Preprocessing Circuits for Partial Discharges Measurement

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Abstract - Normally cavities or voids included in electrical insulation are filled with gases, which have lower breakdown strength than the surrounding insulation. Under the normal working conditions of the insulation system, the voltage across the cavity may exceed the breakdown value of the filling gas and cause a breakdown in the cavity. This phenomenon is called Partial Discharge (PD). This research is focused on methods using basically detection and quantification of PD charge per the voltage pulses in charge sensitive amplifier. Two different principles of processing PD events are used - analog and digital technique. This method is useful for non-destructive and non-invasive on-line diagnostic systems.

Keywords - Preprocessing, pulse shaping, Partial Discharge

1. Introduction

Partial Discharges originated by dielectrically defective parts of the high voltage insulation system result in its degradation, which may ultimately lead to a failure of high voltage apparatus. Partial discharges can be detected and localized by various electric or non-electric techniques. For example PD detection by radio frequency or acoustic emission during discharge and by the after-discharge chemical reactions product such as ozone in gas filled isolation systems. We focused on methods using basically detection of the voltage pulses [1] (see figure 1).

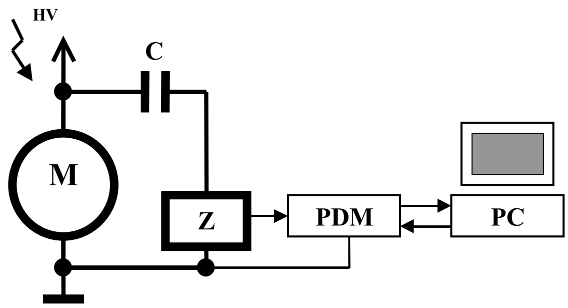

Figure 1. Basic Partial Discharges measurement setup
C - coupling Capacitor, M - electrical Machine,
PDM - Partial Discharge Meter,
PC - Personal Computer

The coupling capacitor C, is connected parallel to the test electrical machine M. This capacitor shows high impedance for power frequency voltage but has low impedance for high frequency signals. Thus, the PD pulses that have short rise times and include many high frequency harmonics pass through the coupling capacitance. These pulses are decoupled by measurement impedance Z connected in series with the coupling capacitor, and after amplification are measured in Partial Discharge Meter (PDM) connected to the PC.

2. Subject and Methods

Preprocessing

Preprocessing steps would be applied because of PD pulses signal extremely wide frequency spectrum.

Partial discharge voltage pulses in solid dielectric systems are short with approximately rise time 10 nanoseconds and exponential falling edge up to 10 nanosecond time constant (see figure 2). These pulses are 10 times longer in liquid dielectric fluids (transformer oil).

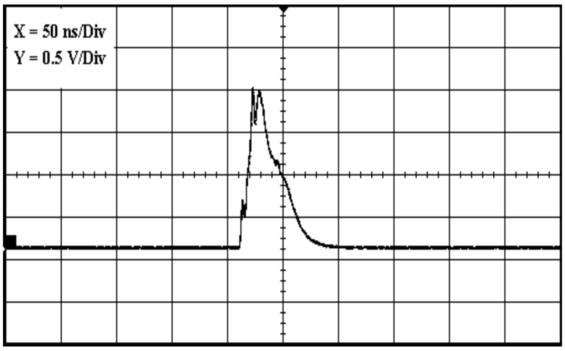

Figure 2. Artificial Partial Discharge pulse from calibrator 1000pC
X = 50ns/Div, Y = 0.5V/Div R_{load} = 50 Ohm

The total charge is computed and converted to DC voltage in charge sensitive amplifier [2] (integrator). The result is DC voltage increased by the each PD event. For proper functionality the charge sensitive amplifier would be zeroed by the master circuit (microprocessor) or by the discharge constant much longer than input charging pulses [3].

Analog pulse shaping

The next step is signal amplifying and shaping from step pulses to relative short but not sharp bipolar or unipolar narrow band pulses in shaping amplifier. This shaping circuit is based on band pass filter with one derivation stage and one or two integration stages, which produced unipolar (after first integration) and bipolar (after second integration) pulses approximately 10 times longer than integration and derivation time constants. At the beginning we chose time constant as one microsecond. Therefore, pre-processed pulses are about 10 microseconds long. Finally these narrow band preprocessed pulses are recorded by peak detector and digitized or shown on oscilloscope. The peak detector is zeroed by the controlling processor (see figure 3).

The voltage on the diagnosed machine power terminal synchronizes the peak detector zeroing, where the coupling impedance is also connected.

