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Mihaela Răduca, Ana-Maria Pittner, Eugen Răduca, Iancu Tătucu

The Synthesis and Analysis of Partial Discharges from Stator Winding Insulation of Hydro Generators

In this paper to perform the partial discharges which appear in stator winding insulation, the main characteristic measures of these, measurement and the results of partial discharges test.

1. Introduction

During exploitation the electrical equipment insulation may be required at supplementary solicitations of voltage, according by commutation over voltages, atmospherically over voltages or accidentally over voltages inducing by defects appeared in using time.

The over voltages can generated in insulation, according with existing conditions, to different electrical phenomenon's, sometimes attend on sonorous and light effects, known over the name: discharges; pierces; arc-over; sparks; primers; effluences; Corona effects.

2. Partial discharges or ionizations

The insulations not be considerate perfectly homogenous. In this, always will find small dimensions goals filled with gas. This gas result from contraction of insulation different constituents or from technological executed process.

Below action of electric field, these goals are ionized and when voltage between opposed faces touch the destructive gradient of closed gas, appear the partial discharges (ionizations).

These partial discharges (PD) depend in number and amplitude by voltage gradient, superficially resistance of goal walls and goal dimensions, by nature and pressure of closed gas.

The energy transmitted to the electrons from electric field is used in the following processes:

- the shocks which going to heating the gas from goal;

- the excitation of gas atoms which produced a emanation of radiations;
- the ionization which multiply the number of atoms;
- electrodes bombardment (goal walls) which determinate the chemical and structure modifications of insulated materials;

The discharge energy transfer on the goal walls in which to develop the partial discharges are made is in two ways:

- through local transfer on one chemical structure, which can determined, in case of high molecular mass substances, a rupture of some connections, or, in another conditions, appear of supplementary connections;
- through heating transfer; the time of exchange being extremely short, this transfer is applied to a little volume of substance and for that the increase of temperature in impact points may induce melting and evaporation of it, or to some components of her.

The apparition and development of these inner partial discharges have a harmful effect on the insulation because these goals became bigger with time, formatted the channels by union of many goals, going out with formation of craters. In this manner, the insulation is loosening and can be appear the pierces which going out at destruction of insulation.

Measurement of partial discharges let us observed from time the increasing of their level, therefore apparition of some evolution defects in insulation mass or general aging of insulation.

3. Characteristic measures of partial discharges

The characteristic measures of partial discharges are the followings:

- the apparent charge of one partial discharge q, is the charge which instantaneous injection to the terminals of tested object, will instantaneous modified the terminals voltage with same quantity like partial discharge it self.
- the medium discharge current I, is the ratio between absolute value sum of apparent charges of partial discharges, on the one time period T:

$$I = \frac{1}{T}\sum_{v(t)}^{v(t+T)}|q_v| , \qquad (1)$$

- the square flow of apparent charges D, is ratio between square sum of apparent charges of partial discharges, on the one time period T:

$$D = \frac{1}{T}\sum_{v(t)}^{v(t+T)} q_v^2 \quad , \qquad (2)$$

- the dissipated power through partial discharges P, is average power supplied at terminals owing to partial discharges on the one time period T:

$$P = \frac{1}{T}\sum_{v(t)}^{v(t+T)} q_v U_v \quad , \qquad (3)$$

where U_v is instantaneous values by v rage of voltage at terminals, corresponding at q charges.

- average ionization current I_m:

$$I_m = \sqrt{2Df_i} \quad , \qquad (4)$$

where f_i is attempt voltage frequency

- the reduction square of apparent charges d:

$$d = \frac{D}{C} \quad , \qquad (5)$$

where C is capacity of insulation.

- reduced ionization medium current i_m:

$$i_m = \frac{I_m}{C} \quad , \qquad (6)$$

4. Measurement of partial discharge level

The measurement of partial discharges is a estimation method of insulation quality, especially, looking over insulation homogenous (presence of goals and impurities in insulation, so also).

In the same time the periodically measurements make at exploitation equipments permit us to observe, in time, the aging process of insulation.

Through the measurement of partial discharges level are understanding the measurement of the following measures:

- apparent charge;
- medium discharge current;
- square flow of apparent charges;
- losses in dielectric owning to discharges.

The choosing of apparent charge, q, as characteristics fundamentally measure of partial discharge permit to measure the individually discharge intensity which are produce in particular points of insulation, independent circuit and measurement apparatus. The apparent charge can determinate the highest discharge (being easy interpretation). This charge are easy measured, and can be follow the discontinuities which going out at release of discharge in other points than in which already exists.

The choosing of medium discharge current, I, reflect the combination effect a lot of discharges. To use in practice of this measure is very difficult. The measurement of square flow of apparent charges, D, have the advantage that the meters are very simple. This measure depends of discharges with low and high intensity, in the same time.

