# EXTERNAL CONDUCTIVE LAYER ON EDP MV UNDERGROUND CABLES LEADS TO NEW OVERSHEATH REQUIREMENTS

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## *ABSTRACT*

*EDP Distribuição is the main Distribution System Operator (DSO) in Portugal and operates approximately 73.000 km of Medium Voltage (MV) network which is comprised by roughly 20% with underground insulated cables. This topology, used mainly in urban areas, is more reliable than overhead systems, but on the downside is harder to perform O&M activities so when an underground system does fail it is more costly and time consuming to repair, making it crucial to ensure the reliability of these systems.*

*Bearing this in mind, EDP Distribuição has taken several measures to improve the reliability of underground networks, such as updating its specifications, launching new cable qualification processes and performing additional acceptance and commissioning tests on MV insulated cables. These actions have been proven vital in guaranteeing the quality of this systems.*

*In order to perform commissioning tests to verify that the characteristics of the oversheath of a MV insulated cable did not degrade over time or during the installation process, it is required that an outer conductive layer is applied directly on top of the oversheath. This conductive layer, which is directly extruded on top of the cable oversheath, is usually black due to carbon black materials used to provide conductive properties to cable compounds. The fact that EDP Distribuição cables have black coloured oversheath brings new challenges for the operators when installing cable accessories that require removal of the outer conductive layer.*

*Hence, this paper presents the evolution of EDP Distribuição MV underground cables, a complete description of the identified challenges, including inputs from O&M structures, and a solution that better fulfils EDP Distribuição requirements.*

## INTRODUCTION

EDP Distribuição is the Portuguese main Distribution System Operator (DSO), operating in all continental territory of the country. The distribution network was comprised, at the end of 2015, of ~14.300 km of Medium Voltage underground insulated cables, which is roughly 20% of the total Medium Voltage network [1]. Also, EDP Distribuição has acquired, in 2015, roughly 585 km of new Medium Voltage underground insulated cables, representing an increase of about 4% of the total underground insulated cables installed.

These MV underground insulated cables are generally more reliable than overhead lines, which are much more exposed and generate most of the short duration interruptions (< 3 min). However, when there is a failure in a MV underground insulated cable it is much harder, costly and time consuming to repair, which makes it crucial to ensure the reliability of these cables.

To guarantee the reliability, EDP Distribuição chose to include in the 2008 revision of the MV insulated cable specification, routine and after installation tests to verify the electrical integrity of the oversheath according to IEC 60229:2007 standard. These were then incorporated within acceptance and commissioning tests respectively. In order to facilitate the realization of those tests, the oversheath requires an outer electrode, for example a conductive layer [2]. This led to the inclusion of an additional requirement in the specification: the incorporation of a non-metallic semi-conductive layer extruded directly above the oversheath, embracing it completely. The resulting cable construction is demonstrated in Figure 1.

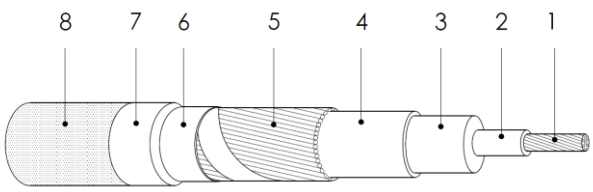


**Figure 1:** EDP Distribuição MV insulated cable construction [3].

The numbers in Figure 1 represent the following components:

1. Conductor;
2. Conductor semi-conductive screen;
3. Insulation (XLPE);
4. Insulation semi-conductive screen;
5. Metallic screen;
6. Longitudinal water tightness layer;
7. Oversheath;
8. **External conductive layer.**

Bearing this is mind, the focus of this paper is to present a brief characterization of the advantages of having an external conductive layer above the oversheath of the MV insulated cables, as well as identifying some challenges that arose from the addition of this layer and presenting a solution for those challenges.

## IDENTIFIED CHALLENGES

The main advantages of having the external conductive layer is to perform after installation tests and to facilitate the realization of the routine test after manufacture or transportation, as the test can be done with the cable placed in the drum.

However, because both the oversheath and the external conductive layers are black coloured, some challenges started to emerge, mostly regarding situations where the external conductive layer has to be removed. These situations were:

i. During laboratory tests
ii. When applying cable accessories

The main reason for the oversheath being black coloured is that, historically, the oversheath of EDP Distribuição MV insulated cables were black, as recommended in IEC 60502-2 standard [4]. Regarding the external conductive layer, it is black coloured because of the content of carbon black that is used to give electrical conductive properties to the plastic compound that allows this layer to be extruded directly on top of the oversheath.

