

NEW TECHNIQUES FOR HIGH VOLTAGE EQUIPMENT MAINTENANCE

Alexandru S. Jude¹, Petru Ehegartner¹, Petru Andea¹ and Flaviu M. Frigura-Iliasa¹¹ Power Systems Department, Faculty of Electrical and Power Engineering, POLITEHNICA University of Timisoara, Romania, E-mail: flaviu.frigura@et.upt.ro

Abstract

This paper presents some basic theoretical aspects concerning the predictive maintenance applicable to high voltage switches as well as (on line and off-line) methods of monitoring and diagnosing the status of their main contacts. All principles are applicable to other many high voltage devices like surge-arresters, separators etc. Some fuzzy-logic algorithms are used to determine the key elements of the predictive maintenance. Those algorithms are implemented into powerful software tools for high voltage equipment maintenance. It is a clear example of implementing technology changes in order to obtain a higher efficiency of some existing equipment with low costs.

Key words: high voltage equipment, maintenance

1. INTRODUCTION

High voltage switching devices (and, generally, all high voltage equipment) are very expensive pieces of equipment. Their normal life is at least 30 years of continuous operating service. So, maintenance is crucial for those pieces of equipment, no matter their construction and destination.

The types of high voltage switching devices in service in the European Union (in 2002) are represented (as percentage) in Figure 1. Since then, no major improvements were carried out, so data are still valid. The situation in Romania is more or less similar.

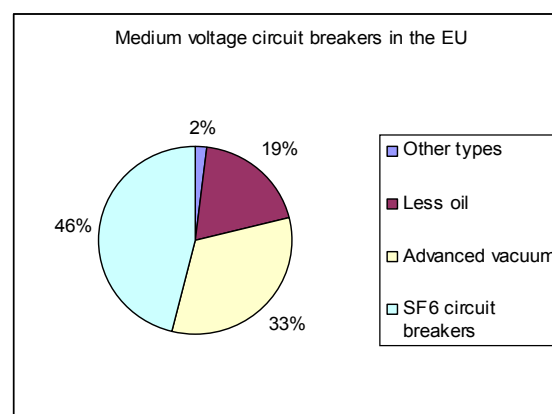


Figure 1. The main types of medium and high voltage European circuit breakers and their percentage in 2002

Monitoring high voltage equipments implies the following three main goals:

- optimizing the equipment maintenance;
- increasing its disposal;

- ameliorating the knowledge concerning assembly functioning.

The present paper refers to the operations, which are necessary to ensure a normal work of the equipments in exploitation, which make up the maintenance of the product.

Maintenance can be:

- curative – detecting and connecting accidental faults;
- preventive – preventing faults throughout periodical interventions;
- predictive – forecasting faults and avoiding their apparition.

All these categories having as main goal amelioration of management and optimization of the use of equipments, goal realized through monitoring and diagnosing techniques.

Monitoring, as an action of measuring and automatic comparing of some peculiar parameters, having referential values of a process or equipment is based on (Pelinici) methods of diagnosis and analysis of appearing faults.

The choice of the number and types of sensors, their location and the establishment of the measuring schemes of the monitored parameters influence decisively the solution of this problem. More over, an adequate system of monitoring – diagnosing must have the following characteristics:

- to be capable of independent functioning;
- to be flexible, adjusting to the user's necessities;
- not to affect the response of the equipment or its reliability;
- to be capable of integration into the command and automation of the monitored installation work.

From the point of view of the resolution of the modeling problem of the monitored system, it can be approached either through optimizing the problem of monitoring – diagnosing following different criteria or through using artificial neuron networks [2]

High voltage isolating switches (SIT) are the largest equipments of the transformers and it is their work that the continuity of electric power supply of the consumers depends on.

The main goals of the SIT predictive maintenance policy refer to:

- collecting, analyzing and interpreting the data of the important working characteristics of the equipment;
- elaborating the informational diagnosis concerning the SIT status to prevent the apparition of its faults;
- reducing the periods of unavailability in order to make work more effective.

The faults in SIT depend on:

- the type of construction,
- the voltage level of the installation,
- the location inside the diagram of primary commutation etc.

In [3] according to some research work done at S.C. Electrica S.A. – Sibiu Branch – there have been established the main sources of faults on SIT:

- an increase in the contact electric resistance corresponding to the close status of these equipment of maneuver – separation;
- breaking of the support isolators respectively acting ones;

- other causes, whose importance is illustrated in Figure 2.

