# Electrical stresses of cable sheaths in normal operation and under fault conditions

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## ABSTRACT

*The extension of the transmission and sub-transmission system will largely be realized by long cables lines. The electrical stresses and their determination for the main XLPE insulation are widely known. Possible overvoltages are covered by the insulation co-ordination procedure. Large voltages can be also effective across the cable sheath. If these voltages lead to stresses larger than the inception field strength of the cable sheath's material, a breakdown is possible. This is critical, because the cable sheath is usually not covered by the insulation co-ordination procedure.*

*In the proposed paper, the results of investigations on the breakdown voltage of typical sheaths are given. The correlation of the inception field strength and the sheath's thickness is shown for AC stress, switching events and lightning impulses. Simulative and analytic approaches to determine the sheath voltages for different configurations of cable systems are presented to reveal critical cases. Conclusions for an adapted screen treatment are given.*

## KEYWORDS

Dielectric sheath-breakdown; Transients on cable sheaths; Transient stresses; Voltage limitation; Sheath voltage simulation

## MOTIVATION

While modern medium voltage networks are almost completely connected by cable, there is also an increase of longer cable systems in the transmission grid and the distribution systems. The connection of offshore wind parks and the expansion of the transmission and the distribution network are no longer conceivable without the use of cables. The limiting values for the voltage stresses of the main insulation are defined by the insulation levels based on the international standard (see IEC 60071:2019, [1]).

The dielectric treatment of the outer protective sheath (hereinafter cable sheath) is usually not covered by the standardization. Only for cables with a special protective function, electrical tests for the cable sheath are required (see IEC 60229:2007, [2]). Therefore, sheaths are in the most cases only designed for mechanical protection. Their dielectric strength is generally not known and not specified. Consequently, an isolation co-ordination of the sheath is currently not possible.

Lately, breakdowns of cable sheaths have been detected. Figure 1 shows the dielectric breakdown of the sheath of a 110 kV cable. Possible causes can be switching and fault scenarios or lightning impacts. For the voltage protection of the sheath it is necessary to know the electrical stresses across the sheath and the electrical strength.

This gave the incentive to experimentally determine the breakdown voltage $U_d$ and the inception field strength $E_i$ of different kinds of cable sheaths. To determine the influence of different voltage forms, the measurements have been performed at 50 Hz AC voltage, as well as with switching and lightning impulses.

**Fig. 1: Cable sheath after a dielectric breakdown**

Also, possible causes for the occurrence of critical sheath voltages are to be shown. Due to the inductive and capacitive coupling between conductor and shield, very high potential differences can occur across the sheath. Even external effects, for example lightning strikes, can cause very high sheath voltages.

## INVESTIGATION OF THE DIELECTRIC STRENGTH OF REAL CABLE SHEATHS

### Measurement setups

Quantitative information about the breakdown voltage $U_d$ and the inception field strength $E_i$ of sheath materials of high voltage cables results from the research of XU [3]. Xu identified the breakdown voltage $U_d$ and the inception field strength $E_i$ (or breakdown field strength $E_d$) of cable sheaths with a direct or indirect method.

The breakdown tests were carried out on sheath materials from different manufactures. For the direct assignment of the sheath-breakdown voltage $U_{d(Sh)}$, the sheath of the tested cable is enclosed with a high voltage electrode. The shield and the conductor are connected to the ground potential. During the breakdown test, the test sample is embedded in insulating oil. This avoids flashovers along the outside of the sheath. The setup is shown in figure 2:

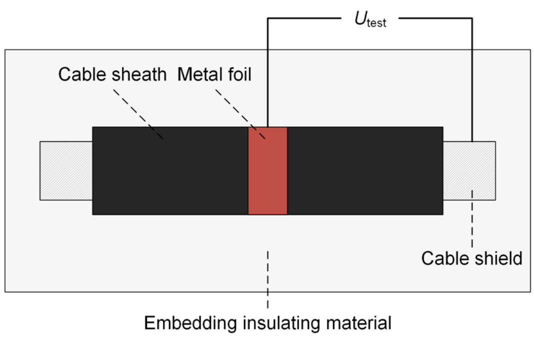


**Fig. 2: Setup for the direct measurement**