EVALUATION INSULATION OF THE STATOR COIL A HYDRO-GENERATORS THROUGH MONITORING THE LEVEL OF PARTIAL DISCHARGES

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ABSTRACT: In this paper we present a procedure for evaluating the isolation of the fixed coil wrapping for a hydro generator, by monitoring the level of partial discharges (PD). The evaluation is aiming to establish the maintenance work that is to be done, with the purpose of restoring the initial performance parameters of the hydro generator. By using this method we can highlight the status of the fixed coil wrapping of a hydro generator, this constituting a good warranty of a correct evaluation of the parameters for the isolation.

KEY WORDS: insulation stator coil, hydro-generators, partial discharges (PD), monitoring.

1. INTRODUCTION

Partial discharges are, in general, a consequence of local concentration of electrical solicitations in the interior or on the surface of isolation. In general, such discharge appears in the form of impulses with a duration less than 1µs [1, 2].

An efficient method of evaluation of the real status of the insulation of fixed coil windings is by monitoring the level of partial discharges, highlighting the eventual in homogeneity in the mass of insulation leading to major deteriorations of the insulation and, finally, stopping the generator from functioning [3].

For an accurate diagnosis of the functional status of the generator we need to locate the defects, this permitting a decrease of the necessary time for screening and repairing the generators [4].

The functioning in nominal parameters of high power electrical machines is depending on the integrity of the insulation of the fixed coil winding who has the greatest contribution in prolonging the lifetime of the machine [5].

In the case when, due to the fabrication process or some external factors, are appearing in homogeneities, this opens the possibility of reducing the lifetime due to the solicitations at the cavities level in the mass of the insulation [6, 7]. So, the real status of the insulation system and the early defects caused by this are major problems confronting both the producers and the users of electrical machines [8].

The knowledge of the technical status of the the insulation of fixed coil windings is essential in appreciating [9, 10]: the feasibility of refurbishment or improvement of the nominal characteristics of great power electrical machines; the potential for a nondisrupted satisfactory functioning for all the lifetime of the machine.

2. MEASUREMENT SYSTEM OF PARTIAL DISCHARGES

The system used for measuring of partial discharges is formed from several subsystems: a coupling device, a transmission system and the measurement device.

The coupling device (Figure 1.b) is, in general, an active or passive network with four terminals, and converts the intensity of the input flow to the exit voltage.

The signals are transmitted to the measurement device through a transmission system. The frequency answer of the coupling device, defined by the ratio of the exit voltage and the input intensity, is chosen so it blocks the loading voltage and his harmonics to reach the measurement device.

Figure 1. The measurement system of partial discharges

The measurement device of PD, together with the coupling device (Figure 1.a) are forming a broadband measurement system of PD [11], characterized by a transfer impedance z(f) having for the frequency values f_1 as the inferior limit and f_2 for the upper limit, and also an adequate attenuation up to f_1 and over f_2.

The answer of this device to an impulse caused by a partial discharge is, generally, a heavily cushioned oscillation. Both the apparent load and the impulse polarity of PD can be determined from this answer. The resolution time of the impulses is less than 5s.

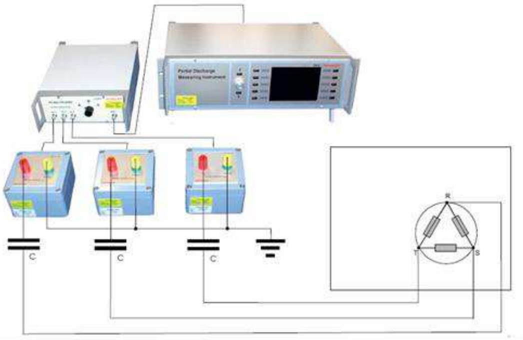

Figure 2. The wiring diagram for the measuring of partial discharges

So, in Figure 2 was presented the wiring diagram for the measuring of partial discharges PD and in Figure 3 is presented the connection mode of the insulators.

