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Research Article

EVALUATION CRITERIA OF CONTACT GROUP TECHNICAL STATE CONCERNING ELECTRICAL APPLIANCES

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Abstract:

The result of the experimental data and thermographic surveys revealed the criterion for the technical condition evaluation of electrical switching devices, which act as the resistance of the contact group of switching. This criterion allows to specify the value of a network equivalent resistance and, therefore, to reduce the error of power loss determination.

Keywords: Electric, power supply, model, converters, electric grid, voltage, devices

1. Introduction

It is known generally that during the operation the contact connections of low voltage devices are subjected to mechanical and chemical influences, which leads to the increase of their transition resistance, and as a result to the overheating and subsequently to destruction under the influence of the load current. The rate of defect development depends on a pin joint design, its location and the intensity of external influences. The time interval between the occurrence of a defect and an alarm output of a contact connection failure ranges from a few months to several years [1]. Until recently the main control methods of a contact connection state was the transition resistance measurement using the bridges and a visual observation. The emergence of light small-sized infrared light (IL) cameras on uncooled microbolometric matrices with the microprocessor processing of infrared images allowed to detect the defects of contact connections at an early stage and monitor the condition of almost all electrical equipment. And this measure reduced the accident rate significantly.

2. Evaluation of Technical State Study Results Concerning Low Voltage Switchgear

The evaluation of the energy facility states, in particular, according to their IR radiation is fairly universal and objective in nature due to the thermoelectric similarity of physical processes and a close relationship of functioning and technical condition quality of switching devices with the associated heat releases (losses).

The thermal state of electrical equipment is evaluated by the normalized heating temperatures (temperature excess above an effective ambient temperature), excessive temperature and temperature change dynamics in time, as well as by the measuring of the actual temperature values within the same phase or between phases in comparison to the temperature on the operational parts of an electrical device.

Often it is necessary to assess the state of underutilized contacts and contact connections at thermal imaging surveys. The recalculation of excess measured temperature values with respect to the normalized one for currents (0,6- 1)$I_{\text{ном}}$ is performed according to the following equation [2]

$$\frac{\Delta T_{\text{ном}}}{\Delta T_{\text{раб}}} = \left(\frac{I_{\text{ном}}}{I_{\text{раб}}}\right)^2, \qquad (1)$$

Where $\Delta T_{\text{ном}}$ and $\Delta T_{\text{раб}}$ – the excess of temperatures at the currents $I_{\text{ном}}$ and $I_{\text{раб}}$.

Permissible heating temperatures and temperature rises above the ambient temperature of contact connections and contacts are normalized [3]. For the contact and contact connections operating at load currents (0.3 to 0.6) $I_{\text{ном}}$, the recalculation ratio has the following form [2]

$$\frac{\Delta T_{0,5}}{\Delta T_{\text{раб}}} = \left(\frac{0{,}5 I_{\text{ном}}}{I_{\text{раб}}}\right)^2, \qquad (2)$$

Where $\Delta T_{0,5}$ – the temperature increase at the current $0{,}5I_{\text{ном}}$.

In accordance with [3] the quality of contact connections used for an electrical connection of wires, cables, electrical device bus arrangement, the movable contacts and other current-carrying connections (bolted, welded, performed by crimping, etc.) are determined using two diagnostic indices:

- Defects coefficient at the overheating K_d of an electrical contact or a branch performed using a particular type of connection;
- Excess temperature T of similar contact connections with other phases $0{,}5I_{\text{ном}}$.

According to its physical nature the defect factor K_d is determined by the ratio of specific heat flow released in a contact connection or a branch, to the specific heat flux, released on the wire outside a contact connection. The specific heat flow from the surface due to heat transfer into the environment and the thermal radiation is determined by the expression W/m^2

$$q = \alpha\,(T - T_{\text{окр}}) \qquad (3)$$

where α - the effective coefficient of heat transfer from the surface; T - the surface temperature; $T_{окр}$ – ambient temperature.

Then the defect ratio is the following one:

$$K_d = \frac{\Delta T_с}{\Delta T_{пр}}, \qquad (4)$$

where $\Delta T_с$ and $\Delta T_{пр}$ – the excess of temperature concerning a contact connection of a switching device and a connected wire outside a reinforcement (at least at the distance of 1m from a clamp) above the ambient temperature when the same current flows through them.

