STUDY ON THE REACTION TO FIRE OF MEDIUM VOLTAGE CABLES SYSTEMS

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ABSTRACT

The uncertainty created by the reaction to fire of medium voltage cables and their accessories installed on trays inside galleries and substations has given rise to this joint project by General Cable, Iberdrola and Red Eléctrica de España. A specification is made for a set of fire reaction tests to determine the most appropriate protection to use.

The study, focused on the test for vertical fire spread cat. A, was carried out on the following cables systems:

- *MV cables with fireproof barriers included in the design*
- *MV cables coated with fireproof paint: efficacy of the different coatings applied*
- *MV cables with clamps or joints: effect of the accessories during the test*

The coatings are ineffective on non-fireproofed cables (type 1) and unnecessary on cables with a high fireproofing level (type 3). The coatings are only effective on cables with a low level of fireproofing (type 2).

Of the two types of fireproof coatings used, the intumescent coatings behave much better than the ceramic ones during the fire test, as they swell, partially covering the empty space between cable triads and, therefore, preventing the fire from progressing.

In relation to accessories, both clamps and joints burn, spreading the fire along the cables during the test.

KEYWORDS

Fire protection; medium voltage cables systems; fireproof coatings; intumescent; ceramic; joints; clamps

INTRODUCTION

At present there are cables to transport and distribute energy installed in galleries and substations without any kind of fire protection. The report presented in Jicable'07 with the title “Fire hazard of MV/HV cables installed in tunnels” established the catastrophic consequences which can result from a fire should the cables installed not have any type of fire protection [1].

The uncertainty created by the reaction to fire of these cables and their accessories, installed on trays inside galleries and substations, has given rise to this project as a result of a commercial agreement between Grupo General Cable Sistemas, Iberdrola and Red Eléctrica de España.

This study assesses the practical effectiveness of the different fire protection technologies. Different levels of fireproofing inherent in the cable design are considered, in addition to external fire protection systems through the use of fireproof coatings. The influence of the accessories (fastening clamps, joints) on the spread of the fire is also assessed.

The following are the main requirements to be able to carry out the project:

- Analyze which medium voltage cable designs are those most installed in galleries and substations and decide which are going to be the prototypes to test
- Decide on the part of Iberdrola and REE which are the fireproof coatings and accessories to be used on the cables systems during the implementation of the project

EXPERIMENTAL

Cables

The three prototypes of cables used for the study have the same design up to the screen phase (aluminium conductor, XLPE insulation and copper wire screen), but their sheaths are different depending on their degree of fireproofing (from less to more):

- Cable type 1, corresponding to a non-fireproofed cable, with DMZ1 polyethylene sheath, according to standard HD 620-1 (section 4.9.1 and table 4C)
- Cable type 2, corresponding to a cable with a low level of fireproofing, with DMZ2 sheath, according to standard HD 620-1 (section 4.9.1 and table 4C)
- Cable type 3, corresponding to a cable with a high level of fireproofing, with fireproof filling plus DMZ2 sheath, according to standard HD 620-1 (section 4.9.1 and table 4C)

They were tested alone to obtain the reference standards. Cable types 1 and 2 were coated with fireproof paint, as the type 3 cables already pass the test for vertical fire spread according to the assembly of triads described below.

The typology of cables chosen (voltage of 12/20 kV and formation of 1x240 mm²) is one of the most sold and installed in medium voltage for galleries and substations.

Coatings

The following paints were chosen to coat the cables to be tested:

- Two intumescent coatings of fire protection (I1, I2)
- Three ceramic coatings of fire protection (C1, C2, C3)

The thickness of the paint applied was in all cases that recommended by each manufacturer, a considerable level of variability existing between them.

The fireproof coatings were applied to each cable individually and then were joined in the form of triads to carry out the tests, although this is not the usual procedure in an installation.

It should be recalled that in an installation the cables are already placed in the form of triads and, therefore, on applying the coatings this will be carried out on each triad and not on each cable individually. This should therefore be taken into account on drawing conclusions for the protection of cables in galleries and substations. A little more thickness of the layer of paint will possibly be needed to achieve the same results as those obtained in this study.

Another factor to be taken into account on coating installed cables is the curing time of the coatings. These vary greatly and go from four or five days to almost a month. These curing time differences can be observed in table 2.

