Exploring the sustainability of cable lines in fire case

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Abstract

This paper presents a statistical analysis of the fire hazard of cable lines. Basic properties of cable lines of different types in a fire are specified. Factors affecting the sustainability of cable lines in the event of a fire are identified. An assessment of the sustainability of cable lines in fire conditions in accordance with GOST IEC 60331-21-2011 and GOST IEC 60332-3-22-2011 was made. The results are used for provision of fire safety in buildings and facilities during their operation.

Keywords: fire danger of cable lines; fire resistance; limit state of the cable; fire spread; fire influence.

I. INTRODUCTION

The sustainability of cable lines in a fire depends upon various factors. Cables utilize combustible materials (electrical insulation, cable sheaths, etc.) and intrinsic heat sources (thermal emission of conductor cores, provoking de-stabilization with subsequent flames proliferation) [1-3]. For example, cables with rubber sheath, with PVC sheaths, with PE sheath demonstrate different resistance under fire conditions. The multitude of insulation types of cable lines stipulates the demand for comparative studies of their behavior in a fire.

Based on statistical data for the past 10 years, it is apparent that 20-25% of fires annually occurring in Russia cause de-stabilization of electric installations, whereas 50-60% of fires occurring in electric installation proper are caused by the insulation of the cable lines.

Cabling utilities of complex topology are distinguished not only by high combustible loads (insulation of the cables), but also by fire proliferation hazards and emissions of gaseous combustion products into the air of the buildings and facilities.

It is well-known that cable sheaths are made of polymer insulation compounds which emit chlorine, bromine, fluorine, sulfur dioxide, etc. which build in combination with water vapor acids and alkalies causing corrosion of metal structures and equipment.

As a consequence of that, studies of sustainability of cable lines in a fire obtain one of the highest priorities in the sphere of fire safety.

II. METHODOLOGICAL BASIS FOR THE RESEARCH

Due to the high intensity of the technical progress, the scale of cable lines is increasing along with the growth of industrial facilities requiring enhanced sustainability under fire conditions. Traditionally, different types of fire-resistant cables are utilized [4-7].

In accordance with Russian codes [8], the following utilities shall retain their functionality in a fire within the time required for their intended performance and escape of people to a safe area: cable lines and wiring of fire-protection systems, of facilities for firemen support, of fire detection systems, of fire annunciation and escape management, of emergency lighting in escape routes, of emergency ventilation and smoke protection, of automatic fire-righting systems, of the internal fire-fighting water pipeline, of emergency lifts for firemen in building and facilities; the power supply lines of the premises of buildings and facilities shall feature emergency trip devices preventing fire occurrence; the installation rules and the specifications of the emergency trip devices shall be selected under consideration of fire safety requirements.

It is well-known that the proliferation of the fire is dependent not only on the cable quantity, but also on the arrangement of the cables in the conduit space.

As an example, Fig. 1 demonstrates that five cables of VVG and NRG type, in most cases, contribute to fire proliferation at vertical samples arrangements. Thereby, stable flame proliferation will be observed when these cables are arranged in a bundle with a gap (Fig. 1). In this connection, all contemporary cable types being fire-retardant in a bundle (non-flammable) shall be tested in bundles of combustible materials with or without a gap, dependent upon the type and the arrangement method thereof in conduit facilities.

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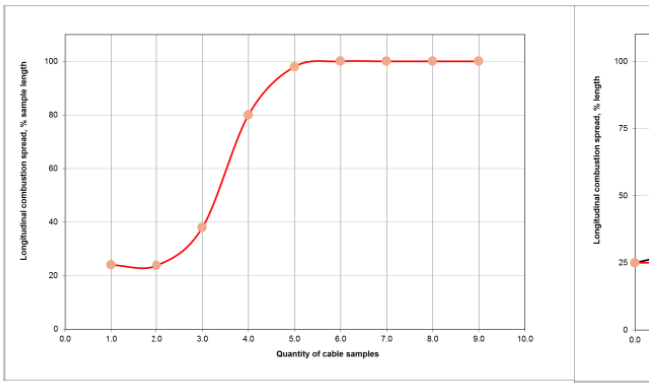

Figure 1. Flame proliferation dependent on cables arrangement.

