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HARMONIZING MV CABLE: RESULTS OF THE EUROPEAN PROJECT EUROMVCABLE

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ABSTRACT

Extruded MV cables have now given more than twenty years of satisfying experience. Today, we can note a large variety of cable constructions in Europe (the Cenelec harmonising document HD 620 describes 84 models !). This paper presents the results of the EuroMVcable project ended in 2004. Electricity companies and cable manufacturers were seeking to rationalise the design of MV cables in Europe and to demonstrate the performances of optimally insulated cables. From a comparative analysis of models, tests, operating requirements and operating practices in Europe, four cable designs were proposed, allowing the majority of the European market to be covered. The paper focuses on the results of investigation tests.

KEYWORDS

MV cables, reduced insulation thickness, long-term test.

INTRODUCTION

Modern extruded insulation MV cables have now given more than 20 years of satisfactory experience as against the early products of the 1960s that gave poor performance.

The CENELEC Harmonised Document HD 620 contains all European MV cable Standards. There are 84 general categories of cables included (over 1000 pages). The variety of cable constructions is due to differences in the use of materials, construction of both of the cable cores and also the packaging (i.e. the many layers of materials and components external to the cores of single and three-core constructions) not to mention the variations due to the different tests called up, test methods and test requirements. The number of designs in European standards is countless.

This paper is related to the work done by the consortium of the European project EuroMVCable. This project funded by the European Community was launched in 2001 and concluded in April 2004 (Fifth Framework Program http://ec.europa.eu/research/fp5.html).

The main objective was to rationalise the design of MV distribution cables both in terms of cost reduction and European harmonisation. During this project, Electricity Utilities and Cable Manufacturers together investigated ways of optimising cables. These investigations focused on the reduction of insulation and oversheath thicknesses but also took into consideration the main technical criteria for a MV cable design:

1. Reliability (reduce failure rate in service).
2. Safety (reduce the number of incidents on distribution networks).
3. Life duration (a "normal life" of 30 years or an "extended life" of 60 years)
4. Operability (simple and cost-effective laying systems and interconnection systems)
5. Environmental aspects (including recycling)

The first part of the project concentrated on establishing the existing situation in Europe. From a comparative analysis of models, tests, operating requirements and operating practices in Europe, the consortium agreed on “preferred designs”, this means optimised designs that should be subjected to be suitable for the widest number of users in Europe. Investigation tests have been carried out on prototypes. As a final step, a draft of a three new specifications for new medium voltage cable designs have been produced on a consensus basis within the project consortium.

MAIN RESULTS OF THE EuroMVCable PROJECT

Comparison of the existing cable design, test requirements and distribution system

The consortium carried out a comprehensive analysis of current MV cable standards and practices in use in France, Germany, Italy, Spain, the UK and also Sweden and Denmark. The team then prepared an “analysis of similarities / differences and background to the differences in the test standards” [1].

This work issued in main lines for the preparation of a set of specifications for a new cable system to be developed in the second phase of the project.

The survey showed quite clearly that distribution system requirements are not identical, for instance, in terms of system voltage (insulation thickness is likely not be the same), fault current, rated maximum temperature (means that, for instance, the same insulating material may not be appropriate across the board).

The very major source of difference comes from **the large range of earth fault current** allowed by the utilities within each country and also differences between countries. The difference in i^2t among the UK utilities alone is more than a factor of 500. Meaning that some have been forced to adopt three-core cables with steel armour wires at one extreme and a 0.2 mm aluminium screened single cored design on the other. A second factor is that there is a differing perception in utilities / national committees regarding the need for effective long-term avoidance of moisture ingress into cables. This is even more important when cables are designed to operate at higher electrical stresses.

All this work led to the conclusion that there is **not a unique cable construction that could be economical for all utilities**. However, the present wide range of cable constructions in Europe could be reduced and optimised.