Among the causes of the increase, in the electric resistance there have been mentioned [3], [4]:

- the decrease in the push force in the contact as a result of the fatigue of the springs used, function of the number of commutations made;
- the reduction of the real contact area, as a result of pollution oscillation and fatigue of the microscopic contact pins;
- the improper maintenance operations etc.

Their effect is an increase in the voltage drop on contacts, while functioning, above the admissible values [3].

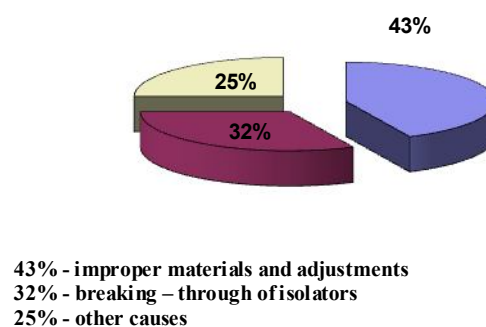


Figure2: The cause of faults in 110 kV exterior isolating switches

Any supplementary post-accident (curative) maintenance operation means supplementary costs and financial and operational losses for the electricity supplier or transporter. Predictive maintenance is, of course, more efficient.

2. TECHNICAL DIAGNOSIS OF ISOLATING SWITCH CONTACTS

Monitoring contact status in SIT is possible on line through the method of using optic fibers installed at the construction of the isolating switch and their connection to an interface for introducing, treating and interpreting data. It consists in analyzing the thermal images appeared and informing the decision staff on the evolution of the contact resistance R_c meant to prevent faults. Knowing the stationary supra-temperature of the contact, τ_c ($\tau_c = \theta_c - \theta_{amb}$) and the intensity of the permanent regime current, I , function of the nature of the superficial material of the contact pieces (copper or silver), there can be determined a voltage drop, U_c ,

$$U_c = R_c \cdot I = \xi \cdot \tau_c^{1/2} \quad (1)$$

respectively, contact resistance, R_c

$$R_c = \xi \cdot I^{-1} \cdot \tau_c^{1/2} \quad (2)$$

which is steadily compared with the admissible limits.

In table 1 [5] for couples of contact pieces of the same material (silver – silver or cooper – cooper) in a new status there have been raised the temperatures and critical voltage drops in contact (when plasticization of materials is possible) as well as the values of ξ factor:

Table 1 - Physical properties for contact materials

Material of contacts in the air in a new status	Critical temperature θ_{cr} [grd]	Critical voltage drops in contact U_{cr} [mV]	ξ [V·grd ^{-1/2}]
Silver–silver	180	93.6	$7.44 \cdot 10^{-3}$
Cooper-cooper	190	94	$7.40 \cdot 10^{-3}$

From relations (1) and, respectively, (2) there has been found out that the modification of the conduction status and increase of the contact surfaces, at work, through impurification with isolating pellicles, respectively, decrease in the pushing contact force, result in an increase of the contact temperature. Monitoring, either directly contact supra-temperature, or voltage drop in it, there can be appreciated with maximum economic efficiency, through predictive maintenance, the proper moment of maintaining works of the contact sub – assemblies of SIT.

Another way of diagnosing the status of the principal contacts of SIT which does not involve the thermal vision equipments, but which can be occasionally or periodically (off line) monitored is based on measuring the electric contact resistance of the equipment, according to the schema shown in Figure 3, [1].

According to this method, applicable to disconnecting the installation, where the checked isolating switch is found, a current of 100 – 1000 A is injected through it, both voltage drop U_2 between the equipment buses and current I through closed contacts of the maneuver / isolating switch apparatus being measured.

The CDR (Contact Disturbance Recorder) acquisition interface records, calculates, compares, transmits to the managing point and stores information obtained through the measurements done according to the schema in Figure 3, recording at the same time the number of commutations N made by the isolating switch between two successive acts of monitoring.

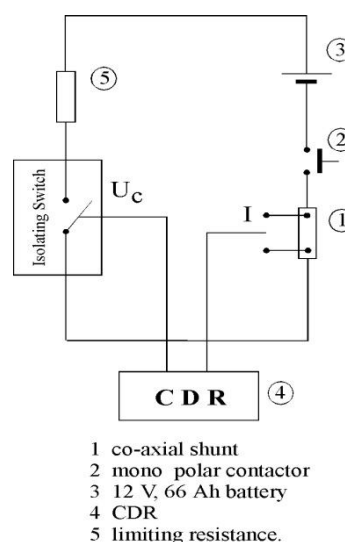


Figure 3. Block diagram of measuring and recording contact resistance

The periodical determination of the resistance contact, which best characterizes the technical status of the commutation sub-assembly of the isolating switch and comparison of this parameter with pre – determined or referential values allows the quantitative appreciation of the current technical status of the equipment.

