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MITIGATION PROCESSES IN INSULATING FOILS AFTER PARTIAL DISCHARGE

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ABSTRACT: *The influence of partial discharge exposure time on the thermally estimated depolarization and on the natural relaxation in polymer dielectrics is described. The polypropylene and polyethylene terephtalate foils were the object of investigations. Study of partial discharge plays an important role in the aging and the rupturing process of solid and mixed insulation systems. The PD analysis is a predictive test which indicates insulation degradation in advance, which may lead to the failure of the system, and it is performed under normal operating conditions*.

KEYWORD: Transformer, Partial discharge, Exposure, Relaxation, depolarization, Foils, Insulation, Influence, Discharge Action

INTRODUCTION

Partial discharge (PD) activity is a prominent indicator of insulation defects. PD conventional electrical measurement has been used for many years as a non-destructive off-line testing technique for insulation evaluation. Conventional PD measurement can detect the permissible discharge quantity, but it is not suitable for online applications due to its requirement on coupling capacitor etc. PD online measurements provide information about insulation faults under operational stress or defects introduced during transportation or installation. In particular continuous online monitoring provides additional information about progressing degradation or deterioration under operational stress, thus preventing the occurrence of breakdown. The foil itself has undergone manufacturing quality control as well as PD testing at the factory before delivery. Any defects such as particles and voids have been removed. For this reason an online PD monitoring system for cables should predominantly cover the accessories, which are more prone to the installation procedure and operational stresses. This paper provided a detailed review of PD data acquisition, transmission and processing methodologies. A continuous PD online monitoring system for cable joints of underground cable circuits, which was based on the optical sensing technique using electro-optic (EO) modulators as investigated by the authors [1], was proposed. This proposed monitoring system does not require any power supply at the site of the foil, as the EO modulators are passive.

The results of the partial discharge action in polymer insulation can be divided as:

A. The results connected with the physical and or / chemical changes of the material structure

B. The results being accompanied by the changes in electrical characteristics o the terial.

The second type of the results of partial discharge action proceeds usually but not necessarily the structural changes of the material. The reason why the electrical characteristics of the material are being changed in this case is the charge injection from the partial discharge source. The charge injection results in the space charge formation with its consequences for the conduction and polarization. The partial discharge stopping is followed by the natural relaxation process during which the space charge is decomposed and the polarization decreases. Thus the problem can be formulated, how is the influence of partial discharge action time on the characteristics of the following relaxation processes [4, 5, and 6].

SCOPE OF MEASUREMENT PROGRAM

It can be expected that the material kind has the essential role in this case, therefore the investigations being described in this task have been carried out on two typical polymer foils:

Polyethylene terephtalate and Polypropylene, both of the thickness 30 µm. The foils were located between the metal electrodes with the air space of 0.3 mm to one of them. The AC test voltage was used with its crest value 1.2* Vo, where Vo is the PD (partial discharge) inception voltage. In such case the PD pulse frequency was always equal 1 – 2 pulses in half period of the test voltage. The time of the PD action was taken as the test parameter.

The PD stopping was so organized as the influence of the instant voltage value to eliminate, thus the test voltage was always switched off in its zero value moment. Immediately after the test voltage switching off the two alternative measurements program were realized Fig. 1.

The measurements of the thermally estimated depolarization current in an open circuit arrangement or the measurements of the effective surface density, time which inform about the naturally estimated relaxation at room temperature [6, 7, and 8].

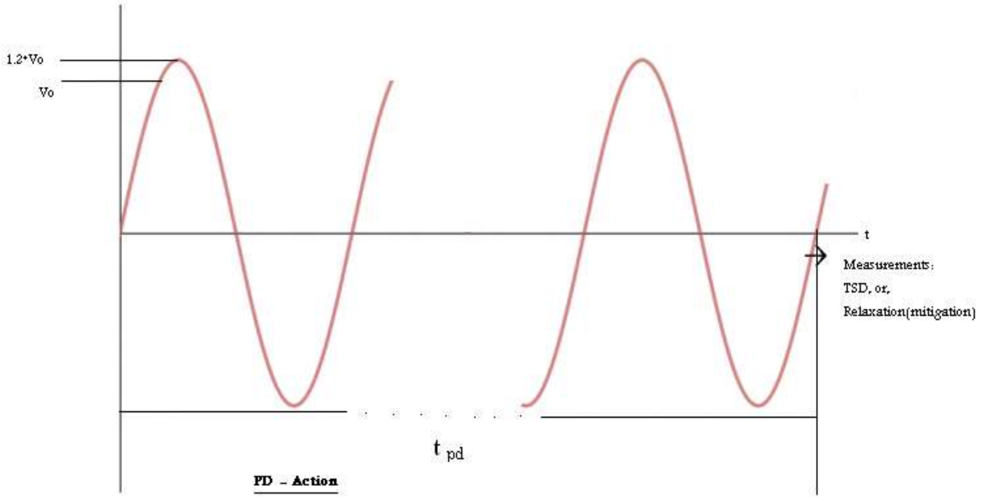

Figure 1. Program of the measurements

RESULTS

The typical examples of TSD, thermo grams are presented in the Fig.2.1 and Fig. 2.2. It can be seen that these thermo grams are more influenced by the partial discharge time in the case of PP-Foil than in PET – one.

