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INFLUENCE OF ACTION TIME OF PARTIAL DISCHARGES ON PROPERTIES OF THE POLYPROPYLENE FOIL

1. Introduction

The system laminated in series: cable paper-polypropylene foil-cable paper was investigated on the start. Such an insulation is called in English PPL - polypropylene laminate.

The laminar insulating system paper-synthetic foil-paper, is used in the capacitor and in the cable manufacturing, in order to improve the constructions applied so far. In the case of insulation of oil-pressure cables, made of polyolefines plastic tapes (polyethylene, polypropylene), there was some trouble with the correct osmotic propagation of oil in the whole volume of the insulation. During the work of the cable, in spite of the use of a special technology, which made it possible to obtain a suitable for the oil damping synthetic foil surface, local drying of the insulation occured; it could lead consequently to its failure. Therefore, paper interlayers began to be applied for the proper damping of the insulation system.

After carrying out investigations in the system with laminar insulation, investigations were performed in the system containing only the polypropylene foil. These investigations were performed in order to estimate the influence of particular parameters of the tested insulation system (size of the gap, height of voltage) on the time to breakdown, and also indirectly - in order to investigate changes in the chamical structure of polypropylene, caused by the action of partial discharges.

2. Investigation of laminar system

The system consisted of cable paper-polypropylene foil-cable paper of total thickness of 180 μm was investigated.

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The polypropylene foil was obtained by drawing to the form of a wide ribbon. To obtain the PPL, hot foil is extruded directly between two rolls on which the cable paper moves. Some kind of "bonding" of this three layers with each other follows. A uniform insulating material is obtained of smaller total thickness than the thickness of particular components. The time to breakdown of the PPL, aged by partial discharges, was defined in the investigations in the system of plane electrodes. An air-gap of 0,5 mm was created above the surface of the investigated sample. The tan δ measurements, for the unaged samples and for a part of samples aged by partial discharges, were performed with the use of Schering's bridge, type 2801. The modification of the polypropylene structure, caused by the influence of discharges was followed by applying the method of infrared spectrophotometry.

The values of time to breakdown of the insulation paper-foil-paper system, aged by partial discharges with free access of air, are shown in the table. These values have been determined for different levels of voltage applied to the system, in which other parameters were constant.

The time to breakdown was determined for the voltage equal to 3; 3,5 ; 4 and 5 kV. The inception voltage of measurable discharges was equal to 2,0 kV.

If we assume, for the investigated system, the time to breakdown determined at the voltage equal to 3 kV, as the value of 100%, then, as it was stated, this time is diminished in 15% at the voltage of 3,5 kV, and in 22% for 4 kV. The strongest reduction in this time, as much as 63%, has been observed in the case of ageing of the PPL by partial discharges at the voltage equal to 5 kV. The figure 1 shows the change in the time to breakdown of the PPL, according to the changes in the value of the voltage applied to the tested system.

The determination of the time to breakdown of the PPL samples aged by partial discharges is a method destroying the material. That is why, the measurement of the dielectric loss factor was performed for unaged samples and only for a part of samples aged by partial discharges. It was performed after 10, 15 and 20 hours of discharge action, breaking the ageing process for the given sample. The figure 2 shows the changes in the tan δ value of the PPL during the action of partial discharges versus the time of partial discharges action. When looking at the relatively great tan δ

values even for unaged samples, it should be kept in mind that the system was aged and investigated with free access of air. Under true conditions, (in cables) this kind of insulation works in the state of saturation with insulating oil, preventing among other things the absorption of moisture by the paper.

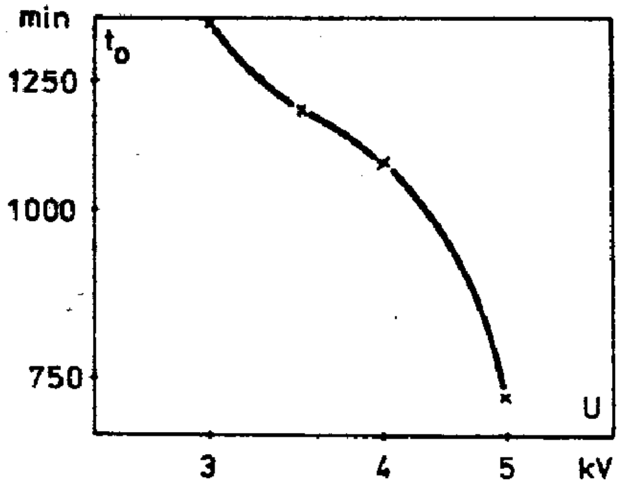

Fig.1. Dependence of time to breakdown of PPL from the value of voltage applied to the investigation system

