PERFORMANCE OF MEDIUM CABLE SYSTEMS ON THE REACTION TO FIRE

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ABSTRACT

The uncertainty created by the reaction to fire of medium voltage cables and their accessories installed inside galleries and substations has given rise to this joint study by General Cable, Iberdrola and Red Eléctrica de España.

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

- MV cables with fireproof barriers included in the design
- MV cables coated with fireproof paint
- MV cables with clamps or joints

The coatings are ineffective on non-fireproofed cables and unnecessary on cables with a high fireproofing level. The coatings are only effective on cables with a low level of fireproofing.

In relation to accessories, both (polyamide clamps and joints that we have tested) burn, spreading the fire along the cables during the test.

KEYWORDS

Fire protection; medium voltage cables systems; fireproof coatings; intumescent; ceramic; IEC 60332-3-22

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].

In recent years accidents have occurred in galleries and substations with different levels of seriousness. Some photographs demonstrating these accidents are shown below (figures 1 and 2):

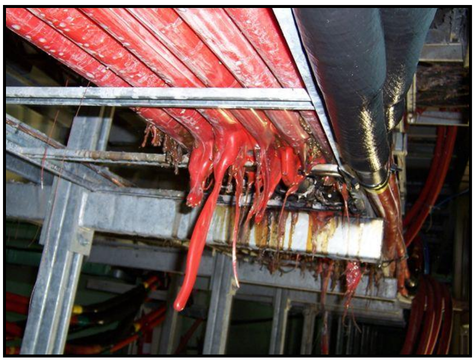

Figure 1

Figure 2

The different accidents occurring, with their related catastrophic consequences, together with 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 study as a result of a collaboration between Grupo General Cable Sistemas, 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.

As basic reference, the following test has been used: 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]. A standardized test was chosen, which allows the use of an already widely tested procedure, which can be repeated and reproduced in other laboratories. However, it has been decided to modify slightly the test to simulate more precisely the true situation of the installation of the cables, so as to be able to determine the most appropriate protection to be used in medium voltage cable systems.

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 mostly installed in galleries and substations in order to decide which are going to be the prototypes to test.
- Establish on the part of Iberdrola and REE which are the fireproof coatings and accessories to be used on 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) (figure 3):

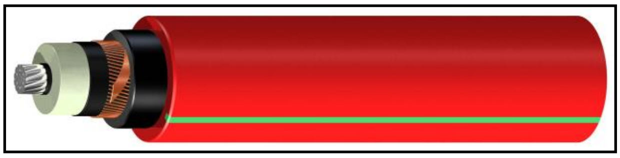

Figure 3

- The LP (Low Performance) cable, corresponding to a non-fireproofed cable, with DMZ1 polyethylene sheath, according to standard HD 620-1 (section 4.9.1 and table 4C)
- The MP (Medium Performance) cable, 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)
- The HP (High Performance) cable, 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. The LP (Low Performance) and MP (Medium Performance) cables were coated with fireproof paint, as the HP (High Performance) cables already pass the test for vertical fire spread according to the assembly of triads described below.

The typology of cable chosen has been voltage of 12/20 kV with section of 1x240 mm², that it is one of mostly sold and installed cables in medium voltage systems for galleries and substations.

Coatings

The following paints were chosen to cover the cables to be tested (figure 4):

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

Figure 4

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 they were joined in the form of triads to carry out the tests, although this is not the usual procedure of 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, with a variability going from four or five days to almost a month. These curing time differences can be observed in table 2.

Accessories

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

- Clamps for unipolar, three-pole or multipolar medium voltage cables or leads (figure 5)

Figure 5

- Straight plug-in joints for cables with synthetic insulation up to 24 kV (figure 6)

Figure 6

Test definition

As indicated above, 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].

The aim of the test was to determine the transmission capacity of the fire through the sheath of a group of cables assembled simulating a real installation.

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 a known, widely tested and reproducible, procedure to be used. This test was modified slightly to simulate more precisely the true situation of the installation of the cables (figure 7).

Figure 7: 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 equipment and tools used during the test are described below:

- Standardized chamber (with emergency extinction)
- Standardized stairs
- Forced ventilation system (5000 l/min)
- Standardized burner/s (with calorific value equivalent to 20.5 kW, using a mixture of propane and air)
- Panel: calibrated gas and air flow meters and manometers at their outlet (measurement of the flow and pressure of the gas-air mixture in the burner)
- System of thermocouples placed at the gate, at a height of 1.5 m and 2.5 m (they do not appear in the standard, only for internal record and indicative values)
- Additional material: timer, tape measure, calliper, scales, sharp object (knife or similar)

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 2.5 m
- Rear length affected: maximum 2.5 m

The area where the sheath material (where there is still sheath) is not detached on scraping it with a sharp object is considered as NOT affected. The height of the affected area is measured from the upper part of the burner.

