PARTIAL DISCHARGE MEASUREMENTS AS A SOURCE OF INFORMATION ABOUT THE TECHNICAL CONDITION OF PILC INSULATED MV CABLES

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ABSTRACT

The paper focuses on the new possibilities of managing a key element of the power supply system: the power cable network. The possibilities are created by the technical condition assessment of power cables based on partial discharge diagnosis at damping (self-extinguishing) AC voltage. Both cable manufacturers and their users pursue to obtain a high technical reliability of the power network. Modern IT and measurement systems make it possible to acquire data enabling a better assessment of the line technical condition. Undoubtedly, among the new data sources there is also diagnostics based on partial discharge (PD) measurement (PD inception voltage, PD extinguishing voltage, the PD apparent charge value for different voltage levels, PD intensity, PD distribution as a function of cable length). Providing a unique data set which describes an insulation technical condition of particular line elements, such a diagnostics creates an opportunity to change the current method of power cable network management to a new more effective one, both technically and economically. Measurements of partial discharges in MV cable network were carried out in one of the distribution companies in Poland in the years 2005-2010. They were intended to develop an optimal method for the use of partial discharges diagnosis in the assessment of technical condition of power cables. The main area of research covered MV cable lines of a total length of 590 km.. The studies on power cables provided a group of measurements for Paper Insulated Lead Covered power cables (PILC). From all the measurements there were selected 18 cases where a cable failure was recorded and the measurements of partial discharges were carried out both before the failure and immediately after the repair of the failure.

Basing on the carried research work and analysis it has been found that:

Basic parameters indicating the risk of the failure are: reduced PD inception voltage and the occurrence of increased PD intensity in a power cable. The study shows that, the lower the PD inception voltage, the higher the percentage of cable sections of an increased PD intensity. Consequently, a greater number of cable sections which can be included to the group of increased risk of failure.

No correlation between the increase of PD value and increasing probability of the failure occurrence has been found..

INTRODUCTION

MV cable network is a complex system of interconnected cable lines and subject to constant changes.

Changes result, inter alia, from carried out repairs of damages and network development. The aging process of individual sections of the cable may be at different stages. Therefore, to effectively manage the cable network, certain knowledge of the technical condition of individual elements (cable segments, joints, connectors) is necessary.

It is not enough to evaluate technical condition of the entire cable line as a homogeneous object since it is not one.

The measurement of partial discharges may be the source of information about technical condition of insulation of individual pieces of cables and accessories.

A lot of information about the parameters of partial discharges (PD inception voltage, PD extinction voltage , PD value for different voltage levels, the intensity of PD, PD distribution as a function of the line length) can be obtained from such measurements.

The key issue is to determine the significance of PD individual parameters in assessing technical condition of the cable line.

Experience gained by the users of measurement systems while taking measurements in exploited networks can be helpful in answering this question.

SCOPE OF THE STUDY

Measurements of partial discharges in a MV cable line (15kV) have been carried out in a distribution company ENERGA – OPERATOR SA within the years 2005-2010. The main area of reasearch covered urban territory (about 950 MV cable lines of the total length of 590 km). In this area, 66% of cable network is made with the use of PILC cables.

Figure 1 shows the graph presenting the PILC cable length in function of the year of construction. Actually the construction of the MV cable network , subject to research, started in 1961, and the use of PILC cables finished in 2007.

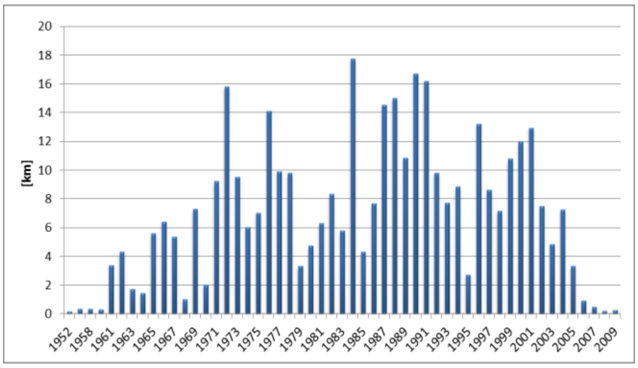

Fig. 1. The length of PILC cables built in MV cable network annually

The measurements of partial discharges in cable lines were performed with the use of SEBA KMT OWTS-25 diagnostic system. The basic information obtained from the analysis of measurements includes:

- PD inception voltage (Ui),
- the average and the maximum values of PD level at Ui,
- the average and the maximum values of PD at Uo,
- the intensity of PD occurrence at Uo,
- the average and the maximum values of PD between Uo and 2Uo,
- the intensity of the occurrence of PD at test voltage between Uo and 2Uo
- distribution graphs of PD value as a function of the cable section length.