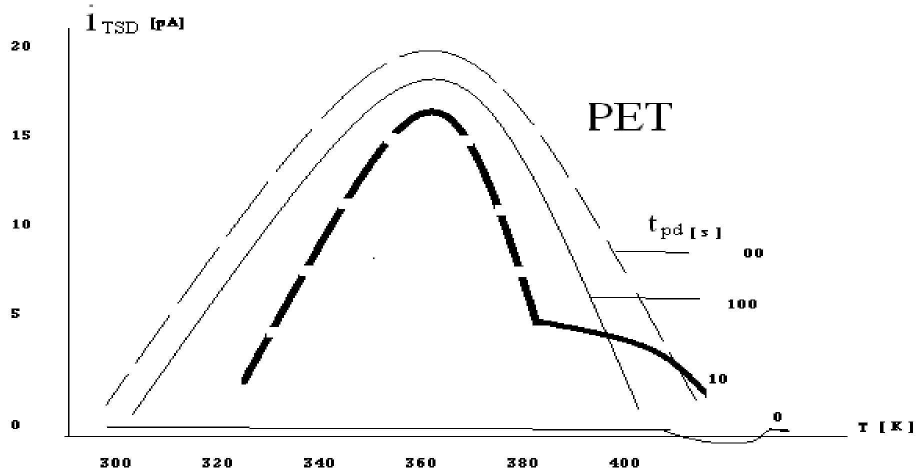

Figure 2.1 Thermally estimated depolarization current in PET-Foil

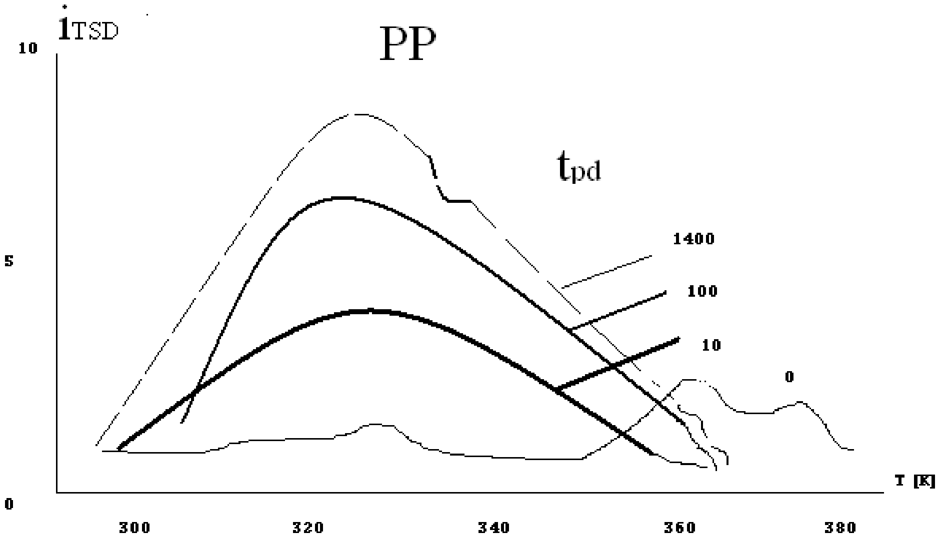

Figure 2.2 Thermally estimated depolarization current for PP-Foil

The curves of the activation energy of thermally estimated relaxation partial discharge time, obtained as the result of TSD- data performance are shows in Fig.3. The typical examples of the kinetic of surface charge density during the naturally estimated relaxation are in Fig.4.1 and Fig.4.2. The history of material i.e. the influence of partial discharge action is also seen in this case.

