Innovative PD site location optimized for FAT in the cable industry

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ABSTRACT

In this paper, the theory of PD site location is described and discussed. A novel method introducing an innovative PD cable location procedure enabling fast, easy and accurate triggering on the PD pulse in the well-established Pulse Diagram (charge over phase) is presented. This approach ensures easy and accurate triggering of the investigated PD pulse and its reflections. Several practical examples of fault location in field are presented and discussed, including difficult failure localization, less than 20 meters from the far end of the cable. In conclusion, a reference is drawn to a new innovative approach enabling users to accurately discriminate failures located at the near and far end of the cable.

KEYWORDS

Partial discharge; fault location; failure location; time domain reflectometry; cable

INTRODUCTION

Apparent charge measurement according to IEC 60270 is performed during high-voltage cable routine tests. In case the partial discharge (PD) level exceeds the specified acceptance limits, PD cable site location functionality enables the operator to locate the position of the failure. Due to various types of cable construction, different insulating materials and insulation wall thicknesses, and variable background noise levels it is difficult to determine an absolute value for the required accuracy of PD site location. However, experience has shown that an accuracy of 1% of the full cable length is achievable. Using commercially available PD site location analyzing systems it is more difficult or even impossible to locate faults closer than 20 m from the far end of the cable. This issue is caused by pulse superposition resulting from the limited PD bandwidth of the test arrangement. An increase of the PD measurement bandwidth will lead to augmented noise levels and sensitivity to high-voltage connection lengths and local reflections.

In this paper the theory of PD site location on high-voltage cables is described and discussed. We present a novel approach for site location enabling the user to trigger on the PD pulse level in the well-established pulse diagram (charge over phase) and hence perform PD site location in a fast, easy and accurate manner.

THEORY

Cable fault location mainly consists of measuring the time between partial discharge pulses. This section covers the basic theory to characterize the relevant parameters for faults located close to the cable ends.

Bandwidth and pulse separation

The Nyquist theorem defines the main relationship between signal bandwidth (BW) and the maximum pulse rate which can be transmitted over a cable. The most well-known application of this theorem is the Nyquist filter – a digital filter used to transmit data in a limited BW reaching the theoretical limit of Equation 1. This limit applies as well to pulses that can be separated and detected without (positive) superposition in PD site location applications.

$$PRF = 2 \times BW \qquad (1)$$

Where:

BW = available bandwidth in Hertz (Hz)
PRF = pulse repetition frequency in Hertz

The optimum BW in time domain PD measurement for distribution cables is up to 20 MHz (but can be less depending on the cable length) which allows to separate pulses as close as 25 ns resulting in a spatial resolution of 2.5 m [1,2,3]. Increased cable attenuation at higher frequencies as well as the influence of the coupling capacitor are the main limiting factors. After each PD event reflections at both cable ends generate short bursts of PD pulses. When PD activity is located close to one end of the cable pulses can superimpose because of the limited BW. In that case, comparison of the pulse widths still allows detecting the presence of two pulses and even determining at which end the pulse activity occurs.

Near and far end pulse patterns

Depending on the PD event location the recorded pulse sequence starts with a single isolated pulse or a pair of pulses.

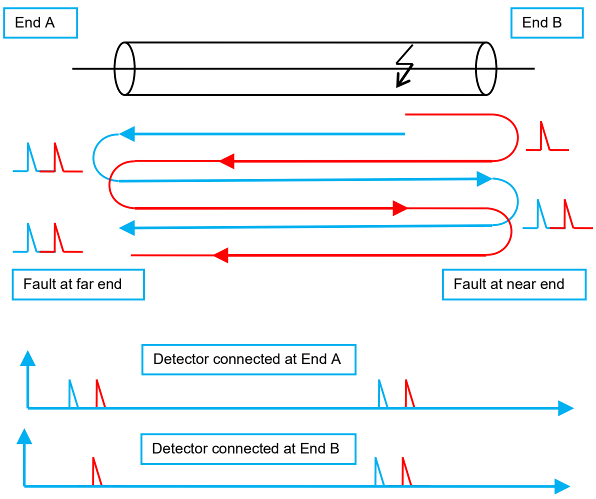

Fig. 1: Near end vs. far end pulse patterns

The subsequent pulses always appear as a pair of pulses. The time between the two pulses of a pair of pulses is proportional to the distance of the fault from the cable end.

When the fault is close to one of the cable ends the pair of pulses appears as a single pulse due to superposition.