THERMAL SECURING OF ELECTRICAL CONTACTS INSIDE OIL POWER TRANSFORMERS

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SUMMARY

In the operation of power transformers of 110kV/MV from substations, these are traveled by faults current results from MV lines damage. Defect electrical contacts are worming when they are travelled from fault currents. In case of high temperatures to achieve over 135 ^{0}C electro-insulating oil from the vicinity of electrical faults contacts self-ignition, liberate gases and is action gas relay. To avoid auto-flammability of electro-insulating oil, the author has designed a security system thermal of electrical contacts defects by pouring fire-resistant polyurethane foam, mastic or mortar fire inside a cardboard electro-insulating cylinder. From practical experience, in the exploitation of power transformers 110kV/MT in oil electro-insulating were recorded some passing disconnecting commanded by the gas protection at internal defects. In normal operation and in the optimal load, nominal currents do not require thermal secure contacts inside electrical transformers, contacts made at the fabrication according to the projects or to repair by solder. In the case of external short circuits close to the substation, the contacts inside electrical transformers, even if they are well made in sizes of Rcontact=10^{-6} Ω, are subjected to short-circuit currents of the order of 10kA-20kA which lead to the dissipation of some significant second-order electric powers 100W-400W on contact. At some internal or external factors who action on electrical contacts, including electrodynamic efforts at short-circuits, these factors could be degraded over time to values in the range of 10^{-4} Ω to 10^{-5} Ω and if the action time of protection is great, on the order of seconds, power dissipation on electrical contacts achieve high values of 1,0kW to 40,0kW. This power leads to strong local heating, hundreds of degrees Celsius and can initiate self-ignition and burning oil in the vicinity of electro-insulating contacts with action the gas relay. Degradation of electrical contacts inside power transformers may not be limited for the duration of their operation. In order to avoid oil burn with gas release near electrical contacts, at short-circuit currents 10kA-20kA, we have outlined the following solutions: covering electrical contacts in fireproof materials that would avoid direct burn oil at short circuit and transmission of heat from electrical contact along the conductors with heat dissipation gradually over time, in a large volume of cooling. Fireproof materials: polyurethane foam, mastic, cement. In the normal condition of operation of transformer, insulating of conductors coils is with paper and insulating oil. Ignition points of its two components, respectively are approximated: 135°C heat for oil and 200^{0}C for paper. In the case of a faulty electrical contact, about 10^{-3}Ω, at short-circuit, temperature can reach for a short time, a value of 300^{0}C - 400^{0}C who ignition the paper insulation and also the oil. By burning oil, there are local gases who disconnect the power transformer. Securing thermal electrical contacts inside the transformer, in cardboard tube with polyurethane foams, mastik or cement, registered at Romanian Patent Office, OSIM, deposit f 2018 0005, ensure avoiding gas release and also gas relay working.

Key words— power transformer, oil insulatation, electric contacts, gases, gas relay

INTRODUCTION

Electrical resistance of contacts are characterized by two components:

-the pressure of the contact

-surface of contact

If the contact surface is a fixed component in the Formula 1 of electrical resitance:

$R=\rho \times l/S$ (1)

contact pressure and the presence of impurities are contributing to the deterioration of the quality in time of electrical contacts. Experience in the operation of transport and distribution installations, shows that most faults that occur in electrical contacts are due to the system of operation of the installations, when short circuit currents reach very large values defect. In the table 1 are a number of theoretical calculations regarding the electric power load on contacts at short circuit. Values were chosen in steps for the resistors and also contact a host of representative values of short-circuit currents.

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TABLE 1 - ELECTRIC POWER LOAD ON CONTACTS AT SHORT CIRCUIT

	R contact	Isc (kA)	ΔP (kw)	Isc (kA)	ΔP (kw)
1	10^{-2} Ω	1,5 kA	**225**	15 kA	**2250**
2	10^{-3} Ω	1,5 kA	**22,5**	15 kA	**225**
3	10^{-4} Ω	*1,5 kA	* 2,25	*15 kA	* 22,5
4	**10^{-5} Ω**	***1,5 kA**	* 0,225	***15 kA**	* 2,25
5	**10^{-6} Ω**	***1,5 kA**	* 0,0225	***15 kA**	* 0,225
6	10^{-7} Ω	1,5 kA	**0,0022**	15 kA	**0,022**

From Table 1, area figures in rows 1-4, contacts are achieved by pressing. Even if at the moment of pressing the contact, resitance are at value of $10^{-4}\Omega$ - $10^{-5}\Omega$, meanwhile, contact pressure decreases their values and migrate to the value of 10^{-3} Ω -10^{-2} Ω. For these values for contacts resistance, power dissipate on contacte are in order of hundreds of kW with strong local heating. Rows 5-6 in the table 1, contacts are made by welding with value of rezistance less than 10^{-6} Ω. Factors which may lead to damage to the electrical contacts inside transformers are mechanical shocks (electrodynamic forces) due to short-circuit.

