Quality Control of XLPE Cables by means of Impulse Voltage Test

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Abstract: High voltage cable lines are rated among the most expensive investments in the electric energy supply system. Due to economic and operational requirements these lines are to live up to the highest expectations as far as reliability and adequate life time are concerned. Therefore it is recommended to undertake impulse voltage tests with increased level apart from tests as provided in the relevant standards. Thanks to these examinations impurities in the insulation and in the interface between insulation and semi conductive layers can be recognized fast and easily for they cause lower levels of the impulse strength. Particularly so-called protrusions in the interface between insulation and semi conductive layers or inadequate adhesion of the semi conductive layers to the insulation, both defects that can occur during the production of the cable, are subjected to the test. During operation these impurities can cause increased local electrical field strength in the insulation as well as water trees and electrical trees. Additionally they speed up the aging process in the insulation of the cable and this can lead to early faults respectively a shorter life time. These production related defects are not detectable by standard tests as partial discharge measurement or voltage tests with power frequency. Due to our investigations and good experience in the field of quality control of XLPE cables we carry out this test for all Austrian and some German utilities.

Introduction

XLPE-cables are state of the art due to sophisticated research and development in high voltage areas of up to 500 kV and represent a reliable means of production. Producers indicate an expectable life span of 30-40 years under normal operating conditions. One of the reasons for the reliability and the big life span of the XLPE-cable is – among others – its extraordinarily careful production during which impurities, protrusions in the interface between semi conductive layer and insulation and inhomogeneities in the structure of the insulation are to be avoided for they can have a considerable influence on the ageing of the cable. With the introduction of the threefold extrusion in the 1980ies making it possible to apply inner semi conductive layer, insulation and outer semi conductive layer in one operation the necessary purity and homogenous structure of the insulation could be achieved. During operation the ageing of the XLPE-insulation is influenced by electric, mechanic and thermal wear as well as by humidity in connection with possible inhomogeneities of the insulation. Inhomogeneities are starting point for “electrical treeing”.

Impulse test voltage for quality control of XLPE insulation

By examining cable samples with impulse voltage test it is possible to discover impurities, protrusions or inhomogeneities in the insulation of the XLPE-cable. Defective areas strongly deteriorate the level of the impulse test voltage of a new cable. Although this test is not provided for in the standards it can be carried out for selected cable samples in the course of prequalification or quality tests as an agreement between cable manufacturer and customer. Experience shows that when determining the state of the insulation and quality of a 20 kV cable one can assume an impulse test voltage of at least 600kV and at least 800 kV for 30 kV cables (independent from cross section of the conductor) – on condition that the structure of the insulation is according to the rules. As for 110 kV cables of good quality the impulse test voltage is beyond 1,5 MV.

For the testing of cables 5 samples per type/cross-section of 20 meters length each are required. For the testing of 20 kV cables no terminations are required. The voltage grading is controlled via the outer semi conductive layer. The ends of the cable are exposed over a length of 4,5 m each until the semi conductive layer and the conductor is stripped for about 10 cm. The conductor and the surrounding aria of the outer semi conductive layer are connected with high voltage and the screen is connected to ground. The test is carried out with the 3,2 MV impulse voltage generator (curve shape 1,2/50 µs) as follows: starting with a voltage level of 350 kV the cable is exposed to 5 impulses of negative polarity each proceeding in steps of 50 kV until 700 kV are reached. From 700 kV up the voltage is increased in steps of 25 kV until breakdown.

Fig. 1 shows a representation of the impulse test voltage of 60 cable samples for 20 kV. The 63% value corresponds to 843 kV. The highest voltage values reach 955 kV, the lowest 680 kV.

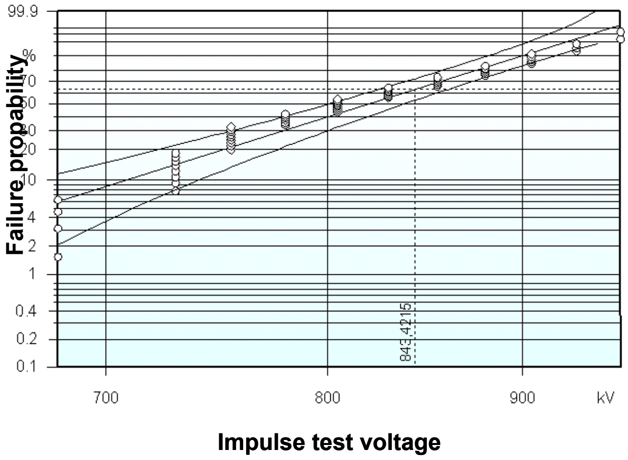

Fig. 1: Weibull-distribution function of the impulse test voltage for 20 kV XLPE cables

Optic examination

If the impulse voltage test shows that levels are too low cable samples in the area of the breakdown or the whole cable itself can be subjected to an optic examination according to the thin film cut method.

