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PERFORMANCE OF MODERN CABLES IN CENTRAL EUROPE

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ABSTRACT

Based on early cable failures intensive work has been made to improve the reliability for crosslinked polyethylene (XLPE) medium voltage cables.

Several important steps have been taken to enhance the performance of medium voltage cables such as

- *Cleaner compounds*
- *Cleaner product handling*
- *Triple extrusion*
- *Extruded outer screens*
- *Use of compounds with improved resistance against water trees*
- *Change from PVC to HDPE jacketing*

After more than 30 years operation of XLPE cables the results of the efforts to enhance the reliability can now be evaluated.

This paper covers the influence of the improvements made on the reliability of selected distribution networks.

KEYWORDS

Medium voltage cables, XLPE, Polymer Modified-WTR-compounds, Copolymer, Insulation, Wet ageing

INTRODUCTION

In the beginning of the 80ies the production of XLPE cables went through several drastic changes to overcome the early failures of first generation XLPE cables. Cable makers introduced triple extrusion and extruded outer semiconductive screens instead of graphite. Additionally the jacketing was changed from polyvinylchloride (PVC) to high density polyethylene (HDPE).

The compound producers took action to improve the cleanliness of their compounds and developed the so called water tree retardant (WTR) concepts, particularly the copolymer insulation [1].

This paper discusses the performance and influence of different changes made to the production of medium voltage cables covering a range up to 36 kV.

PERFORMANCE OF CABLES IN THE NETWORK

The enhanced performance of the water tree compounds have been reported in several publications [2,3,4]. However, as most technical progress has taken place during the last 25 years there is not much published information available regarding its exact contribution to the extension of cable life and reducing failure rates under service conditions. Schädlich *& al* [5] presented some investigations on field aged cables showing the clear superiority of copolymer modified XLPE over additive and classical homo-polymer insulation.

In this publication real failure data can be presented for one German utility, E.ON Bayern, Region Ostbayern.

Figure 1 summarises statistics over the failure rates of cables during the year 2003 to 2005 related to the year of manufacturing, a clear improvement can be seen after the introduction of the second generation cables at the beginning of the 80ies.

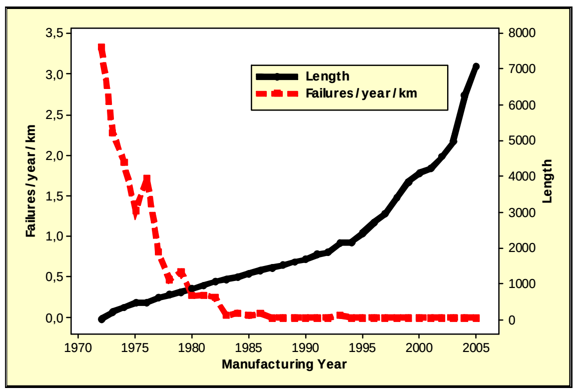

Figure 1. Failure rates of cables in installed at E.ON Bayern, Region Ostbayern

The same observation can be made from failure data from two utilities using two different ways of installation as seen in Figure 2.

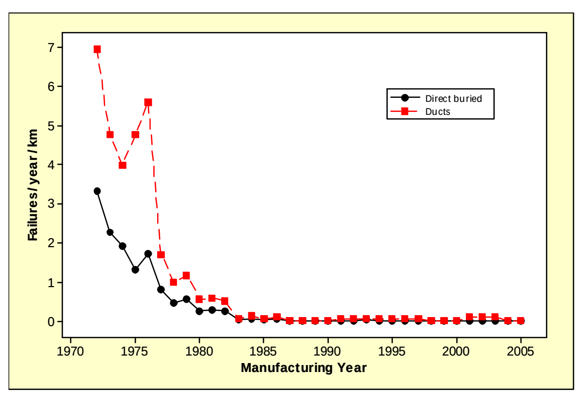

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Figure 2. Comparison of failure rate depending on the installation type (direct buried or laid in ducts)

The difference in the failure rate between the two utilities using different types of installation can have several explanations; either the cables are operated at a higher temperature due to installation in ducts or the reason is due to the use of different compounds or crosslinking process.

In a study made by the FGH institute in Germany the value of the second generation cables is highlighted by extrapolation of the failure rate during the whole life time of a cable. The second generation power cable insulated with polymer modified WTR compounds, commonly called copolymer, is giving a significantly lower failure rate over time as seen in Figure 3.

