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REACTION TO FIRE OF CABLE SYSTEMS

G. DENCHE*
Red Eléctrica de España S.A.U.
Spain

N. GENERÓ
Grupo General Cable Sistemas
Spain

O. RODRIGUEZ
Iberdrola Distribución Eléctrica S.A.U.
Spain

I. ENRIQUEZ
Red Eléctrica de España S.A.U.
Spain

J. BARBETA
Grupo General Cable Sistemas
Spain

Abstract *– The uncertainty created by the reaction to fire of cables and their accessories installed on trays inside galleries and substations led to the project "Reaction to fire of cable systems" as a result of an agreement between the companies General Cable – Iberdrola – Red Eléctrica de España.*
In an initial phase of the project, the reaction to fire and smoke density measurements are compared in samples of Medium Voltage (MV) cables with different types of sheath, normal (N), security (S) and high security (HS), combining different coatings (fireproof paint). Tests are also undertaken, including accessories such as plastic material flanges and splices.
Based on the experience obtained in this initial phase, it is decided to carry out a second study, focused on High Voltage (HV) and Extra High Voltage (EHV) cables, performing tests with different configurations to analyze the influence of the arrangement of the cables on the spread of a fire, given that it is considered that the test standardized in IEC 60332-3-22 cat. A is not the most suitable for HV/EHV cables, due to their greater diameter and higher content of combustible material. Tests are also performed including plastic material flanges and coatings.

Keywords: Reaction to Fire – Fire Protection – High Voltage Cable Systems

1 INTRODUCTION

At present there are cables in the Spanish Electricity Distribution and Transport Network installed in galleries and substations without any kind of fire protection. The article [1] "Fire hazard of MV/HV cables installed in tunnels", presented in Jicable'07, reveals the catastrophic consequences that can arise when a fire occurs in cables without any kind of fire protection.

The uncertainty created by the reaction to fire of cables and their accessories installed on trays inside galleries and substations led to the project "Reaction to fire of cable systems" as a result of an agreement between the companies General Cable – Iberdrola – Red Eléctrica de España.

This study intends to determine the effectiveness of different types of technologies for the fire protection of cables.

- Cable designs with different levels of fire protection inherent in the special reaction to fire properties of their sheaths.
- Application of coatings with special fire properties as an external protection against fire.
- Influence of the accessories (splices, flanges) in the fire performance of cables.

* gdenche@ree.es

2 REACTION TO FIRE IN MEDIUM VOLTAGE CABLES

The tests and results of the reaction to fire study on medium voltage (MV) cables were presented in Jicable'11 in the article [2] "B.3.4 Study on the reaction to fire of medium voltage cables systems".

The cables and accessories tested are summarized below very briefly, together with the conclusions obtained:

2.1 Samples

Cables

Tests were carried out on three types of cable with a similar design up to the metal screen (aluminium conductor, XLPE insulation and metal screen consisting of copper wires), but their external sheath was different, depending on the degree of fire protection, (from less to more):

- Type 1 cable: Normal (N) Sheath without fire protection in polyethylene DMZ1 according to HD 620-1 (section 4.9.1 and table 4C)
- Type 2 cable: Security (S) Sheath with low level of fire protection in polyethylene DMZ2 according to HD 620-1 (section 4.9.1 and table 4C)
- Type 3 cable: High security (HS) Sheath with high level of fire protection in polyethylene DMZ2 according to HD 620-1 (section 4.9.1 and table 4C)

The type of cable chosen (cable of voltage 12/20 kV and cross-section 1x240 mm^2 aluminium) is one of the most commonly installed in the Spanish distribution network in galleries and substations.

The type 1 and type 2 cables were coated with paint in order to have an additional fire protection, while the design of type 3 cable complies with the vertical fire spread test.

Coatings

The following paint types were tested:

- Two types of intumescent paint (I1, I2)
- Three types of ceramic paint (C1, C2, C3)

The thickness of the paint applied was that recommended by the paint manufacturers, there being a great variability between them.

Accessories

The following accessories were tested in order to know their influence on fire spread:

- Single-core polyamide flanges for a single-core medium voltage cable
- Three-core polyamide flanges for triads of medium voltage cable.
- Splices for cables with synthetic insulation up to 24 kV.

2.2 Conclusions

Paint is inefficient in type 1 cables with normal (N) sheath without special fire properties and unnecessary in type 3 cables with high security (HS) sheath with a high level of fire protection. Paint is only efficient in type 2 cables with security (S) sheath with a low level of fire protection.

From among the two paint types tested, the intumescent paints behave much better than the ceramic ones during the fire spread test, since they swell and partially cover the space between the cable triads, thus preventing progression of the fire.