The area called carbonized is actually measured. Although the material has changed colour, if it still maintains plasticity it is not considered as a fire-affected area. Also, it does not matter if it has been cut and detached at the joins.

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 alternative of painting just a 1 m strip (of the total 3.5 m) was considered to be a more risky option. This was proved by 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, showing clearly that a painted strip was not sufficient to stop the fire (figure 8).

Figure 8

It was therefore decided to test the rest of the coatings on completely painted cables and to compare their different behaviours.

The test programme is shown below:

No.	Sample	Standard	Coatings or Accessories
1	HP (High Performance)	X	
2	MP (Medium Performance)	X	
3	LP (Low Performance)	X	
4	MP + I1 complete		X
5	LP + I1 complete		X
6	MP + I1 strip		X
7	MP + C1 complete		X
8	MP + C2 complete		X
9	MP + C3 complete		X
10	MP + I2 complete		X
11	HP + 6 Clamps		X
12	HP + 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 HP (High Performance) 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

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: HP (High Performance) cable, a design initially conceived to fulfil fire category B, satisfactorily passed the category A test with the assembly particularities described above.

Therefore, with an HP (High Performance) design no type of coating is necessary to pass the fire reaction test described in the work plan. In turn, the MP (Medium Performance) and LP (Low Performance) cables, as was expected, did not pass the test by themselves.

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)	Results
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

The MP (Medium Performance) standard cable, although it did not pass the fire test (UNE EN 50266-2-2 with the particularities described above), has a fire behaviour which can be considered as acceptable up to approximately minute 10 – 15.

DISCUSSION

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 HP (High Performance) cable the temperatures remained fairly stable throughout the test, for the MP (Medium Performance) cable and above all for the LP (Low Performance) cable the temperatures shot up, reaching values above 600 – 700 ºC in a few minutes (figure 9). The height of the flame also followed a similar behaviour (figure 10).

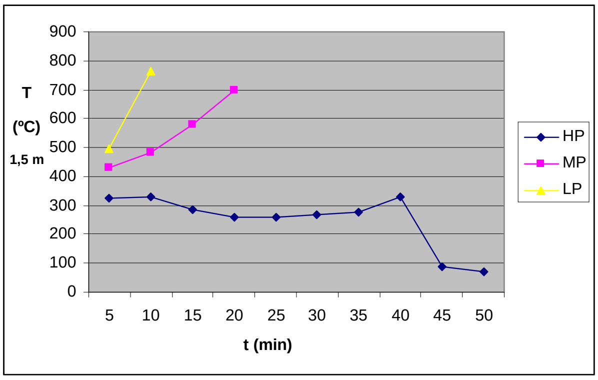

Figure 9: Temperature vs. time

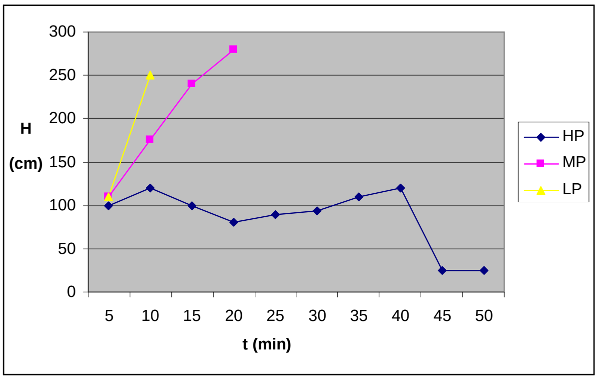

Figure 10: Height of the flame vs. time

From among the coatings applied, the intumescent type was 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.

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.

It should be taken into account that the application of the paint was carried out cable by cable and not on each triad already installed on the test stairs. In a real installation the cables could not be painted one by one, so their efficiency would be reduced in relation to the study carried out. It should moreover be mentioned that the paint has a working life of approximately 10 years, while the working life of the cables is around 40 years. This means that the paint applications should be repeated over the years, repainting the installed triads with the associated cost that this represents.

Figure 11: Intumescent reaction

Figure 12: Non-intumescent reaction

The temperature evolution curves for the cable with intumescent coating are more similar to those of the standard HP (High Performance) 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 13 and 14).

