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AFTER-INSTALLATION TESTING OF HV/EHV EXTRUDED CABLE SYSTEMS – PROCEDURES AND EXPERIENCES

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ABSTRACT

This paper provides an insight into 9 years of IPH experience in after-installation tests of HV/EHV extruded cable systems. From the start, AC tests of very long length of EHV cable systems were performed in combination with sensitive PD measurements to achieve best possible test efficiency.

KEYWORDS

Power cables, testing after installation, partial discharges

INTRODUCTION

In 1998, IPH began to test extruded HV and EHV cable systems after installation. From the very beginning, powerful mobile resonant test systems as well as the ability to perform sensitive on-site PD measurements were indispensable to test very long EHV cable systems. Based on first experiences at 400 kV prequalification tests at CESI (1993-1997), PD sensors directly installed in cable accessories seemed to provide the only solution to achieve excellent PD detection sensitivity independent from the length of the cable system.

Since 1998, approx. 3000 km of HV cables and numerous EHV cable systems were successfully tested.

RELEVANT STANDARDS

Two international standards cover after installation tests of extruded cable systems: IEC 60840:2004 (third edition, effective since April 2004, for cables of rated voltages from 30 kV (U_m = 36 kV) up to 150 kV (U_m =170 kV) [1] and IEC 62067:2001 (first edition, effective since October 2001, for rated voltages above 150 kV up to 500 kV (U_m = 550 kV) [2].

Both IEC standards defined, for the first time, identical requirements for the shape of suitable AC test voltage and for the time of its application:

- substantially sinusoidal waveform
- frequency between 20 and 300 Hz
- time of voltage application equal to 1 hour (at 1 U_0 / 24 h - see remarks below).

For after-installation tests, PD measurements are actually not required by IEC standards.

TEST VOLTAGES

The AC test voltage level for the on-site test of new cable systems depends on the cable rated voltage: it is between 1.7 U_0 and 2.0 U_0 for rated voltages between 30 kV and 150 kV, (according to table 4 in [2]). At higher rated voltages the test voltage levels decrease from 1.4 U_0 (220-230 kV) to 1.3 U_0 (275-345 kV), 1.2 U_0 (380-500 kV) and 1.1 U_0 for cables of 500 kV rated voltage (according to table 10 in [1]). Additionally, IEC 62067 specified testing with 1.7 U_0 / 1 h, for all rated voltages > 150 kV. Both IEC standards accept testing with 1 U_0 / 24 h. The cable system's manufacturer and the user should agree on the test voltage level and the test procedure. To the authors' experience, test voltage levels often exceeded IEC recommendation. Typical test voltage levels were 160 kV for rated voltage 63/110 kV and 254 kV for rated voltage 127/220 kV.

Frequency Range

For AC testing on-site, IEC 60060-3 [3] enables the use of frequency-tuned resonant test systems in the extended frequency range 10-500 Hz. For HV/EHV extruded cable systems, IEC 60840 and IEC 62067 the frequency range is 20-300 Hz. Within this range, AC frequency has only little impact on the short-duration withstand voltage of extruded cables, only round about 10% [4]. The influence on the PD characteristics (PD magnitude, PD pattern) is low as well [5]. Due to the comparable physical processes, an AC voltage test in the frequency range between 20 and 300 Hz is a well-founded alternative to 50/60 Hz tests.

AC online voltages

Line-to-ground voltage

Both IEC standards offer line voltage testing (1 U_0 / 24 h) as an alternative procedure. Obviously, there is no need for an extra test voltage source. In contrast to this advantage there are several disadvantages, namely:

- failures cause a powerful short circuit (line power)
- line voltage testing is not capable of finding even severe defects (without PD measurements)
- tests at rated voltage can uncover neither any subsequent impact of transient overvoltages during normal operation nor any performance losses due to degradation effects
- no incremental increase of the test voltage with PD measurements taken at each step, is performed. This would allow failures to be detected at the lowest possible voltage. Instead, a switch-on transient is produced.
- line voltage usually introduces a high level of inter-ference, which may impact the quality of PD measurements
- line voltage testing removes the opportunity from interference separation by AC phase correlation (difference in AC line and test voltage frequency)
- low test voltage levels may lead to very long PD inception delays

Low efficiency of tests with line-to-ground voltage were