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FIRE INVOLVING AUTOTRANSFORMERS

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Abstract: This work aims to present the general characteristics of power transformers, more specifically, of autotransformers, and what phenomena can cause fire in the installations where they are used.
Keywords: Expertise. Trace elements. Fire. Transformers. Autotransformers.

INTRODUCTION

Among the various annoyances that the Brazilian population faces in their day-to-day lives is the fire. This event is responsible, in most cases, for the destruction of property, displacement of families, closure of workplaces, in addition to, in some cases, causing serious injuries or even death. The number of cases of fires in Brazil has been high. According to data from the Military Fire Department of the State of Goiás, in the state alone, in 2015, 10,806 cases of this nature were recorded. Below, detailed data for the year 2015.

Group	Sub-group/nature	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	TOTAL
Fire in vegetation	vegetation	160	50	17	39	171	615	931	1698	1574	1038	114	63	6.470
	agricultural culture	2	3	1		4	7	21	58	63	27	2	0	188
	subtotal	162	53	18	39	175	622	952	1.756	1.637	1.065	116	63	6.658
Urban fire	residential building	124	120	90	69	97	115	114	137	148	147	100	108	1.369
	vehicles	98	71	73	87	92	66	117	137	104	120	92	93	1.150
	special building	43	22	17	19	33	55	53	56	56	50	20	23	447
	miscellaneous items	52	19	14	18	28	44	38	63	62	44	25	17	424
	commercial building	32	22	18	15	23	23	18	19	35	34	20	13	272
	deposit	21	8	11	7	11	18	31	38	22	29	11	11	218
	audience	13	6	11	14	9	9	13	10	10	14	10	10	129
	concentration	9	2	5	4	8	4	7	6	8	6	2	6	67
	industrial building	2	3	2	2	6	4	4	0	3	3	3	3	35
	school building	1	0	3	3	3	3	2	3	3	0	1	0	22
	hospital building	0	0	0	1		1	3	3	2	1	2	2	15
	transitory building	395	273	244	239	310	342	400	472	453	448	286	286	4.148
	subtotal	557	326	262	278	485	964	1.352	2.228	2.090	1.513	402	349	10.806
	grand total													

Table 1[1]

1 BM/1 - Statistics and Information Analysis - E-mail: bm1@bombeiros.go.gov.br Rua 17, Qd. 2, number: 188 – Air Sector – Goiânia-GO – Zip code: 74.435-250 - Telephone: 3201-1206

There are several causes that can trigger a fire. Those related to the use of electrical equipment (motor, iron, "hair straightener", etc.) occur frequently.

The power transformer is an electrical device that is widely used today.

This type of equipment is widespread in modern society, and its use is widespread in any type of installation involving electricity. And one of the most used models today is the autotransformer, due to several factors: mass, dimensions, etc.

Due to its universal use, it is necessary to verify the possibility of participation of this device in electrical circuits that cause fires. Thus, it is of paramount importance to understand how a power transformer works, and under what circumstances the development of flames from this equipment can be triggered. In addition, what traces must be observed and interpreted by the experts in the transformer after the burn that could lead to the fact that triggered the fire.

Figure 1 – Power transformer in electrical grid distribution

JUSTIFICATION

The present work meets the need to investigate phenomena related to autotransformers, which can trigger fires. What traces can and must be found to determine the transformer as the causative agent of the fire.

Investigation and expert examinations in autotransformers are inserted in scarce works in this field. Many reasons can be pointed out to justify this fact. But two stand out: the first is the difficulty in visualizing the traces from the action of the fire (regardless of the cause) and the other is that in fire investigations where autotransformers are part of the list of traces and the probable cause is related to a short -circuit, the exams end and these equipments are not examined, since the "cause" would already be determined, that is, thermoelectric phenomenon: short circuit.

However, the tests must be prolonged, since short circuits can be caused by overvoltages which, in turn, can be produced by failures in autotransformers.

CONCEPTS AND DEFINITIONS

POWER TRANSFORMERS

They are equipment used in the process of transmission of electrical energy. They use the law of electromagnetic induction, or Faraday's law, as their operating principle. Its statement is:

The value of the electromotive force induced in a loop of area A is equal to the rate of change of the magnetic flux through that loop. Mathematically, Faraday's Law can be written as:

$$\varepsilon = \frac{\Delta\Phi}{\Delta t}$$

The magnetic flux (= B. A. cos *cos* θ) varies when there is variation in the intensity of the magnetic field (B) and the inclination of the area (A) in relation to the field lines.

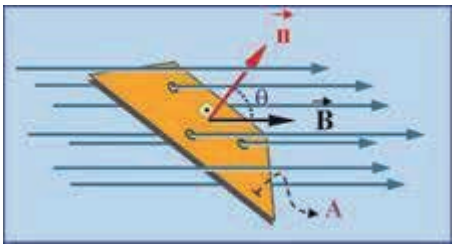

Figure 2[2]

2 http://brasilescola.uol.com.br/fisica/fluxo-magnetico-lei-faraday.htm

The electrical transformer does not perform the conversion of electrical energy into another form of energy, such as an electric motor. Its function, among many others, is to increase or decrease the electrical voltage between two circuits. In the Figure below, we have circuit 1 that operates at a certain voltage and circuit 2, which operates at another voltage.