The measurement of dissipation power through partial discharges, P, is used especially for insulation sample. It have the advantage that if it is known the dielectric constant and loss tangent, tgδ, can be separated the losses produced by discharges to the another losses.

5. The measurements of partial discharges

The partial discharges test in PDA-IV technology it is used to indicate the following causes for deterioration of stator winding:

- The coils and bars which not sufficiently impregnated with epoxi resin
- Insulation mass which was exfoliated (separation of mica band layers) own to overheating and/or thermal cycles.
- The deterioration of semiconductor covering in slot and/or in frontal heads
- Loosen wedges and slot filling owning to manufacturing
- Conductive contaminations at frontal heads which going at phase-mass or phase-phase arc-over

In case of partial discharges test, for each phase are determinate two type of graphs. The first graph is two-dimensional (2D) where is present the impulse numbers (PD/sec) in function of partial discharges (PD) amplitude. The second graph is tri-dimensional (3D).

The each graph resumes two types of measures:

- Peak amplitude, $\pm Q_m$
- Total activity of partial discharges, ±NQN (Normalized Quantity Number).

where:

$\pm Q_m$ is peak amplitude of positive or negative partial discharges corresponding a repetitive rate of 10 pulses per second;

±NQN – is proportionally measure with graph surface below analysed line of positive or negative impulses amplitude and it is the total transfer of charge owning to partial discharges.

The Q_m measure is one rate amplitude of 10 impulses/seconds partial discharges and shows the deterioration in the winding grave point.

The NQN measure is proportionally with total value of deterioration caused by partial discharges activity.

The positive values of +NQN si + Qm measures indicate the presence of partial discharges activity at surface between coil and slot or on the frontal parts surface.

The negative values of -NQN si - Q_m indicate the presence of partial discharges activity at surface between copper and insulation or in insulation between coils.

6. The measurements prosecution

For the partial discharge test, the coils were tested on the stand and the partial discharges test does at phase voltage:

$$U_f = 0.6 \times U_n, \qquad (7)$$

During function of generator the phase winding insulation is applied at phase voltage. Because the coils insulation is imposed at different voltages, so the coils towards null are imposed at low voltages and the coils towards the main terminal are imposed at phase voltage.

For analyse the insulation state in PDA-IV technology each phase supplied separately at outside phase voltage so that the insulation of all coils which compose the one phase is imposed at phase voltage. In this way, the partial discharge activity is high than which appear in generator functioning time. But through this measurement are obtain an exactly appreciation of all phase insulation.

7. The results of partial discharges test

After the tests, are obtained the followings results for characteristics measures ±NQN and ±Q_m. These measures were determinate, with help of couplers,for each phase and obtained results are presented in table 1.

Table 1

Couplers	U=0.6xUn Phase R					
R - C1	+NQN	-NQN	-NQN/+NQN	+Qm	-Qm	-Qm/+Qm
	62	80	1.29	38	39	1.02
Couplers	U=0.6xUn Phase S					
S - C1	+NQN	-NQN	-NQN/+NQN	+Qm	-Qm	-Qm/+Qm
	53	73	1.37	37	48	1.29

Couplers	U=0.6xUn Phase T					
T - C1	+NQN	-NQN	+NQN/-NQN	+Qm	-Qm	+Qm/-Qm
	67	56	1.19	38	36	1.05

R phase The two-dimensional (2D) and tri-dimensional (3D) analysis of partial discharges is presented in figure 1 and figure 2.

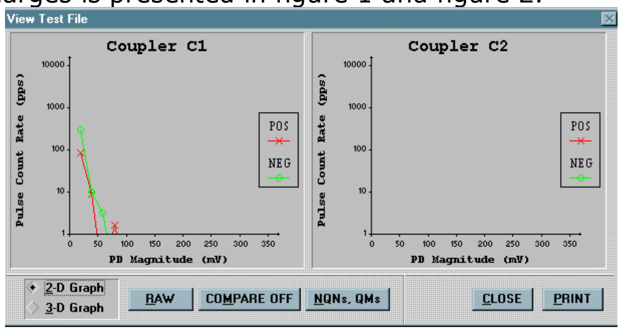

Figure 1. The two-dimensional (2D) partial discharges analysis

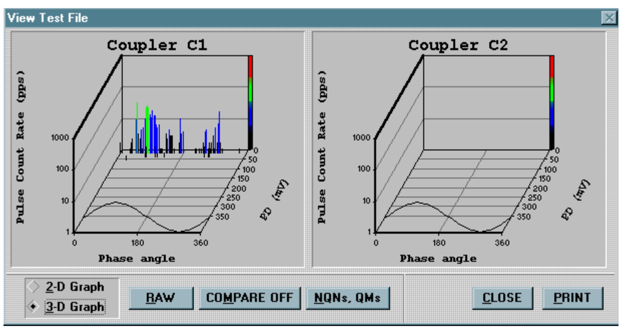

Figure 2. The tri-dimensional (3D) partial discharges analysis

S phase The two-dimensional (2D) and tri-dimensional (3D) analysis of partial discharges is presented in figure 3 and figure 4.

