A NOVEL PARTIAL DISCHARGE CALIBRATOR DESIGN VIA DUAL MICROCONROLLER AND HIGH SPEED DAC

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ABSTRACT

Insulation is a crucial phenomenon for high voltage apparatus. Partial discharge activity affects the service life of the dielectrics. Therefore partial discharge must be less than a specified value for high voltage equipment. An accurate partial discharge measurement strongly depends on scaling of the measurement systems. It is a general method to use a partial discharge calibrator to calibrate partial discharge measurement systems. This paper demonstrates an approach for partial discharge calibrator realization.

I. INTRODUCTION

Existing of the partial discharge may cause a deterioration of the high voltage apparatus insulation and this deterioration may lead to a failure. Due to this failure there will be damages on the electrical networks and humans. So PD measurement is a significant concept for the assessment of electrical insulation of high voltage apparatus. If PD magnitude exceeds acceptable boundaries in the experiments, the service life of the high voltage equipment can not be guaranteed [1].

The reliability of the measurement results is strongly depending on the calibration of the PD measurement system. The purpose of the calibration is to verify that the measuring system will be able to measure the specified PD magnitude correctly. Therefore calibration procedure is very important for experimental setups. So a novel PD calibrator has developed via microcontroller and digital to analog converter chips.

II. THEORY

Partial Discharge Theory

Partial discharge is defined as localized electrical discharge that only partially bridges the insulation between conductors and which can or can not occur adjacent to a conductor. The cavities or bubbles, within the solid or liquid dielectrics, are the main reasons of the PD. Partial discharges which inject charge between terminals of the test object under test can be measure as a current or voltage pulses using a suitable detector circuit. Those current or voltage pulses are converted to the charge quantity which is called apparent charge. The apparent charge is usually expressed in picocoulombs (pC) [2]. The acceptance limits for the PD tests are typically in the range of 5 pC to 500 pC [3]. For example, the internal partial discharges in the metal-oxide surge arrester energized at 1,05 times the continuous operating voltage, shall be ≤10 pC [4].

A simple PD measurement circuit is shown in Figure 1. In the figure U- high-voltage supply, Z_{mi} -input impedance of measuring system, CC -connecting cable, C_a -test object, Ck -coupling capacitor, CD -coupling device, MI -measuring instrument, Z -filter [2].

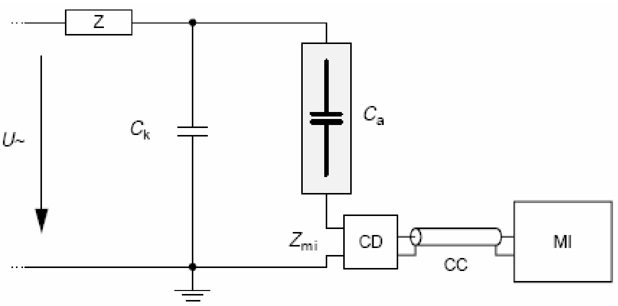

Figure 1. Simple PD measurement circuit

The test object (C_a), produces PD, is connected serial to the coupling device (CD). Partial discharges, which inject charge between terminals of the C_a, cause a current pulse throughout the coupling device. This current pulse, is converted a voltage pulse via CD and transmitted to the measuring instrument with cable (CC). The voltage pulse waveform is depending on input impedance of measuring system. Measuring system input impedance is depending on the impedances of CD, CC and MI. This impedance could be considered as RC or RLC equivalent circuit. The R component represents the resistive load. The current pulse is flowed through it and converted to a voltage pulse. C represents the sum of the input capacitance and the stray capacitance, and L is the total measuring system inductance.

If the current pulse, mentioned above, is considered as a Dirac pulse (no duration time) and inject to the RC or RLC circuits, the gained voltage shape will be as in Figure 2.

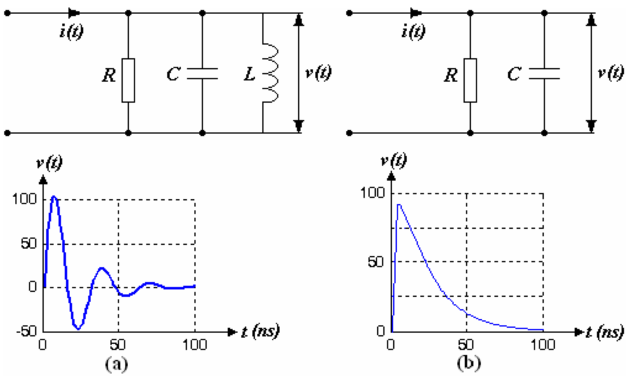

Figure 2. Gained voltage pulse shapes of *RLC circuit (a)* and *RC circuit (b)* depending on current pulse.