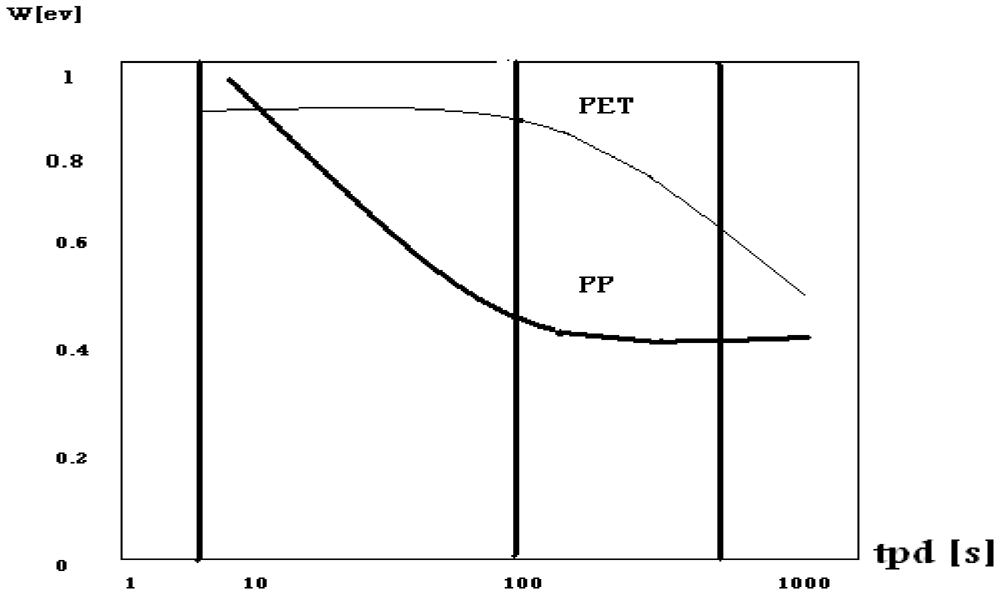

Figure 3. The influence of PD time on the activation energy of thermally estimated depolarization current TSD

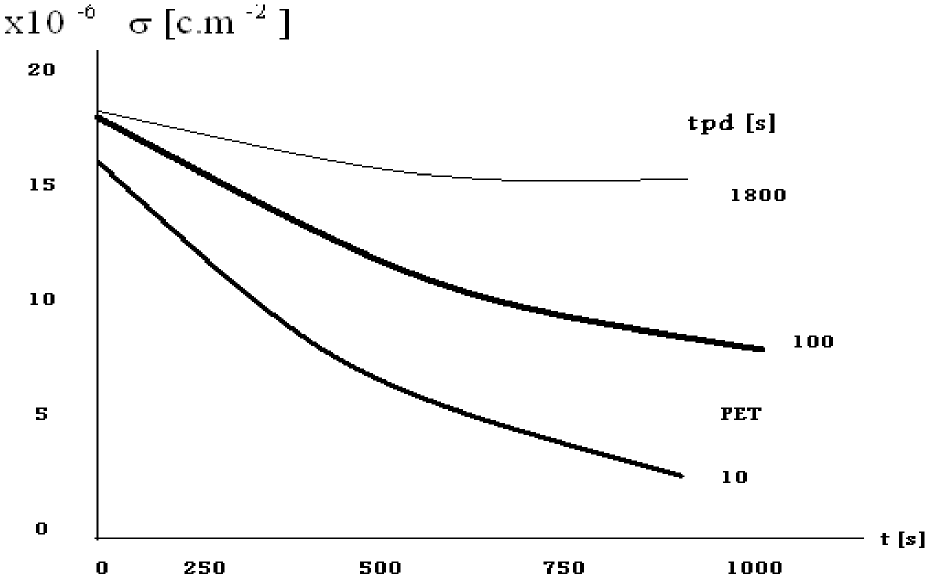

Figure 4.1 The decreasing of effective surface charge density during the natural relaxation for PET-Foil

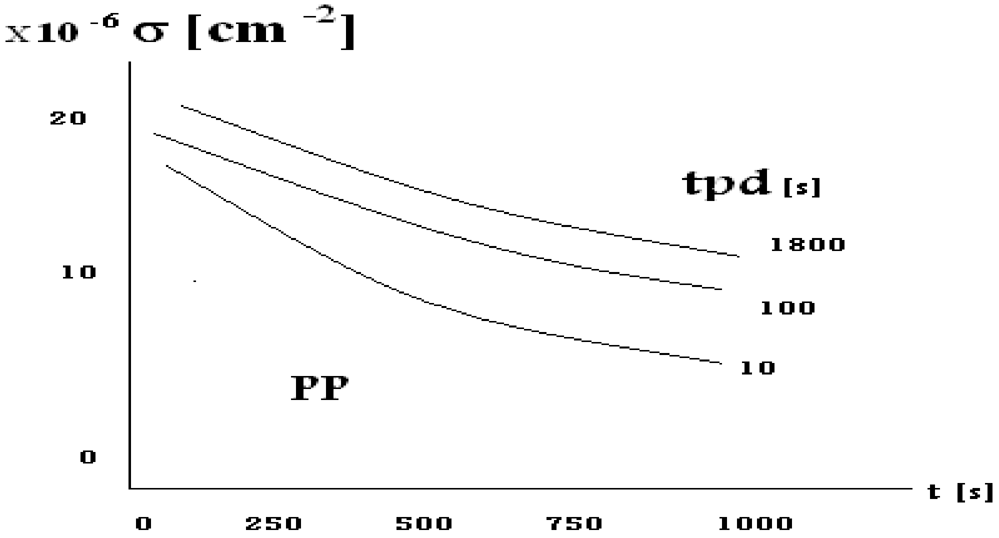

Figure 4.2 The decreasing of effective surface charge density during the natural relaxation for PP-Foil

The time constant which have been calculated from the relaxation curves, are shown in Fig 5. Time of partial discharge exposure. It can be seen that the time constant values are greater for PP-Foil in comparison with PET one and that these values increase with partial discharge time in both materials.