In addition, based on the the graph of discharge distribution as a function of the cable length, the location of discharges concentration along the sections can be determined.

FAILURE CABLES MEASUREMENTS

Performed tests resulted in a group of measurements for PILC cable lines, where, after the completion of the measurement a failure occurred. The analysis performed enabled the selection, from the group, 18 sections, where the failure was of electrical character

Figure 2 provides information on the age of all cable sections, where the failure was electrical in nature.

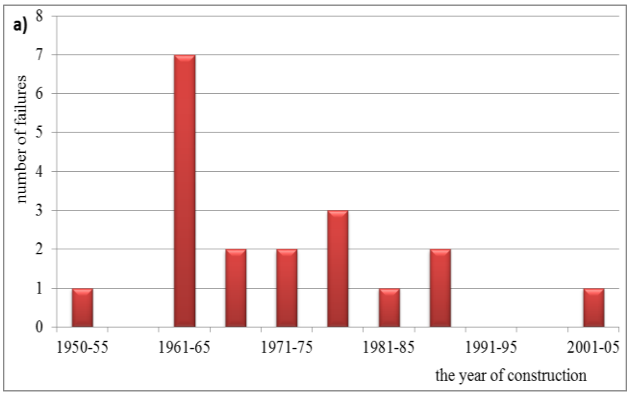

Fig. 2. Power cables failures in the years 2005-2010 as a function of construction year of the cable sections where PD level was measured before the failure

Figure 3 presents PD inception voltage for each cable section, in which partial discharges were measured prior to the power cable failure. Data has been presented in yearly sequence according to the year of cable line construction , starting with the oldest section. The graph shows: the data for the entire section, in which the failure occurred (the whole section comprises also the failure location) and data for the failure location.

In five cases, the lowest inception voltage was off-site the failure location (at failure location slightly lower), and in three cases no partial discharges in the future failure location were reported. In all cases partial discharges inception voltage for a given section of the cable was not greater than Uo.

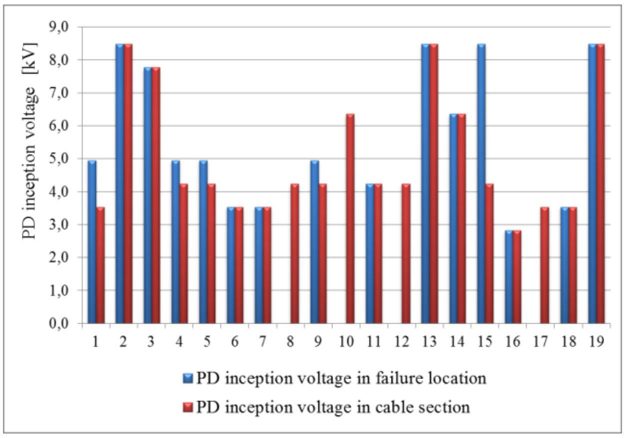

Figure 3. Inception voltage of partial discharges in damaged power cable sections

PILC CABLE LINES STUDY

Figure 4 shows the tested cable sections, depending on partial discharge inception voltage. From 385 PILC cable sections measured, in case of 226 cable sections PD inception voltage was equal to or less than Uo (8.7 kV). This group, as the one threatened with failure, was further analyzed.

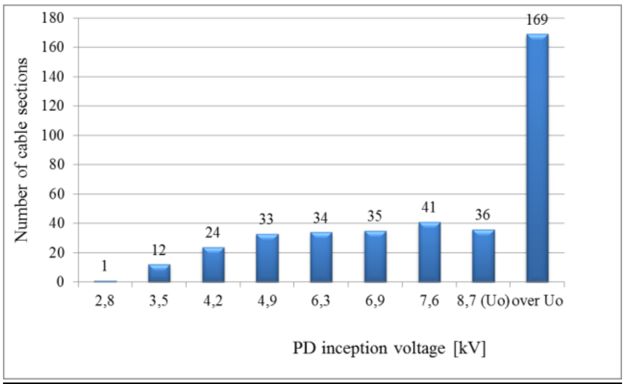

Fig.4 Number of cable sections, in which the PD was measured as a function of PD inception voltage.