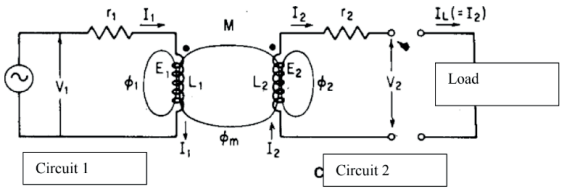

Figure 3 – Circuit of a transformer with its various parameters

The relationship between the two voltages is given by the equation:

$$\frac{N_1}{N_2} = \frac{V_2}{V_1}$$

Where:

V_1	is the supply voltage applied to the primary, circuit 1, in volts
r_1	Primary circuit resistance, in ohms
L_1	Primary circuit inductance, in henries
X_{L1}	Primary circuit inductive resistance in ohms
Z_1	Primary circuit impedance in ohms
I_1	Mean square value of the current drawn from the source by the primary, in amperes
E_1	Voltage induced in the primary winding (or circuit) by all the flux connecting coil 1, in volts
E_2	Voltage used in the secondary winding (or circuit) throughout the flux connecting coil 2, in volts
I_2	Mean square value of the current delivered by the secondary circuit to the load connected to its terminals
r_2	Secondary circuit resistance (excluding load) in ohms
V_2	Voltage appearing at the terminals of the secondary winding in volts
L_2	Secondary circuit inductance in henries
X_{L2}	Secondary circuit inductive reactance in ohms
Z_2	Secondary circuit impedance (excluding load) in ohms
ϕ_1	Flux dispersion component that concatenates coil 1 only
ϕ_2	Dispersion component of the flux that concatenates with coil 2
ϕ_m	Mutual flux, shared by both circuits, concatenating coils 1 and 2.
M	Mutual inductance (a measure of the magnetic coupling) between the two coils (or circuits) produced by the mutual flux in henries.

AUTOTRANSFORMERS

It is a special type of power transformer, where only one coil (winding) is used. This is divided by a tap. These equipment stand out due to their reduced size and mass, consequently, their lower cost compared to conventional transformers (two coils).

Figure 4 – Example of commercialized autotransformer

Conventional transformers can be "converted" into autotransformers. For this to happen, their windings must be connected in series, as in the following figures:

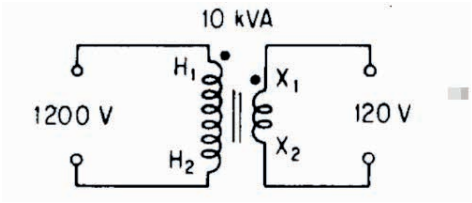

Figure 5 – conventional transformer

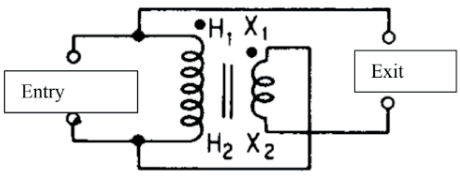

Figure 6 – Conventional transformer connected in series

Its configuration does not provide isolation of the secondary from the primary, which makes this characteristic a negative point for its use.

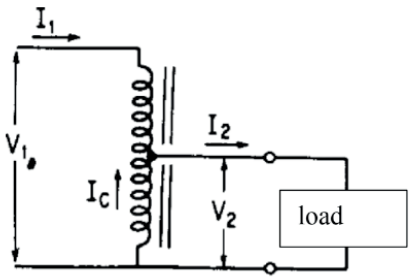

Figure 7 – step-down autotransformer

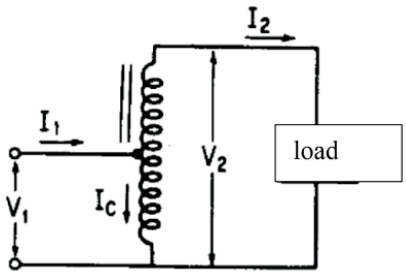

Figure 8 – elevator autotransformer

EXPERTISE

Exam or set of exams that use the scientific method to perform and reach the result.

According to Alberi Espíndula (2009, p. 73), expertise is "(...) a generic expression that includes several types of specialized tests, aiming to clarify a certain fact from a scientific perspective (...)".

TRACES

Every raw element found at a crime scene. They are the pieces that must compose the puzzle (crime scene) at the end of a forensic examination.

Traces, when examined and effectively related to the crime scene where they were found, are classified as evidence.

One of the various classifications of traces is in terms of visualization, in which case they can be visible or latent. Those are perceived with the naked eye, with the naked eye, for example, a gallon of gasoline next to a fire place. Latent traces, on the other hand,

are found only with the use of appropriate equipment or substances, for example, colorless liquid found inside a burned vehicle (accelerant research must be carried out in the laboratory).