FACTORS THAT MAY LEAD TO DETERIORATION OF ELECTRICAL CONTACTS INSIDE OIL POWER TRANSFORMERS

The electrical contacts inside the power transformers both at the manufacturing stage and repairs, to ensure low contact resistance as in beach of $10^{-6}\Omega$ - $10^{-7}\Omega$, the technology is achieved by bonding (welding). Due to its contacts are mounted inside transformers, electrical resistance measurement on each contact at such low values can not be achieved using current kits approx. 2000A with measuring the voltage drops. In fabrication or in repairs power transformers, there are no welding quality control of electrical contacts similar, for example, in aeronautics. In this regard, although an electrical contact made by bonding (welding), video is well done and measurements taken on the continuity of circuits within the values stipulated in the regulations in force, the contact resistance due to bonding (welding) imperfect may be reduced, of the order of $10^{-4}\Omega$ - $10^{-5}\Omega$ with exothermic driven at short-circuit currents. Other external factors which may cause damage to the electrical contacts inside the transformers are mechanical shocks to which the transformer is subjected to loading onto the repair workshop or factory, during transport and installation of the power station. During operation, at external short circuit, conductors carry current transformer windings of large values of 10kA-20kA that are producing significant electrodynamic forces. Let's consider that the transformer is subjected to external short-circuit current of I = 15kA for a duration of 1 second tripping of the protection. In this period of time, electrical conductors both in the medium and high voltage inside the transformer attract or repel each other by an electrodynamic force resulting from the short-circuit current, *I1 = I2*, the length of the wires *l* and a distance *d* between they conformity to the formula (2):

$$F = \frac{\mu I_1 I_2 l}{2\pi d} \quad (2)$$

To simplify the calculations, we consider that the electrodynamic efforts work on one meter of conductor and the distance between two conductors fascilule is about 40 cm (0.4 m), conformity with Formula 3 and Figure 1.

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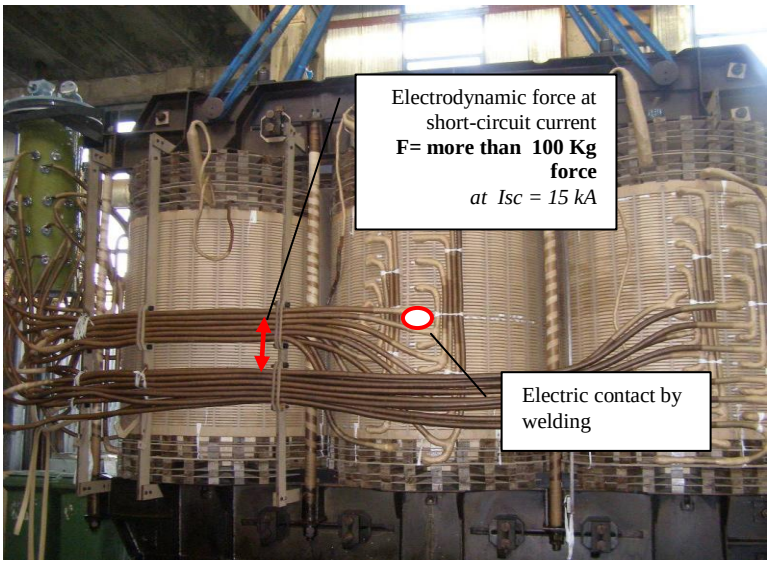

FIGURE 1 - ELECTRIC CONTACTS INSIDE POWER TRANSFORMER

$F = 4\pi 10^{-7} \times (15 \times 10^{3})^{2} / (2\pi \times 0,4) = 112,5$ Kgf (3)

In operation, in the event of defects and short-term hot points in transformers, their monitoring can be done with infrared cameras with 24 hours of 24 hours recording.

Example of damaged electrical contact over time - leading to damage to a power transformer is show in Figure 2.