The best moment of the maintaining is established through fixing a percentage limit of value U_{cr} (Tab.1) which is compared with the current value of the contact voltage drop. U_{CN} , as a result of the measurement of the contact resistance R_{CN} (after N maneuvers with the isolating switch) and of current I recorded by CDR.

Algorithm of establishing the predictive maintenance period of the commutation sub-assembly of SIT could be implemented using FUZZY logic techniques.

The data obtained from the periodical measurements of the contact resistance after N maneuvers with isolating switch R_{NC} are used to calculate nominated error $\delta_j(N)$ versus the value of the same parameter established at the end of the latest revision, R_{CO} .

$$\delta_j(N) = 1 - \frac{R_{CO}}{R_{CN}} \quad (3)$$

as well as the variation of this value after N commutation cycles (between two consecutive measurements) $\varepsilon_j(N)$

$$\varepsilon_j(N) = \delta_j(N) - \delta_j(N-1) \quad (4)$$

Placing $\delta_j(N)$ and $\varepsilon_j(N)$ in fuzzy multitudes of Figure 3 and linking them to fuzzy values SP; MP; LP, we can pass to the calculation of the final functions of output to a fuzzy multitude:

$$\mu_j(SP) = \max_{x_i} [\min(\mu(x_i))] \quad (5)$$

$$\mu_j(MP) = \max_{x_i} [\min(\mu(x_i))] \quad (6)$$

$$\mu_j(LP) = \max_{x_i} [\min(\mu(x_i))] \quad (7)$$

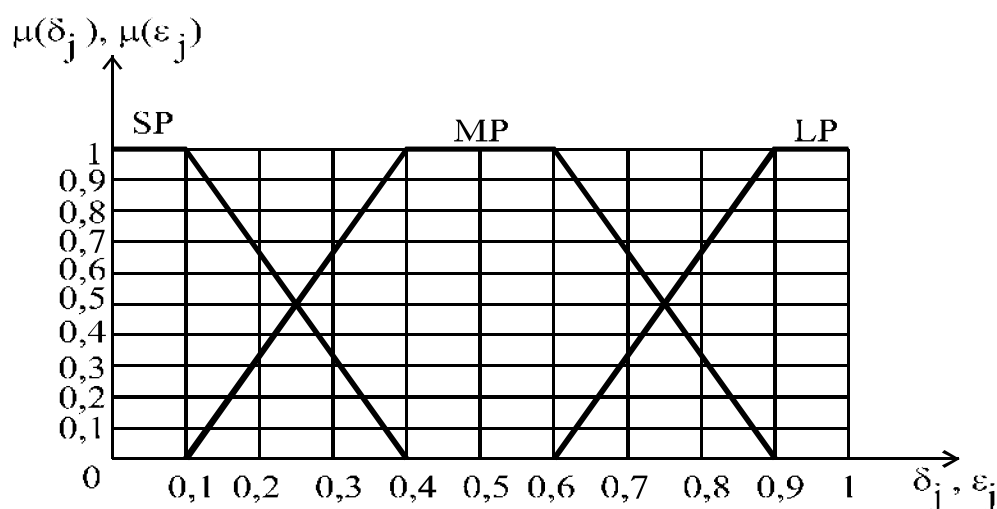


Figure 4: Fuzzy multitudes and belonging functions

The calculation of functions $\mu_f(\text{SP})$, $\mu_f(\text{MP})$ and $\mu_f(\text{LP})$ is realized on the basis of Table 2 and Table 3.

The following step consists of determining belonging function μ output from the algorithm presented in figure 4 in relations:

$$\mu_{\text{output}} = \text{MAX}[\mu_f(\text{SP}), \mu_f(\text{MP}), \mu_f(\text{LP})] \quad (8)$$

Table 2 - Fuzzy rules

$\delta_j \backslash \varepsilon$	SP	MP	LP
SP	SP	MP	MP
MP	MP	MP	LP
LP	LP	LP	LP

Through the conversion of the linguistic value of μ output into a clearly numerical value μ % (representing fatigue of SIT electric contacts in percentage) and comparing the latter with admissible fatigue of SIT electric contacts, μ_{adm} , there has been established the moment of the next diagnosis test and revision.