FIRE

It is the uncontrolled action of fire (thermochemical phenomenon) in places not intended for it and which causes material damage and injuries, often fatal, to living beings. As an example, there is the action of fire in a crematorium, in a normal corpse cremation process that cannot be considered a fire, since the flames would be controlled (limits of action, intensity, etc.).

Not infrequently, fires are set intentionally, either by obtaining insurance, or by feud or revenge. In this case, the causes are characterized by intentional human action.

In order to determine the cause of a fire, that is, what caused it, what factor triggered the beginning of this process, it is necessary to proceed with an expert examination. The expert is the professional who will point out the circumstances and their cause.

METHODOLOGY

In an expert examination at a fire site, one must initially look for the zone of origin, which is the room (smallest compartment) of the property where the fire started. To determine the zone of origin, one must analyze the burning patterns and follow the inverse path taken by the flames and smoke.

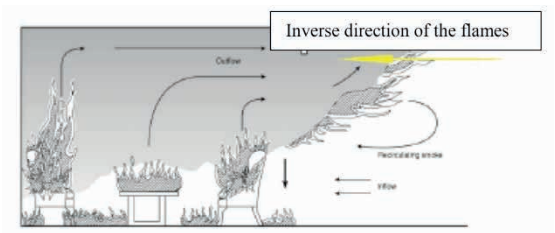

Figure 9 – Path of flames and smoke.

Next, it is necessary to find the initial focus, that is, the point or region where the fire started. In this case, an analysis of the burning patterns is usually carried out and, if necessary, the removal of rubble and burnt objects in order to reach the exact location where the fire started. It is a complex task, because in the initial focus the elements will be damaged and, many times, indistinguishable from the other vestiges present in the place.

Figure 10 – Example of burn pattern.

Finally, the igneous agent must be found, that is, the source of heat that started the whole thermochemical process.

When traces (or pearls) of primary melting are found at the site, which are traces that indicate that the short circuit started the fire, it is necessary to discover the fact that produced this phenomenon.

In some cases, overvoltage or overcurrent are the phenomena that cause the short circuit, since the excess current, beyond what the conductor can withstand, damages the coating and exposes the conductors to contact, causing the short circuit. This process can take years, when the overvoltage or overcurrent does not so much exceed the capacity of the conductor, or it can be almost instantaneous, where current values exceed too much.

Figure11– Conductor removed from the fire site showing traces of fusion.

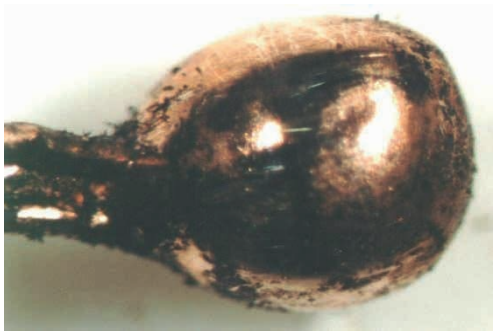

Figure12 – Fusion trace in detail.

Figure13 – Conductors after being subjected to overvoltage.

The aforementioned overloads (overcurrent and overvoltage) are caused by different factors, one of which is failures in autotransformers. These failures appear at junctions a and b in the Figure below, since, at these points, there are high values of electric current, causing heating in these regions and causing rupture, as shown in the figure:

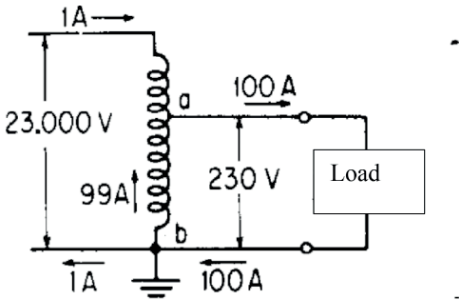

Figure14 – faultless circuit.

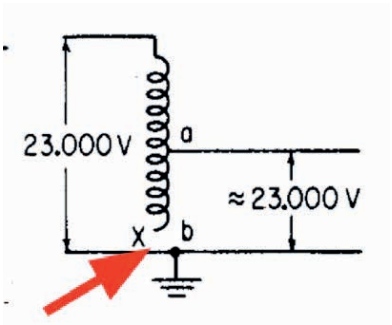

Figure15 – failed circuit.

It can be seen that the rupture at point b causes all the primary voltage to be transferred to the secondary. This fact causes the load and conductors connected to the secondary to be subjected to the same voltage as the primary.

In the example shown, extreme values were adopted, not practiced, for example, in residential power supplies. However, they are useful to show that a circuit that was prepared to operate with 230V will operate with 23000V, that is, 100 times greater.

CONCLUSION

The present work showed that thermoelectric phenomena, more precisely the short circuit, can be preceded by overvoltage. This, in turn, can be caused by faults in the autotransformer to which it is connected. In places affected by fire, where short circuits are the cause, it is necessary that the examinations go deeper in order to look for the fact that produced it. When it is found that the overvoltage gave rise to it, it is important

to check whether there is an autotransformer in the electrical circuit and examine it, as this device may have been the fault that originated the overvoltage found.

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