CABLE STANDARDS GIVE OPPORTUNITIES FOR REDUCTION OF CONDUCTOR METAL RESULTING IN LOWER COST OF LOW VOLTAGE CABLES

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ABSTRACT

The world demand for energy is growing and will continue to grow every year by 3 %. This will mean that more energy will be transported through the distribution networks in the world. In the same time the price of metal has increased by 133 % since the year 2004 which led the utilities and industrial consumers to push more energy through the cable resulting in a higher operating temperature.

Today the reliable distribution of energy is getting more and more a concern to keep production units and offices working 24 hours a day. Already a power cut of 30 min can result in a serious loss of business to the customer. Therefore suitable cables should be installed to distribute the energy. Crosslinkable polyethylene has demonstrated since more than 30 years that is a reliable insulation for high demanding cables. Furthermore the introduction of the silane crosslinking process for low voltage cables has given the cable producers and advantage producing cost efficient cables for the industry.

Application fields for these types of material are broadening and competitive technologies have more recently been developed for insulated overhead and underground cables.

Furthermore the use of a high performance jacketing in the cable performance and costs will be highlighted. This means that cable makers are faced with the challenge to produce more cables on their existing line in a cost efficient way. It also means that utilities needs to install these cables as cheap as possible in a way which provides consumer with the most reliable electricity supply.

XLPE as insulation and HDPE as jacketing give the utilities the possibility to increase the conductor temperature by 20 K compared to PVC. This means that the conductor size that has to be chosen transporting energy can be one size lower than with PVC cables.

This paper will discus the advantages of using a full polyethylene cable for the low voltage network either as distribution cable or in the industrial environment. It will highlight the advantages of modern XLPE/HDPE cables in terms of:

- *Installation costs*
- *Reliability*
- *Operating costs*

INTRODUCTION

The world demand for energy is growing and will continue to grow every year by 3 %. This will mean that more energy will be transported through the distribution networks in the world. In the same time the price of metal has increased by 133 % since the year 2004 which led the utilities and industrial consumers to push more energy through the cable resulting in a higher operating temperature.

The main costs for low voltage network are today:

- Laying Costs
- Metal
- Failures

Network and Installation Costs

Laying Costs

During the laying of low voltage cables it is important that automatic mechanical laying techniques like ploughs can be used.

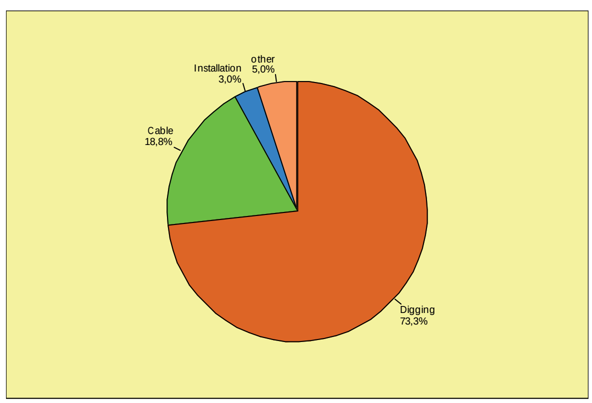


Figure1.: Laying Costs for a 0.4 kV cable

In certain areas the removed earth can be immediately used to backfill the trench. However in most parts of Europe the earth is too rocky to be used for this method. Therefore the cable has to be specially protected. Hence with the use of a high performance high density polyethylene as jacketing, with a high hardness of e.g. 60 Shore D should be used.

Material Costs

Due to the lower losses of XLPE and the higher temperature permitted for XLPE cables the power, these cables can distribute more energy to the customers and can afford a higher peak load.