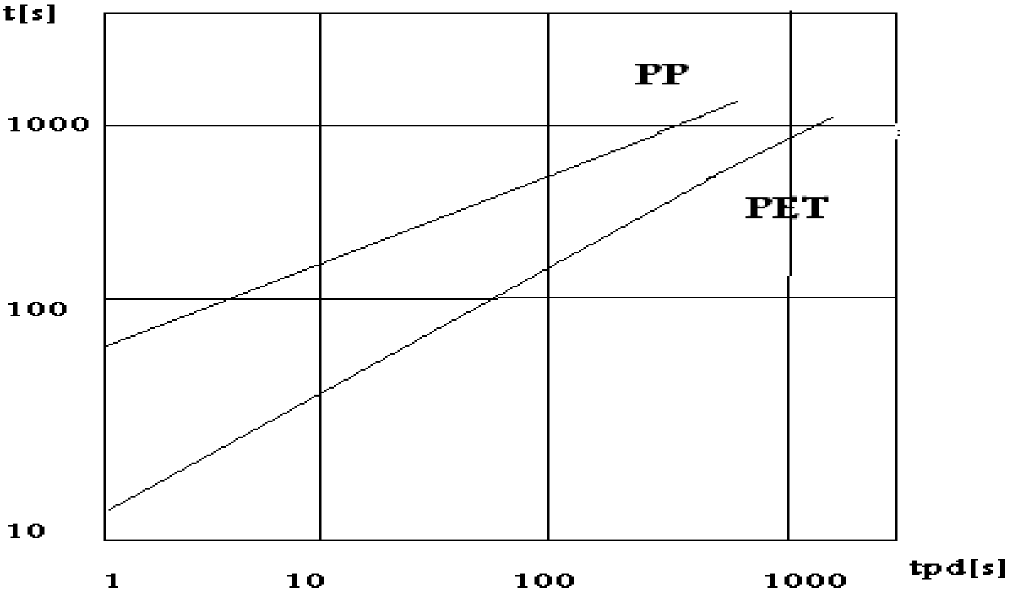

Figure 5. The influence of partial discharge time on the relaxation time constant

The facts are explained in the above presented results:

- The dependence of the TSD activation energy on PD exposure time.
- The dependence of the natural relaxation time constant on PD exposure time.

The first relation can be explained by name of the decreasing of macromolecular bonding forces as the results of electron injection in to the solid dielectric during the PD acting on it. This action has the greater influences in polypropylene because of the less polar structure of this polymer in comparison with the polyethylene terephtalate.

The second relation can be interpreted as the result of the influence of electron injection during the PD action on the product V. t t where V is the density of charge traps in the material and tt is the mean trapping time. The greater is the V. t t value the greater is the relation time constant. Probably the increase of V as the result of the formation of new localized states and traps in the material during the PD action has the essential influence on the relaxation time increase. Thus the charge injection into the material during the PD exposure changes the following natural relaxation process. The possible influence of this electrical result of the PD action on the initiation of material destruction should be yet investigated.

CONCLUSIONS

Partial discharge measurement is a common method for monitoring and diagnostics of power transformers, and can detect insulation malfunctions before they lead to failure. Different parameters extracted from the measured PD activity can be correlated to the PD source, and as a result it is possible to identify the PD source by analyzing the PD activity.

The advantages and limitations of the present PD signal transmission via foil were detailed. Based on the electro optic modulator-based monitoring technique that was investigated earlier, this paper proposes a PD continuous on-line monitoring system for insulating foil. The monitoring system is sensitive, safe, compact, with very little transmission attenuation. Partial discharge phenomenon occurs only within some of the tested foil. The results of extensive charging discharging test shows that partial discharges are only partly responsible for deterioration. A model of PD in an insulated foil is presented and used to dynamically simulate the sequence of PDs. For Partial Discharge (PD) measurement, not only detecting the signal magnitude of PD is enough for evaluating the insulating constructions of HV equipment such as GIS, GIL, power cable, and cable joint, but also localization of the PD position is important to them. PD localization can help to find out the defect point effectively and determine the cause of PD, improve the manufacturing process, and increase the insulating properties.

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