In relation to the accessories, both the flanges and the splices burn, spreading the fire along the cables during the tests.

Installation of type 3 cables

In galleries or areas with a high density of cables, it is recommended to install type 3 cables, since their design satisfactorily complies with both the fire spread test and the smoke test.

In the study carried out, it is verified that there is a great difference in the fire performance between type 3 cable and type 2 or type 1 cable. However, the fire performance of type 2 cable and type 1 cable is not very different.

Installation of type 2 cables

Type 2 cables are installed in galleries with a low density of cables and in mixed installations in which the cables are buried or are a few metres in the air with a high density of cables.

With this cable type, the application of intumescent paint improves their fire performance. However, there are a series of aspects which must be taken into account:

- In the smoke tests performed, the level of transmittance is approximately 50%, the visibility therefore being significantly reduced.
- In the tests, the paint was applied completely and independently surrounding each of the cables which make up the triad. However, in a real installation, the cable surface which can be painted may be much less, above all on triads of cables installed in trefoil formation.
- Following the application of the paint, a curing time should be left, which can vary from 4 or 5 days up to one month, depending on the paint manufacturer.

Installation of type 1 cables

Type 1 cables coated with paint do not pass the fire spread test. Therefore, the only possible solution with type 1 cables installed in galleries is to replace them with type 3 cables.

The installation of type 1 cables is only recommended in completely buried installations.

Accessories

The accessories tested (polyamide flanges and splices) were the cause of fire spread in type 3 cables, while these cables alone, that is to say without flanges, pass the fire spread test. It can therefore be concluded that the accessories (polyamide flanges and splices) have a negative impact in relation to fire spread.

In relation to the flanges, it is recommended to use metal flanges to improve the fire performance of the cables.

3 REACTION TO FIRE IN HIGH AND EXTRA HIGH VOLTAGE CABLES

3.1 Objectives

The main objectives of the second phase of the project can be summarized in the following points:

- Perform a study on the performance of HV/EHV cables in the flame, fire and smoke tests.
- Assess the performance of the cables in different arrangements on the fire ladder and find the best configuration to adopt in real installation systems.
- Study the level of difference in performance of the normal (N) sheaths without special fire properties in relation to thigh securityhe high security (HS) sheaths with special fire properties.
- Observe what effect the incorporation of accessories (flanges and paint) has during the performance of a reaction to fire test on HV/EHV cable systems.

3.2 Samples

The following cable types were tested on performing the fire tests:

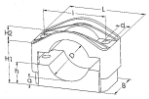
SAMPLE 1 RHZ1-RA+2OL (AS) 127/220 kV 1x630 mm² Al2 H250 with High Security (HS) sheath with special fire properties.

SAMPLE 2 RHZ1 (AS) 230/400 kV 1x2500 mm² Cu2 T810 with High Security (HS) sheath with special fire properties.

SAMPLE 3 RHE-RA+2OL 127/220 kV 1x2500 mm² Cu2 T375 with normal (N) sheath without special fire properties.

SAMPLE 4 RHZ1-RA+2OL (AS) 76/132 kV 1x1600 mm² Al2 H200 with High Security (HS) sheath with special fire properties.

The following coatings and accessories were tested during the second stage of the project:

TRADE NAME OF THE PRODUCT	COMPANY	COMMERCIAL DESCRIPTION OF THE PRODUCT	RISK IDENTIFICATION	IMAGE
CP 679 A	HILTI	Ablative paint for the protection of cables outdoors	Toxic by inhalation	
KOZ TRI 3x	KOZ	Three-core clamp 3x for cables	None	
SE type	DUTCHCLAMP	Single-core clamp 1x for cables	None	

3.3 Tests

The following tests were performed:

- **Reaction to the flame test to standard [3] IEC 60332-1-2:**

  A value is required of A > 50 mm and B ≤ 540 mm.

  This test is performed for different HV/EHV cables (with different sheath materials) and the difference between them is observed in relation to flame spread.

- **Smoke opacity test to standard [4] IEC 61034-2:**

  A value of transmittance is required of ≥60%.

  This test is performed for different HV/EHV cables (with different sheath materials) and the difference between them is observed in relation to smoke production. It will also be performed for the accessories mentioned in the previous section, with or without cable.

- **Reaction to fire test to standard [5] IEC 60332-3-22 (cat. A):**

  Test according to that established in standard IEC 60332-3-22 (cat. A) and tests based on standard IEC 60332-3-22 (cat. A) but with particularities:

  - Test on different arrangements on cable ladder bunched and in trefoil formation, with the aim of assessing which is the best configuration against fire.