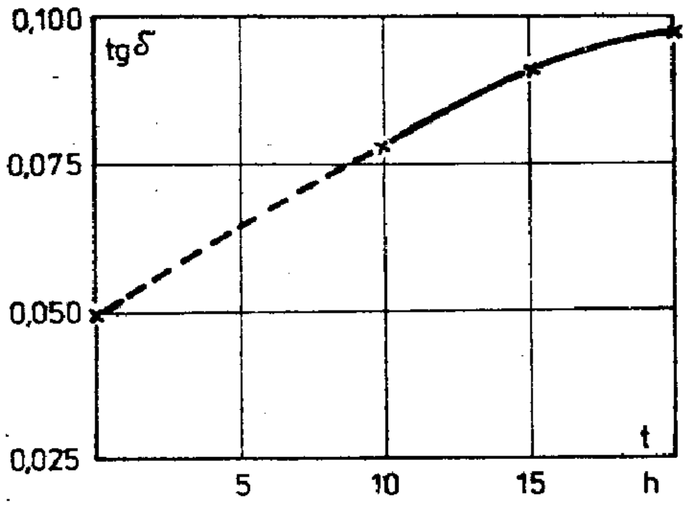

Fig.2. Tan δ of PPL versus the time of discharges action

Unaged samples as well as this aged by discharges were analysed. On account of the non-transparency of the cable paper, it was restricted to taking spectrograms only of polypropylene foil. Partial discharges in the considered system influenced first of all the top layer of the cable paper. Changes in the surface of the paper, caused by the action of partial discharges, could be stated by the unaided eye, even at the shortest ageing time. Whereas, the polypropylene foil, as the IR analysis has shown, changed its chemical structure only after the action of discharges during the period of at least 20 hours. However, it must be emphasised that in true insulation systems (in cables), the paper layer shows a much higher resistance to discharges owing to its insulation oil.

In spectrograms of samples, for which the longest time to breakdown was obtained, it was found that there was a slight increase in intensity of the band in the range from 1710 to 1730 cm^{-1}, i.e. an increase in the carbonyl band; this is the first evidence of the following process of the foil oxidation.

The analysis of spectrograms of the polypropylene foil, aged indirectly by discharges, has shown that apart from changes testifying the initiation of the oxidizing destruction process, a certain increase in intensity of bands, connected with the process of bonding macromolecules, followed. The occurrence of this proces can be concluded on the basis of absorption bands of wave number 1160 - 1130 cm^{-1}, connected with the ester groups C-O-C in which the oxygen atom serves as bridge creating the connection between molecules.

3. The investigation of partial discharges

Samples of polypropylene foil, about 10 μm thick, were investigated. Partial discharges were generated in the air-gap in the system of plane electrodes of the test chamber; figure 3 shows its diagram. Above the top surface of the foil, an air-gap was made, from 0,2 to 2 mm in regulated thickness. Alternating voltage of 50 Hz of value U_p from 1 kV to 5 kV was applied to the top electrode. Partial discharges generated in the tested system were investigated by means of a meter of the MUT 8 type. The total Q charge of discharges, appearing in one period of alternating voltage, was measured. The measurements were performed in time t_p from 1 to 180 minutes, starting from the moment of applying the required test voltage up to the moment of sample breakdown.

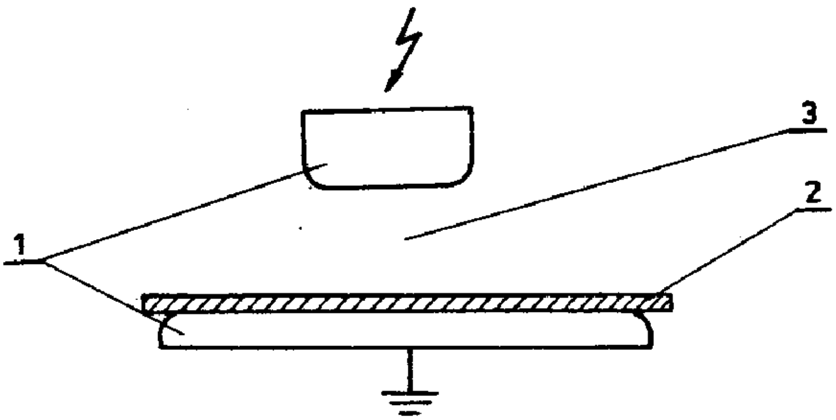

Fig.3. The test cell

1 - electrodes, 2 - polypropylene foil, 3 - air gap "d"