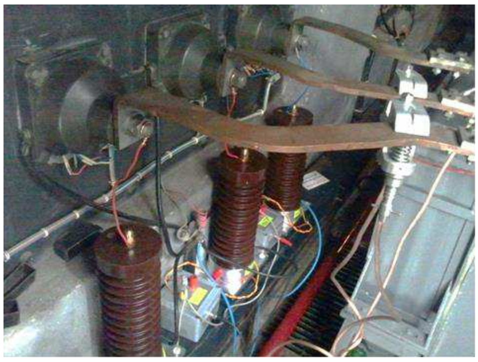

Figure 3. The connection mode of the insulators

3. RESULTS AND DISCUSSIONS

We realised the tests with the generator working in idle mode. We measured the level of partial discharges at different values of voltage at the terminals of the generator: U_{line}=0.8 kV, U_{line}=1.9 kV, U_{line}=2.8 kV, U_{line}=3.8 kV, U_{line}=5.9 kV, U_{line}=6.6 kV.

For each voltage level we determined the levels of partial discharges, for a number of 30 records. Using the average values of the values, we established the average values for each phase.

The results of the measurements of the partial discharges at the terminals of the generator are listed in the following tables:

Table 1. Partial discharges at U_{line} = 0.8 kV

Crt No.	Phase A		Phase B		Phase C	
	U_A	PD_A	U_B	PD_B	U_C	PD_C
	[V]	[pC]	[V]	[pC]	[V]	[pC]
1	0.5	459.4	0.5	525	0.5	651.6

2	0.5	764.1	0.5	642.2	0.5	492.2
3	0.5	426.6	0.5	435.9	0.5	435.9
4	0.5	435.9	0.5	651.6	0.5	628.1
5	0.5	595.3	0.5	567.2	0.5	365.6
6	0.5	440.6	0.5	642.2	0.5	778.1
7	0.5	407.8	0.5	379.7	0.5	539.1
8	0.5	393.8	0.5	435.9	0.5	684.4
9	0.5	735.9	0.5	656.3	0.5	459.4
10	0.5	421.9	0.5	398.4	0.5	754.7
11	0.4	750	0.5	632.8	0.5	351.6
12	0.4	412.5	0.5	370.3	0.5	726.6
13	0.4	656.3	0.5	679.7	0.5	567.2
14	0.4	276.6	0.5	393.8	0.5	698.4
15	0.4	768.8	0.5	670.3	0.5	623.4
16	0.4	389.1	0.5	365.6	0.5	726.6
17	0.4	754.7	0.5	403.1	0.5	351.6
18	0.4	440.6	0.5	360.9	0.5	754.7
19	0.4	581.3	0.5	468.8	0.5	389.1
20	0.4	717.2	0.5	529.7	0.5	721.9
21	0.4	618.8	0.5	346.9	0.5	614.1
22	0.4	407.8	0.5	562.5	0.5	539.1
23	0.4	431.3	0.5	417.2	0.5	712.5
24	0.4	389.1	0.5	365.6	0.5	562.5
25	0.4	459.4	0.5	506.3	0.5	735.9
26	0.4	440.6	0.5	398.4	0.5	473.4
27	0.4	721.9	0.5	557.8	0.5	534.4
28	0.4	567.2	0.5	384.4	0.5	703.1
29	0.4	445.3	0.5	660.9	0.5	543.8
30	0.4	403.1	0.5	431.3	0.5	501.6

The results of the experiments presented in Table 1 are indicating a certain level of disequilibrium at the level of partial discharges between the three phases.

In the conditions of a nominal voltage of 0,8 kV between the terminals of the generator, we notice a low level of the partial discharges of 276.6 pC, reaching a value of 778.1 pC in phase C.

