Concerning the Monitoring of the Electric Contacts Electroerosion of the Circuit Breakers from Medium Voltage Stations of CEZ Craiova

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Abstract - **The monitoring and diagnosis of electrical equipment aims to increase the lifetime of the electrical equipment from the substations for medium and high voltage. This is one of the main concerns of the users of the high voltage equipment aimed at reducing maintenance costs of these. The circuit breaker as complex switching equipment, during the operation, is subjected to the thermal stress due to the action of the load current and short circuit current, in particular. In this context, the electrical erosion of the arcing electrical contacts under the action of the disconnecting current is an important factor in the monitoring and diagnosis of the high voltage circuit breaker. In this article, based on the recorded values of the currents, disconnected by the oil, SF6 or vacuum circuit breakers from the medium/high voltage substations of CEZ Craiova, the admissible number of disconnections and the mass loss of the contacts under the action of cumulative currents reported on maximum short-circuit current are computed. The mentioned above computed values are designed to determine when is the moment of time to replace the contacts with the new ones, by comparison with the values given by the instructions for installation and operation of the equipment provider.**

Keywords - *electroerosion; electric contacts; circuit breakers*

I. Introduction

The monitoring and diagnosis of the technical condition of the switching equipment has the following objectives [1]: the monitoring of the basic functional characteristics of the switching devices (circuit breakers); the prompt detection of the changes of the functional characteristics in order to prevent the circuit breaker failure; the locating of the faults in the case of the capsulated installations; the unnecessary maintenance preventing in order to remove the causes of the defects provoked by the improper interventions; the reducing the lifetime cost; the increasing of the circuit breakers lifetime; the achieving a statistical database relating to the defects and the operating troubles of the circuit breakers. The statistical analysis of the defects emphasizes that over three quarters of the major defects (defects which lead to the disappearance of the main functions of the equipment) are due to of the acting mechanism and the control and auxiliary circuits.

The transformer station 110/20/6kV is located in the south side of Craiova city. The transformer station is the exterior type for 110kV, partially exterior for 20kV and interior type for 20kV and 6kV. The transformer station is equipped with two power transformers, two transformers null+S1 and two single-phase neutral earthing reactors.

The 110kV part of the transformer station is designed with double system of bars and includes: three line cells, two transformation cells, two measure cells and surge arresters, one transversal couple cell. The line cells are: LEA 110kV Electroputere, LEA 110kV Prefabricate, LEA 110kV Center Craiova. The 20kV part of the transformer station is equipped with double system of bars. The 20kV exterior bar is divided by a disconnector STE 35kV, 1250A type.

The primary 20kV circuits from interior station are: a earthling switch, three current transformers type CIRS 20kV 2x100/5/5A, a circuit breaker 20kV, 630A, 510MVA, having an actuation device with accumulated energy in the spring type MRI-2, two selector switch disconnections STI-20kV, 630A, pneumatically actuated.

In the reference [2] the main parameters and characteristics used in the monitoring and diagnosing of the technical conditions of the switchgear equipments in SF6, oil or vacuum are presented. The current path and the contacts have the function to connect, to maintain and to disconnect rated currents, the overload and the short-circuit currents also.

In this case, the monitored parameters are: the contact resistance, the contact temperature, the main contacts position, the load current, the number of switches, the absence of the simultaneity of the contacts acting, the arc time, the contacts speed, the contacts electro erosion. Concerning the auxiliary and control circuits, the monitored parameters are: the voltage, the circuit's continuity, the coil currents, the circuits heating, the insulation resistance, the auxiliary contacts condition. The technical procedures and devices used in the monitoring and diagnosing of the switching function of the circuit breaker are synthesized. Regarding the electro erosion of the main contacts the I2tarc is calculated using the measured values of the time and the currents, or shall be made statistical estimations. To obtain a representative monitoring program, complete information like the following are required: the statistical parameters of the monitorized system, failure type, failure current estimation etc. However, complete information is difficult to obtain. To estimate the electric endurance of circuit breaker thermal erosion or the cumulative electro erosion of contact electrode are used. Additionally, in SF6 circuit breaker the thermal erosion estimation of the nozzle is also important. According to [3], the total admissible electro erosion of the contacts and the nozzle depending on two parameters: the maximum short-circuit current (Isc max) and the admissible number of disconnections (Ne) corresponding to the maximum short-circuit current.