For the assumed air-gap, at a given measuring voltage, a batch of 5 polypropylene foil samples was investigated. The number of samples was thus limited, on account of the rather good repeatability of results - scatter did not exceed 10% of measured sizes of the charge of partial discharges.

Figure 4 shows the results of measurements of the total Q charge versus time of the action of partial discharges, as well as according to the size of the air-gap above the investigated foil sample.

It was found that only in one case, i.e. for d = 0,2 mm and U_p = 2,0 kV, initial increase in partial discharges was observed, and after about 2 minutes from the moment of applying voltage, intensity of discharges diminished, until the occurrence of foil breakdown. In all the other cases, the total charge of discharges diminished together with the passage of time.

Independently of the size of the air-gap, it is obvious that, the lower the test voltage applied to the system is, the smaller the intensity of partial discharges is. Moreover, it was shown that the greatest discharges occurred in the chamber with the d = 0,2 mm gap and then diminished together with the increase in distance d between the investigated foil and the top electrode. When the air-gap was d = 2 mm thick at voltage of about 5 kV, in the system, a breakdown destroying the foil followed.

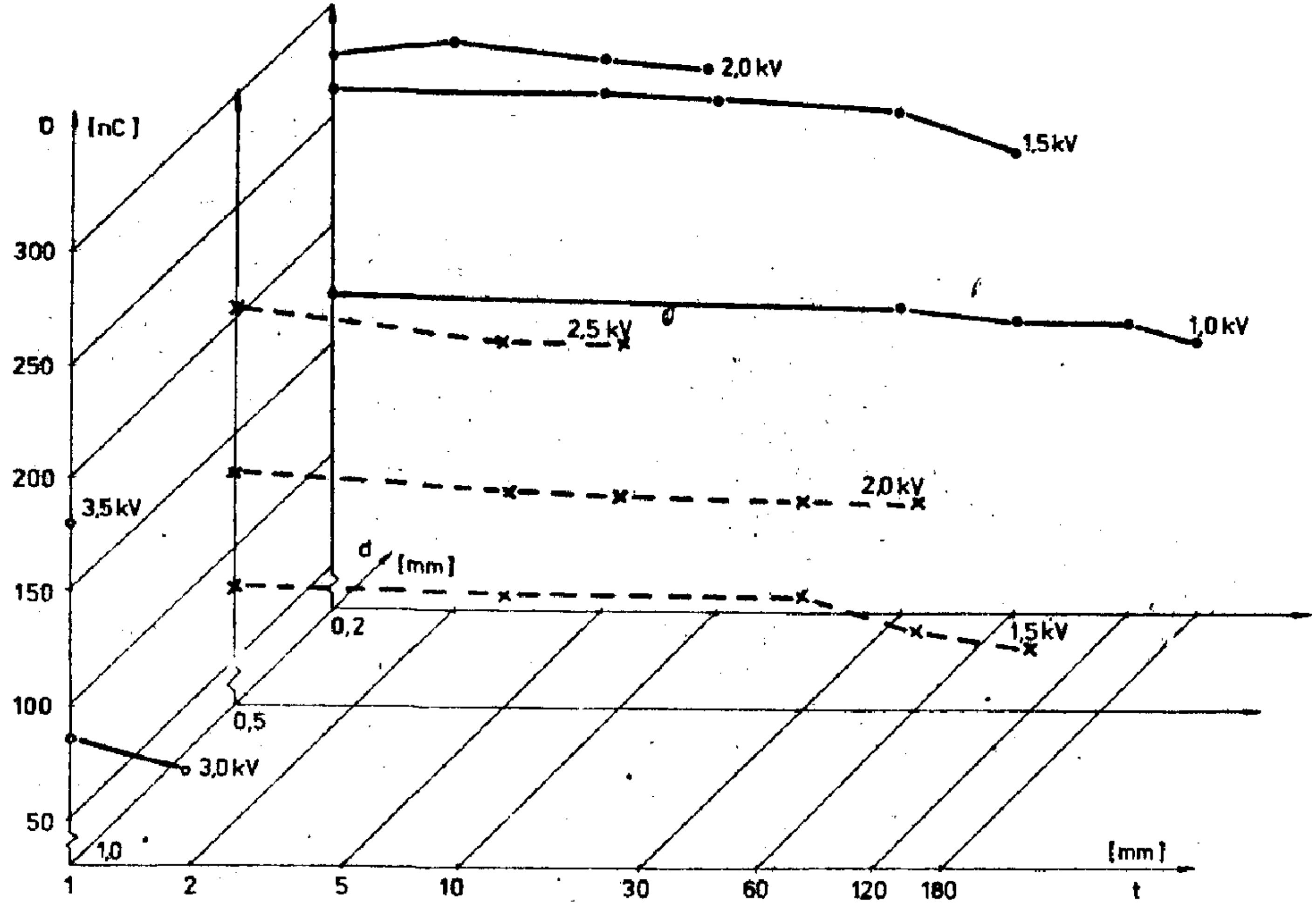

Fig.4. Total charge Q of partial discharges versus time t and dimension of air gap d above the surface of investigated polypropylene foil
.-.-. d = 0,2 mm; x--x--x d = 0,5 mm; o --o --o d = 1,0 mm

This breakdown was preceded by discharges of insignificantly small value of the charge, of the order of some tens of pico-coulombs. The ncrease in the thickness of the gap above 2 mm caused that the discharges, generated in the system, had the values which could not be defined by means of the applied measuring system. In the research chamber with the 0,2 mm air-gap, discharges started at the voltage of 0,8 kV, whereas the breakdown, producing the breakdown of the foil, followed at the voltage of U_p = 3 kV. Investigations for this gap, were performed for a long time,at the voltages of 2,0 kV (66% U_p), 1,5 kV (50% U_p) and 1,0 kV (33% U_p). In the system with the d = 0,5 mm, the breakdown voltage amounted to 4,0 kV, whereas the measurements of partial discharges were made for voltages of 2,5 kV, 2,0 kV and 1,5 kV, i.e. for similar proportional parts of U_p as in the case of the 0,2 mm gap.