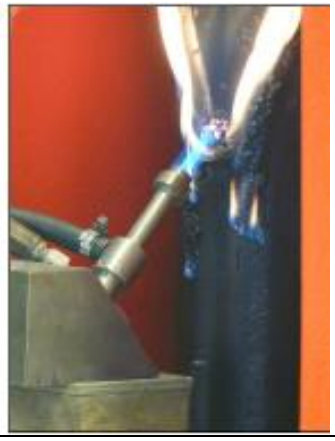
- Test on different levels of separation between cables or triads on ladder, with the aim of observing the influence of the chimney effect in accordance with the distance between cables.

The following test programme was carried out:

TESTS	SAMPLE 1 (127/220 kV 1x630 mm²)	SAMPLE 2 (230/400 kV 1x2500 mm²)	SAMPLE 3 (127/220 kV 1x2500 mm²)	SAMPLE 4 (76/132 kV 1x1600 mm²)
FLAME to IEC 60332-1-2	X	X	X	X
FLAME to IEC 60332-1-2 (1)			X	
SMOKE to IEC 61034-2	X	X	X	X
SMOKE to IEC 61034-2 (2)				X
FIRE CAT. A to IEC 60332-3-22	X	X		X
FIRE CAT. A to IEC 60332-3-22 (3)	X	X		X
FIRE CAT. A to IEC 60332-3-22 (4)	X			X
FIRE CAT. A to IEC 60332-3-22 (5)	X			
FIRE CAT. A to IEC 60332-3-22 (6)				X
FIRE CAT. A to IEC 60332-3-22 (7)				X
FIRE CAT. A to IEC 60332-3-22 (8)				X

In green: **TESTS ACCORDING TO STANDARD**

(1) Special flame test, with the burner raised on a 21 cm platform to be able to observe better the dripping of the polyethylene during the test:



(2) Smoke test carried out on cable of sample 4, coated with ablative paint reference CP 679 A from Hilti:

(3) Non-fire spread test category A, with special assembly of a triad of cables in trefoil formation, on 300 mm ladder and one burner:

(4) Non-fire spread test category A, with special assembly of a triad of bunched cables, separated by half a diameter between them, on 600 mm ladder and two burners:

(5) Non-fire spread test category A, with special assembly of a triad of cables in trefoil formation, on 300 mm ladder and one burner, with three clamps KOZ TRI 3x without metal protection (separation between clamps 120 cm; first clamp at 25 cm from the burner):

(6) Non-fire spread test category A, with special assembly of a triad of bunched cables, separated 140 mm between them, on 600 mm ladder and two burners:

(7) Non-fire spread test category A, with special assembly of two pieces of cable, separated the maximum distance between them (300 mm approx.),

(8) Non-fire spread test category A, with special assembly of two pieces of cable, separated 200 mm between them, on 600 mm ladder and two burners:

on 600 mm ladder and two burners: 	

3.4 Results

The results obtained in the tests performed on the different samples are shown below:

Sample	Sheath type	Fire tests					
		FLAME to IEC 60332-1-2 (A > 50 mm, B ≤ 540 mm)	SMOKE to IEC 61034-2 (T ≥ 60%)	FIRE to IEC 60332-3-22 cat. A (acc. to standard)	FIRE to IEC 60332-3-22 cat. A [3]	FIRE to IEC 60332-3-22 cat. A [4]	FIRE to IEC 60332-3-22 cat. A [5]
1	High security (HS)	**OK** (A = 357 mm; B = 514 mm)	Test 1 - **KO** (54.49%) Test 2 - **KO** (56.12%)	**OK** (1.14 m)	**OK** (0.70 m)	**KO** (3.30 m; extinction caused in minute 20)	**~** (0.50 m; high smoke production and very unpleasant odour)

Sample	Sheath type	Fire tests			
		FLAME to IEC 60332-1-2 (A > 50 mm, B ≤ 540 mm)	SMOKE to IEC 61034-2 (T ≥ 60%)	FIRE to IEC 60332-3-22 cat. A (acc. to standard)	FIRE to IEC 60332-3-22 cat. A [3]
2	High security (HS)	**OK** (A = 340 mm; B = 511 mm)	Test 1 - **OK** (60.90%) Test 2 - **OK** (61.89%)	**OK** (2.20 m)	**OK** (0.60 m)