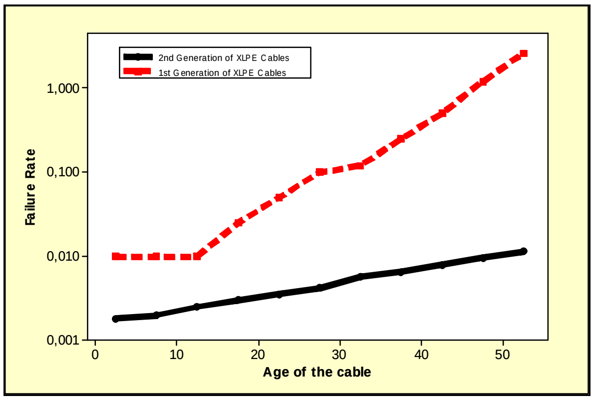

Figure 3. Estimated failure rates of different generations of XLPE cables [6]

CABLE TESTS

In 2000 the wet-ageing test protocol was harmonized in the Cenelec region. This raised a concern in Germany, especially whether this new test would be as stringent as the old one. This concern could not be confirmed as reported by Meurer and Stürmer [7]. Tests have been done to compare the old and the new VDE test. The new German test is indeed based on the same conditions as the Cenelec test. Results, in Figure 4 show that the number of vented trees is lower than before, but the length is significantly longer.

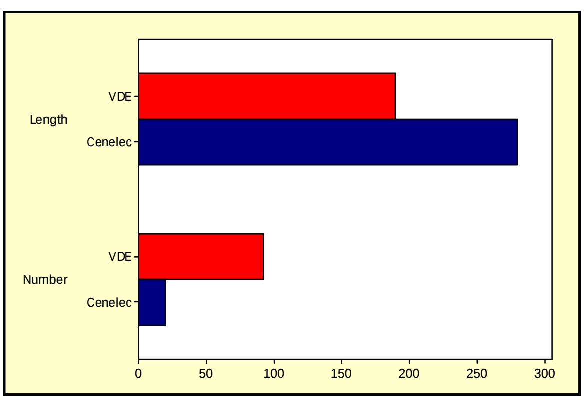

Figure 4. Vented trees observed in two years aged cables according to different test protocols [8]

The overall new results in this test also show that despite the reduction in test temperature and test voltage the test is as stringent as the old one and the requirements on the inner semicon have been increased as a consequence of the new test protocol. The number of vented trees was reduced but under these conditions they are growing faster and thus the danger of an early breakdown during the test has increased [8].

STEPS TAKEN TO INCREASE THE RELIABILITY

So far the paper has covered actual cable failure statistics in some German networks. In the next part, the different improvements that have been made to the compounds and cable manufacturing process are discussed in more detail with supporting experimental data.
These can be summarised as:

- o Use of cleaner materials
- o Triple extrusion
- o Cleaner handling of materials
- o Use of polymer WTR compounds, so called copolymers
- o Change of PVC jacketing to HDPE[9]

Influence of improved compounds

One effort to extend the lifetime of the cable based on the learning from of the early failures was the introduction of polymer modified WTR-compounds in the late 70ies[10, 11]. The resulting performance enhancements have been extensively reported in the past and Figure 5 is highlighting the results obtained in the two-year test according to HD620. Here different medium voltage cables with different voltages and constructions are represented as outlined in the Cenelec harmonized document. The results in this chart are surely not complete, but are based on all data available today to the authors [12].
This database clearly shows the advantage of high performance insulation, here copolymer, over classic homo-polymer insulation. For cables manufactured based on this insulation type, utilities are today expecting a life time of approximately 40 years in service.

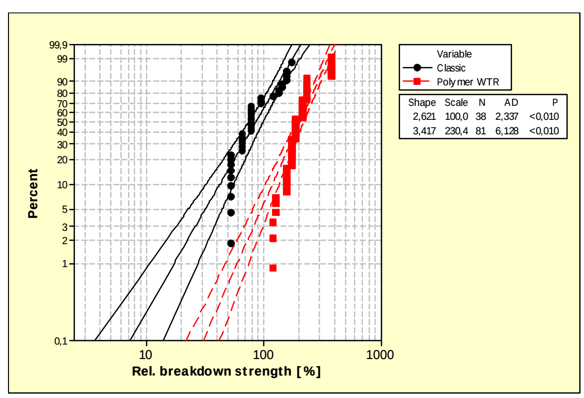

Figure 5. Difference in breakdown strength after two years wet ageing between classic and polymer WTR

insulation

Influence of Cleanliness

A deeper understanding of the cleanliness requirements for MV cables resulted in the introduction of cleaner compounds from the material producers. Today's measurement of cleanliness is made on sizes down to 50 µm and for medium voltage all contaminations larger than 100 µm are specified and all larger than 200 µm are excluded.

Contamination	100-200 µm	200-500 µm	> 500 µm
Low voltage quality (as tested)	12	2	0
Medium voltage quality (as specified)	3	0	0

Table 1. Number of contaminants in different size classes per kg insulation

The material with the higher contaminant content is designed for use in low voltage (LV) applications. Table 1 shows the actual figures on the cleanliness of the LV material used.