The discharges in the system with the d = 1 mm gap were produced at the voltage of 2,6 kV, whereas breakdown occurred at U_p = 4,2 kV. The test system withstood the measuring voltage equal to 3 kV (71% U_p) for the period not longer than 2 minutes.

On comparing the obtained results, it can be stated that the investigated polypropylene foil showed a much greater resistance to sliding discharges of considerable intensity, developing in the system with the d = 0,2 mm, in comparison with the discharges of the corona type, produced in gaps greater in thickness.

The samples of polypropylene foil underwent spectrographic analysis each time. The obtained spectrograms were compared with those of unaged polypropylene. The IR investigations showed that the polypropylene foil changed its chemical structure only after a fairly long time of action of partial discharges. An analogical phenomenon was observed for the PPL system, but in this case changes in the structure followed at least after 10 h of ageing by partial discharges. In the case of considering the system with the foil only, already after a dozen or so minutes of action of partial discharges the occurrence of bloom on the surface was observed (more or less intensive, according to the height of voltage and size of the gap over the surface of the sample). Whereas the polypropylene foil itself, as the IR analysis showed, changed its chemical structure only after the action of discharges, at least during the period of some tens of minutes. Changes in intensity of the carbonyl band (of maximum in the range from 1710 to 1730 cm^{-1}), connected with the oxidation process occuring in polymer, are presented in the figure.

4. Summary

- the investigated system of the PPL always deteriorated its properties in consequence of the partial discharge action; this is illustrated by the decrease of the t_0 and tan δ values, as the time of ageing grew longer,
- the IR analysis has shown that the indirect action of discharges on the polypropylene foil changes the chemical structure of the foil slightly, even when partial discharges have great intensity and act for a long period of time,
- the polypropylene foil shows a considerably higher resistance to sliding discharges, even of considerable intensity, developing in the system with a smaller gap above the surface of the investigated foil, as compared with the resistance to corona discharges, formed in the gap of greater thickness.