Partial discharge diagnostic of medium voltage switch-gears under operating conditions using a special PD-probe

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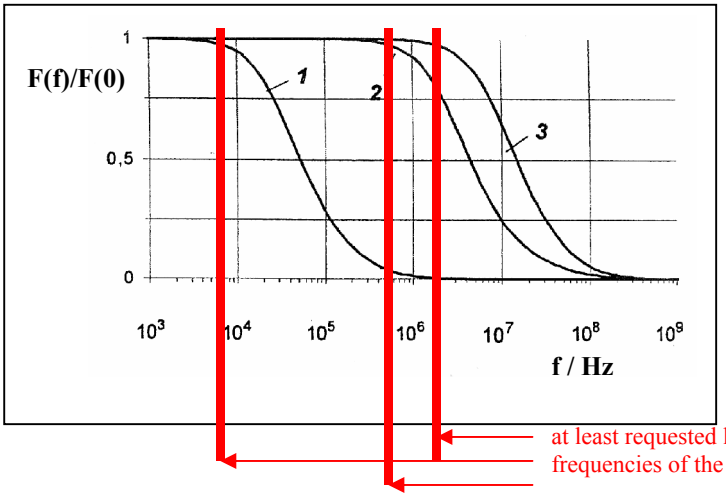
Abstract
As an essential tool for condition based maintenance of electrical equipment, PD measurements under real operating conditions are becoming ever more important. The main problems associated with these diagnostic on-site measurements are the measuring sensitivity and reproducibility of measured values with respect to calibration conditions. This paper discusses the problems of on-site PD measurement in medium voltage switchgear using a special PD-probe. It will be shown, that the maximum PD-sensitivity can be reached by using a capacitive sensor in conjunction with the PD-probe and by connecting of elements with resonance characteristics. For measurements made under operating conditions on real switchgear, a measurement sensitivity of < 20 pC could be reached.

Introduction

Since a long time PD measurements are an essential tool for technical diagnostics of electrical equipments in all stages of their lifetime /1/. Especially for condition based maintenance of electrical equipment under real operating conditions the PD measurements on- site are becoming more and more important, because in this case no switching off of equipment or its costly transport into a testing laboratory doesn´t be necessary. The main problems associated with these diagnostic on- site measurements are the low measuring sensitivity, caused by large electromagnetic interferencies, and the reproducibility of measured values with respect to calibration conditions. It is possible to avoid large electromagnetic interferencies by using nonelectrical measuring techniques as optical or acoustical measurements, but this is problematically with respect to missing correlation between measured values and the basic parameter “apparent charge” /2/. Therefore, the application of electrical measuring techniques for on- site measurements with sufficiently measuring sensitivity and calibrated charge values seems to be necessary. That´s why special PD probes were developed in last years /3/. The paper deals with, how sensitive PD measurements can be provide for on- site measuring of medium voltage switchgears, using such special PD probe.

Measuring principle

The used PD probe is based on the measuring principle of wide band amplifying of PD pulses and following electronic integration for evaluation of the basic parameter “apparent charge” /4/, /5/. The aquisition of PD pulses can be provided as well by electromagnetic field coupling as direct (galvanic) coupling with the test object. Using the field coupling it is necessary of having a non- complete electromagnetic screen of test object, so the field of PD pulses can be spread around the surrounded volume. In this case the PD signals can be aquisited by inductive or capacitive fieldsensors and measured by the PD probe. Concerning the transfer characteristic of such measuring systems it was be shown /5/, that in most cases it can be approximated by a high- pass- filter- characteristic with respectively cut- off frequencies. Using a fieldsensor the measuring sensitivity is mostly depending of the distance to the test object, what can be problematically with respect to the calibration of the whole system. Generally it is requested, that the lower cut- off frequency is located, at least, in the constant part of the transfer characteristic /1/, fig. 1.
In the case of galvanic coupling, at least, the distance dependence of measuring sensitivity is eliminated. This can ever be used, if in the test object any fieldsensors (mostly capacitive) are integrated, e.g. for voltage measurement. Concerning the PD measurement the measuring



1: ~ surface discharge
(t_r / t_f = 1 µs / 5 µs)
2: ~ point discharge
(t_r / t_f = 5 ns / 50 ns)
3: ~ cavity discharge
(t_r / t_f = 5 ns / 20 ns)

(see /1/)

fig. 1: Idealized frequency spectrum of PD pulses and at least requested cut- off frequencies

sensitivity is relatively low with respect to the mostly very low value of their capacitance. This can be verifyed by calculating of a simple capacitive modelling of testing object C_p (fig. 2). As well known, the apparent charge Q_m measured by coupling capacity C_k and related to the real value Q_a can be expressed by

$$Q_m / Q_a = C_k / (C_k + C_p) \qquad (1)$$

So, for a ratio C_p / C_k of 50, only a charge value Q_m of about 2% of Q_a can be measured. It means, e.g., that for a value of Q_a = 100 pC, mostly a dangerous PD pulse, with such a measuring circuit only a value of 2 pC can be measured. In this case, a measuring sensitivity of << 2pC will be requested, such values can not be reached under normally on- site conditions.