But pulse shape of the current i(t) is not exact Dirac pulse in practice, because it has a duration time [5].

If it is assumed that the PD measurement executes with RC type circuit, the obtained voltage shape will be as in Figure 3. It is regarded as a PD pulse. In the Figure 3, $\hat{U}$ represents the high voltage peak value, V_{Ca} represents the voltage across to the test object and V_c represents the voltage across to the cavity which take place inside the C_a. Both of U^+, the PD inception voltage, and V^+, the PD extinction voltage, are dependent on the shape, dimension and location of the cavity.

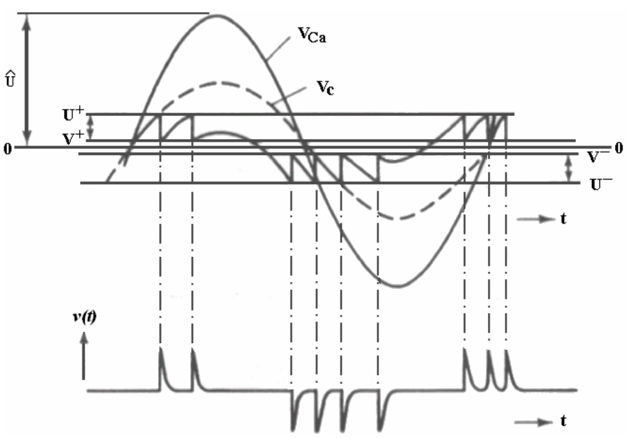

Figure 3. Appearance of PD pulses

The pulse shape of the PD in Figure 2(a) which is obtained with RLC circuits is damped oscillatory pulse (DOP) type. The other PD pulse shape (Fig. 2(b)), which is obtained with RC circuits, is damped exponential pulse (DEP) type. Equation (1) and (2) represent the mathematical models of the pulses.

$$DEP(t) = V\left(e^{-t/t_1} - e^{-t/t_2}\right) \quad (1)$$

$$DOP(t) = V\sin(2\pi f_c t).\left(e^{-t/t_1} - e^{-t/t_2}\right) \quad (2)$$

In these equations, V is the voltage pulse peak value, t_1 and t_2 are the damping coefficients and f_c is the oscillatory frequency [5].

PD Calibrator Design Theory

Detailed DEP type PD pulse shape is given in Figure 4. The notation V is the peak value of the pulse. The acceptable rise time of the pulse is t_r (the time between the 10% and 90% of the V on the front of the pulse), pulse width is t_W (the time between the 50% of V on the front of the pulse and 50% of the V on the tail) and the decay time is t_d (the time between the 90% of V on the front of the pulse and 10% of the V on the tail).

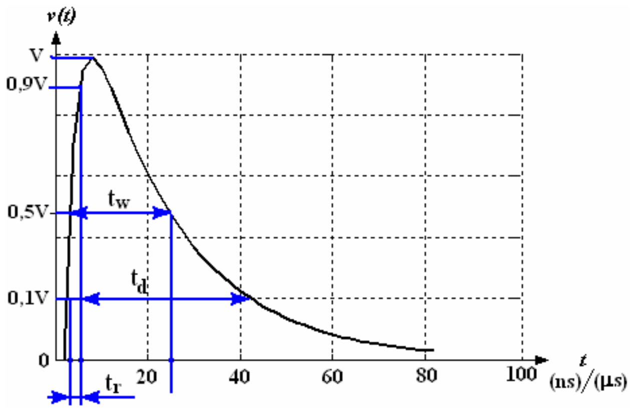

Figure 4. Detailed PD pulse shape (DEP type)

A calibration pulse should be injected to the PD measurement system to obtain the scale factor (k) and to calibrate the measurement system. The calibration pulse shape should be identical to the one in Figure 4. The circuit, shown in Figure 5, could be used to get such an identical pulse shape [5].