Figure 5 shows the number of, built each year, cable sections, in which PD was measured. In addition, the graph shows the number of sections, in certain age groups, in which the partial discharge inception voltage was less than or equal to the rated voltage Uo. With the increase of the lifetime the number of cable sections of the inception voltage not exceeding Uo increases.

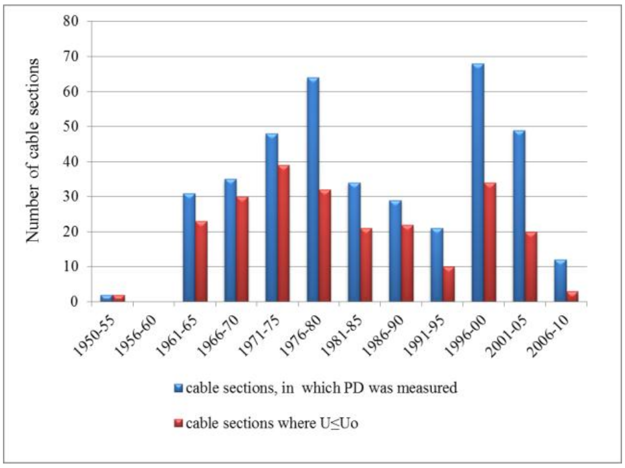

Fig. 5 Number of , built in each year, sections undergoing PD tests

Figure 6 shows the percentage of cable sections of PD inception voltage in different age groups in relation to all measured sections in a certain group. It can be noticed that apart from the increase of the percentage of failure sections along with their increasing age , there is another visible area of growth. It pertains to cable sections from the years 1980 to 1995.

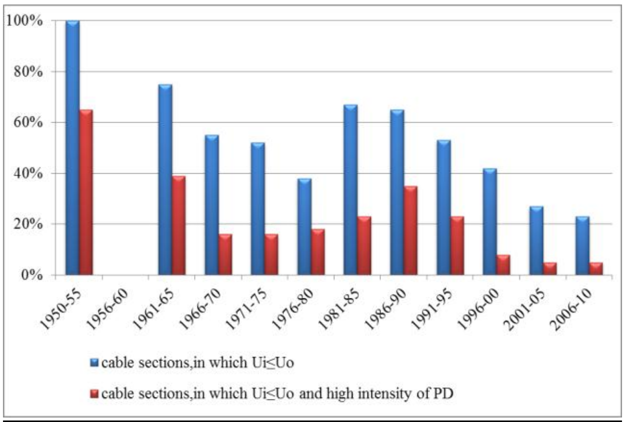

Fig. 6. Percentage statement of cable sections of PD inception voltage equal to or less than Uo.

Figure 7 presents graphs showing the percentage of cable sections with increased PD intensity in relation to all cable sections of a certain PD inception voltage. Together with decreasing PD inception voltage, the number of cable sections with greater PD intensity increases. As results from previous studies, cable sections of increased PD level) have been included in the group of a higher risk of failure. Based on the above it can be concluded that the increase of the potential risk of cables failure, follows the decrease of PD inception voltage in certain cable sections.

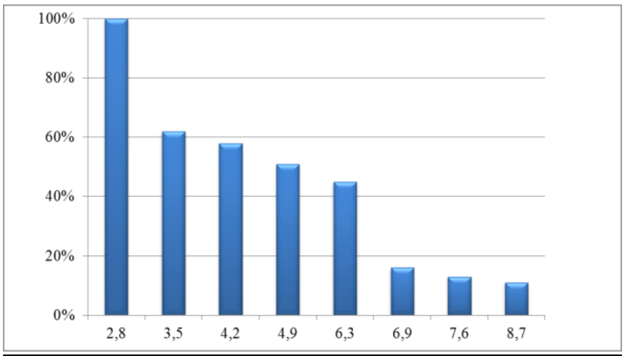

Fig. 7. Percentage of cable sections with increased PD level as a function of PD inception voltage

While analyzing PD inception voltage dependence on the risk of failure in a group of power cables with increased PD level a significant increase of the percentage of cables with failure can be observed together with the decrease of inception voltage (Fig. 8).
The percentage of failure power cable sections increases in case it is analysed in relation to the sections where increased level of PD intensity was stated.
Hardly two sections fom the tested group were characterized with inception voltage equal to 2.8 kV. In both these power cables an increased PD intensity was reported and both cables got damaged. For the inception voltage 3,5 kV, 62% of power cables got damaged and

demonstrated an increased PD intensity. While this percentage was equal to 42% for the entire group of tested cables. For the inception voltage 4.2 kV, the percentage of cables that got damaged and were characterized by an increased PD intensity was equal to 50%, while for the entire group of tested cables it equeled 29%.

