EXPERT INVESTIGATION ON THE CAUSES FOR OCCURENCE OF A BIG FIRE IN AN ADMINISTRATIVE BUILDING

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ABSTRACT: *The paper inhere describes an approach and method for studying and investigating the causes and mechanism for development of an emergency in a power transformer that results in a large fire in an administrative building with lots of casualties and material losses.*

KEY WORDS: Big fire in an administration building, electrical break-down in the insulation of a power transformer, over voltages in power low voltage power line.

INTRODUCTION

Because of its undoubted advantages over other types of energy, that mankind is aware of, in the early twenty-first century, electricity is used in all spheres of human activity: from the most powerful power consumers in metallurgy, mining, oil, gas and chemical industry, water supply systems, transport, energy supplying in residential and office buildings, shopping and cultural centers, to devices for medical diagnostics, communications and toys, in systems for national security and environmental safety of each country.

In order to provide the electricity supply to any electrical users, the necessary transmission and distribution electrical power networks and systems are being built.

Along with its usefulness for mankind, electricity is also a potential source and cause for a number of fires, explosions, industrial accidents and catastrophes, accompanied by great material losses and casualties.

In general, the use of electricity in all spheres of human activity predetermines that most of the fires are caused by emergency situations arising in the electrical power networks, installations and their components.

This is a reason why the task for investigation and clarifying the causes of fires and explosions as a result of failures occurring in electrical power networks and equipment seems to be important to study and solve.

The paper inhere describes an approach and method for studying and investigating the causes and mechanism for development of emergency in a power transformer that results in a large fire in an administrative building with lots of casualties and material losses.

ANALYSIS OF EMERGENCY OPERATION IN ELECTRICAL POWER NETWORKS AND THEIR CONSEQUENCES.

Sources [1, 2, 3, 4] propose a theoretical analysis and experimental study results for various emergency regimes in electrical power networks and the following consequences. All emergency regimes are united mainly into two major groups:

- Emergency operation occurred as a result of surges(over voltages) in the power grid;
- Emergency operation occurred as a result of various types of short circuits.

In order to assess the risk of fires initiated by electric current different instances of emergency regimes in electrical power networks and their consequences are analyzed.

The prerequisite to initiate a fire are at a certain time and place is the coincidence of two events: presence of flammable materials and presence of an energy source capable to ignite these flammable materials.

The operation of electrical power networks and consumers is often accompanied by different kinds of failures that may occur, and as a result the electrical system and respectively the flowing faulty currents to cause fires.

Overvoltage is any operating voltage of the system that is above the nominal voltage levels of the system. Practical interest is cases of over voltages that are dangerous for the insulation of the electrical installation.

Depending on the reasons causing them, overvoltages are divided into two groups:

- External (atmospheric) overvoltages;
- Internal (switching, resonant, arc, transferred over voltages from Medium to Low voltage side of power transformers, etc.)

In the electrical power installations and networks, most often occur switching and arc overvoltages. Ratios of multiplicity for switching and arc over voltages are not large. In [2,3,4] it is shown that the switching current and voltage rise in linear electrical circuits cannot exceed the double amplitude of the steady state magnitude. The same is valid also for arc overvoltages, since the arc ignition and the extinction is equivalent to switching on and off the circuit, in which the arc occurred.

The ratio of multiplicity of resonant overvoltages depends on how the values of active, inductive and capacitive circuitry parameters correspond on the resonance condition. Resonance overvoltages may reach large values (Theoretically up to infinity). If the power network doesn't have inductance in regard with earth, resonant over voltages are not possible to occur.

In the distribution electrical power networks (6 - 10 kV) with insolated neutral, resonance overvoltages are caused by the formation of a resonant circuit consisting of inductance and capacitance between phase conductors and earth. Inductances to earth include voltage measuring transformers, compensating reactors, etc. Electrical power network capacitance is always present between phase conductors and earth and between phases.