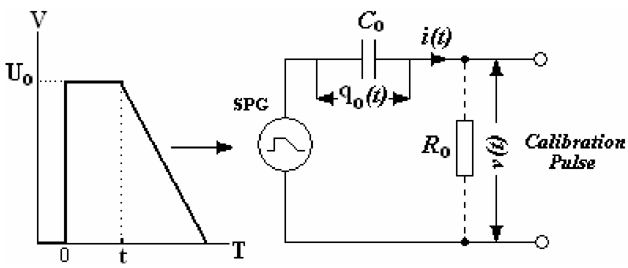

Figure 5. PD calibrator circuit

In Figure 5, SPG represents a step pulse voltage generator and its output waveform is shown on the left hand side of the figure, for one calibration pulse. Output voltage (V) of the SPG is an ideal step voltage pulse (without duration time between 0 and U_o levels). But generation of an ideal step voltage pulse is not possible in practice. If it could be possible to produce an ideal step voltage pulse, the change of the PD calibrator output current i(t), charge of C_o (q_0) and v(t) would be as in Figure 6. If Figure 6 is surveyed, it is understood that calibration pulse i(t) has no rise time or its rise time is extremely small.

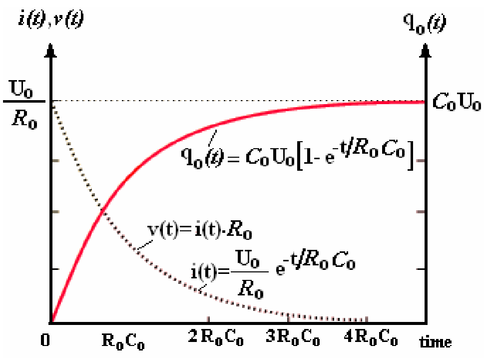

Figure 6. PD calibrator response in case of SPG produces an ideal step voltage pulse.

In reference [2] rise time of the step voltage pulse (SPG output) is allowed up to 60 ns. So, in practical application, rise time of the step voltage pulse will be slower (soft) than ideal one. Consequently step voltage pulse with soft rise time will cause a PD calibration pulse as in Figure 4.

Charge magnitude generated by PD calibrator, can be represented as,

$$q_o = C_o . U_o \qquad (3)$$

III. EXPERIMENTAL

A novel partial discharge calibrator approach is developed to scale PD measurement systems. The construction blocks of the calibrator are shown in Figure 7. Two microcontroller chips are used in the application. One of the microcontrollers is used for peripheral interface control (start/stop and data input buttons, LCD, etc.), the other one is used to drive the digital to analog converter (DAC) chip. The microcontroller has 20 MHz oscillatory frequency (its operating frequency is 5 MHz and command cycle time is 200 ns), which drives DAC.

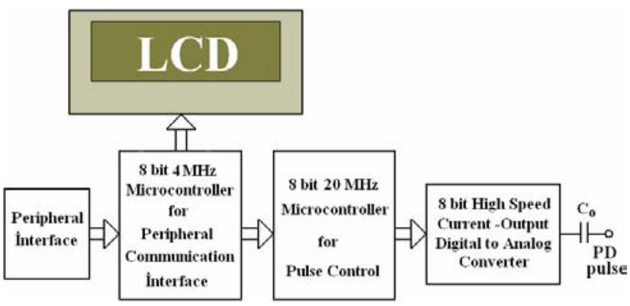

Figure 7. Schematic representation of the PD calibrator

The DAC has very fast settling time (100 ns) and has 8 bit data input (DAC 0800). It controls the analog output with current and generates the step voltage pulse.

The desired calibration pulse data are informed to the calibrator, via peripheral interface, by user. Calibration pulse data consist of charge magnitude- q_0 (pC), repetition number of the calibration pulses within 20 ms period- N_{PD} (for 50 Hz freq.) and phase angle of the first calibration pulse- Φ_{PD} (Fig 8).

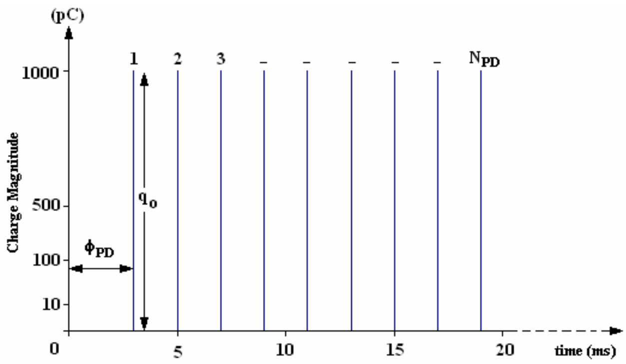

Figure 8. Magnitude representation of the requested PD calibration pulse data

Requested calibration pulse data are received using 4 MHz microcontroller, from the peripheral interface and processed by this microcontroller. The processed data are transmitted to the 20 MHz microcontroller by 4 MHz one. Lastly 20 MHz microcontroller drives the DAC for requested data.

