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50Hz Partial Discharge Diagnostics – Experiences of N-Ergie AG
Minimising cable failures by Reliability-Centered Maintenance of Networks

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Due to market liberalisation, network operators are facing increasing costs. This has lead to the introduction of new investment and maintenance strategies.

Before liberalisation, network operators mainly focused on maintaining a high level of continuity of supply. This was obtained by preventive replacement of (bad) cables, in order to avoid power outages in the future. However, as budgets and staff are being reduced, a tendency towards event-oriented maintenance is currently being observed. This will inevitably lead to more power outages. As the national regulator is planning to penalise network operators in case of poor network reliability, the need for new maintenance strategies arises. These strategies should solve the paradox of „low budgets and high reliability“.

N-Ergie Asset Management tries to solve this paradox with a Reliability-Centered Maintenance Strategy. Maintenance actions are based on the condition and on the importance of each cable in the network, as presented in the action matrix (Figure 1).

The condition of the cable is determined by:
- data about the asset
- diagnostic results

The importance is determined by:
- energy not supplied in case of a failure of the asset
- the asset outage rate
- time needed to take the asset back into service after a failure
- public importance of the power consumer (e.g. airport, railway station, police, hospital, etc.)
- criticality of the asset in the network

Importance is always considered to have a higher priority than condition.
Even if the condition of an asset is assessed „medium“, it may still be replaced if the importance is assessed as very high. Although this exception is not in line with the action matrix, these cases may occur from time to time.

In order to make a better assessment of the cable’s condition, N-Ergie Aktiengesellschaft chose Imcorp’s 50Hz Partial Discharge Diagnostics System for following reasons:
- the test conditions match the service conditions (because of 50Hz test frequency).
- very short dwell time (a few seconds).
- the test results can be compared to the factory test results (e.g. Tan delta).
- the diagnostic system has proven to deliver good results for PILC and extruded cable, splices and terminations.

Examples of delamination in PE-cable, oil-deficiency in PILC cable and poor workmanship in a splice are documented (see further).
The diagnostic tests in the N-Ergie network are performed by the company NexaTec, a 100% daughter company of N-Ergie Aktiengesellschaft. In partnership with Imcorp, NexaTec also offers the cable diagnostic service to other network operators.

Between August 2004 and December 2005, NexaTec has tested 93 cables in the N-Ergie network, which equals a total of 114 km of cable:
- 46 km of extruded cable
- 13 km of PILC cable
- 55 km of mixed cable (PILC + extruded)

At external customers, a total of 84 cables was tested with a total length of 45 km:
- 29 km of extruded cable
- 3 km of PILC cable
- 12 km of mixed cable (PILC + extruded)

Condition \ **Importance**	LOW	MEDIUM	HIGH
BAD	Event-oriented test	Re-test after 1 to 2 years	Re-test after 1 year
MEDIUM	Event-oriented test	Re-test after 5 years	Re-test after 2 to 3 years
GOOD	Event-oriented test	Re-test after 10 years	Re-test after 10 years

Figure 1

The 50Hz Partial Discharge Diagnostic System

The test methodology is based on the principle of reflectometry. The system allows to detect and locate partial discharge signals. The test set-up is shown in figure 2.

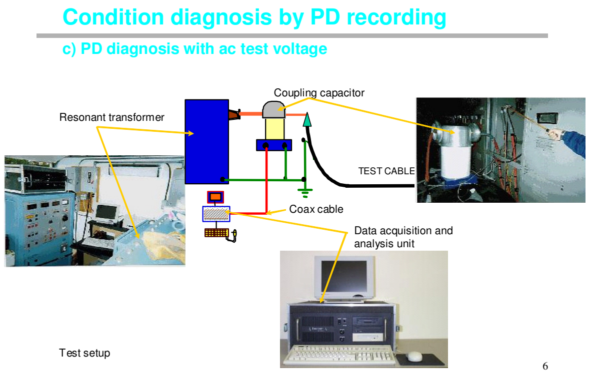

Figure 2

The test is executed in 4 steps:

1. **Measurement of cable length and splice locations**
A pulse generator injects a pulse into the cable from one cable end. Analysis of the reflectogram allows to determine cable length and splice locations.

2. **Calibration and Measurement of sensitivity**
The sensitivity measurement determines the influence of the cable attenuation.

3. **Partial Discharge test with 50Hz**
A resonance transformer supplies the 50Hz voltage. The test is done in different voltage steps.

4. **Signal analysis and test report**
The processing unit captures, saves and analyses the partial discharge signals. Adaptive digital filtering allows detection of even those signals with very low signal-to-noise ratio.
After analysis , a test report is automatically generated. The test operator completes this report with his recommendations for action.

When partial discharge spots have been found, a pinpointing unit, called the „Imcorp Matcher", can locate the exact position of these spots on the cable. The accuracy of location is approximately 0.1% of the total cable length.

