PD diagnosis is an important tool for the asset management.

Category	Reliability status	Condition status	Service life status	Condition index	Required action	Recommendation on maintenance
Normal	No problems	No defects or aging symptoms observed	New or aged	9	No extra attention required e.g. next inspection in 5..10 years	No maintenance necessary;
Defect initiation	No impact on reliability	Certain degree of insulation degradation observed; not harmful defects present	Strongly aged	6	Extra attention is needed e.g. inspection within 1 year	Without any maintenance possible life time reduction
Defect	Asset can still be operated but the reliability is decreased					Maintenance is necessary
Failure	Asset can not be operated	Significant insulation degradation observed and serious defects are present	Nearby end of lifetime	1	Maintenance is necessary; e.g. repair or replacement	Based on economics repair or replacement maintenance is necessary

Figure 12: Example of relation between technical conditions, condition based maintenance index and required maintenance actions

The comprehensive amount of practical experiences with OWTS technology is used to determine threshold levels on empirical bases.

If sufficient PD data for the typical components in MV cables are available statistical PDF evaluation can be used to set relevant boundaries in combination with condition indexes.However, an evaluation based on practical experience permit an orientation regarding the condition and risk

factor of the cable network. This way, the PD diagnosis gives valuable information for necessary maintenance activities, if necessary, and helps to utilise the available budgets effectively.

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