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THE PROBLEM OF THE RELIABILITY OF THE ELECTRIC POWER EQUIPMENT

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Abstract. **The Power Electric Distribution Systems (PEDS) possess a great dynamics of development. Thanks to this phenomenon in the power electric distribution systems (PEDS) the probability of appearance of asymmetrical regimes increase monotonously. As a result of this reliability of the functioning of the power electric equipment installed in the electric knots changes. The asymmetrical regimes in the power electric distribution systems (PEDS) accompanied by the short circuit current are a function of a row determined is a vague factor of probabilistic nature. Coming from it follows that the investigation of the influence of the asymmetrical regim accompanied by the current of the short circuit on the reliability of the Power Electric Distribution Systems (PEDS) is one of the most important problems of the development the Power Electric Distribution Systems. The short circuit currents influence the structural and functional reliability of distribution networks and at the reliability of electrical equipment installation.**

Keywords- *Power Electric Distribution Systems (PEDS),asymmetrical regimen, accompanied, current of the short circuit.*

1. INTRODUCTION

In process, of the development Power Electric Distribution Systems (PEDS) the row of the problems connected with the asymmetrical regim are accompanied by the current of the short circuit. Considering that the very often track record of the development of such systems is more intensive the amount of asymmetrical regimes, which carry the probabilistic nature, increases, the problem of the determination of their influence on the functional reliability of the electrical equipment and the structure reliability corresponding to the electric circuit appears.

2. THE PROBLEM FORMULATION

One of the main aspects in the complex problem of Power Electric Distribution Systems (PEDS) development control is an investigation of short circuit current level effect on installed equipment reliability in Power Electric Distribution Systems units. These investigations are systematized and arise since the reliability of installed electric equipment and the power system as a whole varies with a build-up of short-circuit current levels [1-4].

Out of all electric equipment installed, the circuit breakers are mostly affected by the short circuit current. Therefore, the reliability of not only the switch - gear is dependent on their conditions but their major circuit. The main operations for the circuit breakers involve the turning off from high short circuit currents reaching the mark of dozens of kiloamper at present. A short circuit breaking process should be accelerated (several half-cycles) in order to maintain stability of PEDS operation. Different commutations in the (PEDS) networks generate a transient oscillation process that are a part of the interrupting current that effect results in the action of transient recovery voltage (TRV). When the transient recovery voltage (TRV) is skyrocketing and reaches high values, the circuit breaker misfunctions and that is considered to be its failure. Dependencies of equipment and network reliability of electric power systems anticipated of short circuit current levels in the electric power systems units are given in fig. 1.

For high voltage circuit-breakers there are two types of failures differing one from the other as follows:

a) if immediately after the current transition through zero values the build-up rate of transient recovery voltage is greater than the critical voltage across the breaker contacts $Ut(t) > Ukr(t)$, then a disintegrating arc channel is reformed again due to the heating that occurs when considerable current flows courses a failure of circuit breaker. This type of failures is characterized by energy balance in the arc and is called terminal breakdown of circuit-breakers. Mathematically it can be expressed as follows:

$$Ut(t) > Ukr(t) \qquad (1)$$

b) the second type of failures is an electrical breakdown of breaker insulation gap which can arise as a result of a high value of transient recovery voltage. These two types of failures define the range of circuit-breaker application and normal operation.

$$Ut(t) > Upv(t) \qquad (2)$$

where: $Upv(t)$ - permissible voltage across the contacts of circuit- breaker (kV).

Installed circuit-breakers should not only be used in turning off short circuit currents and operating currents but also in the trouble of free withstanding of mechanical efforts resulted from commutation of these currents as well as from short-circuit steady-leakage current when the circuit-breaker is in "**on**" position [5-7].

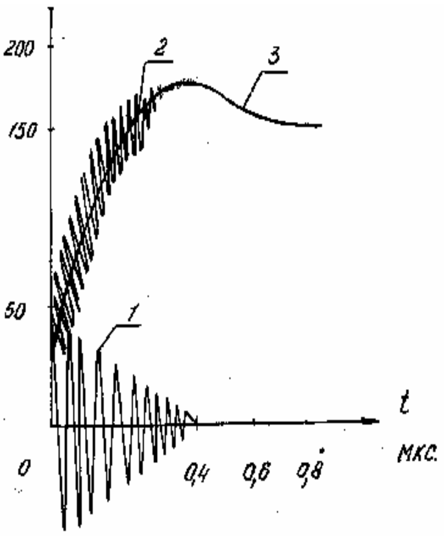

Figure1. The full transition voltage in 10 kV system at short circuit at the distance

L =1,5 km from the transformer station bars.
1.The component from the line side;
2.The full transition voltage;
3.The component from the supply source side.

