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Study Committee B1

Insulated Cables

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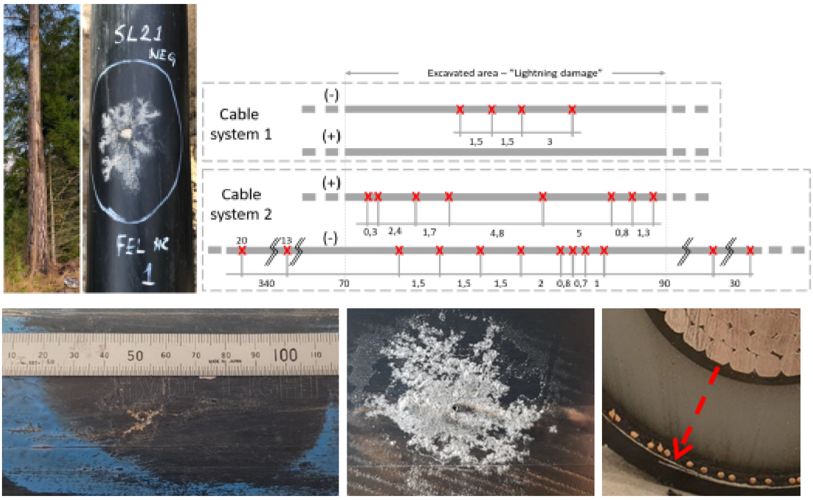
# Lightning strike to ground – a case study about observed cable damages, risk estimation and protection method


Valentinas DUBICKAS*, Erik THUNBERG*, Johan HANSSON*, Andreas DERNFALK**, Peter SIDENVALL**

Svenska kraftnät*, I2G**


## Motivation

This study is about the cable sheath damages caused by lightning strike to the ground in proximity. The sheath damages were found on two parallel HVDC underground cable systems where each of them is nearly 200 km long. The damages were found at 10 locations along the cable route after approximately 7,5 years. Damages were not severe enough to immediately damage the cable main insulation system, however these allowed for water intrusion under the sheath. Observations at the locations also revealed a few lightning damaged trees in the proximity of the cable systems.




## Dissections

The puncture severity ranged from: only damaged HDPE sheath; puncture in Al laminate; somewhat damaged outer semiconductive layer. The circumferential location of punctures was often aligned with the edge of Al laminate seam.

## Testing

Oversheath Lightning Impulse (LI) strength was tested for the cable samples of these particular cable links. It was found to be in the range 115-140 kV. The puncture locations often coincided with aluminum laminate irregularities. The effective breakdown strength including field enhancement effects found from the testing was 25-31 kV/mm.

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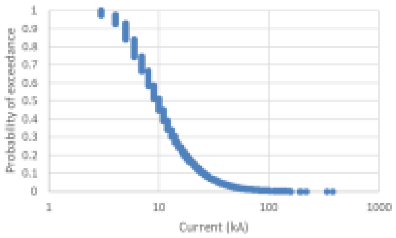
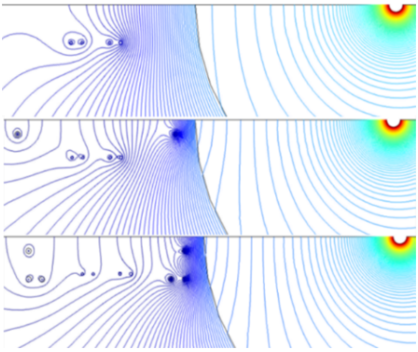
## Risk estimation method

The method was developed for estimating the expected frequency for sheath damages from the lightning strike. It is based on the lightning statistics in the cable corridor, estimation of probabilities for exceeding certain lightning current magnitudes, series of FEM of E-field calculations in the ground caused by lightning current at varying distances, current amplitudes, soil resistivity and knowledge of oversheath LI strength.

- Lightning statistics and current data has been retrieved from Swedish Meteorological and Hydrological Institute (SMHI) for 10 km wide corridor along the cable route during the same period when damages occurred. Estimated average lighting strike density 0,59 strikes/(km² * year).
- FEM modelling showed that field enhancement due to Al laminate irregularities was found to be factor of ca 1,4-2.
- Combining a risk distance from the nearest cable where a strike can be expected to cause damage, together with ground strike density, lighting current distribution and total cable route length, an estimate of the number of sheath damages is found.




| Risk distance (m) | Corresponding lightning current (kA) | Probability to exceed current | Total risk distance (both directions from cable route center) (m) | Number of expected sheath damages per year |
|---|---|---|---|---|
| 3 | 3 | 1 | 8 | 0,8 |
| 9 | 10 | 0,5 | 20 | 0,6 |
| 17 | 30 | 0,07 | 36 | 0,11 |
| 40 | 100 | 0,004 | 82 | 0,018 |
| All | - | - | - | 1,53 |



## Results

The calculated expected sheath damages per year of 1,53 correspond well with the observed 10 damaged locations during 7,5 years, i.e. 10/7,5 = 1,33 which is equivalent to MTBF of 0,5-1 years.

Effectiveness of cable protection against lightning strikes using shield wires was investigated. Introduction of shield wires increased MTBF to 2-4 years for simpler configuration and 10-20 years for more complex.

## Discussion and conclusions

The lightning strike issue was found to be particularly problematic in Sweden and other Nordic countries due to the fact that ground electrical resistivity is generally high here due to presence of bedrock of granite and gneiss (>2500 Ωm).

A protection method using buried shield wires introduced parallel to the power cables was investigated. With increasing complexity of the arrangement, the MTBF could be sequentially improved. The most complex configurations resulted in MTBF of ca 10-20 years, however even simpler configurations can provide adequate protection.