Three draft specifications for optimised cable

Wet and dry designs are widely use in Europe. There are no economical reasons to withdraw one of these two designs. The need to use HEPR at higher temperature of operation made it quite clear that harmonisation on the basis of a single design would not be possible. Both solid and stranded conductor could be used.

Therefore, the consortium eventually narrowed the choice down to three basic types, with a material alternative of polyethylene or an elastomer in one of the designs, meaning that four rationalised designs came out from this study.

Having chosen the cable constructions, then two major cost saving aspects were built into the designs: reduced insulation thickness and reduced oversheath thickness.

From the analysis of similarities / differences and background to the differences in the test standards, the consortium eventually selected tests for the EuroMVcable harmonised test specifications. The selection of tests was based on considerable debate and included a choice of the test methods to be used and also the test requirements.

The EuroMVcable project has of course used these test methods both in the testing programme and the cable specifications written as part of the project. There are a few test methods that require further development and harmonisation, such as the EDF test for insulation and over sheath shrinkage, based on a longer cable sample for example, and it is expected that CENELEC will in the course of time get round to doing this work.

Investigation tests

The main technical challenge focused on assessing an optimal insulation thickness (testing both 20 kV and 33 kV cables with high electrical field values).

Prototypes have been manufactured and a set of investigation tests has been performed, mainly focussed on high gradient cables. Cable systems have been exposed to long-term tests in water as many utilities do in Europe, and to long-term tests directly buried as EDF France is used to carry out. Such testing and comparison of performance in a number of designs had not been undertaken previously (interest of the cross validation).

A synthesis of the investigation tests results is presented below.

Subsidiary studies

Several subsidiary studies were carried out. One of the more substantial and significant studies was that of a **functional analysis of utility requirements**, that will help all utilities, but particularly those who embark on new non-harmonised design changes without reflecting on the many associated aspects that may be affected the change, e.g. the need for new tools and training in jointing, possible mismatch with existing circuits and so on.

A comprehensive calculation study was undertaken covering all MV cable conductor sizes and voltage designations to provide a view of the practicalities of the chosen **electric stress limit on the conductor**. This covers the existing series of materials and extrusion/crosslinking technologies. The second limit for examination was the **maximum stress on the outer screen**, which affects the type of accessories that can be adopted, taking account of design and method of jointing for commercially viable accessories. The value of 2.5 kV/mm adopted was realistic (because already used in Spain and slightly higher than the one fixed in the French specification) but long-term testing had not been experienced at that time especially with different type of accessories.

An **economic study** has been made from manufacturers' data. A manufacturing price comparison was undertaken between actual cables used (non-optimised insulation at 5.5 mm for a 20 kV cable, for example) and the four prototypes of the EuroMVcable project.

Theoretical calculations were made based on a common price for raw materials. Savings that could have arisen from manufacturing process changes were not taken into consideration. Non technical costs have not been taken into consideration either. Depending on the chosen design, the manufacturing cost of the cables can be reduced by between 6 and 12%.

A study of the European cables market giving the cable quantities in use under different headings identified the main common features in Europe:

- Aluminium conductor 150 mm²
- Voltage level 12/20 kV
- Insulation XLPE (wall thickness 4.5 to 5.5 mm)
- PE oversheath

This revealed the technical feasibility of harmonizing the cable core.

SYNTHESIS OF INVESTIGATION TEST RESULTS

Cable design tested

Four rationalised designs came out from this study, and four samples were manufactured for testing.

Sample A was a 20 kV reduced thickness XLPE insulated laminated foil protected cable, manufactured with a solid conductor in purpose to give new information regarding to thermo-mechanical behaviour of such solid conductors.

Sample B was a 20 kV reduced thickness XLPE insulated laminated foil protected cable with additional metallic screen in the form of copper wires. This combination is in use at present in northern Europe.

Sample C was a 20 kV reduced thickness HEPR insulated copper wire screen cable with no longitudinal water barrier and low permeability oversheath. Some companies in Spain and in the UK use this insulation material.

Sample D was a 33 kV reduced thickness XLPE insulated, copper wire screen cable with MDPE oversheath (no longitudinal water barrier).