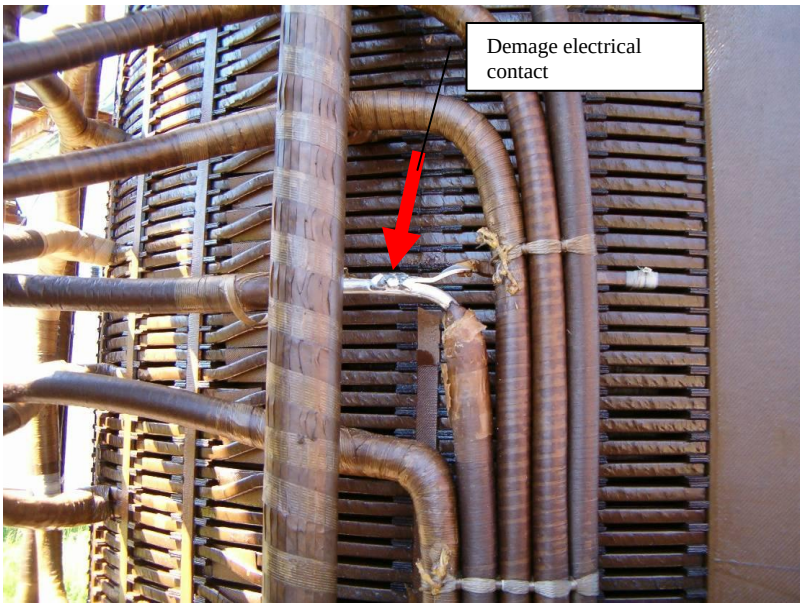

FIGURE 2 - EXAMPLE OF DAMAGE ELECTRIC CONTACTS INSIDE POWER TRANSFORMER

At the 110kV/MV and MV/LV transformer repair workshop in Campina, Romania, in over 50 years of experience, when disassembling them for repairs, engineers have in many cases discovered faulty electrical contacts.

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SELF-IGNITION OF OIL AND DISCONNECTING POWER TRANSFORMER BY GAS PROTECTION

At operation power transformer in short-circuit, the electrical contacts transit by current of 10kA-20kA, conduct at localized heating or hot spots that can cause self-ignition insulating oil and paper insulation. According to the technical characteristics, electrical insulating oil and paper have the following flash points, conformity to Table 2.

TABLE 2 - FLASH POINTS FOR OIL AND PAPER

oil – normal regim in function	**max.** 70 ^{0}C
Flash point - oil in use	***min. 135 ^{0}C***
Flash point – paper	**200 - 275 ^{0}C**
Thermal decomposition of the wood begins at temperatures above 105 °C; 200 °C, is greatly accelerated and the maximum amount is 275 °C. A thermal degradation of the wood, may occur during prolonged exposure to temperatures below 100 °C. Wooden flashpoint is between 200° C and 275 ° C. In the absence of oxygen, the result is the pyrolysis.	
Degradation of paper	*temperature - min. de 70 ^{0}C*

In the normal operation of the transformer, insulating paper of conductors is soaked with oil. The flashpoint of the two components, oil and paper, are close thermally, about 135^{0}C and 200 ^{0}C. In Figure 1 it is seen that all the electrical contacts are wrapped with insulating paper, but due to its soaking, the oil is in direct connection with the hot electrical contact. The power dissipated on the damage electric contact in conformity with Figure 2, it is about 22.5 kW, which is equivalent to the simultaneous operation of 22 kitchen hot plates of 1 kW power each and the temperature far exceeds the electrical contact more than 200 ^{0}C. At this temperature, insulating oil burn instantly releasing gas and consequently burn also the insulating paper.

THERMAL SECURING OF INTRNAL ELECTRICAL CONTACTS INSIDE OIL POWER TRANSFORMERS USING FIREPROOF MATERIALS

Degradation of electrical contacts inside power transformers may not be limited for the duration of their operation. In order to avoid oil burn with gas release near electrical contacts, at short-circuit currents about 10kA-20kA, we have outlined the following solutions:

- Covering electrical contacts in fireproof materials that would avoid direct burn oil at short circuit
- Transmission of heat from electrical contact along the conductors with heat dissipation gradually over time, in a large volume of cooling

Fireproof materials:

- polyurethane foam

FIGURE 3 - FIREPROOF MATERIAL - POLYURETHANE FOAM

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FIGURE 4 - FIREPROOF MATERIAL – EXPANDED POLYURETHANE FOAM

- mastik

FIGURE 5 - FIREPROOF MATERIAL - MASTIK

- cement

FIGURE 6 - FIREPROOF MATERIAL - CEMENT

From laboratory tests, polyurethane foam, mastik and cement do not react with the oil inside transformer and are chemically stable. At the repairs workshop in Campina, Romania, it is being studied to find thermal insulation

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solutions for the electrical contacts in the repaired transformers. For new transformers, solutions can be found from the design phase to ensure the thermal protection of the transformer contacts.