The following figures show microscope takings of thin films of the defective areas of two samples with low voltage levels. The electrical trees on the rim of the breakdown channel are showing, that the breakdown is directed inwards for both defective areas. Because of field geometry breakdowns in homogenously isolated cables are always directed outwards. Breakdowns with an inwards direction can only occur with abnormal local field distortion in caused by inhomogeneities in the insulation respectively in the interface between insulation and semi conductive layers. The latter inhomogeneities didn't show any particularities during the optic examination. The interfaces were smooth and no irregularities occurred. Figs.2 and 3 show shots of sample 1. In Fig. 2 one can recognize an impurity of about 55 µm.

Fig. 2: Impurity of 55 µm in sample 1, impulse test level 480 kV

Fig. 3 shows electrical trees directed to the conductor (inwards) starting from small impurities in the insulation.

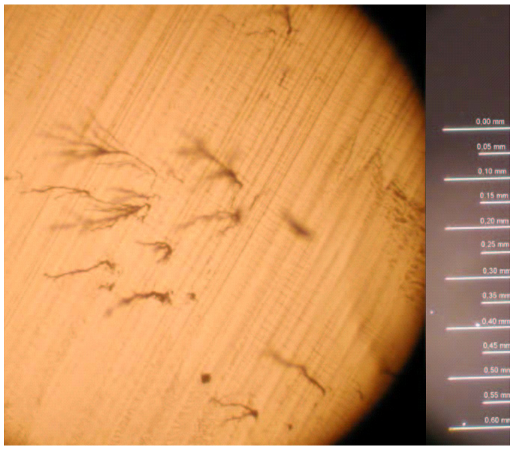

Fig. 3: electrical trees in sample 1, directed to the conductor, impulse test level 480 kV

Fig. 4 shows a thin film cut with Electrical trees in the area of the breakdown of sample 2, directed to the conductor, impulse test level 530 kV.

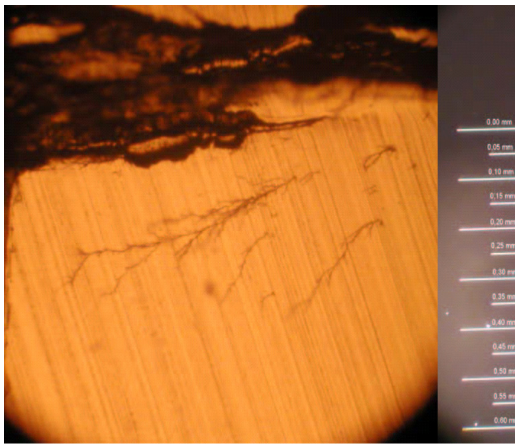

Fig. 4: Electrical trees in the area of the breakdown of sample 2

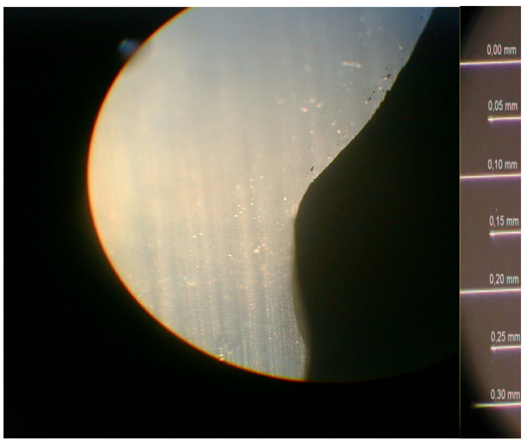

Fig. 5: Protrusion in the interface between insulation and inner semi conductive layer, impulse test level 530 kV

Conclusions

The control of the quality of the insulation of XLPE-cables by determining the level of the impulse test voltage enables us in particular to detect inhomogeneities in the isolation respectively at the interfaces between insulation and semi conductive layers because they manifest themselves in a strongly reduced impulse voltage level and cannot be detected with any other test. Especially new cables are subjected to this test as a control of their quality, but it can be used for older cables as well in order to determine their remaining electric strength. Additional optic examinations give information about the reasons of poor quality.

Literature:

Woschitz, R.: „High Voltage Lines“, *lecture notes*, *Graz University of Technology, 2003*

Woschitz, R.: „Guideline for the Quality Control of XLPE Cables by means of Impulse Voltage Test”, *instruction for use for Austrian utilities, Graz University of Technology, 2004*