It is known, that if, during the operation, electrical or optical wires or cables are subject to joint conduit installation, then, the combustion proliferation test results must be obtained exactly for bundles. A bundle is a group of parallel cables clamped together in a single conduit.

During bundle operation, the following distinctive features shall be considered:

- The biggest quantity of combustibles (cable insulation), experiencing the impact of an external fire source, as well as of the fire occurring when cables are burning;
- Joint arrangement of cables during the installation;
- The temperature of the gaseous combustion products emitted by a cabling bundle is considerably higher than that of a single cable;
- Increased emission of gaseous combustion products by a cable bundle at a certain increased temperature;
- Cable design, e.g. armored or armor-free, multi-core or single-core.

III. EXPERIMENT

The fire resistance of the cable is evaluated in accordance with Standard [9] "Fire-exposure testing of electrical and optical cables. Retaining of functionality". The sustainability assessment of a vertically arranged cable bundle is performed in accordance with [10] "Cable lines. Retaining of functionality under fire conditions. Test method".

Based on the applicable testing method, a sample is bundled in the lab imitating a joint installation. The number of the cable sections in the sample is dependent on the quantity and the density of non-metallic cable material. Cables and wires labeled as "НГ" (Russian for "fire-retardant") are subject to mandatory fire-safety tests. The essence of the method is that cable sections are bundled on a test rack and put vertically into a combustion chamber and exposed to flames. Upon finishing the test, the smoldering cable shall get extinguished by itself. The length of the charred cable section shall not extend beyond 2.5 meters. Such cable is deemed to have passed the test.

Based on the requirements to such tests [11], the sample shall contain several cable sections of at least 3.5 m each sampled from one reel.

The number of the cable sections in the section shall be selected in a manner that the rated volume of non-metallic materials is finally equal to 7 liters per 1 running meter of the sample length.

The cable section constituting the sample shall be tempered prior to the test commencement at (20±10) °C for at least 16 hours. The cable sections under test shall be dry.

Such experimental studies were conducted with the following samples:

1) KG 3x50+16-0.66 cable with rubber sheath;
2) AAShv 3x120-10 cable with PVC sheath;
3) Cable with PE sheath. TPPeP 50x2x0.4.

These samples consisted of three bundles of cable sections, each one of at least 3.5 m each.

The proliferation of the flames is determined on the length of the damaged cable section. The present test can be a proof of limited flame proliferation along the cable.

The experimental procedure is as follows:

- three bundles of three types of cables are fastened to the rack;
- the bundles are exposed to flames within 40 minutes;
- the air flow velocity through the test chamber is maintained till the flames go totally out;
- after the exposure to the flames is finished, the sample is carefully wiped. Soot on the sample is admissible if its surface is undamaged; softening or deformation of non-metallic material of the sample is admissible, too. As flames proliferation value, the length of the damaged section is taken (in meters, from the bottom of the burner to the end of the charred section), and it is determined as follows: pressure is exerted on the cable with a sharp tool like a knife blade; the elastic-to-brittle transition place on the sample surface is considered to be the end of the charred section;
- the exposure to the flame in the test chamber is stopped in 28 min 54 seconds due to the fact that the fire has reached the middle of the bundle of cable sections;

Experimental results:

- the charred section of the cable bundles of KG 3x50+116-0.66 rubber-coated cable was 2.5 m;
- the charred section of the bundle of AAShv 3x120-10 cable with PVC sheath was 2.3 m;
- the charred section of the cable section bundles of TPPeP 50x2x0.4 Polyethylene-coated cable was 2.2 m.

The length of the charred cable section measured from the bottom of the burner shall not exceed 2.5 m.

The recommended requirement to the assessment of the results corresponds to the obtained experimental value recorded in the technical report [12].

The results demonstrate that these cables have passed the tests.

IV. CONCLUSION

Studies of the specifics of the sustainability of cable lines under fire conditions demonstrate dependence on the insulation of the cable lines, on the cable types and on the installation method.

The safety of cable lines is indispensable for integrated safety of buildings and facilities, as well as for their further operation.

The results of the study described herein can be taken for the design of cable lines and electrical installations, compilation of technical document packages and specifications.

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