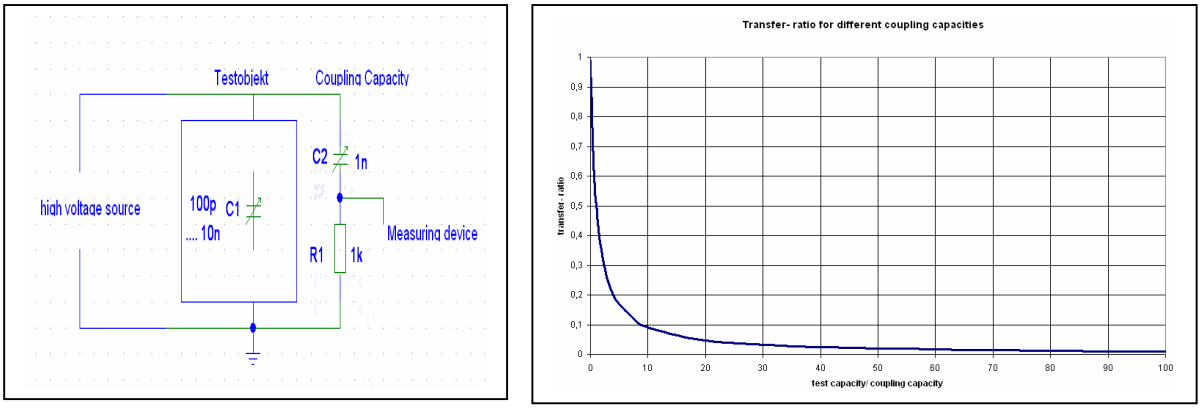


fig. 2: Measurable charge values for capacitive coupling

On the other hand, concerning the reproducibility and with respect to the calibration problems this measuring technique should be applied. It will be shown below, that even with such measuring circuits using a certain modification of testing arrangement a significant improvement of measuring sensitivity can be reached.

PD measurements on medium voltage switchgear

The type of used switchgear will be applied very often as a so- called ring- main- unit in MV-grids. In the typical construction of such switchgears a capacitive fieldsensor is integrated for voltage indicating, with a value of 10… 20 pF. Usually, this fieldsensor is free connectable also under operating conditions, so it can be used, in principle, even for PD measurements.
At first, the frequency characteristic of this field sensor, alone and with the PD probe, was be measured*), fig. 3.

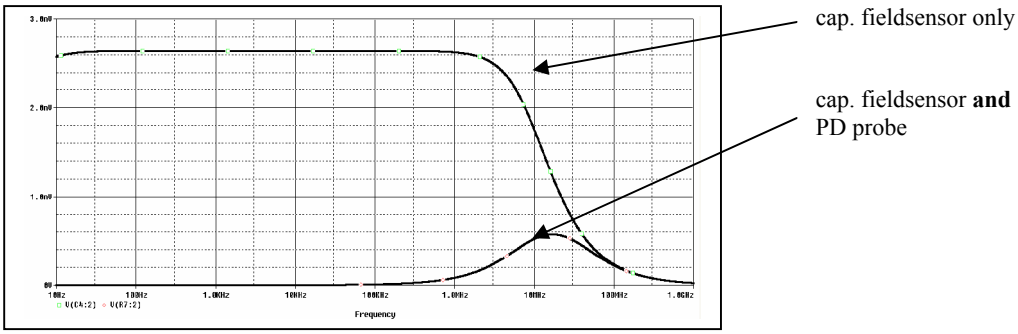


fig. 3: Frequency characteristic of fieldsensors alone and with the PD probe

As expected the frequency characteristic of the fieldsensor with the PD probe is very limited caused by the very low capacity of fieldsensor (~ 18 pF) and the mentioned high- pass-characteristic of the PD probe. Concerning further the large attenuation by the capacitive ratio (see (1)) and the usually existing electromagnetic disturbance level, so on- site measurements cannot be provided under these conditions.
It can be assumed, that the cut- off frequency of PD probe cannot be changed significantly, so an improvement of frequency characteristic can be reached only by changing the testing arrangement. Because under operating conditions a modification of test object can be excluded, so it was investigated, that connecting a normally used Cable- part this behaviour can be improved. At first, the frequency characteristic was simulated by PSPICE (fig. 4).