For all cable samples, insulation thickness has been chosen based on a maximum insulation screen stress of 2.5k V/mm.

		A	B	C	D
Core, Alu 150 mm²	Solid, Ø=13.2 mm	●			
	Stranded, Ø=13.9 mm		●	●	●
Insulation	XLPE 20 kV, 4.3 mm	●	●		
	XLPE 30 kV, 6.33 mm				●
	HEPR 20 kV, 4.6 mm			●	
External semicon	Bonded, 0.5 mm		●		●
	Strippable, 0.5 mm	●		●	
Screen	Aluminium foil	●			
	Aluminium foil + copper wires		●		
	Copper wires			●	●
Outer sheath	MDPE, 2.5 mm		●		●
	LLDPE, 2.2 mm	●			
	Polyolefin Z1, 3.0 mm			●	

Test program

The specification project is a combination of design and functional requirements. Tests related to harmonisation work do not form part of the brief for this group. This is the responsibility of a CENELEC working group. It was decided not to carry out such tests.

The consortium preferred to concentrate on tests that will provide a technical assessment and confidence in these new designs. The consortium decided on a test series that were subjected to give information on the long-term behaviour of the cable systems and to confirm the boundaries for the reduced insulation / reduced oversheath thickness adopted in this project and the performance of currently available accessories. Although both these attributes had been adopted previously by several utilities, a comprehensive international evaluation of the changes had not been made. The EuroMVCable project addressed this with well chosen short term and also long term tests, selected from an international collection, thus providing a more comprehensive study, leading to higher confidence.

Hereafter, the test schedule carried out on the four samples:

- Hot Impulse test to breakdown
- Bending test
- Sidewall pressure test
- Impact test
- Abrasion test
- Long term tests in water
- Thermo mechanical test *[directly buried]*

Results

Long term tests in water

This test evaluates the dielectric performance of reduced insulation in aged in water.

Harmonize regime HD 605 § 5.4.15 was used:

- Water temperature of 40 °C +/- 5 °C and voltage applied 3 Uo.
- Breakdown before and after preconditionning (500 hours at 55 °C), 6 samples each time[1].
- Breakdown after 6, 12 and 24 months, 6 samples each time.

Samples A, B, C and D pass the harmonized test.

The use of an homopolymer XLPE against water treeing was successfully investigated. This has been tried several times in the past but did not succeed. This result has emphasized the significant improvements of manufacturing processes during the past 20 years.

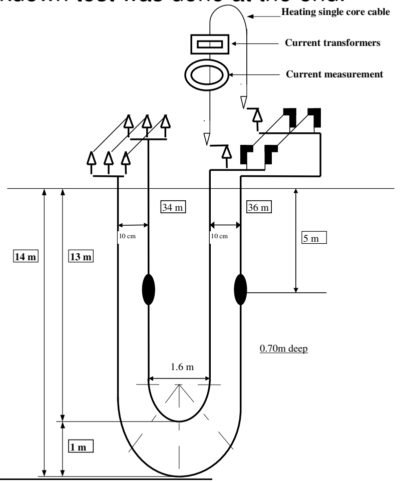
Thermo mechanical test:

The purpose of this test is to evaluate the thermo mechanical and electrical behaviour of cables in real condition of installation (buried with accessories).

The test procedure was HD 605, sub clause 5.4.1, and accessories were installed on the loops.

- Sample A installed in trefoil configuration with cold Shrink joints (3 bodies), heat shrink joint (3 bodies: 2 with mechanical connectors and 1 with deep indent connector), termination and separable connectors.
- Sample B installed in trefoil configuration with cold shrink joints (3 bodies), heat shrink joint (3 bodies), termination, separable connectors, German design connectors.
- Sample C installed in trefoil configuration with cold shrink joints (3 bodies), termination and separable connectors.
- Sample D installed in trefoil configuration with cold shrink joints (3 bodies) and cold shrink termination.