Accessories

The following accessories were chosen to assess their influence on the spreading of fire:

- Clamps for unipolar, three-pole or multipolar medium voltage cables or leads
- Straight plug-in joints for cables with synthetic insulation up to 24 kV

Test definition

The study was performed using as reference the test to IEC 60332-3-22 (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) [2]. Although in actual fact the cables in galleries and substations are mainly installed horizontally, the vertical arrangement of the test chosen makes the test tougher and allows an already widely tested procedure to be used. This test was modified slightly to simulate more precisely the true situation of the installation of the cables (figure 1).

Figure 1: Cables on the stairs forming two triads

For all the tests, the cables were arranged on stairs forming two triads, separated by a diameter of cable.

The following are the main test parameters:

- Time of application of the flame: 40 minutes
- Number of burners: 1
- Effective width of the standardized stairs: 300 mm

And the requirements for fulfilment of the test:

- Front length affected: maximum 2,50 m
- Rear length affected: maximum 2,50 m

Test programme

The test programme carried out is presented in table 1. It is observed that the sequence begins with the tests of the standard cables. The first three tests are used as reference to compare the behaviour of the cables with that of the cables coated with fireproof paints or with accessories in the assembly.

Initially, the tests on completely painted cables (the whole length of 3,5 m) were chosen as a safe option, while the alterative of painting just a 1 m strip (of the total 3,5 m) was considered to be a more risky option. This was verified testing the first of the coatings with a painted strip of between 1,5 m and 2,5 m of the total 3,5 m. It was clearly observed that a painted strip was not sufficient to stop the fire. It was therefore decided to test the rest of the coatings on completely painted cables and to compare their different behaviours.

No.	Sample	Standard	Coatings or Accessories
1	Type 3	X	
2	Type 2	X	
3	Type 1	X	
4	Type 2 + I1 complete		X
5	Type 1 + I1 complete		X
6	Type 2 + I1 strip		X
7	Type 2 + C1 complete		X
8	Type 2 + C2 complete		X
9	Type 2 + C3 complete		X
10	Type 2 + I2 complete		X
11	Type 3 + 6 clamps		X
12	Type 3 + 4 joints		X

Table 1: Test programme

In relation to the accessories, it was decided to test the clamps on the one hand and the joints on the other on type 3 cables, which already pass the test by themselves. In the case of test 11, it was performed by placing six polyamide clamps on the assembly, three on each triad.

RESULTS

The results obtained from the test programme are shown in table 2.

No.	Average thickness paint layer (mm)	Curing time (days)	Maximum length affected (m)
1	-	-	**1,09**
2	-	-	**3,50**
3	-	-	**3,50**
4	0,87	14	**1,05**
5	1,34	14	**3,50**
6	1,28	14	**3,50**
7	3,49	4	**0,62**
8	2,15	30	**2,29**
9	5,55	4	**0,75**
10	1,66	7	**1,42**
11	-	-	**3,50**
12	-	-	**3,50**

Table 2: Results

All the cables tested were previously conditioned for a minimum of 48 hours and a maximum of 96 hours, at a temperature of 60ºC.

Prior to assessing the best protection for cables installed in galleries and substations, the behaviour of three cables called reference standards was studied: type 3 cable, a design initially considered to fulfil fire category B, satisfactorily passed the category A test with the assembly particularities described above. Therefore, with a type 3 design no type of coating is necessary to pass the fire reaction test described in the work plan. In turn, the type 2 and type 1 cables, as was expected, did not pass the test by themselves.

DISCUSSION

The type 2 standard cable, although it did not pass the fire test by itself, has a fire behaviour which can be considered as acceptable up to approximately minute 15.

Comparisons of temperature and height of flame *vs.* time were carried out for the 3 standard cables, with the aim of better understanding the evolution of the tests.

The temperature was measured with a thermocouple situated at a height of 1,5 m within the test chamber, while the height of the flame was recorded every 5 minutes of the test to see its evolution.

While for the type 3 cable the temperatures remained fairly stable throughout the test, for the type 2 and type 1 cables the temperatures shot up, reaching values above 600 ºC in a few minutes (figure 2). The height of the flame also followed a similar behaviour (figure 3).