On the other hand, taking into account the expression for the amount of heat the defect factor can be defined as follows

$$K_d = \frac{I^2 R_{кс}}{I^2 R_{пр}} = \frac{R_{кс}}{R_{пр}}, \qquad (5)$$

where I – current power; $R_{кс}$ and $R_{пр}$ – electrical resistance of a switching device and a wire contact connection respectively.

In a general case the technical condition of an electric contact connection is the current function, the area of a contact connection, a tightening torque (for a bolted connection), and also depends on the presence of corrosion, fouling, etc. Thus, determining the ratio of temperature excess by the means of thermal equipment and using the expressions (4) and (5), one can indirectly evaluate the technical condition of a pin connection.

According to the testing standards in the energetics [2] it was decided to assess the state of a contact connection in the following way: if $K_d < 1,2$ is the initial degree of failure, then a constant monitoring is required; $1,2 \leq K_d \leq 1,5$ is the developing defect one should take corrective measures for the immediate withdrawal of an equipment failure; $K_d > 1,5$ – an alarm defect, an immediate reinforcement removal or replacement is required.

The excess temperature is the exceeding of the mean measured temperature in a controlled unit over temperature of other phase similar units which are in the same conditions.

The resistance of the switching device contact connection [1]

$$R_{кс} = 2\sqrt{\lambda} F \left(\frac{T_{раб} F k_т + R I^2}{I^2 \sqrt{k_т S}} \right), \qquad (6)$$

where λ is the thermal conductivity of a conductor material, 390 W/(m·К) for copper; $k_т$ – heat transfer coefficient, W/(m^2·К); $S_к$ – contour area of contact connection touch pad (Table 1), m^2; F – the cooling surface of the length unit, m^2; $R = \rho_0(1 + \alpha T_{раб})/S$ – conductor length unit resistance in ohms; I – current through a contact (Table 2), A; $T_{раб} = \Delta T + T_н$ - contact connection switching device temperature, К; ΔT – excessive temperature, the exceeding of a controlled unit measured temperature in comparison with the similar units of other phases in the same conditions (Table 2); $T_н$ – contact connection temperature of a switching device at operational parts of an electrical device, К.

Contact connection temperature of a switching device at the operational parts of an electrical device [4]

$$T_н = \frac{I^2 (T_{доп} - T_{окр})}{I^2_{доп}} + T_{окр}, \qquad (7)$$

where $T_{доп}$ – the permissible temperature of device part heating at an ambient temperature of 40 °C, the values of permissible temperature rises for the devices operating at ambient temperature, which differs from the adopted one (40 °C), should be amended so that the allowable temperature of unit parts defined as the amount of excess and estimated ambient temperature remained unchanged [5], $T_{окр}$ – ambient temperature, К.

Table 1: The values of contact pad sizes for the power contacts of low-voltage switchgear.

Item №№	Switchgear name	Rated current, A	Contact pad size, mm^2
1	Automatic switch АП50Б 2М ТУ16-522.139-92Д	1,6 ÷ 6, 3	Line length: 6 mm
		10 ÷ 25	12,5
		40 ÷ 63	30,0
2	Automatic switch АЕ2040 ТУ3422-027-05758109-2007	10 ÷ 16	20,0
		20 ÷ 63	30,0
		80 ÷ 125	40,0
3	Automatic switch ВА21-29М ТУ16-90 ИКЖШ.641211.002ТУ	1,6 ÷ 25	30,0
		31,5 ÷ 63	32,0
4	Automatic switch ВА13-29 ТУ16-88 ИКЖШ.641152.021ТУ	1,0 ÷ 25	30,0
		31,5 ÷ 63	32,0
5	Automatic switch А63-М ТУ16-91 ИКЖШ.641112.001ТУ	1,6 ÷ 25	30,0

The resistance calculation results of the contact connections among switchgear are shown in Table 2.

The theoretical results are in a good agreement with the experimental data, according to which the resistance of switching devices, measured by microohmmeter Ф 4104–M1 does not differ from the calculated value by more than 15%.

Fig. 1 shows the dependences of contact connection resistance concerning defective switching devices on a contact connection temperature determined during the thermographic examinations at various load factors.

It is not difficult to notice that the actual excess temperatures of switching devices under the same operating conditions are not equal ones during measurement (operating current and load factor). The inequality of temperature leads to the fact that the contact connection resistance of switching devices also have different values. The reason of this are the films formed on the contact surfaces of the devices.

The thermographic inspection of low voltage network equipment revealed that an unacceptable temperature rise of a contact connection takes place in faulty nodes - switching devices due to the presence of film surface and contact surface defects.