Table 2. Partial discharges at U_{line} = 1.9 kV

Crt No.	Phase A		Phase B		Phase C	
	U_A	PD_A	U_B	PD_B	U_C	PD_C
	[V]	[pC]	[V]	[pC]	[V]	[pC]
1	1.10	2015.6	1.10	1171.9	1.10	1312.5
2	1.10	984.4	1.10	843.8	1.10	1031.3
3	1.10	1640.6	1.10	656.3	1.10	1453.1
4	1.10	1078.1	1.10	792.2	1.10	1781.3
5	1.10	1031.3	1.10	1195.3	1.10	1218.8
6	1.10	1171.9	1.10	1500	1.10	2062.5
7	1.10	937.5	1.10	750	1.10	1078.1
8	1.10	1968.8	1.10	1171.9	1.10	1500
9	1.10	1218.8	1.10	1312.5	1.10	1921.9
10	1.10	2015.6	1.10	1265.6	1.10	1734.4
11	1.10	1031.3	1.10	984.4	1.10	2109.4
12	1.10	1640.6	1.10	796.9	1.10	1968.8
13	1.10	1921.9	1.10	750	1.10	1218.8
14	1.10	1593.8	1.10	937.5	1.10	1125
15	1.10	1734.4	1.10	1064.1	1.10	2015.6
16	1.10	937.5	1.10	1195.3	1.10	890.6
17	1.10	1875	1.10	796.9	1.10	1875
18	1.10	1406.3	1.10	1078.1	1.10	2109.4
19	1.10	1687.5	1.10	1359.4	1.10	1875
20	1.10	1078.1	1.10	656.3	1.10	1359.4
21	1.10	1921.9	1.10	1195.3	1.10	1734.4
22	1.10	1125	1.10	1500	1.10	1312.5
23	1.10	1453.1	1.10	984.4	1.10	1031.3
24	1.10	1078.1	1.10	1359.4	1.10	1875
25	1.10	1171.9	1.10	796.9	1.10	1500
26	1.10	1781.3	1.10	1171.9	1.10	1031.3
27	1.10	1125	1.10	843.8	1.10	1781.3
28	1.10	984.4	1.10	1078.1	1.10	1312.5
29	1.10	1078.1	1.10	1406.3	1.10	1312.5
30	1.10	1171.9	1.10	937.5	1.10	2109.4

The results of the experiments presented in Table 2 are indicating a certain level of disequilibrium at the level of partial discharges between the three phases.

In the conditions of a nominal voltage of 1,9 kV between the terminals of the generator, we notice a medium level of the partial discharges of 656.3pC, reaching a value of 2109.4 pC in phase C.

Table 3. Partial discharges at U_{line} = 2.8 kV

Crt No.	Phase A		Phase B		Phase C	
	U_A	PD_A	U_B	PD_B	U_C	PD_C
	[V]	[pC]	[V]	[pC]	[V]	[pC]
1	1.60	1734.4	1.60	1500	1.60	2015.6
2	1.60	2671.9	1.60	1546.9	1.60	1734.4
3	1.60	1781.3	1.60	1546.9	1.60	3093.8
4	1.60	2906.3	1.60	2484.4	1.60	2062.5
5	1.60	1593.8	1.60	1593.8	1.60	1781.3
6	1.60	2484.4	1.60	2812.5	1.60	2156.3
7	1.60	2671.9	1.60	2203.1	1.60	3140.6
8	1.60	2156.3	1.60	3187.5	1.60	1828.1
9	1.60	1640.6	1.60	2296.9	1.60	1500
10	1.60	1500	1.60	2718.8	1.60	2953.1
11	1.60	1687.5	1.60	2203.1	1.60	2343.8
12	1.60	1453.1	1.60	2296.9	1.60	2484.4
13	1.60	1546.9	1.60	1640.6	1.60	2109.4
14	1.60	1781.3	1.60	2156.3	1.60	2296.9
15	1.60	2625	1.60	1734.4	1.60	1781.3
16	1.60	1406.3	1.60	1546.9	1.60	1453.1
17	1.60	2390.6	1.60	2531.3	1.60	2812.5
18	1.60	1640.6	1.60	1593.8	1.60	1875
19	1.60	1546.9	1.60	2812.5	1.60	2484.4

20	1.60	2859.4	1.60	2203.1	1.60	1734.4
21	1.60	1687.5	1.60	3046.9	1.70	2812.5
22	1.60	1687.5	1.60	2343.8	1.70	2109.4
23	1.60	2765.6	1.60	2625	1.70	3234.4
24	1.60	2343.8	1.60	1734.4	1.70	1781.3
25	1.60	1734.4	1.60	1593.8	1.70	2390.6
26	1.60	1781.3	1.60	1546.9	1.60	2109.4
27	1.60	2906.3	1.60	2296.9	1.60	2531.3
28	1.60	1640.6	1.60	1500	1.60	1828.1
29	1.60	2859.4	1.60	2156.3	1.60	2296.9
30	1.60	2250	1.60	1312.5	1.60	2859.4

The results of the experiments presented in Table 3 are indicating a certain level of disequilibrium at the level of partial discharges between the three phases.