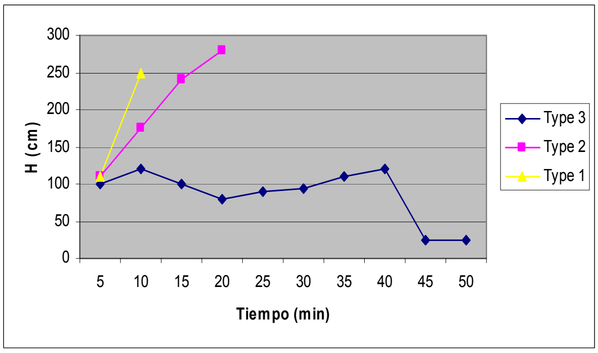

Figure 2: Temperature *vs.* time

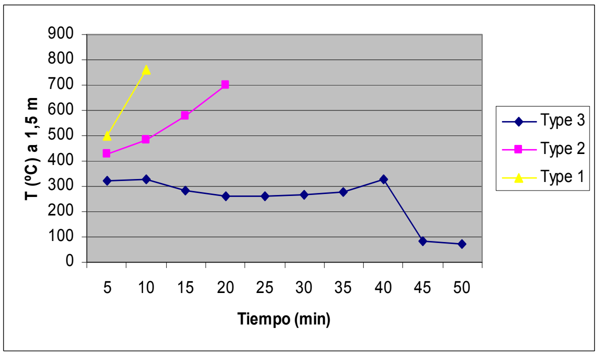

Figure 3: Height of the flame *vs.* time

From among the coatings applied, the intumescent type is the one with the best behaviour in the fire test. The reaction of the intumescent coating consists of swelling almost immediately and, consequently, the empty space between triads of cables is reduced, almost disappearing at some points. The speed of progress of the fire is thus reduced (figure 4).

On the contrary, the ceramic paints do not have this effect, so the thickness of the layer and its homogeneity become more decisive parameters on passing or failing the test (figure 5).

Figure 4: Intumescent reaction

Figure 5: Non-intumescent reaction

The temperature evolution curves for the cable with intumescent coating are more similar to those of the standard type 3 cable, while with the cable with ceramic coating the temperatures rise more sharply throughout the test. Moreover, the maximum temperature values reached by the cable with intumescent coating are much lower than those reached by the cable with ceramic coating (figures 6 and 7).

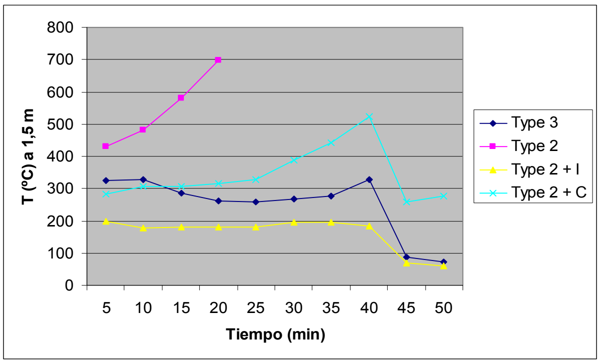

Figure 6: Temperature *vs.* time

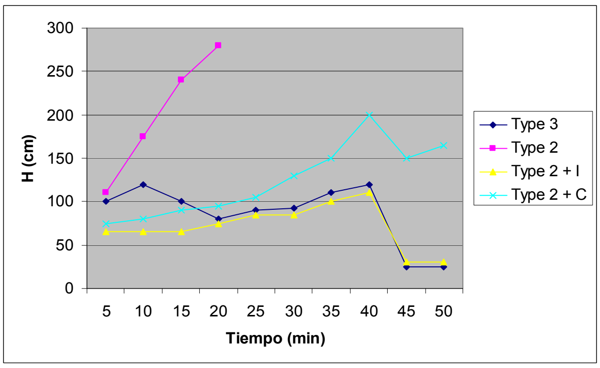

Figure 7: Height of the flame *vs.* time

From among the intumescent type coatings (I1 and I2), the former was the one with the best behaviour. With just an average thickness of the layer of paint of 0,87 mm, the length affected was approximately 1 m.

Coating I2, on the other hand, was a little thicker and the cable burned on 1,5 m. Furthermore, it was necessary to provoke the extinction one hour after the test (as indicated by the standard) and, although it passed the test, this fact is not a good indicator.

The evolution of temperatures for these two intumescent coatings (I1 and I2) presents a similar curve although with lower temperature values for I1. Indeed, this was one of those with the best behaviour in the fire test.

In relation to the non-intumescent type coatings (C1, C2 and C3), the cable which behaved the best was the C1 with a length affected of 0,62 m, but it should be taken into account that it had a considerable thickness of paint (3,5 mm).