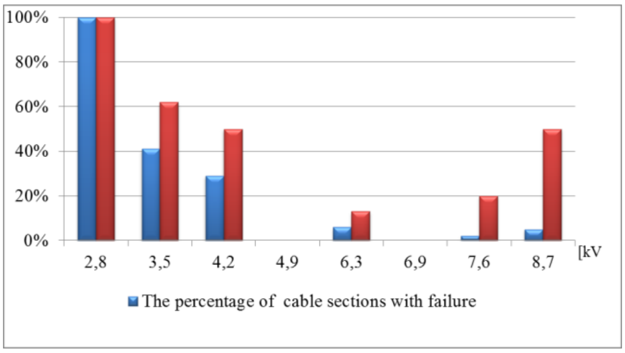

Fig. 8. The percentage of power cables with failure with respect to cables with the increased PD intensity detected

Another area of study was the analysis of possible relations between the power cable failures and the value of partial discharges. The study was carried out on a group of cable sections for which PD inception voltage was not greater than Uo. While testing that group of cables no relation between the PD value at inception voltage, and the PD value at voltages Uo and 2Uo was detected.

Fig. 8 summarizes, obtained during the study, PD values at the inception voltage and Uo voltage for each power cable section. Each of the presented drawings comprises a group of tested cable sections with the same PD inception voltage. The blue bars represent the discharge value for each cable section at the inception voltage. Cable sections have been presented in the order starting from the lowest PD value, at discharge inception voltage. Green or red bars indicate discharge values at the test voltage equal to Uo. Red colour indicates a group of cable sections that were damaged prior to the measurement. Green colour indicates results obtained for the remaining power cable sections (sections that have not got damaged). At no voltage level no relations between PD value at inception voltage and Uo voltage have been reported.

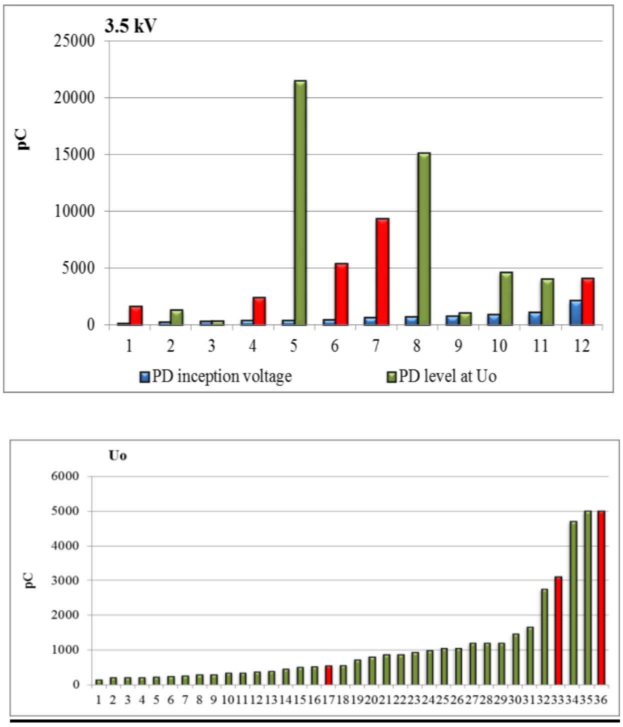

Fig. 9. Summary of measured cable sections for an exemplary PD inception voltage

CONCLUSIONS

Exclusively selected parts of the analysis carried out on the basis of measurements of partial discharges in PILC cable lines have been presented in the article. The main conclusions from the research are as follows:

- There is a relation between the PD inception voltage and the cable insulation condition. Along with the decrease of PD inception voltage the probability of failure – insulation deterioration increases. There have been reported no cable failures at PD inception voltage greater than Uo
- Probability of failure increases in areas of increased PD intensity
- With the increasing service life of a PILC cable (insulation aging) the probability of cable lines failures increases.
- No correlation between the PD and the probability of failure has been stated. Failures in the measured cable sections did not occur in places of the highest PD value exclusively
- Although the PD value increases with the increase of the test voltage, no relation between test voltage changes and PD value changes has been stated.

- Essential in the use of partial discharges diagnosis is having precise and updated information on MV cable network. This information should include data about cable sections, cable joints and heads.

Diagnosis based on partial discharges measurements provides very valuable information necessary to evaluate the technical condition of PILC cable networks. It may be a key element in this assessment.

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