Partial discharge (PD) locating in gas-insulated switchgear (GIS)

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Abstract

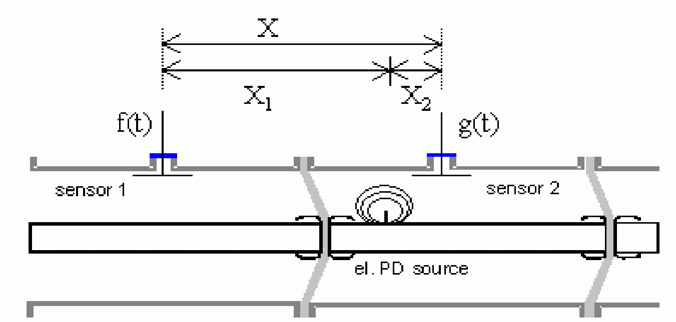
In times of liberalisation of energy market it is very important for an utility to reduce costs. A condition based, effective and fast maintenance strategy is essential. In case of GIS, a sensitive PD detection and a fast and exact locating is advantageous. This paper describe the possibilities of measurements with UHF-sensors in time and in frequency domain.

1. PD locating in GIS

The very fast electric pulse, of rise time below 1 ns, emitted by a PD source, propagates in all direction along the GIS duct.
A simple and obvious way of locating is the measurement in the time domain. With the time-of-flight measurements a PD locating is possible.
An other method is to use the frequency domain. The interference phenomena of two sensor signals, which are added, should give information about the time delay between the signals.

1.1. Time-of-flight measurement

By the time-of-flight technique the time difference between the wave fronts arriving at two couplers can indicate the location of the PD source. The time difference (Δt) is in general in tens of ns range, so a fast digital oscilloscope has to be applied for measurements [1]. In case of different signal-to-noise ratios (SNR) of the two signals, the measurement of the time difference Δt is not easy in all cases.



$$X_1 = \frac{X - (X_2 - X_1)}{2} = \frac{X - \vartheta_c \cdot \Delta t}{2}$$

Figure 1: Defect location by time-of-flight measurement and calculation of X_1

1.2. Interference measurement

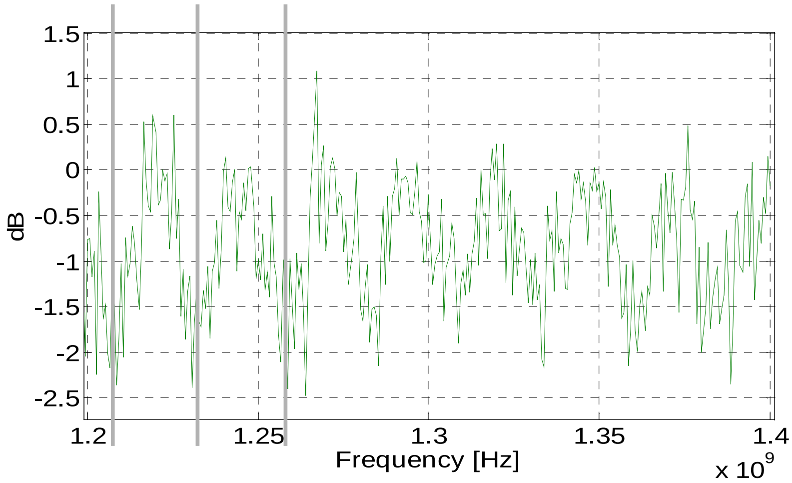
The hardware for measurements in frequency domain is cheaper than the hardware for measurements in time domain with comparable bandwidth. So a measure procedure with a spectrum analyser, instead of a digital oscilloscope, could be interesting.
The idea is based on the displacement law of Fourier-Transformation.

$$F\left[f\left(t - t_0\right)\right] = F\left[f\left(t\right)\right] \cdot e^{-j\omega t_0}$$

The PD sensor signals f(t) and g(t) are added and measured by a spectrum analyser (|F[g(t)+f(t-t_0)]|). Furthermore, the PD signal f(t) and g(t) are measured also independently by a spectrum analyser (|F[f(t)]| and |F[g(t)]|). If these three results are combined in the following way, the time difference t_0 will be estimable.

$$\frac{\left|F\left[g(t)+f\left(t-t_0\right)\right]\right|}{\left|F\left[g(t)\right]\right|+\left|F\left[f(t)\right]\right|}=\left|\cos\left(\frac{\omega\cdot t_0}{2}\right)\right| \qquad \textit{in case of } f(t)=g(t).$$

The signal, which is combined in this way, show interference phenomena and has equidistant minima. For example t_0 = 39,34 ns; a minimum at 1210 MHz, next one at 1235 MHz, and at 1260 MHz and so on (see Figure 2). So the Δf = 25 MHz and the estimated time difference is 1/Δf = 40 ns



$$\frac{\left|F\left[g(t)+f\left(t-t_0\right)\right]\right|}{\left|F\left[g(t)\right]\right|+\left|F\left[f(t)\right]\right|}$$

Figure 2: Measurement with a PD-Source in a configuration where only a TEM-wave propagates

There are similar interference phenomena for f(t) = x • g(t) (x is a constant scaling factor), too.

Normally the measured UHF signals are more different at different sensor positions in GIS than a constant scaling factor. This is caused by the different wave modes, which propagate in the GIS. The different wave modes has different speeds and the measurability of some modes depend on the sensor position [2].

Higher modes are able to propagate at frequencies above their own critical frequency (f_c), which depends on the geometry of the GIS. Above the lowest critical frequency of all modes (in GIS the f_c of TE_{11}), this method doesn't work effective. At very low frequencies the sensors are less sensitive and there is much noise, too. So the success of this method determined by the usable band-width between these frequencies.

References

[1] CIGRE TF 15/33.03.05, PD Detection System for GIS: Sensitivity Verification for the Method and the Acoustic Method, Electra No 183, April 1999

[2] M.D.Judd, B.F.Hampton, O.Farish, Modelling PD excitation of UHF signals in waveguide structures using Green´s functions, IEE Proc.-Sci Meas. Technol. Vol. 143, No. 1, January 1996