OPTIMIZATION OF THE CIRCUIT BREAKER MAINTENANCE USING THE DISTRIBUTION OF SWITCHING NUMBER

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Abstract – The primary switching components of the power systems have a very important position, especially the circuit breakers which have the role to set up and to break the nominal current and the short circuit currents, deliberately and automatically, depending on the working conditions. The present paper proposed a method to determine the permitted average switching number between two revisions, based on the influence of the interrupted current value.

Keywords*: short-circuit current, admitted switching number, circuit brea ers.*

1. INTRODUCTION

The safety of electrical power system depends by their equipment technical state, safety influenced by the way of working in the commutation process. The safety function of the circuit breakers represents their capacity of working without fault, during a given time period and conditions.
The circuit breakers from the electric power systems are submitted during the working to electrical, mechanical and climatic stresses. These stresses have effects to a wear speed process of the circuit breakers, having as effect the decrease of the disconnecting number for a certain disconnected current, as much as the stresses are most intense. To determine the average number of disconnecting between two revisions of the circuit breakers, we need to collect data of the real exploitation. The data obtained have to include information on estimated numbers of operations per year for both fault and nonfault situations.
The manufacturer company offers information about the limited number of disconnecting, between two revisions, our purpose is to have a cumulative number of disconnecting, for fault and nonfault situations.
In most of the technical domains we tend to use the mathematical modeling and simulations instead of experimental data collecting from the real exploitations, because the least one is more expensive and takes time.
From this reason the evaluation of the average number of disconnecting between two revisions of the circuit breakers supposes a new approach, that of the modeling of the circuit breakers behavior to the various disconnected currents values.

2. ASPECTS REGARDING THE CIRCUIT BREAKERS WEAR

The most important factors to assess the technical state of the medium and high voltage circuit breakers are interruption medium and the electrical contacts wearing. Wearing it is depending on the realized commutation number, on the current values on which the disconnecting were realized and also on the duration of the switching time interval.
In the specific literature there are analytical relations regarding the estimation of technical state of circuit breaker, looking to following factors: the masse wearing of the breakers contacts, the contact resistance, the wearing of the electro-insulation system, the wearing of the interrupting medium, the switching time interval etc., all factors being a cumulative process, depending on the switching number and on the switched current values [1].
This way to identify the wearing state of the circuit breakers is as correct and accurate as difficult to be applied in practice, considering its large number of involved random variables.
The safety operation of the circuit breakers supposes to maintain the wear under a certain limit, specified to every type of breakers. Reaching this limit means running out of the breakers and start the maintenance program.
The wear limit, after that the circuit breaker pass in the maintenance program, may be adopted after an admissible switching number, depending on the disconnecting current values, this number being based on the experience from the exploitation.
To know the state of the circuit breakers, there are different methods to pursue and to diagnose, methods assuring important information regarding the wearing process. The main methods to diagnose of the circuit breakers state are based on the contacts resistance evaluation, on the contact weakened or the acoustic diagnose.
In many cases, the circuit breakers are not included in a real time monitoring program, so it is very important, based on the information we already based on the previous experience, to determine the possible evolution of the admitted switching number between two consecutive revisions. The information regarding the technical state of the circuit breaker must be

analyzed in order to establish the evolution of the characteristics of the wearing process.

An important character of the interrupting medium is its electric endurance. The electric endurance is appreciated according to a large switching number for a certain value of the nominal current. Relevant information, regarding the evolution of the wearing process is given by the manufacturer company, with the diagram of maintenance or of the admitted number of disconnections between two consecutive revisions, information that reflects the dependence between the disconnected current and the admitted maximum switching number [2].