Special features of the PD calibrator can be stated as,

- Calibration pulse charge magnitude (q_0) could be changed from 10 pC to 1000 pC,
- Repetition number of the calibration pulses (N_{PD}) for a cycle (20 ms) may be up to 50 (for $\Phi_{PD}=0^o$),
- Phase angle of the first calibration pulse can be adjusted in the range of 0^o to 360^o.

Since C_0 has a constant value, output charge magnitude (q_0) of PD calibrator is varied only by U_0 parameter. For example if C_0=100 pf and U_0=10 V, according to the equation (3), the charge q_0=1000 pC, if U_0=5 V, then q_0=500 pC etc.

IV. DISCUSSION

The step pulse voltage generator (SPG) output waveform of the realized PD calibrator is given in Figure 9. Rise time of the step voltage pulse is relatively larger than that, specified in the Ref. [2]. In order to decrease rise time of the pulse, it may be convenient to use faster micro-controller and DAC.

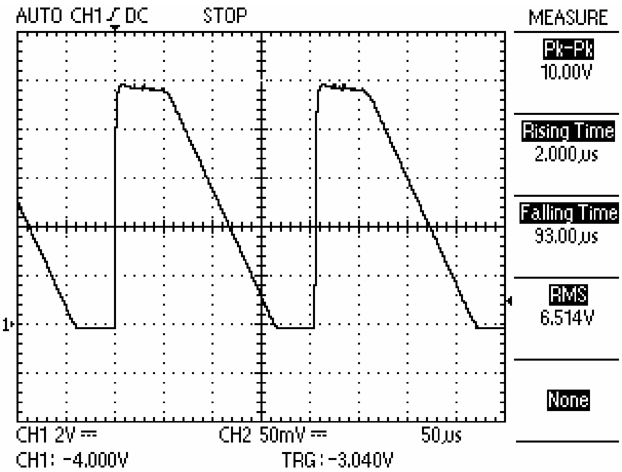

Figure 9. SPG output of the calibrator

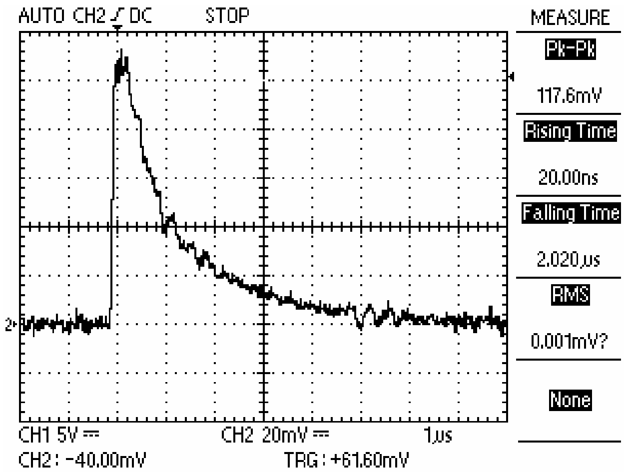

Figure 10. Output voltage waveform of the calibrator

On the other hand, the output voltage waveform of the calibrator is shown in Figure 10. The waveform was obtained with a capacitance of C_o=151 pF and a resistor of R_o=100 Ω. It is necessary to apply certain methods in order to reduce the noise level, which occurs on the calibration pulse.

V. CONCLUSION

Calibration of the PD measurement system is as important as PD measuring. Because service lives of the high voltage insulators considerably depend on the PD intensity. If PD intensity could not be measured accurately, assessment of the insulation quality will be wrong. For the accuracy of the PD measurements, calibration procedure should be carried out. The way to calibrate PD measurement system is to use a calibrator.

A new PD calibrator is developed to support PD measurements. New calibrator has dual microcontroller to get fast operating time.

On the other hand a DAC chip is used to generate PD calibration pulses with fast character. The DAC has fast settling time and controls the self analog output with current. So, U_0 and charge magnitude q_0 could be varied in a wide interval.

It is supposed that, the calibrator could be response the users' desires with peripheral interface control. And this advantage could provide to users an advanced calibration tool, for the PD measurement systems.

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