Suitability of test voltages applied to high and extra-high voltage extruded cables and cable systems for quality acceptance during commissioning and for condition assessment during operation

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ABSTRACT

For factory tests voltage level and wave shape of high and extra high voltage (HV/EHV) cables are determined by the standards of insulation coordination grown in a century. However for on-site tests the difference between quality acceptance tests of new cable systems and diagnostic tests of service-aged cable systems is often neglected.

Various types of test voltage are explained in terms of test voltage level, conformity to relevant standards and physical behaviour of the insulation material. Reasons are given why new cable systems shall be tested by AC voltages, which are very similar voltage shapes as applied during factory testing.

KEYWORDS

HV cable testing, test methods, insulation coordination

INTRODUCTION

On-site tests are conducted to approve the quality of a newly installed cable system after laying, or as a diagnostic test after some years of operation. In each case decisions with great impact are made depending on the result of the test: In the first case the aim is to ensure that the cable has not been damaged during laying and especially joints and end terminations have been installed properly. In the second case it is to find possible insulation weaknesses or defects that originate from ageing of the insulation early enough, so that action can be taken during regular or scheduled maintenance and not as emergency reaction after cable failure.

Various test methods are currently in use or discussion, each with different test durations, voltages and evaluation criteria. For choosing the correct test method for a certain cable to be tested the parameters to be considered are the purpose of the test, the rated cable voltage, cable design and geometry, the age of the cable, known results of previous tests, and types of defects on which the test may be concentrated in case of a diagnostic test.

CHARACTERISTICS OF TEST METHODS

To examine the usability of a test, several properties and characteristics of the test method need to be considered.

Effectiveness of a test

For both after-laying and diagnostic maintenance tests the intention is to find those defects in a cable system that likely would cause a failure in service, while causing no damage to insulation that is healthy or only contains defects which are too small to lead to breakdown.

A quality acceptance test has to be effective for all possible types of defect, while a diagnostic maintenance test might be conducted with a specific target to check for a certain type of defect only. In this case it is sufficient to use a test method effective for that type of defect.

Voltage testing is always a statistical process [6], **there is no such test that will find all dangerous defects while never causing damage to parts of insulation that contain no or only minor defects**. The probabilities for a wrong result of a test depend on the voltage wave shape, test voltage value, duration, etc. Different test parameters alter the probabilities, for example by reducing test duration or test voltage value the probability of damage of healthy insulation is reduced at the cost of also reducing the capability of proving a defective cable to be faulty.

Diagnostic measurements such as PD and tan δ increase the effectiveness of a test, since the added diagnostic information allows finding more defects without increasing the risk of damage to healthy insulation.

Representation of stresses in service

Test voltages shall "produce the same dielectric effect in the insulation as overvoltages in service" [8]. Especially for quality assurance tests insulation coordination requires that the after-laying test should correspond to the AC prequalification test of the cable system, the AC type test of the cable and the accessories, the AC sample test of the cable in the factory, and the AC routine test done in the factory, and also to the AC operating stress. Diagnostic maintenance tests are more free in their choice of methods, since the outcome is not an acceptance criterion.

For test voltages of the same type as the operating stress the electric field distribution in the insulation is the same as in service conditions, for the healthy cable insulation as well as for the field around the various types of defects and in the accessories with their complicated multi-layer dielectric. **For a HV AC cable this requires testing with AC of a frequency in the same order of magnitude**. For other test voltage wave shapes it has to be proven if the effects in healthy and defective insulation are the same.

The life expectancy of XLPE, or the necessary time to fail a cable with defects depends on the applied test voltage, a life time exponent ≥9 is given by [16], see also figure 1.

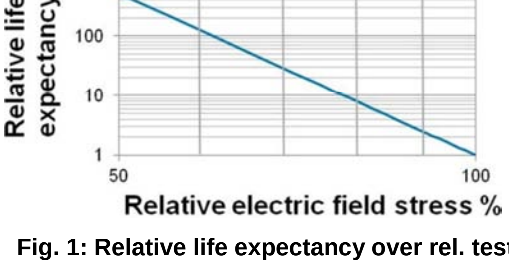

Fig. 1: Relative life expectancy over rel. test voltage

By applying a test voltage higher than the rated voltage failure mechanisms are accelerated, so that defects can