Overvoltages are one of the main causes for insulation failures in electrical power networks, as a result of the following conditions:

1. Full electrical breakdown in solid insulation (active insulation resistance becomes equal to zero). In this case short-circuits occurs, which are accompanied by large currents and usually relay protection switches off the damaged electrical system or power line.

2. Incomplete breakdown of solid insulation (active insulation resistance is not equal to zero). The resulting short-circuit current (leakage) doesn't have big enough value to trigger the over-current relay protection. In the place where insulation is damaged a process of intensive heating occurs, which finally results in insulation ignition. This case is the most dangerous in terms of fire and explosion hazards, caused by the effect of electrical current.

3. Burning of electrical arc in gaseous insulation (in the air), where in the process of arc ignition and extinction the temperature rises to 3000°C or more. At such high temperatures all flammable materials located in the burning arc vicinity are likely to cause fires (in public and residential buildings or industrial sites).

Statistics [5-9] today presents information about fires in various public, residential and industrial buildings and explosions in various industrial sites in the mining, oil, gas and chemical industries, accompanied by great material losses and casualties, arising from faults occurring in the electrical power networks and systems. Experts investigating these accidents and catastrophes, by rule, explain the causes for these fires in their expertise as a result of short-circuits, without reflecting the reasons for these short-circuits and their mechanism.

Moreover, it is necessary to know, that short-circuits are not always the major cause of accidents and catastrophes, since in most of the cases these faults are eliminated by the relay protection devices, especially installed for that reason.

The term "overvoltage" is also not mentioned in most of the expert's reports. The occurrence of over voltages is associated with complex surges, and the study of these surges requires a serious knowhow and training in the field of Electrical Engineering, the Theory of electrical power networks and Mathematics.

There are numerous cases of fires with heavy losses. Specialists investigating the causes of these fires have the necessary training in extinguishing fires, but they do not have the qualification to explain the reasons for the occurrence of such fires, caused by short-circuits, especially in the cases when the over-current protection has not triggered.

ANALYSIS OF THE EMERGENCY OPERATION OF THREE-PHASE POWER TRANSFORMER AND THE OCCURRENCE OF AN INSULATION BREAK-DOWN BETWEEN THE HIGH-VOLTAGE WINDING AND THE TRANSFORMER FRAME

In order to study the processes in this emergency mode, the equivalent wiring diagram of the electrical power network and the power transformer is shown in Fig. 1. The transformer primary windings are "star„ connected with insulated neutral, and the secondary windings are "star „connected with neutral grounded through an active resistance r_0 (Y/y0).

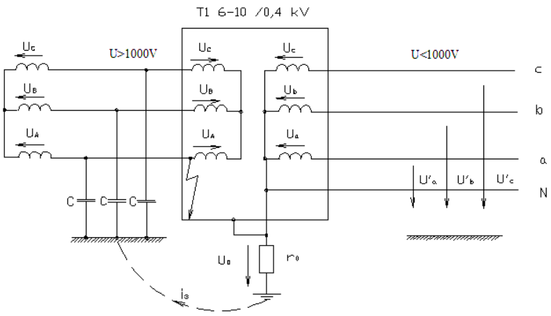

Figure 1. Equivalent circuit diagram of electrical power network for studying the emergency mode of a power transformer 6(10)/0,4 kV in case of insulation break-down between the high-voltage winding and the transformer frame, where:

U_A, U_B, U_C, u_A, u_B, u_C - instantaneous values of transformer's phase-to-neutral primary and secondary voltages;

u'_A, u'_B, u'_C - instantaneous values of phase-to-earth voltages at 0,4 kV;

u_0 – iInstantaneous value of transformer's neutral, voltage for the time of the transient process;

C – phase-to-earth capacitance of the medium voltage side 6(10) kV.

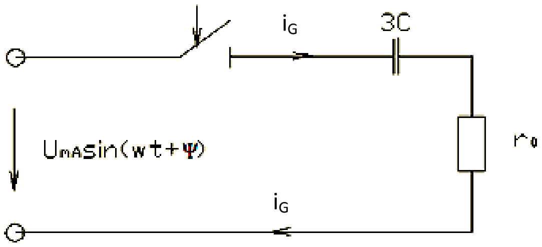

Figure 3. Calculation circuit of the electrical power line.