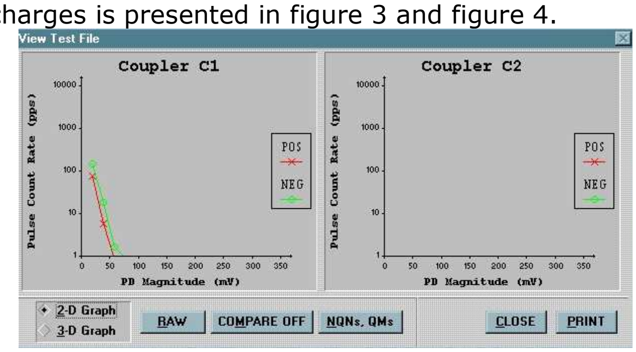

Figure 3. The two-dimensional (2D) partial discharges analysis

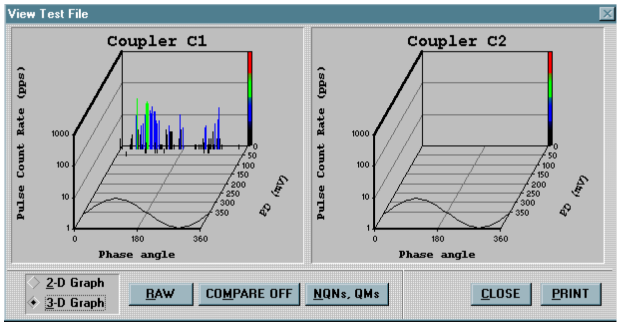

Figure 4. The tri-dimensional (3D) partial discharges analysis

T phase The two-dimensional (2D) and tri-dimensional (3D) analysis of partial discharges is presented in figure 5 and figure 6.

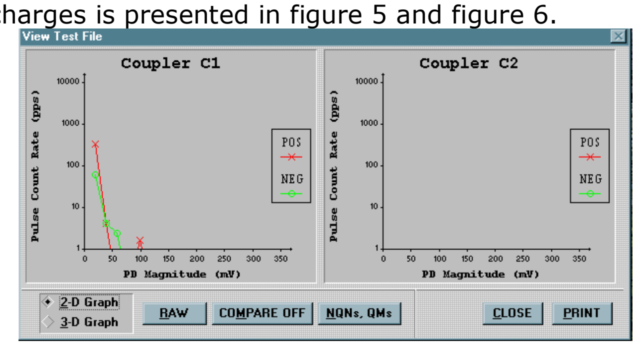

Figure 5. The two-dimensional (2D) partial discharges analysis

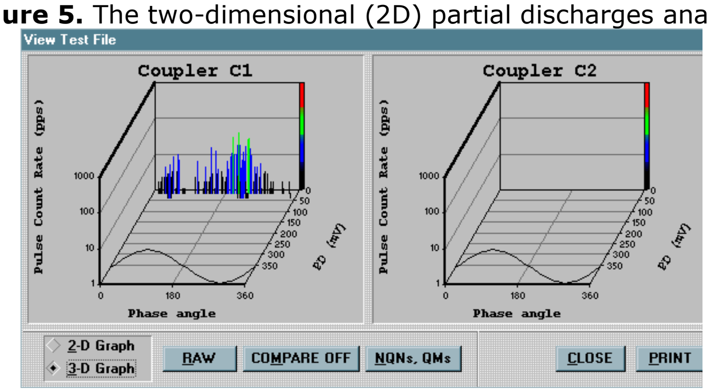

Figure 6. The tri-dimensional (3D) partial discharges analysis

8. Conclusions

Measurement of partial discharges permits understanding of their level, in time, therefore apparition of evolution defects in mass of insulation or general aging of insulation.

Through characteristic measures of partial discharges can be appreciate the insulation state.

From graph analysis, in stator coils insulation, on the all phases are obtain an intense activity of partial discharges in winding, being at admissible limit in generator functioning.

For generator safety function impose replacement of winding insulation in maximum 1÷2 years.

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Addresses:

- Lector eng. Mihaela Răduca, "Eftimie Murgu" University of Romania, Piaţa "Traian Vuia", nr. 1-4, Reşiţa, raducamiha@yahoo.com
- Ass. eng. Ana-Maria Pittner, "Eftimie Murgu" University of Romania, Piaţa "Traian Vuia", nr. 1-4, Reşiţa, pittneram@yahoo.com
- Prof. dr. eng. Eugen Răduca, "Eftimie Murgu" University of Romania, Piaţa "Traian Vuia", nr. 1-4, Reşiţa, e.raduca@uem.ro
- Conf. dr. eng. Iancu Tătucu, "Eftimie Murgu" University of Romania, Piaţa "Traian Vuia", nr. 1-4, Reşiţa, i.tatucu@uem.ro