On-site Partial Discharges Measurement of XLPE Cables

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Abstract — The contribution deals with the methodology of on-line measurement of partial discharges in XLPE cables. After the specification of measuring methodology and used apparatus the evaluation of the measured data follows. Contribution gives an example of a real on-site measurement on 110kV XLPE cable power line in operation.

Keywords — Partial discharges, on-line measurement, XLPE high-voltage cables.

I. Introduction

Presence of partial discharges is a key indicator of the real state of a cable insulation system. By measurement of partial discharges it is possible to identify them and take actions to prevent unexpected failure in the power system. To achieve this goal several methods exist.

When the presence of partial discharges in an insulation system of medium-voltage cables is investigated, according to European standard STN EN 60270, using of a galvanic method is usual. Mentioned methods are mostly off-line, which means that the line needs to be switched off. This methodology requires a discharges-free power source and a suitable analog or digital measuring system. As soon as the length of investigated cable exceeds several hundreds of meters, the demand for the installed capacity of the power source grows. The measuring apparatus in most cases is supposed to be mobile, so the needed power supply has larger dimensions, and weight of course. These facts justify the search for other than off-line partial discharge monitoring options.

As said for medium-voltage cables of greater lengths, the problem is with the discharge-clean power supply capacity. For high-voltage cables such a power supply cannot be described as mobile because of weight and dimension as well. To eliminate the need of huge power supply for off-line measuring and to enable to investigate the power line in operation a new methodology is a necessity.

Recently most interesting methods are that can identify discharge activity on-line, that means without the need of switching the devices or parts of power line off. On-line partial discharges can be investigated by several procedures:

Spot testing (test time from 15 minutes to few hours per circuit) is widely used on transmission lines,

Continuous partial discharges monitoring (test time from several hours to few days) is mainly used on distribution networks,

Permanent partial discharges monitoring is not widely used as yet. [1]

II. Spot Testing

The advantage of this methodology is that there is no need to isolate the investigated circuit. Cables can be tested in operation conditions and it allows an efficient planning of further investigation and localization of failure in case, when significant discharge activity is present.

The measuring apparatus consists of an oscilloscope based system with four-channel capturing (shown in Fig.1), filter to eliminate radio frequency interferences, high frequency current transformers (shown in Fig. 2) and transient earth voltage sensors (shown in Fig. 3).

The discharges diagnostic unit is based on a high-speed data acquisition of partial discharges signals at sample-rates between 100 and 500 MS/s. Detecting and storing of the signals at high-resolutions allow to analyze and classify the pulses based on their true wave-shapes.

Fig. 1: Measuring apparatus

Fig. 2: HFTC sensor [2]

Fig. 3: TEV sensor [2]

The data acquired synchronously with the power cycle of the applied test voltage enables to save phase distribution of apparent discharges. High-frequency current transformers measure partial discharges in the investigated cable when right attached at the termination shield. [1]

The transient earth voltage sensor is a small radio frequency aerial which can detect the high frequency discharge pulses coming for example from the inside of the switchgear, bushings, etc. These pulses tend to have pulse widths of a few tens of nanoseconds, and act as a good medium for the non-intrusive partial-discharge detection. [2]

Evaluation of the measured waveforms can be performed using the PDGold or ScopeControl software. Mentioned tools utilize the partial-discharge "event recognition" to find short duration, high-frequency pulses and classify them as discharges with the origin in the cable, local equipment or noise.

Cable pulses are characterized as monopole shape current-impulses detected by high-frequency transient-current sensors. They are integrated and their magnitude given in (pC). They could originate from the cable, cable termination or transformer.

Local pulses have a large amount of high-frequency content (>5MHz). They are detected from sources near to the measurement point by both high-frequency current transformers and transient earth voltage sensors. The magnitude of these signals is calculated in dB.

Limit values for partial-discharge apparent-charge observed in XLPE low- to medium-voltage cables and their terminations in general are summarized in Tab. 1. For high-voltage cables, of course, there is no tolerable level of the discharge activity. That means, any discharge activity detected in these cables require further localization and repair.

Tab. 1: Limit values of partial-discharge apparent-charge

0 - 500 pC	Acceptable level
500 - 1000 pC	Recommended to monitor discharges level
1000-2500 pC	Potential risk, recommended the periodic monitoring
> 2500 pC	Serious risk, location of the source and subsequent repair needed

III. PROVIDED MEASUREMENTS

Online discharge activity measurements were carried out as part of a preventive maintenance in order to determine the status of the high-voltage cable insulation system. The measurements were performed on two cable lines with lengths of 430 and 635 meters, each of which consisted of two parallel cables per phase. Cables have the XLPE insulation system and composite terminations on both ends.

A cable shielding on substation side is directly grounded as shown in Fig.4 on the left; the transformer- side is

Fig. 4: Connections of sensors during measurements

connected to ground over a varistor as shown in Fig.4 on the right.

The cables were tested from both ends. The discharge signals were measured using high-frequency current transformers placed around the cable shielding followed by the transient earth voltage sensors located at the bottom terminals. The sensors were fitted separately for each pair of cables for each phase.

Figures in Tab.2 show the observed discharge activity consisting of interferences at frequencies of 270, 540 kHz and 1,1 MHz together with a noise during measurements. After filtering the noise out from the acquired signals and making corrections to discharge activity resulting from substation electronic device interference captured by the capacitive transient earth voltage sensors, the resulting phase-distribution of partial-discharge apparent charge had the amplitude below 0,5 pC. That means this time no harmful partial-discharges were detected in tested objects.