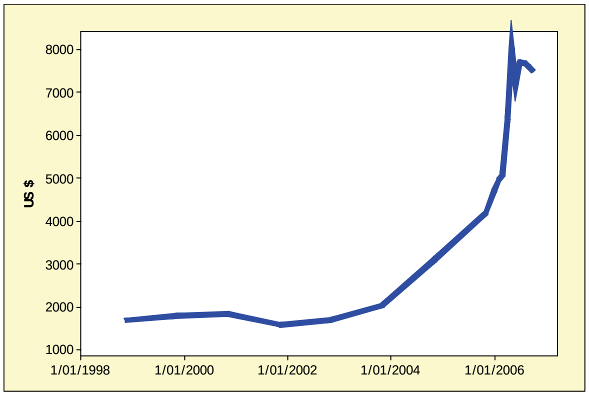


Figure 2..: Copper price over the years

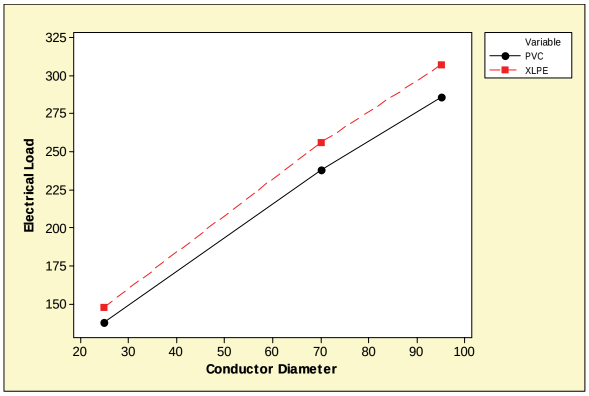


Figure 3.. Electrical load depending on the conductor size for 0.6/1 kV cables

This means that for a 95 mm² copper conductor you can distribute 10 % more energy with an XLPE cable than using a PVC cable. Additionally the insulation thickness is for PVC insulation 1.6 mm and for XLPE only 1.1 mm according to HD603. Utilities can use smaller cables that are easier to handle, since the half only half of the weight of a PVC-cable.

LOW VOLTAGE APPLICATIONS

One of the main applications of crosslinkable polyethylene is as insulation for 1kV underground, industrial and overhead cables. Due to better electrical properties and a higher temperature rating these cables have a much higher power transmission capacity for a given conductor dimension compared with the traditionally used PVC cables. The improved electrical property results in significant material savings due to decreased insulation thickness. Besides lower cost, higher distribution reliability is reached, due to an increased overloading and short circuit resistance.

Property	PVC	LDPE	XLPE
Density, kg/m³	1350-1450	923	923
Max. conductor temperature, °C	70	70	90
Max; short circuit temperature, °C	150	150	250
Thermo oxidative ageing requirements	80 °C, 7 days		135 °C, 7 days
Loss factor (tan δ)	0.007	0.0003	0.0005
Power factor	0.03	0.00112	0.00115
Volume resistivity, Ω cm	10 13 – 10 14		> 10 16
Brittleness temperature	-9 - -20		< - 60
Water absorption mg/cm²	~ 2.5	< 0.1	< 0.1

Table 1: Comparison of PVC, LDPE and XLPE insulation compounds

Scorch retardant copolymers have simplified the extrusion process and made it possible to use ordinary PE/PVC extruders. The ambient curing process has further reduced the cost producing XLPE low voltage cables
The introduction of the ambient curing technology showed that low voltage cables according to IEC 60502 could be produced using standard extruders having a length reaching from 18 to 34 L/D. The processing speeds that can be reached are up to 1500 m/min. The crosslinking of insulations thickness up to 2.5 mm takes place even in the northern part of Europe outside in the storage area.
For many constructions it is also possible to run insulation and jacket in cascade.

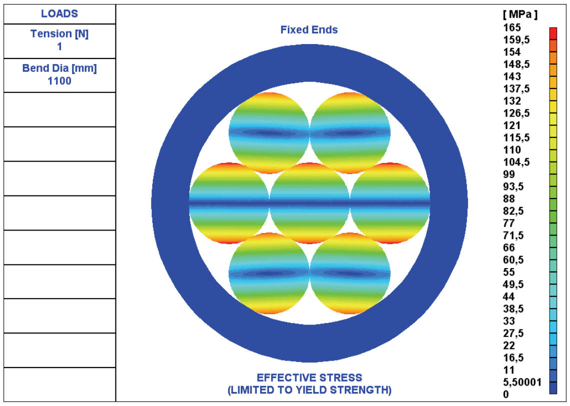
Cable flexibility

One of the properties which is important for the cable usage is the cable flexibility. Although this property is not very significant at the laying in ground, the parts of cables entering the transformer station must have increased flexibility.