At the moment when an insulation break-down occur between phase A and the frame of the power transformer, a transient current i_G arise, as a result of which the transformer housing and the neutral of the secondary side obtain transient voltage u_0. If the magnitude of this voltage u_0 reaches a significant value, then the low-voltage electrical network supplied by the secondary side of the transformer will obtain severe overvoltage, with all resultant consequences.

If the phase-to-earth voltage of the faulty conductor (phase A) with insulation breaks-down is denoted with the expression bellow:

$$u_A = U_{mA}\sin\left(\omega t + \Psi\right) \qquad (1)$$

Then the transient voltage upon the neutral with resistance r_0 will be:

$$u_o = \frac{U_{mA} r_0}{z}\left[\sin\left(\omega t + \Psi - \varphi\right) - \frac{\cos\left(\Psi - \varphi\right)}{3\omega C r_0} e^{-\frac{t}{3 r_o C}}\right] \quad (2)$$

, where

$$z = \sqrt{r_0^2 + \frac{1}{9\omega^2 C^2}};\ \varphi = arctg\,\frac{1}{3\omega C r_0}$$

Since $r_0 << \frac{1}{3\omega C}$, $\varphi \approx\sim -\frac{\pi}{2}$

In the initial moment, when the insulation faults occur ($t = 0$) for $u_0\left(0\right)$ is obtained:

$$u_0\left(0\right) = \frac{U_{mA}}{z \cdot 3\omega C} sin\Psi \quad (3)$$

From (3) it follows that the in the first moment of the transient process (t = 0), the voltage upon resistor r_0, via which the neutral of transformer's secondary winding is connected to earth doesn't depend on r_0, but on the electrical line capacitance and the initial phase Ψ .

In the most unfavorable case, when $\Psi = \pm\frac{\pi}{2}$, the grounding grid voltage reaches maximum value. For example, for a rated voltage of 6 kV $u_0\left(0\right) = 4{,}9$ kV and for rated voltage of 10 kV $u_0\left(0\right) = 8{,}2$ kV .

Under these conditions the voltage on the phases of the side 0,4 kV to ground will be determined by the expressions [5]:

$$\begin{cases} u_a^{'} = u_0 + u_a = u_0 + U_{ma}\sin\left(\omega t + \Psi\right) \\ u_b^{'} = u_0 + u_b = u_0 + U_{mb}\sin\left(\omega t + \Psi - \frac{2\pi}{3}\right) \\ u_c^{'} = u_0 + u_c = u_o + U_{mc}\sin\left(\omega t + \Psi - \frac{4\pi}{3}\right) \end{cases} \quad (4)$$

From (3) it follows that, if the phase voltages on the secondary side $0{,}4$ kV of the transformer u_a, u_b and u_c are not taken in consideration, since their voltage is negligible compared to the impulse voltage u_0, then the three phases and the neutral conductor will have the same potential to earth u_0. For rated voltage $U_n = 6$ kV $u_0\left(0\right) \approx 4{,}9$ kV and for $U_n = 10$ kV $u_0\left(0\right) \approx 8{,}2$ kV .

A very important and essential conclusion is: Since the potential difference between the wires in the electrical power network 0,4 kV is equal to 0, then it is not possible an insulation break-down to occur between phase conductors, and respectively short-circuit currents will not flow through the line, and the short-circuit overcurrent protection will not trip.

EXPERT ANALYSIS OF THE CAUSES FOR ARISING AND RAPID DEVELOPMENT OF A LARGE FIRE ON SEVERAL FLOORS OF AN ADMINISTRATIVE BUILDING

Information is provided in [5] about a massive fire in an administrative building with casualties. The expert commission that investigated the causes for the fire considered that the main cause of the fire was a result of un-extinguished cigarette left by undisciplined smoker.