In the conditions of a nominal voltage of 2,8 kV between the terminals of the generator, we notice a high level of the partial discharges of 1312.5 pC in the B phase, reaching a value of 3234.4 pC in phase C.

Table 4. Partial discharges at U_{line} = 3.8 kV

Crt No.	Phase A		Phase B		Phase C	
	U_A	PD_A	U_B	PD_B	U_C	PD_C
	[V]	[pC]	[V]	[pC]	[V]	[pC]
1	2.20	1968.8	2.20	1687.5	2.20	4031.3
2	2.20	3703.1	2.20	3375	2.20	3703.1
3	2.20	1921.9	2.20	1875	2.20	2484.4
4	2.20	2109.4	2.20	2015.6	2.20	3046.9
5	2.20	2250	2.20	2859.4	2.20	4218.8
6	2.20	3140.6	2.20	3375	2.20	2671.9
7	2.20	3843.8	2.20	1734.4	2.20	3937.5
8	2.20	2671.9	2.20	2953.1	2.20	2343.8
9	2.20	3703.1	2.20	3656.3	2.20	2390.6
10	2.20	1921.9	2.20	2109.4	2.20	2812.5
11	2.20	3281.3	2.20	3375	2.20	2156.3
12	2.20	2250	2.20	1828.1	2.20	2484.4
13	2.20	2953.1	2.20	3468.8	2.20	1781.3
14	2.20	2250	2.20	1828.1	2.20	2812.5
15	2.20	2437.5	2.20	3281.3	2.20	3281.3
16	2.20	3656.3	2.20	1734.4	2.20	2578.1
17	2.20	2109.4	2.20	2109.4	2.20	2812.5
18	2.20	3796.9	2.20	3375	2.20	2859.4
19	2.20	2437.5	2.20	1921.9	2.20	3140.6
20	2.20	3609.4	2.20	3468.8	2.20	3609.4
21	2.20	2109.4	2.20	2015.6	2.20	2531.3
22	2.20	2015.6	2.20	1921.9	2.20	3984.4
23	2.20	3656.3	2.20	3046.9	2.20	2953.1
24	2.20	2015.6	2.20	2765.6	2.20	4312.5
25	2.20	3843.8	2.20	3328.1	2.20	2578.1
26	2.20	2484.4	2.20	1875	2.20	1781.3
27	2.20	3937.5	2.20	3468.8	2.20	4218.8
28	2.20	2296.9	2.20	2015.6	2.20	2718.8
29	2.20	1781.3	2.20	1875	2.20	2578.1
30	2.20	3609.4	2.20	2765.6	2.20	4078.1

The results of the experiments presented in Table 4 are indicating a certain level of disequilibrium at the level of partial discharges between the three phases.

In the conditions of a nominal voltage of 3,8 kV between the terminals of the generator, we notice a high level of the partial discharges of 1687.5 pC in the B phase, reaching a value of 4312.5 pC in phase C.

