A NEW APPROACH TO AVOID NEGATIVE SUPERPOSITION ERRORS FOR PD MEASUREMENTS ON LENGTHS OF EXTRUDED POWER CABLES

Kay **RETHMEIER**, Alexander **KRAETGE**, Michael **KRUEGER** Omicron, (Austria), kay.rethmeier@omicron.at

ABSTRACT

PD in cables cause double pulses due to the signal reflection from the far cable end. As a result, the PD bandpass filter cannot determine the correct value of the Apparent Charge. As positive superposition errors can be tolerated, negative signal superposition causes dangerous under-estimation of the involved PD charge. Considering the regulations of the standards IEC 60270 and IEC 60885-3 with respect to the PD bandpass characteristics, the double pulse problem can be solved by using a synchronous 3-band filter, not affected by resonance faults, showing no significant under-estimation of the Apparent Charge value.

KEYWORDS

Partial Discharge, PD, cable, cable length, IEC 60270, IEC 60885, resonance, negative superposition, apparent charge, multi-band PD measurement.

INTRODUCTION

Partial discharge measurements are used as one of the quality control tests for extruded power cables. One important requirement is to allow an accurate measurement of single PD faults, independent from their position in the cable length. Due to their traveling wave characteristic, PD pulses do propagate in both directions, causing reflections at the cable's ends. A PD measuring system located at one end of the cable will therefore react on these groups of double pulses by superposed oscillations of the PD bandpass filter system. Depending on the double pulse distance these oscillations may lead to an over-estimation (positive superposition error) or to a dangerous under-estimation (negative superposition error) of the "real" Apparent Charge q of the PD fault. In the worst case, a PD fault may not be detectable at all during the PD measurement. These so-called "forbidden lengths" of a cable with negative superposition errors, showing an under-estimation of the Apparent Charge, depend on the PD fault position in the cable length, but also on the PD filter settings selected at the PD instrument. For a systematic analysis of these "forbidden lengths", double pulse diagrams have to be plotted once a year for every PD test facility, as demanded by the IEC standard 60885-3 [1].

OVERVIEW: STANDARDS

PD measurements generally have to be performed compliant to the IEC standard 60270 [2]. Besides defining the expression "Apparent Charge" as the most important value for the PD measurement itself, this standard describes the measuring setup with HV source, coupling capacitor, measuring impedance and PD measuring system. The test object (DUT) is reduced to a discrete capacitor, characterized by its capacitance (Farad) only. For cables, the simplification of modeling the DUT as a single capacitor cannot be tolerated, as PD pulses propagate along the cable. Therefore, not the complete cable capacitance is involved in the resulting charge transfer process. Consequently, the cable has to be modeled with distributed capacitances or as a transmission line. This fact was also recognized by the authors of the IEC 60270 and considered in the informative annex C ("Measurements on cables, gas insulated switchgear, power capacitors and on test objects with windings") of the standard. It is stated, that the Apparent Charge measured at the terminals of the cable is not equal to the charge at the PD fault position due to traveling waves, reflections and resonances. Finally, the IEC 60270 as a horizontal standard is not specific enough for HV cables. As a consequence the "cable" standards IEC 60840 [3] (<150 kV) and IEC 62067 [4] (>150 kV) do not refer to the IEC 60270 at all, but only to the IEC 60885-3 ("Electrical test methods for electric cables – Part 3: Test methods for partial discharge measurements on lengths of extruded power cables"), where the double pulse problem is discussed in detail. The topics of double pulse discrimination and double pulse superposition are also addressed in the IEC standard 60034-27 [5] (rotating machines) as well as in the CIGRE guide 366 [6], showing the oscillating PD signals of double pulses right after passing the PD bandpass filter system in a very vivid manner.

SUMMARY OF IEC 60885-3

The standard gives valuable background information on the nature of PD on cables, behaving as traveling waves, and about attenuation effects reducing the Apparent Charge level more and more with increasing PD propagation path. The main focus lies on the double pulse nature of PD on cables, as PD pulses (nearly) always appear as pairs due to the signal reflection from the far cable end. These double pulses can cause resonance problems of the PD bandpass filter, leading to an increased Apparent Charge value of up to 200% or to an reduced value close to 0% of the originally involved charge. With respect to uncertainties, a charge under-estimation of -10% is tolerated by the standard. To be aware of this problem, double pulse diagrams have to be plotted once a year for every PD test facility or after major repairs or changes of the PD measuring setup.

SPECTRUM OF DOUBLE PULSES

As the frequency spectrum of a single PD pulse is similar to a Dirac pulse, broadbanded and more or less of horizontal development with increasing frequency (see fig. 1), the frequency spectrum of a double pulse pair shows regular repeating minima and maxima (see fig. 2).

This frequency behavior is caused by the λ/4 resonance (and multiples of λ/4) of the cable, where the original signal at the beginning of the cable line (measuring position, near end) is eliminated by the delayed and therefore phase-shifted reflection from the far cable end. As a result, not all spectral components of the signal can exist due to this elimination process.