Sample	Sheath type	Fire tests

		FLAME to IEC 60332-1-2 (A > 50 mm, B ≤ 540 mm)	FLAME to IEC 60332-1-2 (A > 50 mm, B ≤ 540 mm) [1]	SMOKE to IEC 61034-2 (T ≥ 60%)	SMOKE to IEC 61034-2 (T ≥ 60%) ONLY single-core flange Dutchclamp
3	Normal (N)	~ (material melted but not carbonized; the screen can be seen)	~ (material melted but not carbonized; drips below the distance permitted)	KO (39.91%)	OK (72.90%)

Sample	Sheath type	Fire tests						
		FLAME to IEC 60332-1-2 (A > 50 mm, B ≤ 540 mm)	FIRE to IEC 60332-3-22 cat. A (acc. to standard)	FIRE to IEC 60332-3-22 cat. A [3]	FIRE to IEC 60332-3-22 cat. A [4]	FIRE to IEC 60332-3-22 cat. A [6]	FIRE to IEC 60332-3-22 cat. A [7]	FIRE to IEC 60332-3-22 cat. A [8]
4	High security (HS)	OK (A = 318 mm; B = 510 mm)	OK (1.10 m)	OK (0.70 m)	KO (3.30 m; extinction caused in minute 18)	KO (3.30 m.)	OK (1.70 m)	KO (3.30)

4 CONCLUSIONS

Flame performance

A HV/EHV cable designated (S), with security against the flame, must be designed with a sheath with a certain degree of fireproofing in order to guarantee good performance in the test to IEC 60332-1-2 and, more importantly, good performance against a flame occurring in a real installation.

In the tests undertaken it is revealed that, on cables with a normal (N) sheath, the polyethylene drips downwards, introducing the risk of setting fire to other elements of the installation. Polyethylene is therefore completely inadvisable for type (S) fireproof applications.

Smoke performance

The smoke test to IEC 61034-2 is very critical for cables with a large diameter. Compliance with the test is compulsory for HV/EHV cables with (HS), high security, properties.

The results of the tests performed show that the smoke test is not very repetitive if the environmental conditions change, and whether or not a blank test is previously performed. The following are the main conclusions of the analysis of the tests undertaken on HV/EHV cables:

- The result of the first test of the day improves if it is performed before a blank test. The fact that the sheet of the smoke test chamber is heated means that the smoke mixture is more homogeneous inside the enclosure. Standard IEC 61034-2 indicates that “if it is necessary” a blank test can be undertaken before the first test. It is recommended to carry out this test provided that a previous smoke test has not been performed.
- The ambient temperature and temperature inside the chamber influence the final result. The higher the temperature, the better the result.
- The real transmittance in the chamber after a test does not return to 100% until 30 minutes have passed with the chamber closed and the smoke extraction in operation. The recovery level was measured on numerous occasions and it was decided to establish a minimum of 30 minutes between one test and the next one, so as not to start the following test with any remaining smoke in the chamber, which would distort the result.

Fire performance

All the HV/EHV cables designated (HS), High security, which were tested in this study, successfully passed the fire test category A to IEC 60332-3-22.

Once the test had been passed according to the standard, two different configurations were basically tested, triads of cables in trefoil formation and triads of bunched cables, in order to simulate with greater precision the real conditions of an HV/EHV cable installation.

The main conclusion is that the fire performance of the configuration of triads of cables in trefoil formation is much better than the configuration of triads of bunched cables. The cables in triads in trefoil formation protect themselves against the fire on acting as a group or block against the flames. The bunched cables in triads each act independently against the flames, in addition to leaving spaces between them which favour the progress of the fire (chimney effect).

However, if the configuration of bunched triads was necessary, it is recommended to space the cables with a minimum of 300 mm between them, since it has been proven that starting from this separation between cables the chimney effect produced in a fire is reduced or even cancelled out. If the cables are not in contact, that is to say they are separated, the closer together the cables are the worse their fire performance will be, creating a passage for the fire to continue to make progress.

Finally, in relation to the clamps KOZ TRI 99-120, they performed very well in relation to non-fire spread, acting as firebreaks, but on the contrary they emitted an unpleasant odour and smoke which is undesirable in any cable installation that has to be accessed in the event of fire.

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[3] IEC 60332-1-2:2004 “Tests on electric and optical fibre cables under fire conditions - Part 1-2: Test for vertical flame spread for a single insulated wire or cable - Procedure for 1 kW pre-mixed flame

[4] IEC 61034-2:2005 “Measurement of smoke density of cables burning under defined conditions - Part 2: Test procedure and requirements”

[5] IEC 60332-3-22:2000+AMD1:2008 “Tests on electric and optical fibre cables under fire conditions - Part 3-22: Test for vertical flame spread of vertically-mounted bunched wires or cables - Category A”