In the following sections, it will be presented details about the identified challenges, split between the two situations stated before.

### Laboratory Tests Challenges

During type and sample tests, done in laboratory, some difficulties were encountered, mainly because some manufacturers were not used to manufacture MV insulated cables with black coloured oversheath and with the external conductive layer directly extruded on top of it.

One of the tests that posed a challenge was the dimensional verification test, particularly the oversheath dimensions since it is not possible to clearly see the separation of both components. On top of that, if we removed the external conductive layer, it is not possible to guarantee that some bits of the oversheath won't also be removed, thus making the test inaccurate.

The other test that posed some challenges, was the test for determining the mechanical properties of the oversheath. This test requires the preparation of standard test pieces, and because of the said inexperience, the test pieces that were prepared were cut directly from the oversheath, without removing the external conductive layer. This caused the tensile tests performed on the test pieces to give strange results, as shown in Image 1, where the material corresponding to the oversheath did break, but the material corresponding to the external conductive layer stretched without breaking, thus providing inconclusive information about the test result. However in this case, the tests can be done correctly if the external conductive layer is removed prior to the preparation of the test pieces.

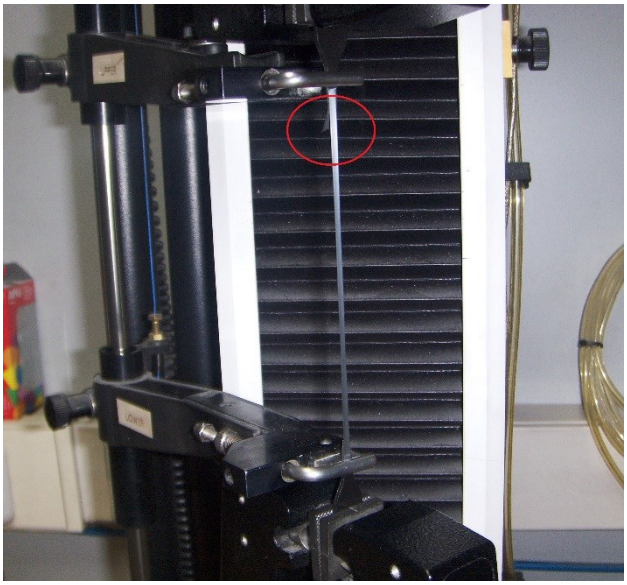

**Image 1:** Result of tensile test to verify the mechanical properties of the oversheath, performed in a test piece with oversheath and external conductive layer.

### Challenges Applying Cable Accessories

The 2008 revision of EDP Distribuição MV insulated cable specification, which among other modifications, introduced the external conductive layer, led to the acquisition and installation of those cables. However, because of the new external conductive layer, some procedures needed to be updated, for instance, when applying cable accessories, like joints or terminations.

These procedures now require the removal of the external conductive layer when preparing the cable to install the cable accessory. This is essential to ensure that there is enough clearance between the metallic screen and the external conductive layer in order to prevent any tracking/flashover when the after installation test to verify the electrical integrity of the oversheath is being conducted. The removal of the external conductive layer is illustrated in Images 2 and 3, and due to the fact that both this layer and the oversheath are black coloured, the operator must confirm that the conductive layer was completely removed with a multimeter. This confirmation is crucial, because besides the fact that there is no visual difference between these cable components, the thickness of the external conductive layer varies between different cable manufacturers.

**Image 2:** Process of removing the external conductive layer (1).

**Image 3:** Process of removing the external conductive layer (2).

This led to the first challenge, which is the need for the operator to check thoroughly with the multimeter if the external conductive layer was completely removed. This process represents an increase in the overall application of the cable accessory of approximately 3 minutes per accessory. Bearing in mind that EDP Distribuição installs approximately 4300 joints annually, at the end of the year it represents at least an increment of 215 work hours, which impacts directly the cost of installation.

The other challenge arising from the application of cable accessories, besides the increase in time, is when for any reason the operator does not completely remove the external conductive layer. If this happens when applying a joint, afterwards during the after installation test to verify the electrical integrity of the oversheath of the cables in the circuit, the result will be a false positive. In other words, the result of the test will indicate a possible problem in the oversheath of one cable, when in fact the only problem was that the external conductive layer was not completely removed when applying one joint.

