Study Committee B1

Insulated Cables

10106_2022

FIRE RISK FROM XLPE CABLES IN AIR

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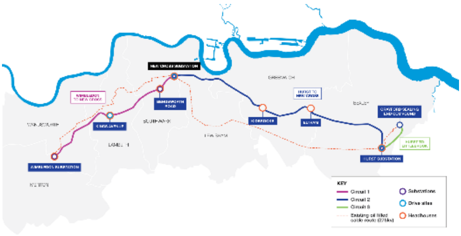
Motivation - London Power Tunnels

National Grid Electricity Transmission (NGET) is in the process of replacing EHV cables that form a large part of the transmission network feeding London.

The second phase of the project, London Power Tunnels 2, is currently under construction. This will consist of 32.5km of force-ventilated underground tunnel, each section accommodating 2x 275/400 kV cable circuits, there are 9 head houses and 4 substations.



London Power Tunnels 1 (During Construction)

Previous cable tunnel construction by NGET incorporated substantial fire safety precautions for both personnel protection and asset security.

Whilst tunnel design measures have virtually eliminated the risk of a fire being initiated from an ‘external’ source, the risk of a cable electrical fault remains. Such faults can dissipate a large quantity of energy and the assumption had been that XLPE cables could self-ignite and then sustain fire following an internal fault. As the fire loading of the cable is high, this was a matter of concern. However, little was undersood about internal faults and their likelihood to cause fire.

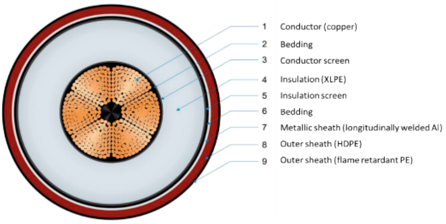
To address some design challenges, the Project needed to better understand the fire performance of XLPE cable used in tunnels. A series of tests was thus commissioned to collect data.

Method/Approach

The tests were performed on samples of 400 kV XLPE cable that had been installed on an earlier tunnel project. This is typical of cables purchased by NGET for tunnel installation. Key features are:

- 2500mm² copper conductor.
- Welded aluminium sheath.
- Bi-layer oversheath, with fire retardant outer layer.
- Satisfies the requirements of IEC 60332-1-2 (tests for vertical flame propagation)

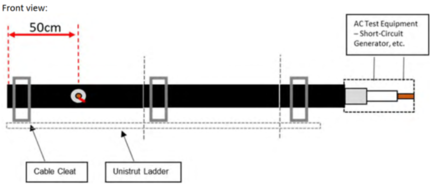
Cables of this general construction have been demonstrated to exhibit good resistance to an external fire source.



Experimental Setup

The tests were designed to replicate an internal fault caused by an electrical breakdown of the XLPE insulation. They were carried out at a SC test station with a test circuit capable of delivering fault currents representative of worst-case conditions on the UK 400 kV network. Tests were performed at fault currents up to 63 kA (rms).

Each cable sample was prepared by drilling a radial hole through the XLPE insulation and inserting a thin copper wire to initiate a ph-E fault between the conductor and aluminium sheath.



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continued

Experimental Setup (cont)

The tests were recorded using high-speed and thermal imaging cameras.

The following tests were performed:

	Fault current/duration	I x t (A.s)
Test 1	35kA / 140ms	4.90 x 10^3
Test 2	45kA / 140ms	6.30 x 10^3
Test 3	55kA / 140ms	7.70 x 10^3
Test 4	63kA / 140ms	8.82 x 10^3
Test 5	45kA / 300ms	13.5 x 10^3
Test 6	63kA / 105ms	6.62 x 10^3

Test Results

As expected, each fault simulation resulted in the ejection of a jet of plasma from the fault point and along the axis of the hole that had been drilled in the insulation during preparation of the sample. Visual and thermovision records showed that the jet formed a narrow cone with the highest temperatures at its centre.

Visual evidence following an in-service cable fault is consistent with a highly directional plasma jet being ejected, confirming that the test outcomes were as expected from an actual fault event.

The condition of the cable following the tests is shown in the following images.

- Fault cleared in normal unit protection operating time
- Fault cleared in delayed (CB fail operating time)

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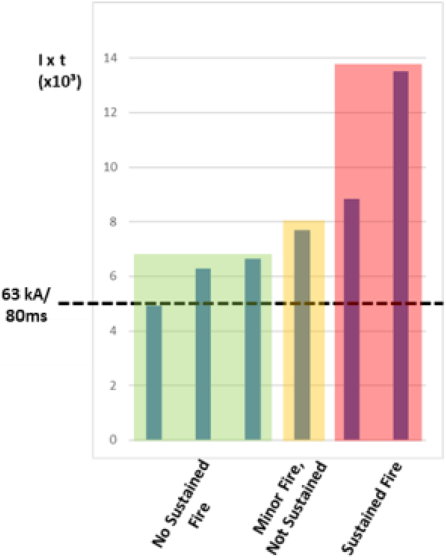
Test Results (cont)

- Our analysis for the tested 400 kV Al Sheath XLPE cable with fire retardant layer indicates that only faults with an I x t (current x time) threshold above 8000 A.s are expected to result in a sustained fire.
- This threshold substantially exceeds the normal maximum fault current/fault clearance time experienced on the UK transmission system. However, a delayed fault clearance may exceed this figure.



- During the tests, no evidence was seen of fire spreading beyond the immediate vicinity of the fault. Further testing (not reported in this paper) has confirmed that, in general, fire propagation is minimal for this type of cable.

Conclusions

- The laboratory fault simulation tests have indicated that, under normal operational conditions on the UK NETS, 400kV XLPE cables with a fire-retardant oversheath are not expected to initiate a sustained fire as a result of an internal fault.
- There is, however, a risk that at higher system fault levels a fault, that is not cleared by fast main protection systems, could result in a sustained fire.
- The immediate effects of the fault that were observed in all the test cases would present a significant risk to personnel in the immediate vicinity. Whilst the plasma jet ejected from the fault was highly directional, the effects in the confined space of a tunnel could be unpredictable and the pressure pulse may present hazards over a wider area.
- The tests demonstrated that the plasma jet did not present a serious risk to the integrity of other cable assets at a separation distance of 2m, representing the separation between circuits installed on opposite sides of a cable tunnel. The plasma jet/pressure pulse may, however, affect other tunnel equipment that is not adequately protected
- Where a sustained fire was initiated by the fault, the post-fault effects did not present an immediate risk to personnel or other assets. Following Test 4 the fire was left to develop over a period of 15 minutes and over this time the effects were very localised.
- The results of the fault simulation tests provide strong evidence that the risk of a sustained fire is linked to the energy released in the fault.
- Due to the non-linear electrical characteristics of fault arcs, it is understood that the energy released in a fault is proportional to I x t, where I is the rms fault current and t the duration of the fault.
- The above information has allowed NGET to carry out probabilistic analysis of cables catching fire using cable fault frequency, fault levels and protection operations information. This has then informed the life safety aspects of the LPT tunnels design.
- NGET have undertaken further tests to determine if a sustained fire can propagate to an adjacent phase or ramp up in intensity. Results indicate that this is not the case, and that in most orientations any fire self-extinguished in less than one hour. However, this performance will clearly depend on the construction of the cable.