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MODELLING AND PHASE ANALYSIS OF INTERNAL PARTIAL DISCHARGES

Abstract: Paper deals with modelling of various types of surface discharges. Different electrode systems and insulating materials were used to create models. Phase resolved partial discharge analysis was applied to partial discharge signal and characteristic fingerprints are shown in the paper.

Key words: apparent charge, partial discharges, surface discharges, phase resolved analysis

1. Introduction

High voltage insulation of stator coils belongs to the most important parts of high voltage rotating machines. One of the best electric non-destructive method which enables proper diagnostics of stator insulation is partial discharge method. This method provides valuable information related to the state of insulation and enables early revelation of weak sites in stator insulation of high voltage rotating machines.

2. Insulation of high voltage coils

Insulating system of high voltage rotating machines is created by combination of insulating materials. Lifetime of insulating system is dependent on operating conditions of machine, correct choice of insulating materials and technology of their processing.

Partial discharges occurring in stator insulation of high voltage rotating machines can be divided into two main categories: *internal* and *external.*

To internal discharges belong *cavity discharges* and *electrical treeing.* Gas filled cavities can accrue due to improper technology of processing or they can occur during operation due to layering insulation caused by temperature or vibrations. Electrical treeing consists of hollow channels created by repetitive partial breakdown of dielectrics, locally occurring in areas with very strong electrical field. Strong electrical field occurs in the vicinity of sharp

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edges, metal snobs, conductive or semi-conductive layers, which can accrue during manufacturing of high voltage coil.

To external discharges belong *corona discharges* and *surface discharges.*

3. Discharges occurring on the surface of solid dielectrics

If voltage is led to high voltage coil, than insulation material is in series with air slot and earthed part of stator. If voltage across the slot reaches ignition value, partial discharges can occur in the slot. These discharges can deteriorate surface of insulation. For that reason, internal protective layer is applied on the surface of each high voltage coil. Main function of surface protection is to eliminate air gap between insulation and earthed stator. This protection consists of conductive layer laid on the part of surface of high voltage coil which is put into the stator slot.

Electric stress is the highest in sites, where high voltage coils terminate from stator. Because the tangential component of electrical field is present here, there are good conditions for formation of leakage surface discharges. To eliminate these discharges, semi-conductive protection is laid on the surface in sites, where coils terminate from stator. Function of this protection is to decrease potential of conductor in the face of earthed stator.

During operation, conductive and semi-conductive layers are often damaged due to vibrations. Moreover, surface of slot is not smooth, which causes local increase of strength of electrical field and occurrence of partial discharges. To model surface discharges, special made device has been constructed which consisted of two electrodes. Between electrodes it was possible to insert board made of insulating material. The first electrode was Rogowski electrode with diameter od 48 mm which modelled high voltage part of coil. To model non-homogenities that can occur on the slot surface, three type of electrodes were used:

- copper spherical electrode with diameter of 50 mm,
- copper rod electrode with the radius of termination of 15 mm,
- steel needle electrode.

Air gap in the stator slot was modelled by the change of distance between non-homogenous electrode and surface of insulating board (dx = 0; 0,2; 0,5 mm).

4. Results

In Figures 1, 2 and 3 are results obtained when insulating board was glass, distance was set to 0,2 mm and three types of electrodes mentioned above (copper rod, copper sphere and steel needle) were used. Testing voltage was 4 kV.

Inception voltage for rod electrode was 2,75 kV, for sphere electrode 4 kV and for needle 1,2 kV. From figures it is clear that shapes of fingerprints differ from each other, maximum values of apparent charge are 550 pC for bar electrode, 500 pC for sphere electrode and 1500 pC for needle electrodes.

In Figures 4, 5, 6 are the results obtained when insulating board was glass, testing voltage was 3,3 kV, only needle electrode was used and distance between needle electrode and board was changed; dx = 0 mm, dx = 0,2 mm and dx = 0,5 mm. The lowest values of appa-