The carried out analysis has examined the three constructions of 1 kV cables NYY (PVC/PVC), N2XY (XLPE/PVC) and N2X2Y (XLPE/HDPE) and compared the flexibility of the insulated cores and of the entire cables.

Comparison of insulated cores flexibility

Bending moment 1.95 Nm



Bending moment 2.08 Nm

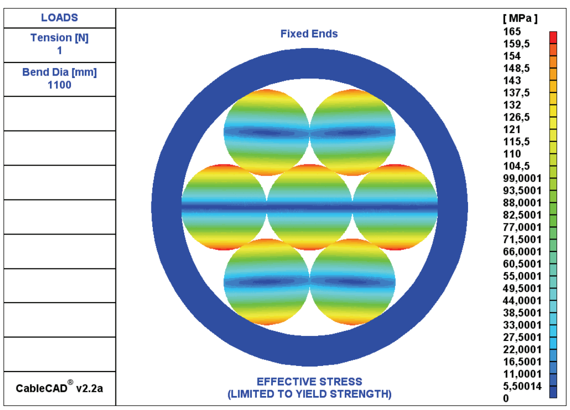


Figure 4.: Strains in insulated cores PVC 35 mm^2 and XLPE 35 mm^2

Bending moment for conductor

Picture 2 shows the strains in the insulated cable cores if the cores are separately bent at 1100 mm radius. The bending moment is almost identical for both cores 1.95 Nm and 2.08 Nm, the bending moment of the conductor itself to the same radius is 1.90 Nm. It means that the majority of strain happens in the conductors, and that the insulation impact at the cable cores flexibility is negligible.

Comparison of finished cables flexibility

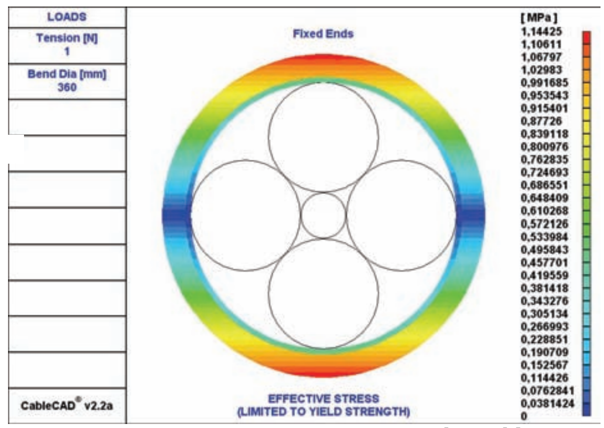


Figure 5.: Strains in NYY 4x35 mm2 0.6/1 kV cable
Bending moment for radius 360 mm 25.08 Nm

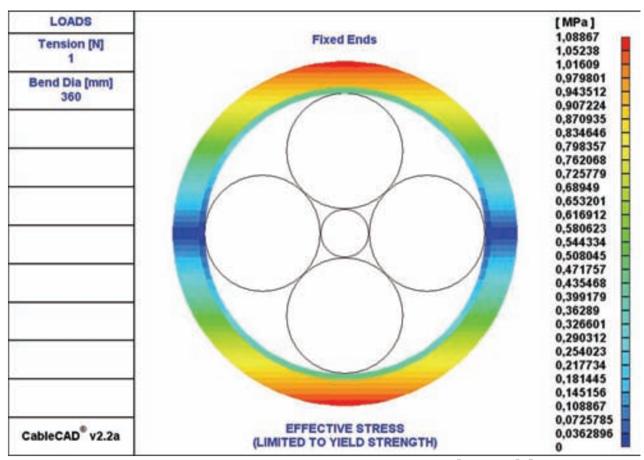


Figure 6.: Strains in N2XY 4x35 mm2 0.6/1 kV cable
Bending moment for radius 360 mm 26.36 Nm