At the same time, information was obtained from random citizens who have been witnesses of the fire, claiming that the fire has developed at instantaneously at the whole area, comprising the two floors of the building.

A reasonable question is: Is it possible an un-extinguished cigarette to cause the rapid development of a fire not only on a large area, but also on two floors at the same time?

Energy reserve in an un-extinguished and burning cigarette is too small to pretend to be a cause of a massive and powerful fire.

In this case, causes for the massive fire should be sought in another, powerful and likely source of energy. For instance such source of energy could be an overvoltage with large multiplicity, occurred in the low-voltage electricity system.

Most often, such overvoltages arise in the electrical power networks $0{,}4$ kV with directly earthed neutral in case of single-phase-to- earth fault between phase conductor in the high-voltage side ($6/10$ kV) and the transformer's metal frame.

The fire development mechanism could be explained as follow:

- Upon the occurrence of insulation break-down in phase A on the high-voltage side $6/10\ \text{kV}$ transient process initiate; Since transformer's metal frame is directly grounded with the low-voltage neutral earthling system, the earthing system with resistance r_0 obtains impulse overvoltage $u_0(0)$ which can reach very large values(transferred voltage between high and low-voltage side, as mentioned above for $U_n = 6\ \text{kV}\ u_0(0) \approx 4{,}9\ \text{kV}$ and for $U_n = 10\ \text{kV}\ u_0(0) \approx 8{,}2\ \text{kV}$);
- This voltage surge is transferred in the overall low-voltage building electricity system, causing in the initial moment massive and high-temperature arcing (with temperatures up to $3000\,℃$) between low-voltage phase conductors and grounded object in the building (metal pipes, building reinforcement, etc.);
- These massive arcs instantaneously ignite all flammable materials on all floors.

COLLECTION OF ADDITIONAL INFORMATION TO CLARIFY AND PROVE THE CAUSE OF THE FIRE

In compliance with the regulations [7, 10] it is necessary to collect evidence by which conclusively to clarify and prove the possible causes for the massive fire that has resulted in major property losses and casualties.

The necessary information needed for the investigation is in the following aspects:

- ✓ Condition of the building electricity system after the fire has been distinguished (fuses, circuit breakers, etc.);
- ✓ Status of the power transformer supplying the administrative building after the fire;
- ✓ Reports on the results of recent laboratory measurement of power transformer's parameters, ensuring its safe and reliable operation;
- ✓ Protocol on the results of a complete technical expertise about power transformer's condition after the fire;
- ✓ Clarification of the question: Are there special design solutions that are applied for protection against transferred high-voltage surges from the medium-voltage side to the low-voltage building electricity system?
- ✓ Approved executive and operational plans of the electrical power system, including the distribution power transformer and an electrical installation wiring diagram in the building;
- ✓ Testimony of witnesses in regard with the initiated fire.

CONCLUSIONS

At the beginning of the XXI century electricity is the most used form of energy in all spheres of human activity. Statistics show that this type of energy appears to be one of the main causes of fires, explosions and industrial accidents, accompanied by major material losses and casualties.

The research and analysis of fires and the occurrence of various faults and failures in power grids and electrical systems is a solid and objective source of information and knowhow and respectively it has to be used to take adequate measures and solutions to enhance the safe and efficient use of electrical energy.

The complexity of emerging issues and problems to solve (finding the causes of fires, accidents and catastrophes in all spheres of human activity, which uses electricity) requires special knowledge and training in regard with the theory of electrical engineering, power grids and mathematics, etc. in order to provide quality mathematical modeling and analysis of complex projects in the field of electrical power engineering and supplying, improving the level of safety and reliability of electricity systems initially in the design phase.

It is of key importance to train and prepare professionals, to acquire knowledge, skills and experience to perform qualitative and quantitative risk assessment of the use of electricity in different areas of modern life.

Despite of the significant achievements for risk assessment in regard with the operation of complex technical systems that are under operation in the twenty-first century, our tertiary education doesn't develop specialized training courses and programs for studying the theory of risk and its use to solve practical problems.

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