The total admissible electro erosion may be used to determine the admissible number of disconnections at any interrupted current. The thermal erosion or the relative electro erosion corresponding to a current is proportionally with the admissible number of disconnections.

The major parameters that influence the aging of the circuit breaker are [3]: a) the switching conditions (number of switches – connect and disconnect), b) the technical parameters (the peak current, the DC asymmetrical component, the arc time, the contact separation angle, the arc energy, the integral idt and I2t, the polarity), c) the circuit breaker type and the constructive solution (arc extinction system, dimensions and shape of the contacts, the contacts material, the movable contact speed).

II. Data Acquisition And Data Processing

Necessary data to evaluate the contacts electro erosion were acquired from protection system F650 of a medium voltage SF6 circuit breaker, type FG3, produced by Schneider, which is located in Ghercesti transformer station, owned by CEZ. These protection systems are used for all electric equipments from transformation stations, not only on the new circuit breakers but also on the old ones. Such protection systems are able to store the last 20 events of the equipment protected by them. For circuit breakers, a recording contain collected data in a range of time between one to two seconds. On this range of time, the currents, the voltages and the operating state of the circuit breaker (connected/disconnected/RAR) are graphically represented on every moment of time

The recorded data from the protective systems may be visualized using the program SIGRA 4 part DIGSI software provided by SIEMENS. For the FG3 type SF6 circuit breaker, data record such as: the disconnected currents corresponding to the three phases R, S, T and the arc durations, are presented in Table I.

To estimate the technical condition, knowing the contacts electro erosion it is very important to know the number of switches and the currents values as well as the switching arc duration. Concerning the medium voltage circuit breaker, the time during of the switching arc. The mass loss from the contacts through the electro erosion m, can be computed using the empiric formula [4]:

$$m = a \times I^{b} \times ta \quad [\text{mg}] \qquad (1)$$

where:

I is the RMS of the interrupted current, in [kA];

ta – arc time duration, in [ms];

a, b – constants depending on the contacts materials; for copper-tungsten contacts: a=0.274; b=1.81.

By applying the relation (1) on the recorded data from the protection systems, the computed data are presented in Table II.

In the figure 1 the mass loss through the electro erosion depending on the ratio ki between the recorded disconnected current and the rated short circuit current value I rscmax=16kA ratio [4].

TABLE I.
THE SF6 FG3 CIRCUIT BREAKER - RECORDED DATA

No	IR [A]	IS [A]	IT [A]	ta [ms]
1	4200	4560	4360	27.3
2	4320	4400	4480	27.3
3	5000	4480	4320	27.4
4	1316	6.8	1332	22
5	2228	2216	14	32.8
6	896	904	6.8	25.7
7	832	852	25.6	49.2
8	592	7.2	4.8	27.3
9	1076	5.6	9.2	31.3
10	1088	7.2	5.6	30.3
11	728	7.2	5.2	26.3
12	2192	6.8	2200	33.3
13	2160	19.6	2164	27.5
14	2016	9.68	2020	27.3

TABLE II.
THE MASS LOSS FROM THE CONTACTS - THREE PHASES OF SF6 CIRCUIT BREAKER

No	mR [mg]	mS [mg]	mT [mg]
1	0.0018	0.0025	0.0019
2	2.8961	0.0035	0.0022
3	4.2263	0.0035	0.0025
4	4.3211	0.0031	0.0028
5	7.3672	0.0046	0.0070
6	8.2032	0.0036	0.0111
7	22.16	0.0114	0.0583
8	26.6098	0.0207	24.7467
9	34.5666	13.3928	57.1114
10	34.3649	14.3217	62.0673
11	30.7208	56.0662	55.3878
12	122.5395	224.7154	217.8938
13	106.49	191.2792	182.7503
14	137.7365	195.6193	189.8881