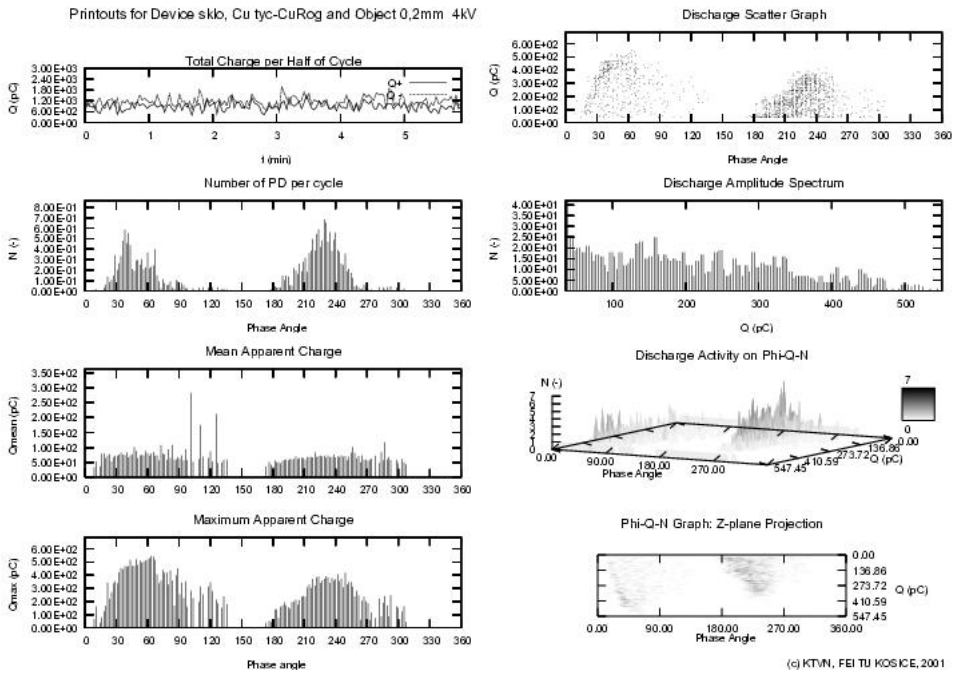

Fig. 1. *Phase resolved partial discharge analysis; copper rod, dx = 0,2 mm, glass,* $U_t = 4$ *kV*

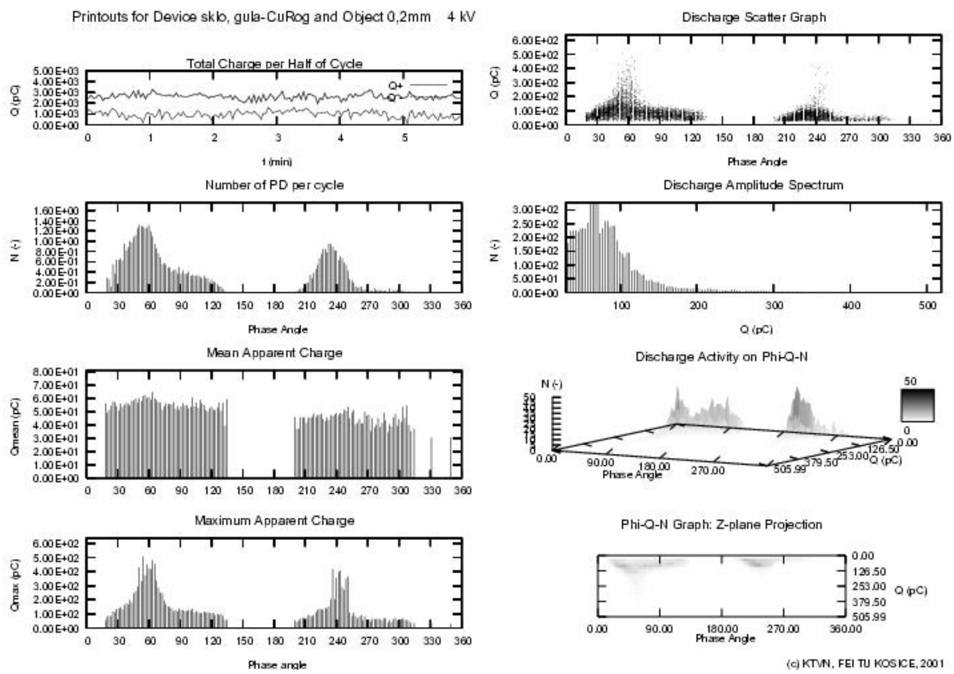

Fig. 2. *Phase resolved partial discharge analysis; copper sphere, dx = 0,2 mm, glass,* $U_t = 4$ *kV*