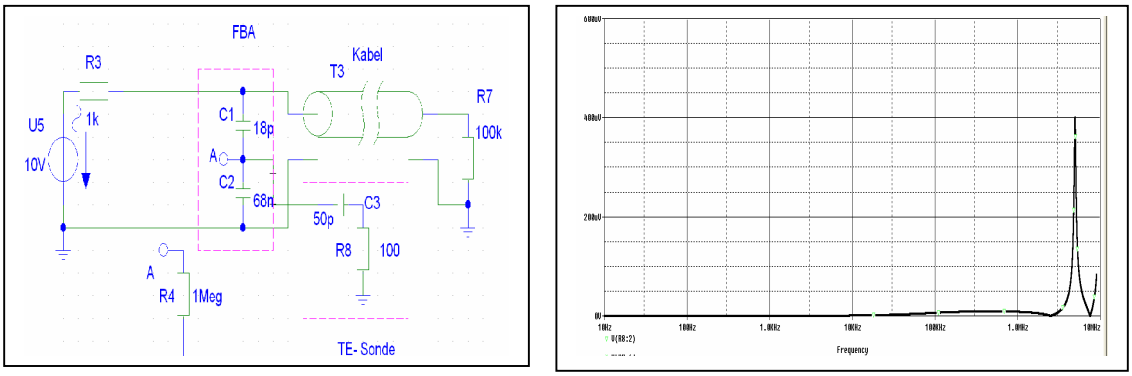


fig. 4: Frequency characteristic of fieldsensor with PD probe with parallel cable- part

Under these modificated conditions a (first) resonance peak is occurring at ~ 5 MHz. This means, that connecting an appropriate resonance circuit parallel to the hv potential into the test object a significant improvement of the frequency characteristic and, therefore of the measuring sensitivity, can be reached.
However, this effect can be used for the sensitive measurements only, if the additional resonance peaks are located into the frequency spectrum of pd´s (see fig. 1). A further condition is that the

measuring device has either an appropriate wide band measuring characteristic (like the used PD probe), or the possibility for changing the measuring frequency in the interested range is given.
These results were tested under testfield conditions (screening lab) by calibration procedures of different testing arrangements and measuring systems (PD probe, classical TE- measuring system TETTEX, fig.5).

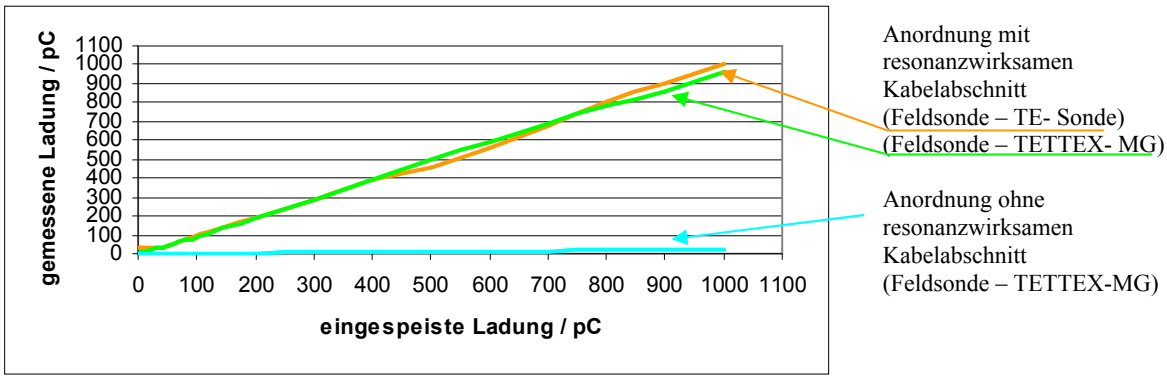


fig. 5: Measuring sensitivity for different testing arrangements

Even under these conditions the improvement of frequency characteristic could be confirmed. Without additional cabelpart the measuring sensitivity is unacceptable low, with this part and its resonance character the measuring sensitivity will be significantly improved.
These results were used successfully for on- site measurements in practice, where a measuring sensitivity of < 20pC was reached.

Summary

For medium voltage switchgear the measurement possibilities for on- site PD tests under operating conditions were investigated. It was be shown, that using an integrated into the switchgear capacitive sensor in connection with a special PD probe in principle sensitive PD tests can be provided. On condition that appropriate resonance elements like cabel- parts will be connected a sufficient measuring sensitivity can be reached. This testing arrangement can be used in principle even for similar configurations.

References

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