The conductor temperature was 100 °C +/- 5 °C for XLPE and 115 °C +/- 5 °C for HEPR. A voltage applied was 2 U_0 during 5000 h with 210 thermal cycles (8 h heating/16 h cooling). A Breakdown test was done at the end.



[1] Breakdown test before ageing will be done even if not specified in HD 605. In this case, no need to do the optional test at 10 Uo.

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This test confirms the good thermo mechanical behaviour of solid conductor in twisted conditions (no distortion of the triplex due to abnormal conductor elongation).

The thermo mechanical behaviour of copper wires screen combined with aluminium foil was successfully investigated (no crack on the sheath, no corrosion of aluminium foil, good sticking of the aluminium foil overlap, insulation core undamaged). Especially, the indentation of copper wires in the outer semiconductor was slight. Nevertheless, some significant marks on the aluminium foil have been observed.

Reduced oversheath thickness showed also good performance (no dangerous indentation damage). Shrinkage values measured during accessories examination were between 5 and 10 mm for samples with aluminium foil.

Samples A, B, C pass the test. Test on cable D (33kV) could not be achieved because of issues with accessories due to an insufficient accessory pressure on the reduced diameter insulation.

Impulse test to breakdown

The purpose of this test was to examine performances of reduced insulation thickness cables . Procedure was as follows:
- Bending test, according to IEC 60 502-2 § 18.1.4., except that no PD will be done after bending

- Hot impulse tests, according to IEC 60 502-2 § 18.1.7, except that no voltage test will be done after[2].

A	B	C	D
Between 290 - 380 kV	Between 380 - 470 kV	Between 190 - 286 kV	Between 520 - 700 kV

The breakdown values are significantly higher than the standardised value (125 kV for a 20 kV cable). It shows that the technical limits of the cable with reduced insulation thickness are still far from the working condition.

Bending test

Reduced insulation thickness has **no effect on the cable performance** for the bending test[3]. Nothing visible was observed neither on the external sheath nor the cable core. Furthermore, no change in PD values has been measured.

Abrasion and Impact tests

These tests have been carried out on different designs of medium voltage cables with standard or reduced thickness of the outer sheath.

An abrasion test was performed according to the test procedure HD620 5G.2 with 12 kg and 42 kg for the following samples:

2 mm PE (France); 3 mm PVC (France); 2,5 mm Polyolefin (Spain); 2 mm PE (UK); 2,2 mm PE (Italy).

An abrasion test was performed according to the test procedure HD620 5G.2 with 12 kg , 24 kg and 36 kg and an impact test following the HD629 standard for the samples :

Previous samples and 2,5 mm PE (France); 2,5 mm PE (Germany); all EuroMVcable samples

After impact test, no critical damage of the insulation could be observed.

The abrasion results (depth of tool penetration in the outer sheath and in insulation layer) on PE cables are rather consistent and show that the protection level increases with the outer sheath thickness. The protection level is quite equivalent to PVC cables.

The results of both tests done in abrasion and impact show that **the thicknesses which were adopted in this project enable to reach good mechanical performance**.

Conclusions

All the tests which have been done, have allowed to **demonstrate the good performance of reduced thickness for the cable insulation as well as the oversheath**.

Regarding the behaviour of accessories, the standard accessories already used on the network. pass the long-term thermo-mechanical test.

Field experimentation

In addition to laboratory tests, field experimentations have been done in Paris and Rome between 2003 and 2004.

Installation work in Roma on cable B

Scope of field experimentation was either to check the cable handling during laying operation and to verify the joints' capability to work in service properly if assembled in unbalanced way (35 mm^2 cable v/s 150 mm^2 cable).

A total length of 225 m of cable B was installed, mainly in a PE duct (around 200 m) and the remaining in tunnel. No difficulties were encountered.

The existing cable to be jointed was a stranded conductor Al 35 mm^2, HEPR insulation 5.5 mm, insulation screen easy strippable, metallic screen Al foil 0.15 mm thickness and MDPE oversheath)

Main features of accessories: Heat shrink joints and heat shrink terminations type. These accessories are of normal use on standard insulation cables.