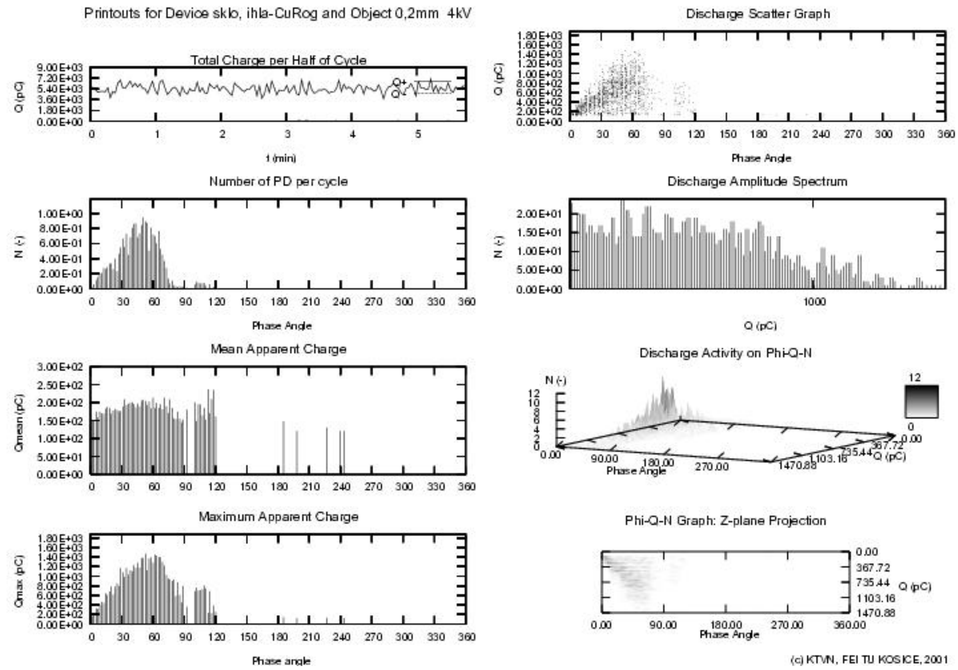

Fig. 3. *Phase resolved partial discharge analysis; steel needle, dx = 0,2 mm, glass, U_t = 4 kV*

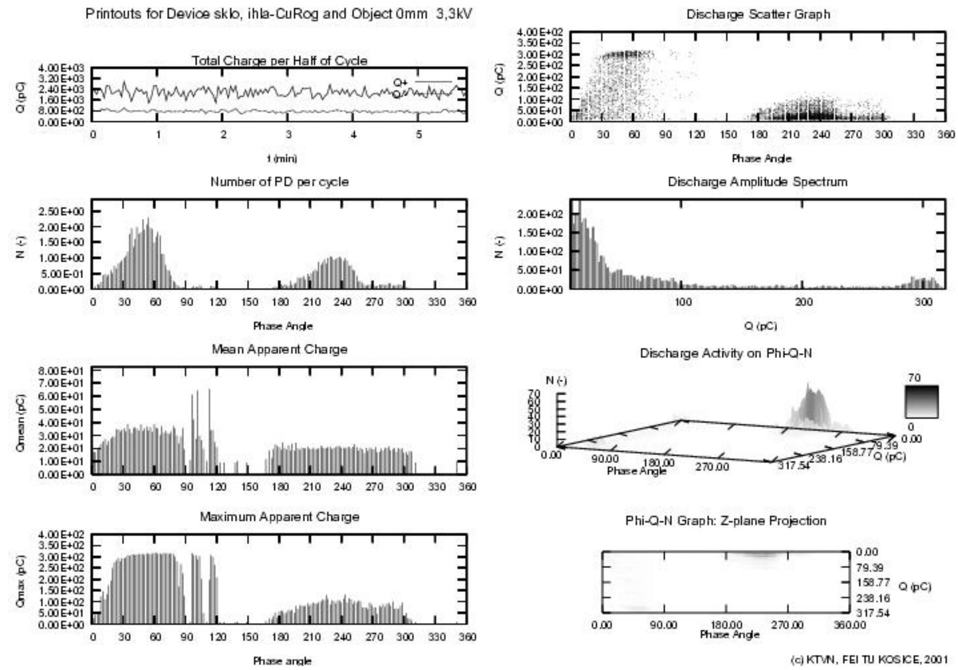

Fig. 4. *Phase resolved partial discharge analysis; needle electrode, dx = 0 mm, glass, U_t = 3,3 kV*