Coating C3 also behaved well and the length affected was 0,75 m. However, in this case the average thickness of the layer of paint was over 5 mm, a value twice the average thicknesses of the rest of the coatings.

In relation to test C2, it came close to the fulfilment limit, burning around 2,3 m, with a thickness of the paint layer of 2,15 mm.

Finally, the accessories, both clamps and joints, burned vigorously and spread the fire along the cable. The tests were carried out on cables type 3, which pass the test by themselves, to see the effect of the accessories.

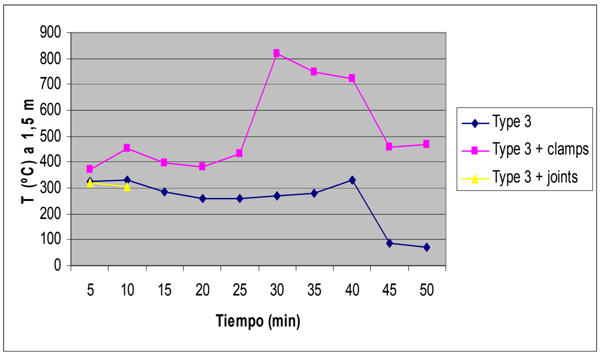

Figure 8: Temperature *vs.* time

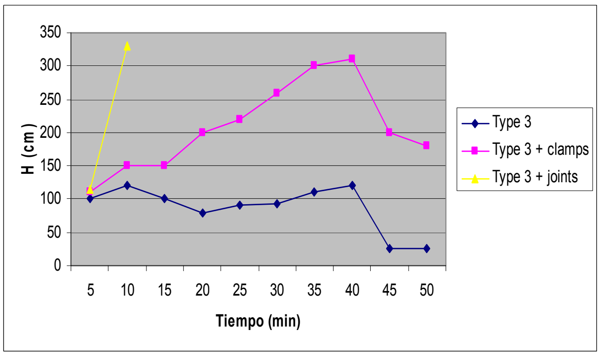

Figure 9: Height of the flame *vs.* time

We should recall that for cable type 3 the temperatures remained fairly stable, so the negative effect of the accessories is clear, both for the temperature reached and for the height of the flame.

CONCLUSIONS

Installations of type 3 cables

In this case the outdoor zones or galleries where the density of cables is high are identified.

It is recommended to install type 3 cables, which by themselves satisfactorily pass the fire and smoke tests, respectively.

It was verified that there is a great difference between the fire behaviour of type 3 cables and the behaviour of type 2 or 1 cables, while the difference in behaviour between the latter two is not so significant.

Installations of type 2 cables

With these installations the galleries with a low density of cables are identified, in addition to the mixed installations, where there are on the one hand buried cables and on the other hand some metres in the open air with a high density of cables.

In this case, the application of intumescent paints helps to improve the fire behaviour of type 2 cables. There is, however, a series of aspects to consider.

Special attention should be paid to the smoke test, during which the transmittance value fell to levels of approximately 50%. This means that during a fire the visibility would be significantly reduced.

Another aspect to take into account is the minimum thickness of the layer of paint to guarantee the good fire behaviour of the cable. During the tests, the cables forming triads were completely coated one by one, while in a real installation the accessible surface area which could be coated would be much less. It is therefore recommended to apply an average thickness of the layer of paint of 3 mm (a value above those tested in this project).

In relation to the previous point, the difficulty of access to the galleries for the application of the paint will also influence the surface area that it will be possible to coat with paint.

Finally, the ampacity of these cables will be reduced.

Installations of type 1 cables

Here the buried cables without fireproof requirements are identified.

The type 1 cables coated with fireproof paints do not pass the fire test. Therefore, the only immediate solution at present appears to be their replacement and the installation of new circuits.

Accessories

The accessories tested (polyamide clamps and joints) are the cause of the spread of the fire in a test with type 3 cables, which by themselves pass the test satisfactorily.

They will therefore have a negative impact in relation to the spreading of the fire. In relation to the clamps, the use of metallic clamps is recommended for fireproof requirements, thus preventing them from being the cause of a fire spreading.

REFERENCES

[1] Christian Philippczyk et al., 2007, “Fire hazard of MV/HV cables installed in tunnels”, Jicable’07, International Conference on Power Insulated Cables

[2] International Electrotechnical Commission, 2009, “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”, Group Safety Publication, Geneva, Switzerland