No difficulties were found. Tools currently used for standard insulation cables were used as well as heating and installation procedures and jointers did not encounter any trouble in assembling works.

The cable was put in operation in May 2004 and since then it has been working in continuous service.

Paris experimentation on cable A

Main features of accessories: cold shrink joints; short internal terminals.

Main features of existing cable to be jointed to cable A: Cable 20 kV 95 mm^2 manufactured in 1983, installed in

[2] The impulse tests shall be applied according to procedure IEC 60230

[3] Bending diameter as depending on cable diameter is smaller than for standard cable.

1984

Main conclusions:

a) Tools: for strippable semi-conductor, a tool is used to make an incision which helps the stripping. The cutting depth could be not suitable to all the semiconductor thickness (in case of preset adjusting tool). This issue must be taken into account when designing the cable.

a) Solid core: this is more convenient for the setter, because there is no "string" effect as in stranded core. On the other side, in case of cable curve, the radius will be less homogeneous for a solid cable than for a stranded cable.

Furthermore, one could think that some undesirable radius can appear on cable when pulling cables on running wheels (perhaps foresee a test for this type of cable in future?)

DRAFT SPECIFICATIONS OUTLINES

The cable constructions agreed were more or less the following:

The cable core:

Stranded or solid conductor with a reduced insulation thickness, insulation in XLPE or HEPR, with the option of an external semi-conducting screen which is strippable or non-strippable.

The oversheath, radial and longitudinal water barriers and metallic screens:

Three designs are favoured, one is radially watertight and includes a laminated foil, and the second is the same but will also include a copper wire screen for higher earth fault levels. The third is for a non-radially-watertight construction with a copper wire screen.

The first two designs will be longitudinally watertight. The optimal thickness of the outer sheath is not easy to decide as Utilities in the consortium use various thicknesses and various ways to install their cable. It appears that it will be necessary to carry a comparison of mechanical strengths of presently used cables and to compare installation methods so as to decide on the toughness and thickness of oversheaths.

Optimised insulation thickness

Any reduction in thickness has to be balanced against other parameters such as cable capacitance, expense of jointing MV accessories. The following stresses have been considered acceptable to be evaluated within this project:

- Conductor screen stress: 4.0 kV/mm

- Insulation screen stress 2.5 kV/mm.

The proposal was also made to test reduced oversheath.

CONCLUSIONS

The aim of the project was to optimise the cable (reduction of insulation and outer sheath thickness) as well as introducing more rationalisation of cable design in Europe.

The works produced by the EuroMVcable project demonstrate the good performance of reduced insulation thickness for the MV cables.

The four cable designs selected during the project are cost-effective as the quantity of raw materials involved in their manufacturing is less than that for cables made till today. The interest about this peculiarity has been demonstrated by several utilities, resulted in purchasing for their MV networks such cables starting from 2003-2004.

Regarding the behaviour of accessories, the standard accessories already used on the networks made of standard insulation cables passed the long-term thermo-mechanical test. This is a very encouraging test result, as it demonstrates that most of the existing standard accessories are suitable for using at higher stress gradient for the main cross-section. Nevertheless, in some case, dimensional compatibility problem could be met between cable and accessories and then should lead to modify accessories.

The cable specifications that have been written could be submitted to CENELEC within this year, probably by more than one national committee, first for enquiry and then for inclusion in HD620. Authors are convinced that the harmonised designs and test requirements, together the hoped quick endorsement into an European Standard, will form the basis for an increasing number of European utilities seeing the merits of reduced materials content and harmonisation.

Saving and adequate performance are today available.

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REFERENCES

1. "Investigations on MV Polymeric cables aimed at a rationalized European standard" Jicable 2003

2. *HD 620 S1 – A1* : Distribution cables with extruded insulation for rated voltages from 3,6/6 (7,2) kV to 20,8/36 (42) kV.