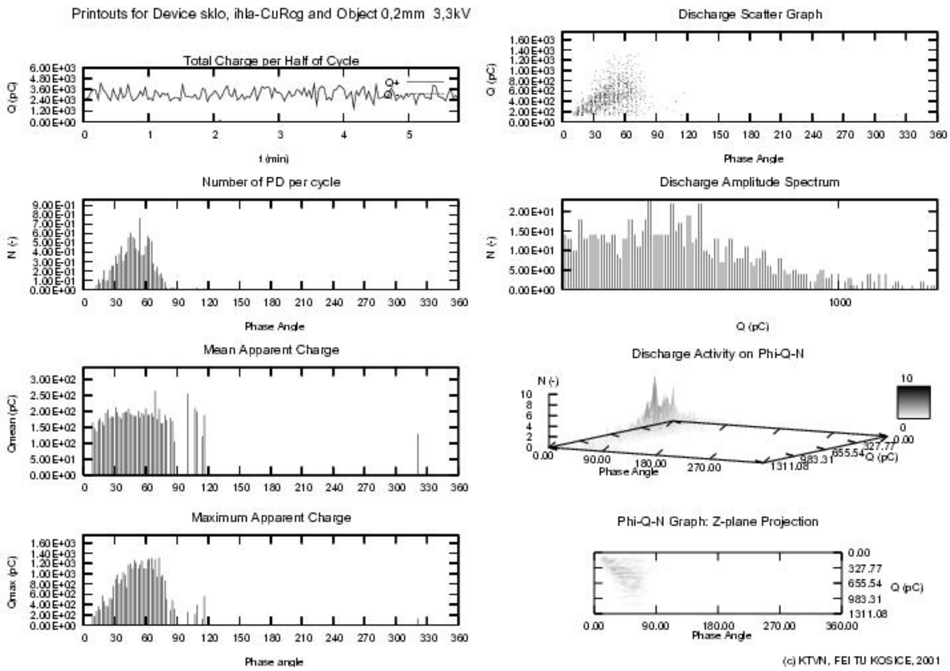

Fig. 5. *Phase resolved partial discharge analysis; needle electrode, dx = 0,2 mm, glass, U_t = 3,3 kV*

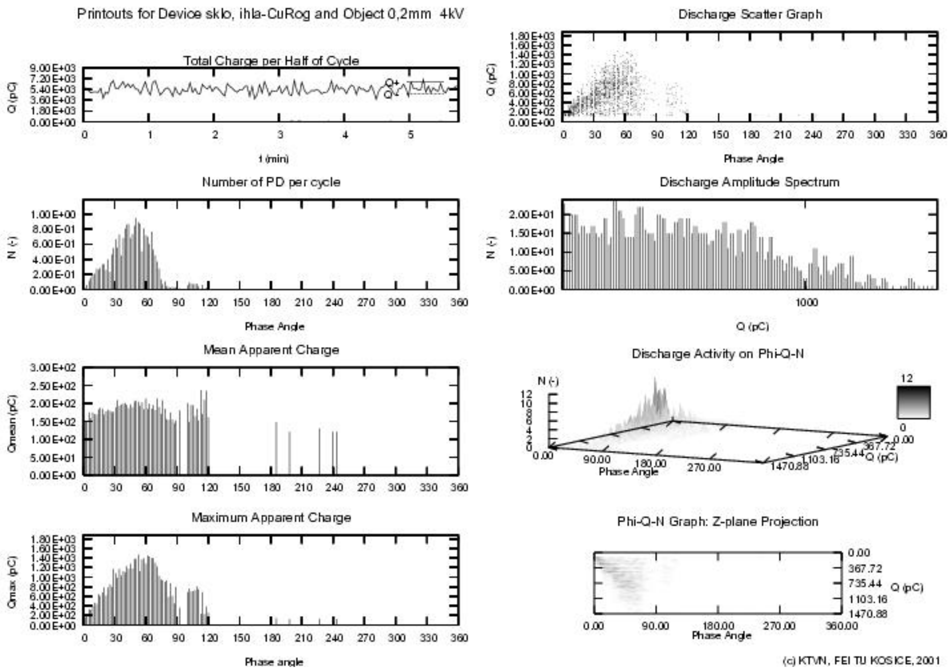

Fig. 6. *Phase resolved partial discharge analysis; needle electrode, dx = 0,5 mm, glass, U_t = 3,3 kV*

rent charge were obtained, if dx = 0 mm (350 pC), the highest values were obtained, if dx = 0,2 mm (1400 pC).

5. Conclusion

Measurements of surface discharges have shown, that obtained fingerprints are very variable and they vary in dependence on the type of insulating material, type of electrodes and distance of electrodes from insulating board. Similar cases can occur when performing partial discharge measurements on electric machine or generator. Fingerprints obtained from models can help us to define the type of failure occurred on real measured object more precisely.

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