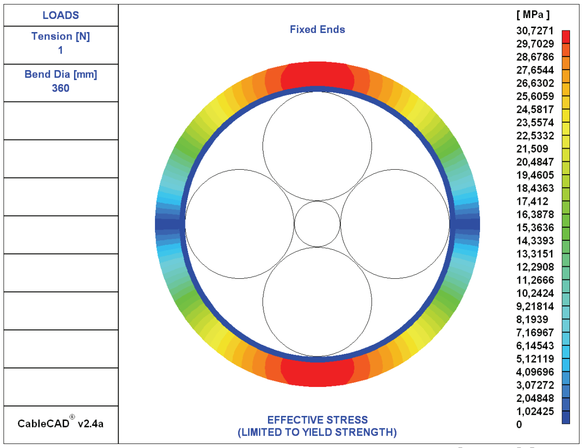


Figure 7. Strains in N2X2Y 4x35 mm2 0.6/1 kV cable
Bending moment for radius 360 mm 99.33 Nm

From the cores represented in picture 2 are stranded 1 kV cables PP, XP and XE in pictures 3 to 5. Below the pictures are stated the bending moment values necessary for cable bending at 180 mm radius. The pictures show only the sheath strains, but the bending moment calculations have considered also the bending moments of the entire cable (stranded cores, filler and cable sheath). The bending moment values are 25.08 Nm for NYY, 26.36 Nm for N2XY and 99.33 Nm for N2X2Y. For completely identical elongation the sheath strains of NYY and N2XY cables are some 1 MPa, while for N2X2Y they amount to 30 MPa. Such strains cause a significantly higher moment necessary for the bending of N2X2Y cables than the moments which are necessary for NYY and N2XY, i.e. the flexibility of the PE cables is lower. But elongation at break for PVC is 50% lower then HDPE. That means that minimum bending radius for N2X2Y cables is much lower that for NYY which is another advantage of N2X2Y cables.

CABLES RELIABILITY DEPENDING ON SHEATH AND INSULATION OF CABLES

An increased number of evidences prove that the cable sheathing has an important influence on the useful life of cables. The failure rate depends largely on the sheathing material. Minor sheath damages usually occur during the cable laying process. More damage resistant sheaths prolong the useful life of cables in further cable usage.

Sheathing material	HDPE	PVC
Impact resistance kJ/m²	18	9
Hardness Sh. D	65	37

Table 2 – Sheathing materials properties

Water absorption

As stated in Table 1, PVC absorbs several times larger water quantities than XLPE. The water absorption leads with time to the weakening of the insulation properties of the material and finally to the breakthrough of the cables. The cables with PVC sheath and insulation are subject to this phenomenon, while the cables with XLPE insulation are far more resistant to the presence of moisture, regardless of the sheath (HDPE or PVC).

Jacketing of underground cables

There is more and more evidence that the jacketing of cables has an important influence on the lifetime of the cable. The failure rate is depending heavily on the type of jacketing that is used in the cables application as it is outlined in figure 12.

Furthermore the system outages using an XLPE/HDPE can be reduced significantly. Below the outages from a European grid are highlighted. It can clearly be seen that using an XLPE cable together with a tough jacket is giving a reduction of the outages by more than 50 %. This further increases the reliability of the grid.

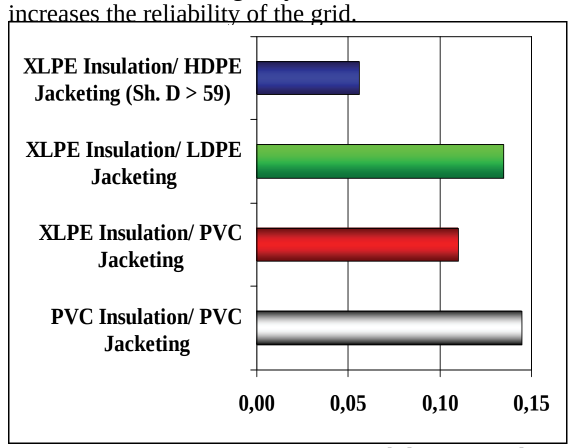


Figure 8.. System outages per system kilometre and year

Laying Costs

A significant cost factor during the installation of cables is the laying costs. These can depend on the area where the cables are installed. In figure 8 typical costs for an installation of a low voltage network are highlighted.