INDUSTRIAL TECHNOLOGIES TO SECURE ELECTRICAL CONTACTS IN CARDBOARD TUBE

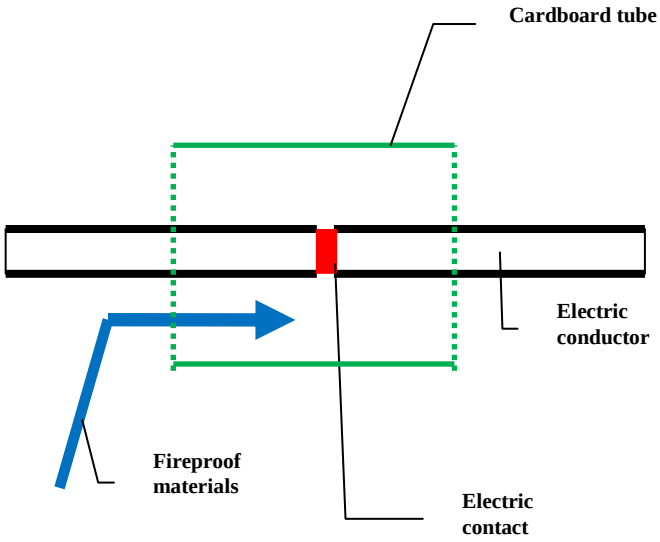

FIGURE 7 - SECURE ELECTRICAL CONTACTS IN CARDBOARD TUBE – 2 CONDUCTORS

According to the section of conductors and joined position of electrical contacts inside power transformers, can use all three fireproof materials in any combination:

- Fireproof foam adheres well to metal surfaces
- Mastik fills easy all gaps in insulating cardboard tube
- Mortar fire resistant to temperatures of 1400^0C

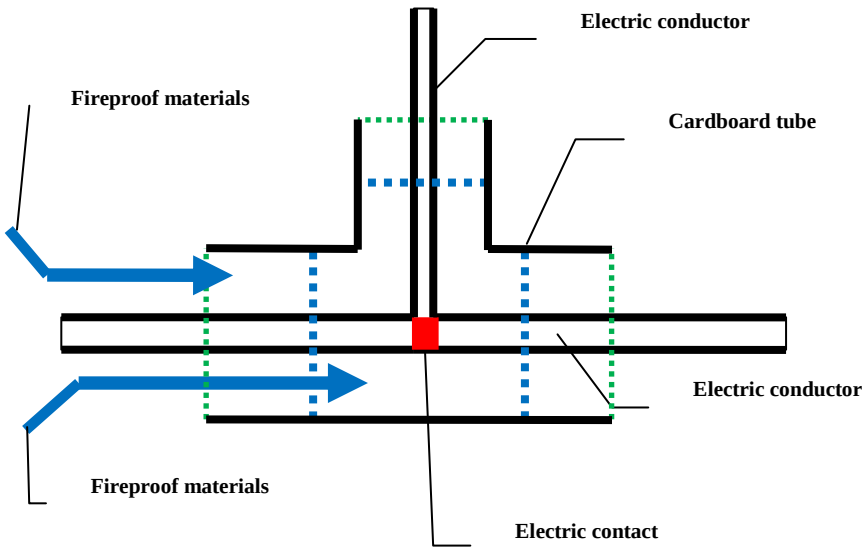

FIGURE 8 - SECURE ELECTRICAL CONTACTS IN CARDBOARD TUBE – 3 CONDUCTORS

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Regardless of the fireproof materials used to cover electrical contacts, it is important that they must be isolated and sealed inside cardboard tubes, show in Figure 9, to avoid oil penetration in the electric contact area. In this way, there are avoid partial discharge in transformer operation.

FIGURE 9 - CARDBOARD TUBES

CONCLUSION

- Online monitoring of short circuit current transiting the transformers in power stations using SCADA system can give value information about the electrodynamic efforts in coils and also about the vulnerability of electrical contacts.
- Securing thermal electrical contacts inside the transformer in cardboard tube with polyurethane foams, mastik or cement ensure avoiding gas release and gas protection working with disconnect electricity feeding at customers.

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