A test was made with 15 kV cables according to HD620 using the same material but with two different cleanliness levels. The data presented in Figure 6 shows that 50 % of the cables did not survive the test and failed at 3 Uo before the complete ageing time of two years was reached. Two out of six cables even failed before one year. The investigation showed that the breakdowns were caused by bow-tie trees growing from contaminations within the insulation. Cables produced with a higher cleanliness level easily survive two years and had electrical breakdown values clearly over 10 Uo. Experience has shown that these cables will last longer than 40 years whereas cables with a higher contamination rating this long life time cannot be guaranteed.

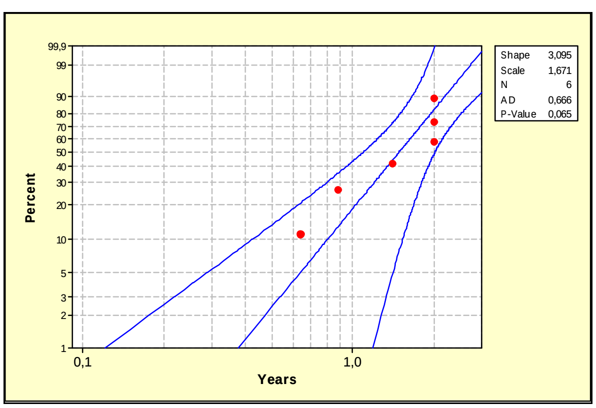

Figure 6. Ageing time until failure for the cable insulated with a material having a LV cleanliness level.

Influence of material handling

Another step made for producing high performance cables was a cleaner handling of the material during the whole production process, i.e. meaning polymerization, compounding, packaging, transport and handling at the cable producer.
Introduction of bulk handling, Figure 7, reduced the possibility of introducing contaminations during handling by 97 % based on the reduction of number of handling steps to unload the material.

Figure 7. Bulk handling of insulation compound

As an additional example of the effects of a cleaner handling, a wet ageing test has been performed on a 15 kV cable with a 150 mm² conductor produced before and after the installation of a clean room
The results in Figure 8 clearly highlight the effect of cleaner handling even if this type of installation is not particularly necessary for production of medium voltage cables. An inspection of the cables after ageing revealed an 80% reduction of the number of bow-tie trees in the cable produced after the installation of the clean room.

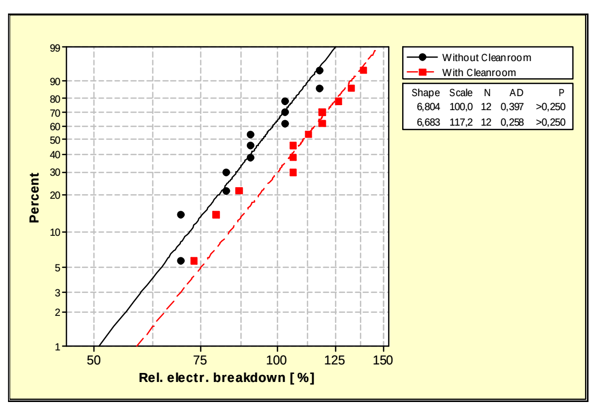

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Figure 8 Influence of clean room material handling

Effect of extrusion technique

A further step to produce high performance cables was the introduction of triple extrusion, which is today mandatory for EHV-cable production. Both cables were insulated with the same type of materials.

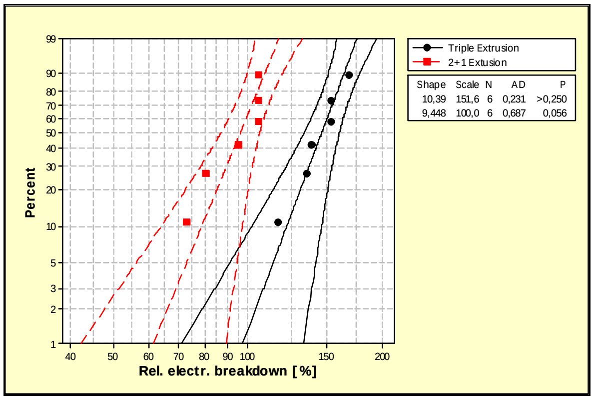

Figure 9. Relative electrical breakdown strength depending on extrusion techniques.

The results based on a 15 kV 240 mm² cable, shown in Figure 9, are demonstrating the clear improvement of the electrical performance of cables produced using the triple extrusion technique.

CONCLUSIONS

Since the introduction of XLPE for medium voltage distribution cables, several steps were taken to drive the electrical failure rate of theses cables down to close to zero. Each step in itself would have already prolonged the lifetime of a cable and increase the reliability of the medium voltage distribution network.

Together as industry partners; equipment manufacturers, compound producers and cable makers have all made step changes in their respective process resulting, as evidenced from cable failure statistics, to a more reliable medium voltage distribution network. This is of benefit to both the community as a whole and to the utilities for which every blackout today is immediate headline news.

Today the average outage time in Germany is as low as around 19 min per customer [13].

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