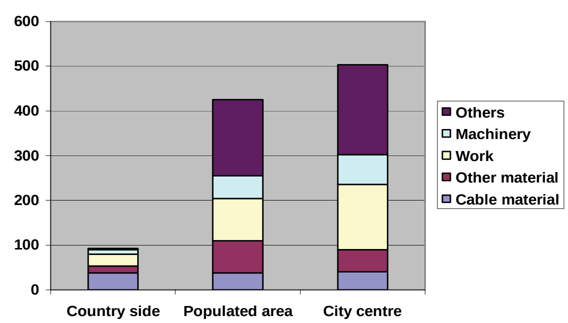


Figure 9.. Laying costs

By using a high density jacketing with a high hardness, e.g. Shore D ~59, the laying costs can be reduce significantly. The trenches can be smaller and the risk that the cables are damaged during installation is lower. Additionally the earth that is obtained by digging the trenches can be used to fill it again, instead of sand reducing further the costs. In figure 12 the costs are outlined from a utility that has introduced a hardness specification in 1985. They could keep their installation costs under control and could improve the performance of their grid.

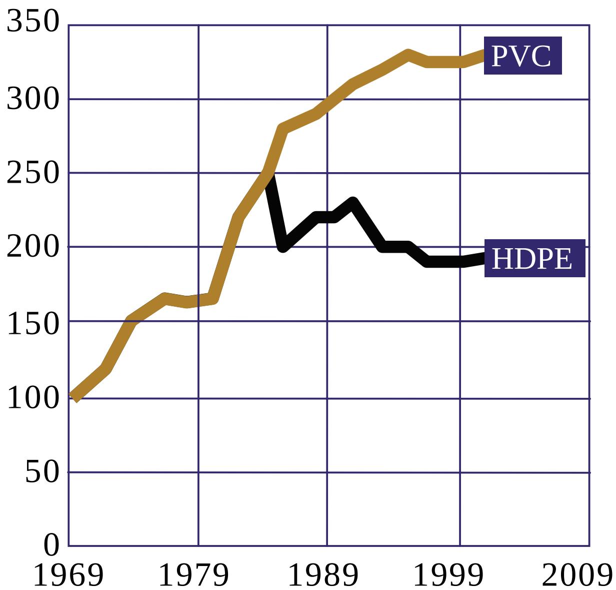


Figure10.: Evolution of the laying costs

Flame retardant jacketing

Furthermore there are requirements for jacketing materials to be used as low smoke flame retardant application, since on advantage of PVC is its flame retardency.
New development has been improved the property giving a flame retardant jacketing that is fulfilling IEC 80671 ST 7 requirements and HD620 DMZ-1 requirements.
It can be used in tunnels and due to his low moisture permeability also for underground cable without changing the cable type. The same extrusion speeds than with standard jacketing material is obtained.

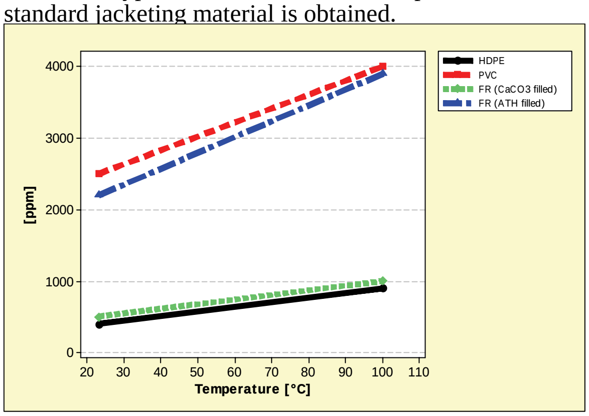


Figure11.: Water absorption

In the past NHFR jacketing had the disadvantage that these materials were too soft and the water absorption was too high. Today however there are flame retardant materials on the market that have a hardness of around 56 (Shore D) and the water absorption of pure polyethylene, whereas cables sheathed with PVC does not keep the cable dry.
This advantage is already used for extra high voltage projects and is under development in several European countries for low voltage installations.

CONCLUSIONS

In this article it was demonstrate that using XLPE as insulation for low voltage cables gives you the following advantages:

- Thinner cables due to better electrical properties of XLPE compared to PVC
- Smaller conductors or higher load due to better thermal properties of XLPE
- Reducing the laying costs by using HDPE jacketing
- Reducing the failure rate of the grid by using XLPE/HDPE cables
- Having an environmental free alternative to PVC when flame retardency is required.