Table 5. Partial discharges at U_{line} = 5.9 kV

Crt No.	Phase A		Phase B		Phase C	
	U_A	PD_A	U_B	PD_B	U_C	PD_C
	[V]	[pC]	[V]	[pC]	[V]	[pC]
1	3.40	3234.4	3.40	6093.8	3.40	5390.6
2	3.40	3843.8	3.40	3796.9	3.40	4546.9
3	3.40	3093.8	3.40	6140.6	3.40	6093.8
4	3.40	6750	3.40	3750	3.40	4593.8
5	3.40	3750	3.40	6562.5	3.40	5812.5
6	3.40	6234.4	3.40	3843.8	3.40	6750
7	3.40	4265.6	3.40	3796.9	3.40	4359.4
8	3.40	6281.3	3.40	5578.1	3.40	6421.9
9	3.40	4125	3.40	4265.6	3.40	4078.1
10	3.40	6703.1	3.40	3796.9	3.40	6046.9
11	3.40	3937.5	3.40	3890.6	3.40	4359.4
12	3.40	3187.5	3.40	3750	3.40	6046.9
13	3.40	3890.6	3.40	3796.9	3.40	4031.3
14	3.40	3843.8	3.40	3703.1	3.40	5250
15	3.40	6750	3.40	5859.4	3.40	4546.9
16	3.40	4546.9	3.40	3796.9	3.40	4078.1
17	3.40	6234.4	3.40	5906.3	3.40	6796.9
18	3.40	4312.5	3.40	4312.5	3.40	4500
19	3.40	6421.9	3.40	6656.3	3.40	4546.9
20	3.40	4546.9	3.40	3843.8	3.40	4265.6
21	3.40	5296.9	3.40	6140.6	3.40	4406.3
22	3.40	3140.6	3.40	3703.1	3.40	6984.4
23	3.40	5296.9	3.40	3750	3.40	5156.3
24	3.40	3843.8	3.40	5765.6	3.40	4687.5
25	3.40	4265.6	3.40	3937.5	3.40	5718.8
26	3.40	6796.9	3.40	6140.6	3.40	6046.9
27	3.40	6234.4	3.40	3703.1	3.40	4312.5
28	3.40	4265.6	3.40	4171.9	3.40	5812.5
29	3.40	6375	3.40	5859.4	3.40	6000
30	3.40	3609.4	3.40	4359.4	3.40	6843.8

The results of the experiments presented in Table 5 are indicating a certain level of disequilibrium at the level of partial discharges between the three phases.

In the conditions of a nominal voltage of 5,9 kV between the terminals of the generator, we notice a very high level of the partial discharges of 3140.6 pC in the A phase, reaching a value of 6984.4 pC in phase C.

Table 6. Partial discharges at U_{line} = 6.6 kV

Crt No.	Phase A		Phase B		Phase C	
	U_A [V]	PD_A [pC]	U_B [V]	PD_B [pC]	U_C [V]	PD_C [pC]
1	3.80	6281.3	3.80	4968.8	3.8	8296.9
2	3.80	5015.6	3.80	6750	3.9	5625
3	3.80	5906.3	3.80	4171.9	3.8	7968.8
4	3.80	4875	3.90	4687.5	3.8	5109.4
5	3.80	5812.5	3.90	6562.5	3.8	5859.4
6	3.80	7078.1	3.90	4218.8	3.8	7968.8
7	3.80	4359.4	3.80	6703.1	3.8	6609.4
8	3.80	6703.1	3.90	4312.5	3.8	8296.9
9	3.80	4875	3.90	6562.5	3.8	5437.5
10	3.80	6281.3	3.90	3843.8	3.8	5906.3
11	3.80	4687.5	3.90	6609.4	3.8	5296.9
12	3.80	5437.5	3.90	4406.3	3.8	5906.3
13	3.80	8296.9	3.90	6656.3	3.8	7687.5
14	3.80	5953.1	3.90	4359.4	3.8	6328.1
15	3.80	7875	3.90	4265.6	3.8	8203.1
16	3.80	5812.5	3.90	4218.8	3.8	5437.5
17	3.80	8109.4	3.80	4218.8	3.8	8109.4
18	3.80	5578.1	3.90	4406.3	3.8	4640.6
19	3.80	6703.1	3.90	4312.5	3.8	5859.4
20	3.80	7875	3.90	6750	3.8	5203.1
21	3.80	6140.6	3.90	4640.6	3.8	8390.6
22	3.80	4500	3.90	4312.5	3.8	4734.4
23	3.80	5812.5	3.90	6656.3	3.8	4546.9
24	3.80	4453.1	3.90	5859.4	3.9	8015.6
25	3.80	8062.5	3.90	3937.5	3.9	6140.6
26	3.80	3890.6	3.90	6703.1	3.8	6000
27	3.80	8156.3	3.90	6515.6	3.8	7781.3
28	3.80	5203.1	3.80	4078.1	3.9	6843.8
29	3.80	8296.9	3.80	4828.1	3.9	5296.9
30	3.80	4968.8	3.80	4312.5	3.9	4500

The results of the experiments presented in Table 6 are indicating a certain level of disequilibrium at the level of partial discharges between the three phases.