Table 3 - Decision table of fuzzy multitudes and belonging functions

x_i	Input	output		
	$(\delta_j, \varepsilon_j)$	$\mu(x_i, \text{SP})$	$\mu(x_i, \text{MP})$	$\mu(x_i, \text{LP})$
x_1	(SP,SP)	1	0.5	0
x_2	(SP,MP)	0.5	1	0.5
x_3	(SP,LP)	0.5	1	0.5
x_4	(MP,SP)	0.5	1	0.5
x_5	(MP,MP)	0.5	1	0.5
x_6	(MP,LP)	0	0.5	1
x_7	(LP,SP)	0	0.5	1
x_8	(LP,MP)	0	0.5	1
x_9	(LP,LP)	0	0.5	1

A simple algorithm for calculating the predictive maintenance period of a SIT, based on this fuzzy-logic method is shown below:

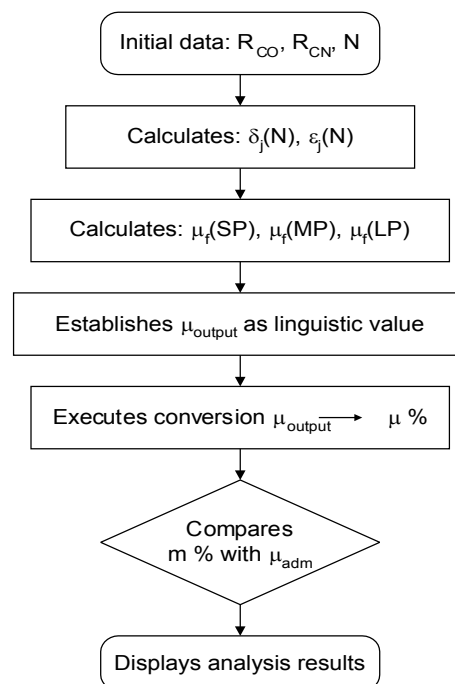


Figure 5. Block diagram of the algorithm used for establishing the period of predictive maintenance of SIT electric contacts

3. CONCLUSIONS

The methods presented in this paper allow high confidence diagnosis of the technical status of the commutation sub-assembly of high voltage isolating switches providing detailed information on: the electric contact resistance, the fatigue degree of main contacts and the best moment for predictive maintaining works with this equipment.

The monitoring off line system of contact resistance of the isolating switches found in high voltage stations presented in the paper allows the prevention exploiting of their breaking increasing the efficiency of the activity through the periods of unavailability, respectively increasing the reliability if these equipments.

Extending the application of the diagnosing methods, recommended for a large number of high voltage installations we could obtain data banks concerning the parameter we are interested in – contact resistance – this allowing a report on the tested equipments at this data banks, thus ameliorating the knowledge about their work in order to optimally forecast the period of safe usage.

REFERENCES

1. Barkan, P., Deni, J. A., McCabe, A. K., Reckleff, J. G., Scherer, H. N., Woodward, R. C., (1988), *Méthodologie pour la surveillance de l'état des disjoncteurs des haute tension*, Rapport 13.04, CIGRE,.
2. Bouchon – Meunier, B., Nguyen H., (1996), „Les incertitudes dans systèmes intelligents” Presses Universitaires de France, Paris

3. Bourkes, P.D., Kayafs, F.A., Machias, A.V. (1988), „Specified current in emergency load switches”, *IEEE Proced.*, vol.135, Nr.4, p.330-333.
4. Moldovan, L., Vasilievici, A., Suciu, I., Andea, P., Vătău, D., (1996), „Cercetări asistate de calculator privind ameliorarea unor contacte electrice de la echipamentele electrice”, research contract. no.75/1994, UP Timișoara, FRE Sibiu, Timișoara.
5. Postolache, O., Poiată, T., Zaharia, Iustina (1998), „Utilizarea rețelelor neuronale artificiale în monitorizarea sistemelor de tip distribuit” vol. *SIAE, Galați*, , p.41-45.
6. Vătău, D., Șurianu, F., Moldovan, L., (1999), „Switch contacts state prediction of high voltages devices” *Proceeding of 19th International Conference on Electric Contact Phenomena*, Nuremberg
7. Vătău, D., (1998), „A supra evaluării Fuzzy a duratelor de viață a întreruptoarelor de înaltă tensiune”, vol.*SIAE, Galați*, 1998, p.416 – 420.