This problem has a great monetary impact, because it requires that the joints, already underground, must be located and remade.

## SOLUTION

In 2014, when EDP Distribuição started to work in the revision of the MV insulated cables specification, it was clear that something must be done to address the identified challenges.

After internal discussion, and talking with manufacturers, the solution found was to change the colour of the oversheath. This solution provides visual identification of every component of the MV insulated cable, which facilitates the realization of laboratory tests like the dimensional verification and the verification of the mechanical properties of the oversheath, as well as allowing the operator in the field to be faster and more reliable, mitigating the challenges addressed in the previous section. Additionally, this solution does not have a significant impact in the cost of the MV insulated cables.

Image 4 shows one sample of a MV insulated cable that has a red coloured oversheath and on top of it an external conductive layer.

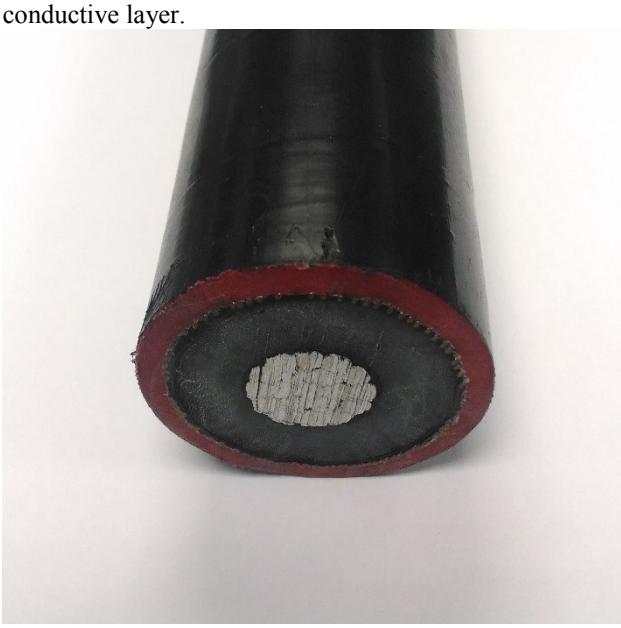

**Image 4:** MV insulated cable sample with external conductive layer and red coloured oversheath.

This solution was considered in the 2015 revision of the MV insulating cables specification [3], and represents one of the features that demonstrates our interest in being on the leading edge of the cable specifications.

## CONCLUSIONS

This paper is aimed at all of those that are involved in choosing or specifying Medium Voltage insulated cables. It states some advantages of having an external conductive layer that were identified, such as the ease of performing acceptance and commissioning tests to verify the electrical integrity of the oversheath. It also provides some insights in anticipating or troubleshooting some challenges that might arise from having both components with the same colour, like the difficulties in conducting dimensional verification tests and the results of not completely removing the external conductive layer when applying cable accessories. Finally, it proposes a solution that was already adopted by a DSO with the size of EDP Distribuição.

In conclusion, this paper demonstrates that, to take full advantage of the external conductive layer, we also need to be aware of how it performs with other components of the MV insulated cable, which in this case has led to the change of colour of the oversheath. That allowed us to benefit from all the advantages of having an external conductive layer, with none of the drawbacks.

## REFERENCES

[1] EDP Distribuição, 2016, *Regulamento de Acesso às Redes e às Interligações do Setor Elétrico, Artigo 20º - Informação a prestar pelos operadores das redes. Caracterização das Redes de Distribuição a 31 Dezembro 2015,* Portugal, 6.

[2] International Electrotechnical Commission (IEC), 2007, *IEC 60229 Electric cables – Tests, on extruded oversheaths with a special protective function*, IEC, Geneva, Switzerland, 5-9.

[3] EDP Distribuição, 2015, *DMA-C33-251/N Condutores isolados e seus acessórios para redes. Cabos isolados de media tensão. Características e ensaios*, EDP Distribuição, Lisboa, Portugal, 10-14.

[4] International Electrotechnical Commission (IEC), 2005, *IEC 60502-2 Power cables with extruded insulation and their accessories for rated voltages from 1 kV ($U_m$ = 1,2 kV) up to 30 kV ($U_m$ = 36 kV) – Part 2: Cables for rated voltages from 6 kV ($U_m$ = 7,2 kV) up to 30 kV ($U_m$ = 36 kV)*, IEC, Geneva, Switzerland, 43.