Thus, the resistance of devices increased on the average with respect to the initial value:

- For circuit breakers ($I_{ном}$ = 100A) by 2.1 times;
- For contactors ($I_{ном}$ = 100A) by 2.3 times;
- For magnetic starters ($I_{ном}$ = 100A) by 2.2 times;
- For switches ($I_{ном}$ = 100A) by 1.8 times;
- For packet switches ($I_{ном}$ = 100A) by 1.7 times.

According to technical operating conditions the resistance exceeding ratio is determined by the following formula:

$$K_{пс} = \frac{R_{кс}}{R_{ко}}, \qquad (8)$$

where $R_{ко}$ is the initial resistance of a contact connection for a switching device [6] [6]; $R_{кс}$ – the actual resistance of a switching device contact connection, determined by (6).

The dependence of a switching device contact connection resistance on the contact connection temperature is shown on fig. 2.

At that the resistance of a switching device contact connection is determined by the contact connection temperature function at various means square factors of a shop network load.

Table 2: Thermographic survey data.

Item №	Faulty node	Defect type	November 2011		March 2012		March 2013		Device current $I_{РАБ}$, A			Contact resistance $R_{К.С}$, mOhm		
			excess actual temperature	excess design temperature	excess actual temperature	excess design temperature	excess actual temperature	excess design temperature	November 2011	March 2012	March 2013	November 2011	March 2012	March 2013
1	Switch	BKS heating	$63,9^0$	$255,6^0$	$35,5^0$	$37,8^0$	$34,1^0$	$50,3^0$	45,0	47,5	42,0	1,57	1,19	1,03
2	Packet switch	BKS heating			$5,2^0$	$15,3^0$	$10,6^0$	$240,0^0$		33,3	31,0		0,57	0,61
3	Magnetic starter				$67,1^0$	$654,6^0$	$10,3^0$	$34,7^0$		26,8	27,4		16,52	16,21
4	Circuit breaker	BKS heating	$68,1^0$	$106,4^0$	$68,5^0$	$207,2^0$	$72,8^0$	$500,0^0$	40,0	38,8	39,1	6,79	6,84	6,22
5	Circuit breaker	BKS heating			$100,5^0$	$496,3^0$	$20,9^0$	$103,2^0$		22,5	22,5		8,34	6,58
6	Contactor				$73,2^0$	$269,0^0$	$24,2^0$	$76,3^0$		52,1	48,6		7,23	5,36

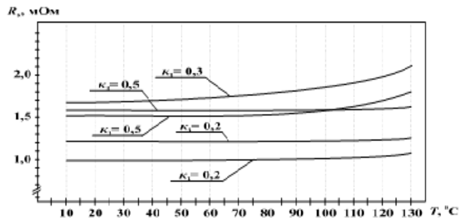

Fig. (1) – The dependence of a contact connection resistance within the defective magnetic starter PML 1220 from contact connection temperature, according to the results of thermographic examination at different load factors.

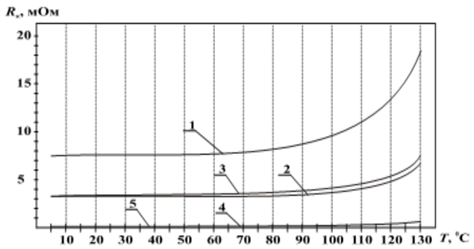

Fig. (2) – The dependence of the contact connection resistance among switching devices on a contact connection temperature at k_3 = 0,3 (1 – magnetic starter PML 1220; 2 – circuit breaker AE 2040; 3 – contactor KT 6013Б; 4 – disconnecting switch (switch) BP 32-31; 5 – packet switch BП 2-40)

3. Conclusions:

The result of experimental studies of thermographic survey data revealed the evaluation criterion for the technical condition of electrical switching devices, which is represented by a contact group resistance. This criterion allows taking into account the dynamics of electricity loss value change, determined by the value of the effective current square and the equivalent resistance, including the resistance of lines and electric devices.

They established multiplicity (excess) ratios of contact resistance value according to their permissible overheating with respect to the nominal values characterizing the technical status of low-voltage switching devices.

4. Summary: Thus, the obtained experimental data allow us to draw up the balances of power, to predict the changes of electric equipment technical condition and can be used during the evaluation of electrical grid reliability characteristics, as well as during the scheduling of preventive maintenance, inspections and replacement programs of the relevant electrical equipment.

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