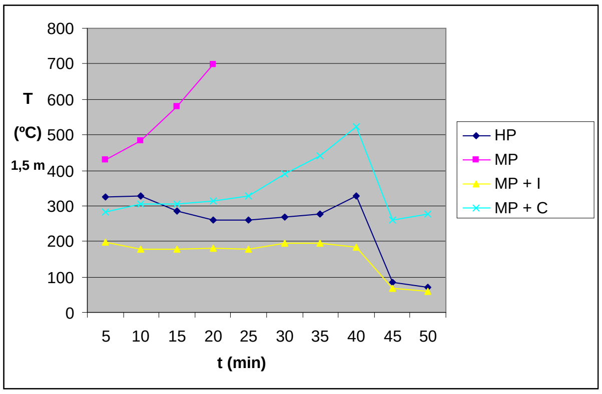

Figure 13

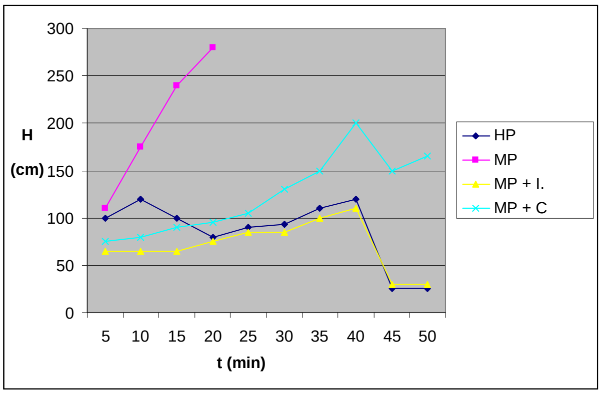

Figure 14

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 following results and conclusions were obtained:

The cable which behaved the best was the C1 with a length affected of 62 cm, 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 75 cm. However, in this case the average thickness of the layer of paint was over 5 mm, a value at least 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 HP (High Performance) cables, which pass the test by themselves, to see the effect of the accessories.

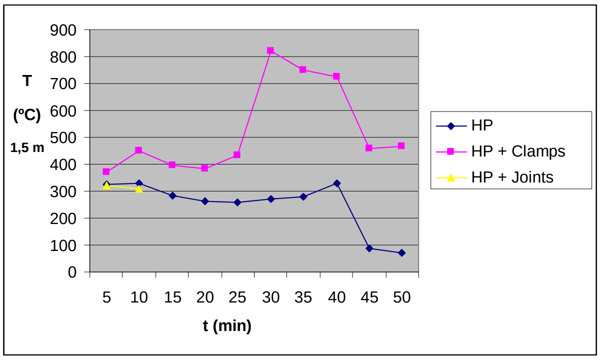

Figure 15

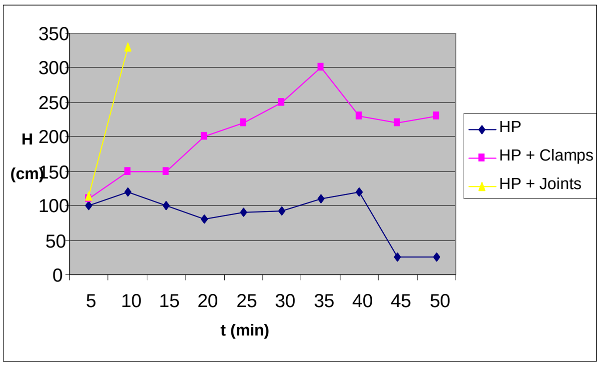

Figure 16

We should recall that for HP (High Performance) cable 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

In view of the results obtained, three types of installations can be distinguished:

- Installations of HP (High Performance) cables
- Installations of MP (Medium Performance) cables
- Installations of LP (Low Performance) cables

The conclusions obtained from the study are detailed below for the three different types of installations, and for the accessories tested (clamps and joints).

<u>Installations of HP (High Performance) cables</u>

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

It is recommended to install HP (High Performance) 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 HP (High Performance) cables and the behaviour of MP (Medium Performance) or LP (Low Performance) cables, while the difference in behaviour between the latter two is not so significant.

Installations of MP (Medium Performance) 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 MP (Medium Performance) 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 would mean 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 some 3 mm (a value above those tested in the 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 LP (Low Performance) cables

Here the buried cables without fireproof requirements are identified.

The LP (Low Performance) 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 HP (High Performance) 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, it should be mentioned that those tested within the framework of this study, in polyamide, did not pass the fire test. Moreover, opaque smoke was produced during the test. For these reasons the use of metallic clamps is recommended for fireproof requirements, thus preventing them from being the cause of a fire spreading.

As for the joints, it is advisable to avoid installing them in critical areas. For example, in a 600 m long gallery it is not necessary to install joints inside the gallery. They can be installed before or after it.

REFERENCES

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