IV. Conclusion

As contribution briefly describes, on-line measurement of the partial-discharges, more precisely so called “Spot testing” is a method, which almost does not affect the operation of investigated power system elements. It is no need to use an external low-discharge power supply; the whole apparatus is mobile, in comparison with galvanic off-line methods less complex, less susceptible to interferences and noise. Nowadays, for periodic testing of supported high-voltage XLPE cables this method seems to be most effective. However, it does not enable exact localization of a failure in case of a higher observed apparent charge in phase-distribution. To reach this goal, still usual off-line methods are required providing more diagnostic parameters, as these in insulation system capacity or loss factor.

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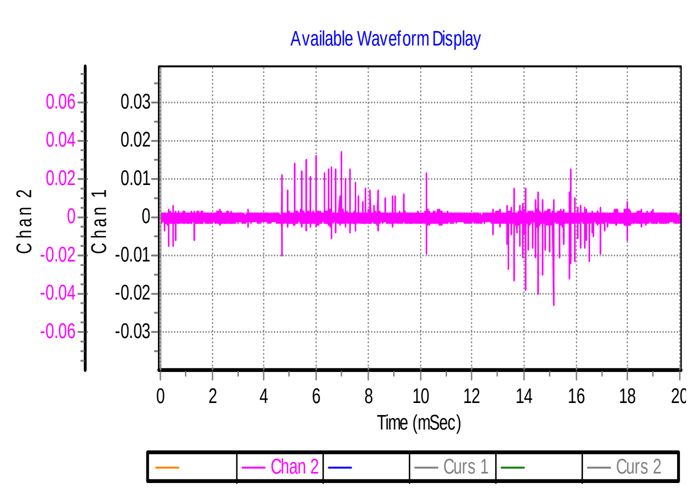
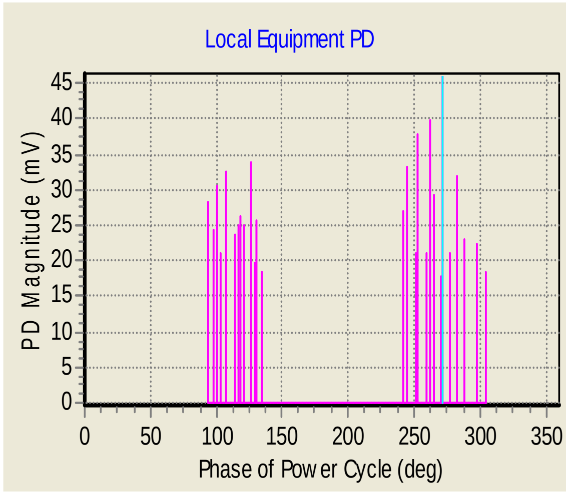
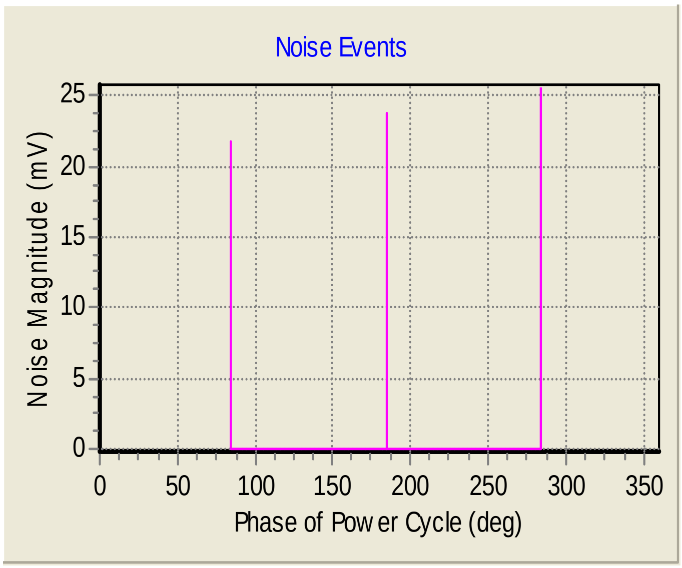
Tab. 2: Limit values of partial-discharges' apparent-charge



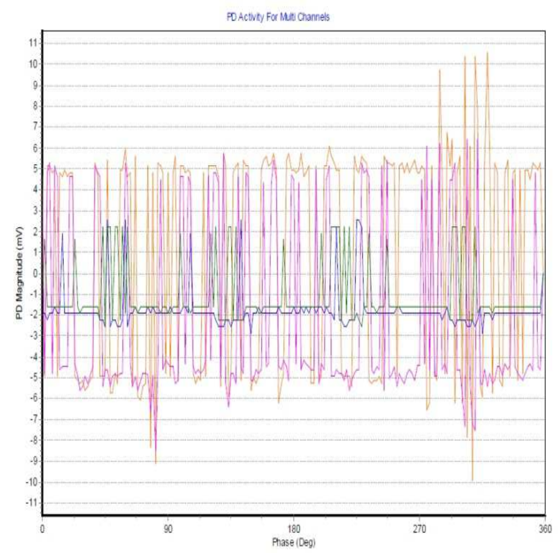
Partial-discharges in time-domain (HFCT)



Partial- discharges in phase-domain (TEV)



Noise in phase-domain (HFCT+TEV)



Partial-discharges in phase-domain (HFCT-TEV)

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