Equivalent number of disconnections (Ne) represents the switches number needed to get the same electro erosion of contacts like in case of a single interruption at 0.5 Iscmax [4]. For the short-circuit currents values under 0.35 Ir, equivalent number of disconnections is computed with the following formulas:

$$N_e = 1.83 \cdot \left(0.35 \cdot \frac{I_R}{I}\right)^3 \qquad (2)$$

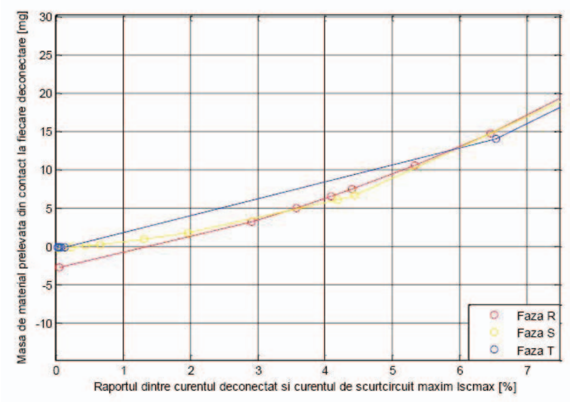

Fig. 1. The mass loss vs ki, SF_6

For the short-circuit currents values higher than 0.35… Iscmax, the equivalent number of disconnections is computed with the following relation:

$$N_e = \left(0.5 \cdot \frac{I_R}{I}\right)^{1.7} \tag{3}$$

The equivalent number of disconnections computed with the formula (2) is graphically represented in Fig. 2.

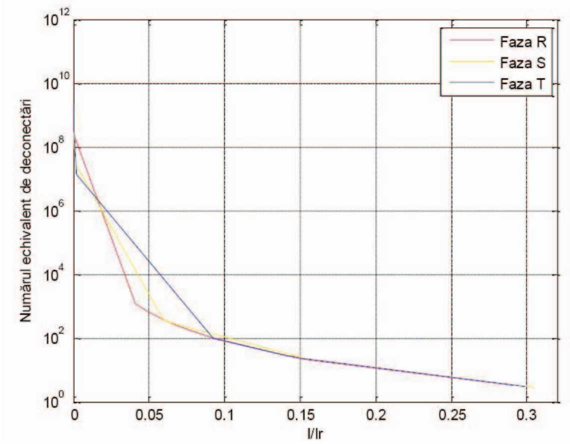

Fig. 2. The equivalent number of disconnections vs ki - SF_6

Recorded data for the vacuum circuit breaker are presented in Table III.

For the vacuum circuit breakers there is no contact maintenance but only the secondary circuits maintenance. If the vacuum compartment of the arc extinction has failure it is replaced as a whole, not only the contacts.

The equivalent number of disconnections for vacuum circuit breakers is shown in Fig. 3.

Concerning the oil circuit breakers, because of a high number of recorded disconnection currents values are assessed with higher or smaller values than 0.5kA, the recorded data are computed and shown in Table IV.

TABLE III.
THE SF6 FG3 CIRCUIT BREAKER - RECORDED DATA

No	IR [A]	IS [A]	IT [A]	ta [ms]
1	900	0.1416	0.1416	34.8
2	56.4	460	440	18.3
3	62.4	464	444	17.3
4	60.4	468	452	22.3
5	41.6	2160	2140	25
6	41.2	2148	2124	21.9
7	468	12.8	13.6	21.8
8	19.2	15.6	532	27.4
9	488	480	17.6	22.9
10	420	396.4	436	27.4
11	24.4	936	20.4	16.4
12	888	968	18	27
13	1180	30.4	1180	21.9
14	21.68	1440	1452	21.9
15	748	19.88	740	16.4
16	20.8	856	424	21.9
17	596	30	596	22.9
18	387.6	46.4	404	27.3
19	404	52.8	424	19.5
20	22.04	19.36	404	18.9
21	16.8	9.8	408	16.4
22	16.16	424	14.16	16.4
23	412	21.96	21.52	18.7
24	14.6	13.44	448	18.7
25	28	4040	3800	26.1

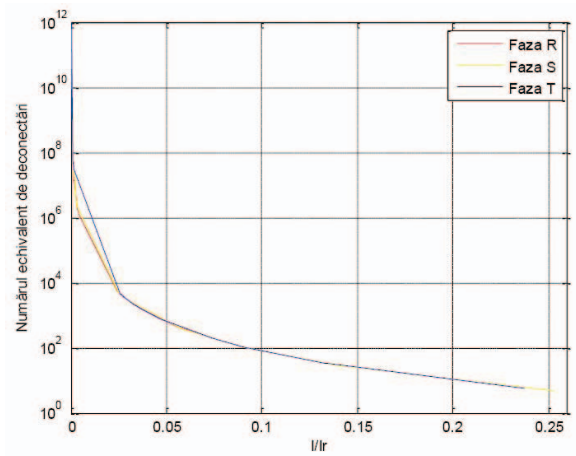

Fig. 3. The equivalent number of disconnections vs ki <1 ratio - vacuum circuit breakers