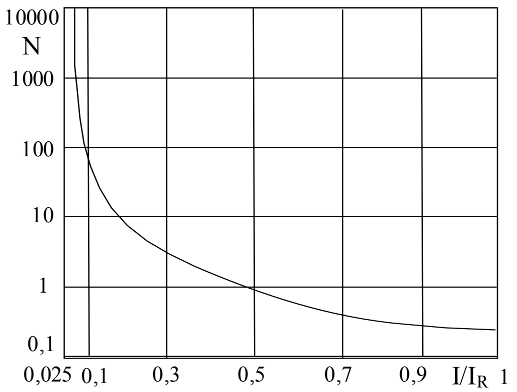

Figure1: The equivalent number of disconnecting depending on the disconnected current

In the diagram we noted:

N - the switching number till the maintenance;

I – the effective value of the disconnected current;

I_R – the break current value.

Based on this diagram we can establish the switching number for a certain current value. This information can be used to establish the technical state of the circuit breakers also their wearing speed, having a strict evidence of the disconnected current. At the achievement of the number of the admissive disconnecting, established for each circuit breaker, we will pass the breaker in the maintenance program.

3. THE AVERAGE SWITCHING NUMBER

The switching number can not be settled as a constant value, neglecting positions of the circuit breaker in the electrical power network. The reliability indices of the circuit breakers depend on their location and on their functions into the electric power network structure.

Starting from this information we can transform the random variable of the short circuit current into a variable of the switching number accepted between two successive revisions. Thus, the current values from a certain interval lead to a switching number at a given moment, superior limited by the accepted limits, leading, thus, for a certain wearing degree [3], to the probability of the currents appearance into a certain interval:

$$P = \int_{I_1}^{I_2} f_i(i)di \quad (1)$$

where, the values I_1 and I_2 are the limits of the analyzed interval.

Next, we will present the way to determine the distribution of the accepted switching number between two revisions, starting from the circuit breaker maintenance diagram and the short-circuit currents distribution.

To determine the probability distribution function of the switching number of the circuit breakers, we must transform the short circuit current variable into a new variable of accepted switching number using the relationship between the two variables described by the maintenance diagram:

$$f\ (\ ) = \Im\left[f_I(I)\right] \quad (2)$$

where, $f\ (\ )$ and $f_I(I)$ represent the probability distribution function of the variables number of the accepted switching number, respectively of the short circuit current. The function $\Im$ represents the dependence between the two variables described by the maintenance diagram. Short representation of the transformation is presented in figure 2.

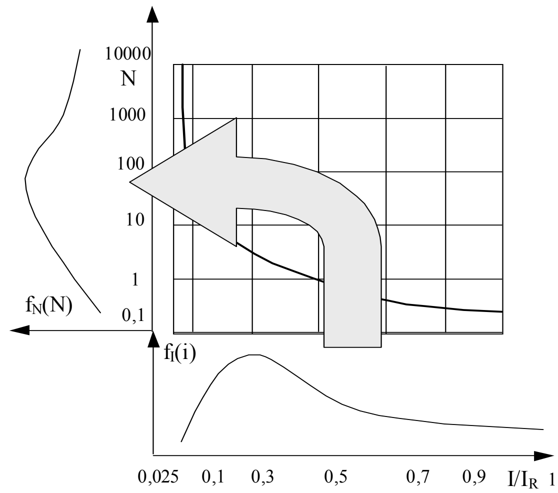

Figure 2: Transformation of the short circuit current

To determine the average switching number we will start from the switching number distribution:

$$M(\ ) = \int_0^{\infty} \cdot f\ (\ )\, d \quad (3)$$

Setting thus the medium value of the accepted switching number between two successive revisions, and the condition that it is fulfilled, we must impose the analysis of the probability distribution function of the switching number of the circuit breaker, taking into account its wearing speed.

4. STUDY CASE

Based on the information concerning the dependence between the accepted switching number and the disconnected short circuit current, we will determine the probability distribution function of the switching number for a circuit breaker located in a radial line circuit. For that, we will consider the fault as being feed from a source, having the short circuit power S_k, strong enough to consider the fault as being feed from a source with an infinite power with a pure sinusoidal voltage with a constant amplitude and its own impedance Z_k. We can consider the source as being an infinite power, if its own impedance is maximum 10% from the total impedance of the circuit till the fault location.