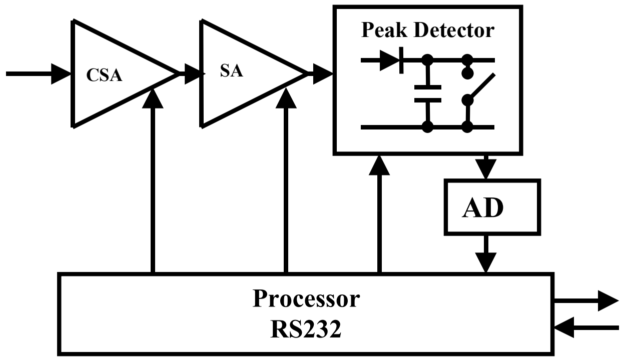

Figure 3. Partial Discharge meter with analog pulse shaping
CSA - Charge Sensitive Amplifier, SA - Shaping Amplifier, ADC - Analog/Digital converter

In the realized PD meter sample, shaping amplifier and charge sensitive amplifier are replaced by passive coupling network on logarithmic amplifier input (see figure 4). This technique have major advantage of superior dynamic range (92dB with Analog Devices AD8307 log. amp.) and lower number of analog components. The passive coupling network realizes band pass filter 30-300kHz, but these cutoff frequencies are not finally evaluated. The filter output signal is logarithmized in logarithmic amplifier and maximal value is held in peak detector.

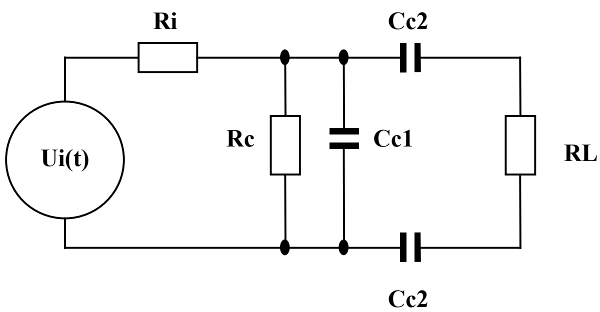

Figure 4. The input passive coupling network
Ui(t),Ri – PD source and its coupling impedance equivalent circuit, Rc, Cc1, Cc2 – input coupling components,
RL – logarithmic amplifier input resistance

Digital pulse shaping

Alternatively we focused on direct digitalization of the step pulses (see figure 5) with high speed ADC and fast digital processing by Field Programmable Gate Array (FPGA). In FPGA there are included shaping circuits, peak detector and storage memory for PD time distribution figures.

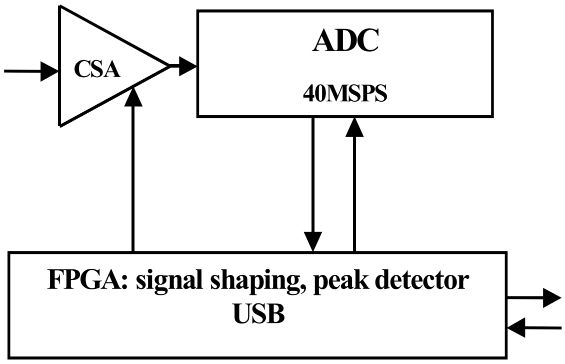

Figure 5.Digital Partial Discharge meter
CSA - Charge Sensitive Amplifier,
ADC - Analog/Digital Converter,
FPGA - Field Programmable Gate Array

For this type processing the shaping techniques as described above are not suitable, because of heavy computing amount is needed for them – a lot of multipliers-dividers and summators. Shaping circuits are realized as digital delay lines and substractors that produce sharp digital pulses. The pulses are accumulated for increasing signal to noise ratio. The digitally shaped pulses are sharp and short. In case of 40 MHz ADC clock and the pulses eight or four ADC clocks long and output pulses are 200 or 100 nanosecond long (for our example). By the digital method increasing of time resolution is reached, because "dead time" of the aparature is as short as time resolution. This digital technique also has possibilities of good pile-up pulse rejection.

3. ACKNOWLEDGEMENT

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4. CONCLUSIONS

The digital shaping technique looks be perspective, because it’s next important advantages: small count of analog circuits and high EMI immunity. In other hand analog technique uses relative simple components. Used coupling technique is non-invasive and is suitable for new or installed machines on-line predictive diagnostic. If the measurement equipment is synchronized with proper AC line sources of PD can be localized in tested power machines.

REFERENCES

[1] European Standard EN 60270:2001
[2] Lemke, E.: *A new PD measuring procedure based on the evaluation of cumulative charge* - Conference of PD in Electrical Insulation Bangalore/India (1976) 1 - 22
[3] M. Kriz, J. Vedral: *Quantification of Partial Discharges Charge* – Conference Measurement 2003 Smolenice/Slovakia (2003)