The growth of short-circuit currents in EPS units has revealed a limited applicability of air circuit breakers under conditions of non-distant short circuits.

The rate of transient recovery voltage build-up and arc formation process is proportional to the interrupted current, while breaking capacity varies in inverse proportion to the square of short circuit current.

The breaker capacity to interrupt any type of short circuit is characterized by time variation rate of the current across the contacts (**di/dt**). If this rate is not greater than (**di/dt) < 10 A/msec**, then the period of recovery voltage and arc sparking is minimum and the circuit breaker is capable to interrupt any type of short circuit. If **(di/dt) > 40 A/msec**, then the interrupting of such a type of short circuit turns out to be questionable for any type of circuit breaker. Thus, to enhance the breaking capacity it is required to increase considerably the number of gaps or gas pressure in them. Shah a redesign of installed circuit-breakers requires great capital costs. That is why the problem of how to optimize the circuit-breaker design remains up-dated. To solve this problem one should have a deep insight into the subject and the knowledge of physical process when simulating arc sparking and extinguishing in a gas flow.

Out of the all possible emergency situations the most interesting ones from the point of investigation are those that create the hardest conditions for breaker functioning which are characterized by peak parameters: voltage recovery rate **(dU/dt),** current variation rate (**di/dt**),peak value of TRV (**Ut**) and short circuit current level **(Ic)**.

Failure analysis indicates that electrical breakdown takes place when short circuit occurs across the breaker terminals. In most cases terminal breakdown occurs when short circuit takes place at non-distant point create the heaviest and hardest conditions for circuit breaker operation. The transient recovery voltage value depends on the voltage across the arc and on residual current of short circuit. Therefore when installing the circuit breakers in the knots of the power electric system it is required to take account of expected levels of short circuit currents in these knots, as well as the breaking capacity, their terminal and dynamic stability. In this case a three phase short circuit is regarded as a design value. The impeded turn-off value is taken into account through the factor that corrects for impeded turn-off of short-circuit and TVR value.

$$K_t = Ic / Iap \qquad (3)$$

where :Ic- expected current value of three-phase short circuit at the given point of network;

Iap.- allowable peak value of short circuit current for the given device.

Reliability of circuit breakers installed in the units of power system depends on the number of operations and the expected value of interrupted short circuit current. When estimating the effect of short circuit current levels on circuit breaker reliability it is necessary to take account of not only the value of the interrupted short circuit current but its thermal action as well.

One of the parameters that characterize reliability of circuit breakers is the rate of their operation. For its estimation a proper mathematical model is elaborated which permits to take account of circuit breaker functioning rate and number of possible operations up to the removal from service for preventive repair depending on the value of interrupt short circuit current. The rate of circuit breaker failures depend on the value of interrupted short circuit current [1-4].

$$\lambda(t) = f\,(I^{(1)} c,\ I^{(3)} c\,) \qquad (4)$$

Failure probability is defined from the expression

$$P(t)=e^{-\lambda\tau} \qquad (5)$$

When failure probability values are known at initial period of service and removal from service to preventive repair **(λ_1, λ_2)** for complete restoration of breaking capacity, one can determine a fail safety margin for a circuit breaker:

$$\Delta P(t) = e^{-\Delta\lambda\tau} \qquad (6)$$

where: $\Delta P(t)$ - permissible value of failure probability drop before removal from service to due preventive repair;
$\Delta\lambda (t) = (\lambda_1(t) - \lambda_2(t))$ - difference of operation rate at the initial period of circuit breaker service **(λ_1)** and at the end of its removal for capital repair **(λ_2).** The number of circuit breaker operation depending on the rate and probability of their failure is determined from the following expression:

$$n = n_o * e^{-\lambda\tau} \qquad (7)$$

where: $\mathbf{n_o}$-number of circuit breaker opera-tions when the interrupted short circuit current is equal to 10% from rate value in accordance with STANDART- 687 - 89.

A check-up of circuit breakers for thermal stability should be carried out for each of them with regard of real service conditions. In this case:

$$B_k(t) < I^2 (t)\, dt \qquad (7)$$

where: t - thermal stability time;
I^2 (t) - constant of a periodic component damping of short-circuit current. The relationship between the number of proper functioning, operation reliability and the value of interrupted current of three phase short circuit current is given in fig.2.