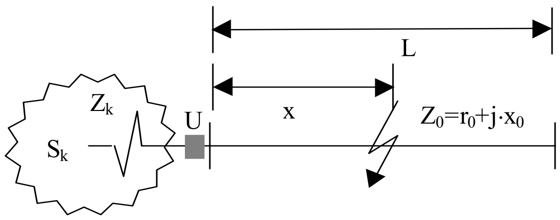

Figure 3: Radial line power subsystem

where:
S_k [MVA] – the short circuit power at the station bus level;
Z_k [Ω] – the short circuit impedance at the station bus;
Us [kV] – the source phase voltage;
Z_0 [Ω/km] – the specific line impedance;
L [km] – the length of the line.

Taking into account the case of one line, as we presented in the figure 3, in the case of a fault to the distance x from the source, the value of the short-circuit current is [4]:

$$I \;=\; \frac{S}{+\ _0 \cdot x} \tag{4}$$

Considering that all points on the line have the same fault probability, this means that the probability distribution function of the fault location on the line is uniformly distributed, and the distribution function of the short circuit current is:

$$f_I(i) = \begin{cases} \dfrac{S}{L\ _0 i^2} & for \quad \dfrac{S}{L\ _0 + \ S} \le i \le \dfrac{S}{S} \\ 0 & else \end{cases} \tag{5}$$

The relation $f_I(i)\ \ 0$, for each I outside the presented limits is included here as being a mathematical completion. The graphical representation of this function is given in figure 4.

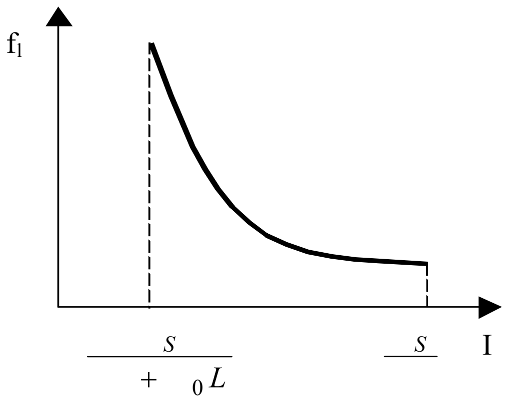

Figure 4: The probability distribution function of the short circuit current.

For the circuit breakers with few oil, of type IO and IUP, the equivalent number of disconnections is calculated with the relation [1]:

$$= c\left(\frac{I_R}{I}\right)^d \tag{6}$$

where, c and d are constants specific to each type of circuit breakers. Thus, for IO circuit breaker c=6,77 and d=1,817, and for IUP circuit breaker c=4.224 and d=1.355.
The admitted switching number depends on the short circuit on the line, so, starting from the short circuit distribution we can establish the distribution of the switching number:

$$f\ (\ ) = \frac{S}{d^d L\ _0 I_R} \cdot \left(\frac{}{c}\right)^{\frac{(d-2)^2+d}{2d}} \tag{7}$$

for the adequate interval to the short circuit current values from the relation (5). The average value of the switching number is determined using the relation (3), for which the association will be done in function of the short circuit current values from the expression (5), the average switching number being:

$$M(\ ) = \frac{2d^{1-d}}{L\ _0[(d-2)^2+3d]} \cdot \left(\frac{I_R}{S}\right)^{\frac{(d-2)^2+d}{2}} \cdot \\ \cdot \left[\left(L\ _0 + \ _K\right)^{\frac{(d-2)^2+3d}{2}} - \ _K^{\frac{(d-2)^2+3d}{2}}\right] \tag{8}$$

5. CONCLUSIONS

The method to determine the probability distribution and the average switching number of the circuit breakers can be applied, in order to evaluate the technical state of the circuit breakers

This involves the necessity to monitor the switching process, focusing on the disconnecting current values, with the main benefits like the extension of circuit breaker life, increasing time intervals between maintenance revisions. For that, the circuit breaker is necessary to have a surveillance system (in real time), or the line endowed with defect locators and its indications could be used to monitor the circuit breakers.

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