Three case studies (all testing by NexaTec):

Case study 1: extruded cable
During test of an extruded cable, discharges were located at 59 meters. Based on the Imcorp interpretation criteria, the problem was assessed as an Electrical Tree or a delamination. The utility investigated and informed NexaTec of the result: a clear delamination case (see figures 3 and 4).

Interpretation	
Sensitivität	*Durch die festgestellte Kabelsensitivität kann man mit sehr hoher Wahrscheinlichkeit davon ausgehen, dass in der Kabelstrecke keine anderen TE-Stellen (mit kleineren pC-Werten) mit einer Einsetzspannung unter 2,5 Uo vorhanden sind.*
	Das Kabel wurde nach der Messung wieder in Betrieb genommen.
L1	Kein Handlungsbedarf nötig.
L2	TE bei 59m möglicherweise el. Tree oder Leitschichtablösung
L3	Kein Handlungsbedarf nötig.
Handlungs-empfehlung	Ersetzen der Teilstrecke von 55m bis 67 m (L2). Position mit Matcher bestimmen und nach Reparatur nochmals nachmessen.

Figure 3: Test report excerpt, showing interpretation and recommendation for action (Handlungsempfehlung)

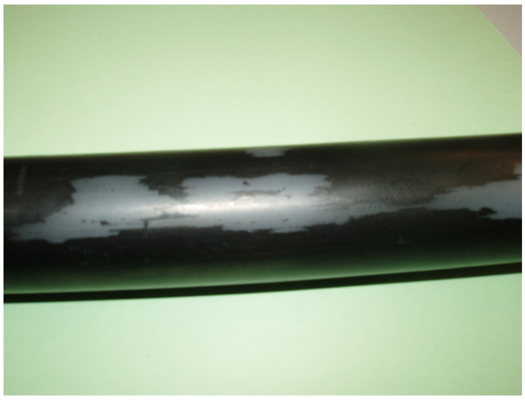

Figure 4: Delamination

Case study 2: PILC cable
During test of a PILC cable in the N-Ergie network, discharges were located in 2 phases in the same zone of about 30 meters of length (see figure 5). The recommendation for action was: replacement of this 30 meters cable section.

After investigation, cracks were found in the lead sheath and the paper was dried out in a limited section of the cable. (see figure 6)

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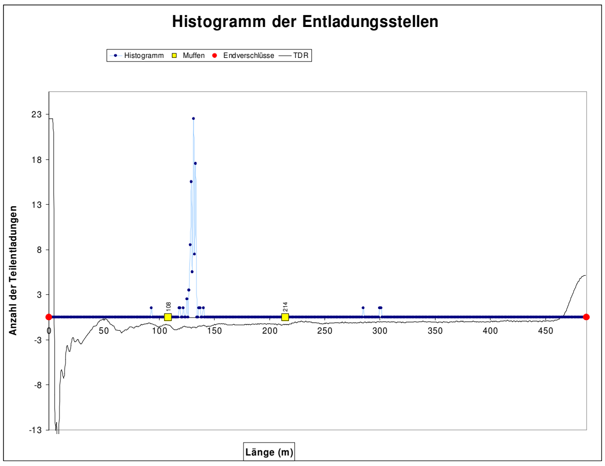

Figure 5: discharges in a limited zone of about 30 metres

Figure 6 investigation results
Transition dry - wet

Figure 6: investigation results:
Cracks in the lead sheath

Case study 3: splice
During test in the N-Ergie network, discharges were detected in a splice. Investigation of the splice revealed that the splice had not been installed correctly.
(see figure 7)

Figure 7: Splice body not correctly positioned

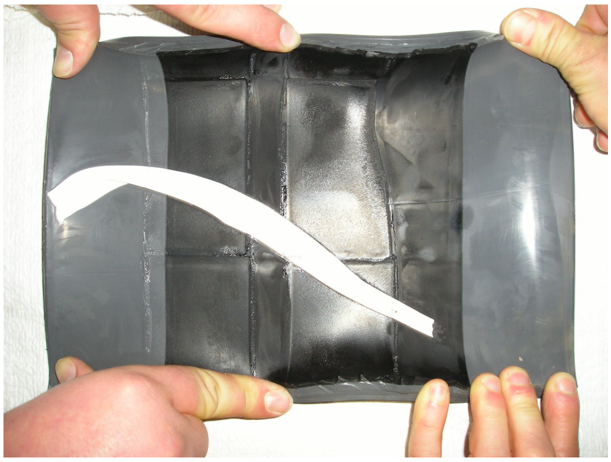

Figure 7: Tape left behind in the splice body

CONCLUSION

The 50Hz partial discharge test has proven to be an important element of the reliability centered maintenance strategy. For further optimisation purposes, N-Ergie Aktiengesellschaft, NexaTec and Imcorp have started a 4-year joint research project at the University of Erlangen, Germany. Goal is to learn more about the relationship between aging mechanisms, remaining cable life and diagnostic test results in PILC cables.