In the conditions of a nominal voltage of 6,6 kV between the terminals of the generator, we notice a very high level of the partial discharges of 3843.8 pC in the B phase, reaching a value of 8390.6 pC in phase C.

For this reason, in the case of the hydro-aggregates which present high levels of partial discharges, we can reccomend including a protection systems against overvoltage, in order to avoid some possible break down.

The measurement results of the level of partial discharges for the average values of voltage are given in the Table 7 and in Figure 4, where are presented the average values of partial discharges levels on the three phases for: U_{line} = 0,8 kV; U_{line} = 1,9 kV; U_{line} = 2,8 kV; U_{line} = 3,8 kV; U_{line} = 5,9 kV; U_{line} = 6,6 kV.

The results of the measurements presented in Figure 4 are highligting the possible degradations of the insulation of the tested generator, especially in phase C, in the situation that the level of partial discharges exceeds very much the maximal recommended value.This fact can be attributed to the high level of condense we stated on the cooling pipes which are passing over the rotor.

Urgent thermic insulation measures are to be adopted for the cooling pipes and for the water chambers of the cooler of the axial bearing.

Table 7. Average values for the partial discharges

Crt no. / Average values for U_{line} [kV]	Phase A		Phase B		Phase C	
	U_A [kV]	DP_A [pC]	U_B [kV]	DP_B [pC]	U_C [kV]	DP_C [pC]
0,8	0.43	523.76	0.50	494.69	0.50	587.35
1,9	1.10	1395.32	1.10	1051.73	1.10	1554.70
2,8	1.60	2057.83	1.60	2092.21	1.62	2253.14
3,8	2.20	2792.20	2.20	2570.32	2.20	3029.70
5,9	3.40	4835.95	3.40	4689.07	3.40	5282.83
6,6	3.80	6100.00	3.87	5160.95	3.82	6400.01

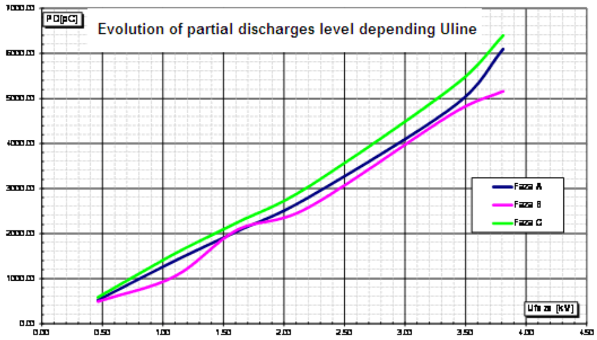

Figure 3. The partial discharges levels on the three phases

Consequently, some measures for the verification and rehabilitation of the insulation of the fixed coil winding are mandatory.

4. CONCLUSION

For a better understanding, we made the measurements on the same hydro generator at great intervals of time. This permitted to us to notice that the level of partial discharge is approximately constant. We also can state that there is a corresponding behaviour of the isolation during the use of the hydro generator under the conditions of high level of partial discharges.

Also, those measurements have highlighted another important component of the high level of partial discharges that produce the apparition of superficial partial discharges [12]. These superficial partial discharges are due to the impurities of the conducting dies and polishes that cover the active surfaces within the magnetic core and the frontal parts of the hydro generator wrapping.

Methodical long time measurements are demonstrating that the level of partial discharges can be influenced positively or negatively, according to the applied technology on occasion of the repairs. So, on occasion of each repair, preventing measures for the exterior wrapping of the coils are mandatory.

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