TABLE IV.
THE MASS LOSS FROM THE CONTACTS R PHASE - OIL CIRCUIT BREAKER

I [kA]	N [number disconnect]	mR [mg/ disconnect]	mtotal [mg]
<0.25	27	0.6017	16.2459
0.5	7	2.1098	14.7686
1	10	7.3980	73.9800
1.5	5	15.4113	77.0565
2	3	25.9405	77.8215
2.5	5	38.8495	194.2475
3	2	54.0386	108.0772
3.5	1	71.4295	71.4295

The equivalent number of disconnections computed with formulas (2) and (3) is represented in Fig. 4. Because of the high number of recorded data, the curves corresponding to the three phase are very close, for which reason the figure below shows only the zone where the curves can be seen individually.

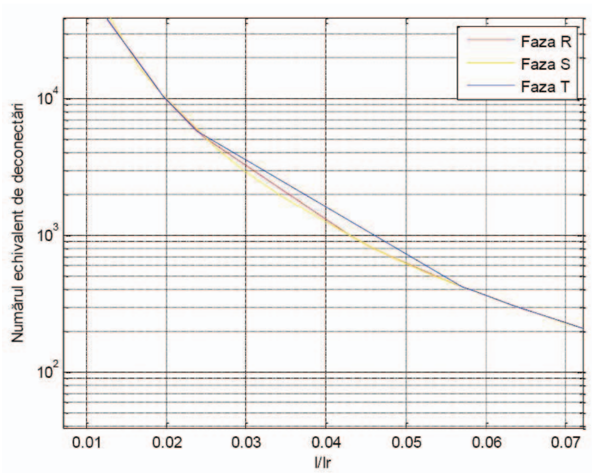

Fig. 4. The equivalent number of disconnections - oil circuit breaker

In the Fig. 5 the contacts mass loss variation vs ki ratio, for oil circuit breaker is presented.

From the graphics analysis, it can be noticed that while the ki ratio, increases the equivalent number of disconnections decreases, respectively the mass loss from the contacts increases . These conclusions are available for all types of circuit breakers for which recorded data has been made. The graphics were obtained in Matlab using the smallest squares method for recorded data processing. The computed values are designed to determine when is the time to replace the contacts with the new ones, by comparison with the values given in the instructions for installation and operation of the equipment provider.

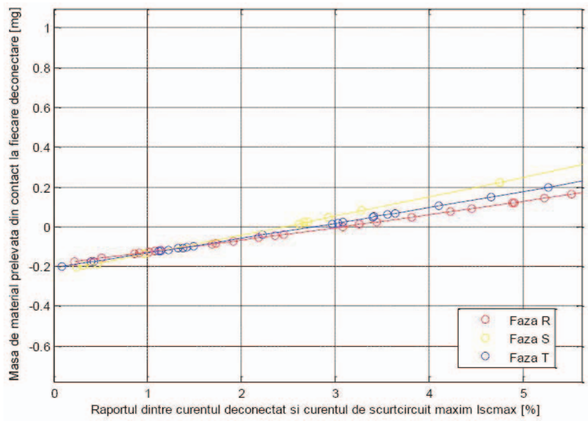

Fig. 5. The contacts mass loss vs ki - oil circuit breaker

III. CONCLUSIONS

In order to increase the lifetime of the circuit breakers from medium/high voltage stations of CEZ Craiova, the monitoring of the contacts electroerosion is an important objective of the electrical equipment users. Consequently, based on the recorded values of the disconnected currents by the circuit breakers in oil, SF6 or vacuum, the admissible number of disconnections and the mass loss of the contacts under the action of the cumulative currents reported on maximum short-circuit current are computed. The computed values help to determine the moment of time for the contacts replacement with the new ones, by comparison with the values prescribed in the instructions for installation and operation of the equipment manufacturers

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