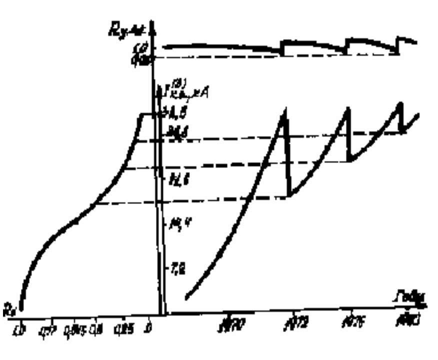

Figure 2. Equipment and network reliability of electric power systems anticipated levels in the electric power systems units.

Another factor characterizing the serviceability of the circuit breaker for installation in the given knot of network is its breaking capacity. In conformity with GOST 687-89 the breaking capacity is estimated by rated periodic current of interruption **Ion** as well as by rated proportion of a periodic current.

$$Bn = Iap(t) / Ip(t)\ \sqrt{2}\ \pi \qquad (9)$$

where: Iap(t); Ip(t) - values of a periodic and periodic currents at breaking moment. In this case a reliable operation of circuit breakers is a function of short-circuit current, TRV build-up rate, fail-safety probability and number of their proper functioning [5-7].

$$R(t) = f\,(Is^{(3)}, P, n, U_{TR}) \qquad (10)$$

$$R(t) = Is^{(3)}(t)(\omega\tau+\gamma\tau\lambda)dt / n \sqrt{2}\ \pi \qquad (11)$$

The relationship between the number of proper functioning, operation reliability and the value of interrupted current of three phase short circuit current is given in table 1

Table 1

$\frac{I^3_{s.c.}}{I^3_{S.C.}}$	0.08	0.16	0.25	0.50	0.75	1.00
N	32	26	20	15	12	10
R	.0.996	0..998	0.999	0-.999	0. 993	0- 991

Probability of fail-safe operation is considered to be the parameter that characterizes the reliability of circuit breakers and depending on their service period duration it can be determined from the expression:

$$P(t) = e^{\ -\lambda(x)dx} \qquad (12)$$

The density of breaker failure probability λ(t) is determined with regard to values of failure rate as follows Q(t):

$$Q(t) = \lambda(t) * P(t) \qquad (13)$$

Relationship between fail-safe operation time and the duration of service represents a complicated function of several variables that with probability (P = 0.97) can be expressed by Fibula distribution :

$$f(t) = \alpha(t) * e^{(\alpha-1)\, t/T} / T \quad (t > 0) \qquad (14)$$

where: T - fail-safe operation time;
α(t)>0 - distribution form parameter.
The account of the rise in failure the rate of breakers operating under improper conditions or being on the boundary of breaking capacity as the well as account of rise in the failure rate of circuit breakers equipped with automatic recluses is defined as follows when turning of short circuit :

$$a_B = (1 + a_B^0 * K_A) * K_T * a_B \qquad (15)$$

where: a_B - index for variability of automatic recluses (AR) ($\mathbf{a_B}$ = 1) when AR operates; and ($\mathbf{a_B}$ = 0) when AR is not available); $\mathbf{K_A}$ - factor taking account of relative failure rate of malfunctioned automatic recessing elements; $\mathbf{K_T}$ - factor that corrects the impeded turn-off of the short circuit and rises the value of interrupted short-circuit current; $\mathbf{a_B^0}$ - damage rate in the given type of circuit breaker in the process of its functioning.

Failure analyses indicates that about 25% of malfunctions take place as a result of damage of their external insulation, that is why it is required to introduce the adjustment coefficient $\mathbf{K_A = 0.25}$ with corrects the circuit breaker reliability drop because of external damages. With regard to the effect of short-circuit current levels and external damages that are independent of short circuit current levels, the reliability of circuit breakers can be determined as follow:

$$R(t) = K[(\omega\tau+\gamma\tau\lambda\ dt)/(I_{ko}/I_{kn})]/n\sqrt{2}\ \pi \qquad (16)$$

It follows from the expression (16) that the reliability of circuit breaker operation directly depends on the value of short circuit current in the units of power system although this dependence is not of explicit nature.

3. CONCLUSIONS

1. Estimation analysis of short-circuit current level effect on circuit-breaker reliability shows that their trouble-free operation depends on the value of interrupted short circuit current which in its turn is not liniar and dependent on transient recovery voltage build-up velocity as on the number of proper operations.
2. Expected levels of short-circuit current should satisfy technical requirements of installed circuit breakers. If not, these circuit breakers arc not capable to interrupt short circuit this causing breakdown of the power system.
3. With a rise of short circuit current levels in the units of power system it is necessary to up-date the installed circuit breakers or to work out specific designs and measures aimed to restrict the rise of short-circuit current levels so that their value measures be up to the breaking capacity.
4. To simulate a quantitative reliability of circuit breaker operations depending on the value of interrupted short-circuit current and transient recovery voltage build-up velocity a mathematical model has been worked out.

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