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A Study on Simultaneous Measurement of Partial Discharge in Epoxy Resin Insulator using IMC and Rogowski Coil

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ABSTRACT

In practice, field measurement of partial discharge is easily suffered by interferences due to the noisy signal has been mixed with the resulting partial discharge signal. Therefore, the detection and measurement of PD are important to monitor the insulation life in high voltage (HV) power equipment. The paper presents the simultaneous measurement of partial discharge (PD) pulse parameters using the impedance matching circuit and the Rogowski coil sensor to study the features of partial discharge on the epoxy resin insulator. Two different thicknesses of samples were used to observe the PD pulse parameters with the voltage applied vary depending on the thickness of the sample to attain constant electric field intensity for both samples. The step response parameters resulted from the measurement can be used as a time domain features to discriminate various types of PD in HV power equipment. Thus, the PD can be observed clearly, maintenance can be performed, and the performance of the power system can be improved.

1. Introduction

The study on the partial discharge (PD) of solid insulator has been a critical issue to ensure that the insulating function remains in good condition during operation [1-7]. PD is electrical discharge that partially bridges the isolation between conductors, as result of electrical stress in or on the surface of insulation [8]. PD also one of the factors that could lead to failure of electrical equipment, could destroy insulation and cause ageing of insulation. PD which occurs on the surface of a solid dielectric material in an HV insulation system due to corrosion processes, also can occurs when the tangential field component surpasses the discharge field intensity over the material's surface [9-11].

By detecting and measuring the PDs, any maintenance and assessment of the equipment insulation can be quickly solved and any catastrophic failure of the electrical equipment can be avoided [12]. Many different methods of PD detection have been researched for over 100 years [13-

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15]. The conventional method that can be used is by measuring the electrical current associated with the PD pulses. PD waveforms are generally seen as having a sharp rise time, typically in the realm of nanoseconds, with a short duration in the order of 10 ns [12]. Normally, a PD current pulse can be identified by a number of discharge properties, including the peak value, rise time (10% to 90% of maximum pulse levels), decay time (90 % to 10% levels), and pulse width (time difference between 50 percent levels) and the frequency spectrum of PD signal contains dominant frequency components ranging between kHz to tens of MHz [16].

Numerous approaches and techniques, such as acoustic emission measurement, capacitive coupler, or impulse current measurement, have been widely employed conventionally, to take quick and accurate action whenever a PD occurs [17]. Unfortunately, noises such as Radio Frequency (RF) and pulse-shaped noise has been a significant issue in PD measurement which limits its utility as a tool for evaluating insulation status and detecting defects in power plant insulation [17,18]. Thus, in this work the detection of the PD pulse is performed by using an impedance matching circuit (IMC) and simultaneously measured by using Rogowski Coil (RC) sensor for comparison purpose. The PD signals detected by IMC and RC sensor were analyzed and evaluated to determine PD pulse parameters such as amplitude voltage, rise time, peak time and settling time.

2. Methodology

2.1 Samples

Araldite Rapid epoxy resin, which manufactured by Huntsman has been used for the sample preparation. A small volume of epoxy resin and hardener is mixed with the ratio 1:1 in a small cylindrical mould. The sample was prepared in different thickness, which consisted of 1.60 mm and 1.73 mm, with 50 mm diameter for both samples. The schematic diagram which consisted of a 25 mm diameter cylindrical high voltage electrode and test sample as shown in Figure 1.

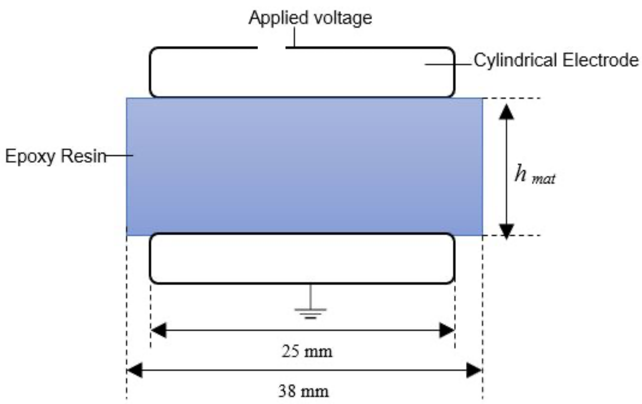


Fig. 1. Schematic diagram of the test sample

2.2 Measurement

Figure 2 shows the PD measurement circuit diagram used in this work. The experimental setup of PD measuring system was configured according to the recommendations of IEC 60270, consisting of a coupling device, a transmission system, and a measuring instrument as shown in Figure 3. The frequency response of the IMC used enables analysis of the signal in the range up to 1 GHz, while the RC sensor is in the range from 0.5 MHz to 25 MHz. The electric field intensity of 5kV/m is constantly applied to both samples. Thus, the applied voltages for the samples thickness of 1.60 mm and 1.73 mm are set at 8 kV and 8.65 kV, respectively. The PD signal was measured using the Teledyne LeCroy digital oscilloscope with specifications of 4 channels, 2.5 GS/s sampling rate, 600 MHz bandwidth, two 200 Mpts memory modules, and high-speed USB 2.0 interface. PD current signal induced in the test sample was detected synchronously by IMC and RC sensor.

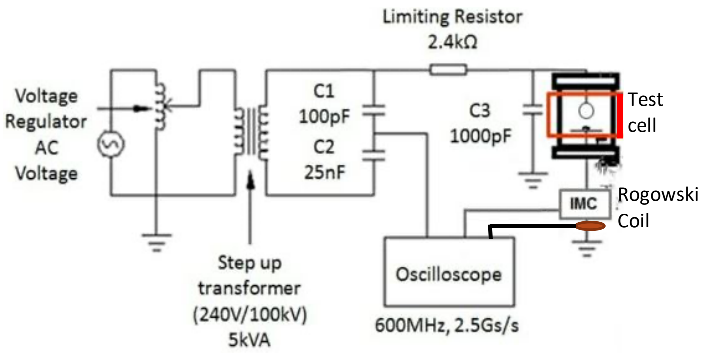


Fig. 2. Circuit diagram of PD measurement system

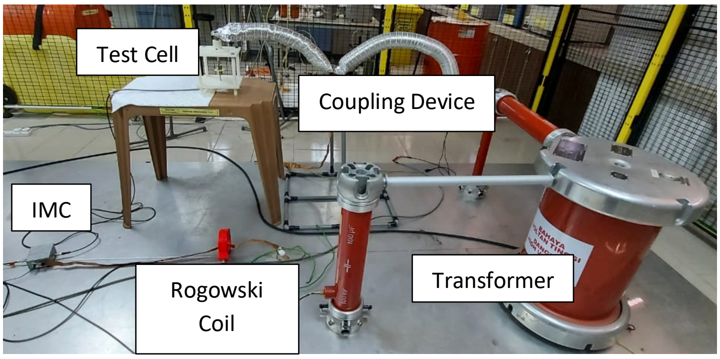


Fig. 3. Experimental work in laboratory

3. Results

Figure 4 shows the PD pulses occur within 2.5 cycles of AC applied voltage captured by the IMC and RC. Most of PDs was occurs in the positive half cycle than the negative half cycle. Based on the figure, the PD pulses captured by IMC have a larger amplitude voltage compared to PD pulses captured by RC.

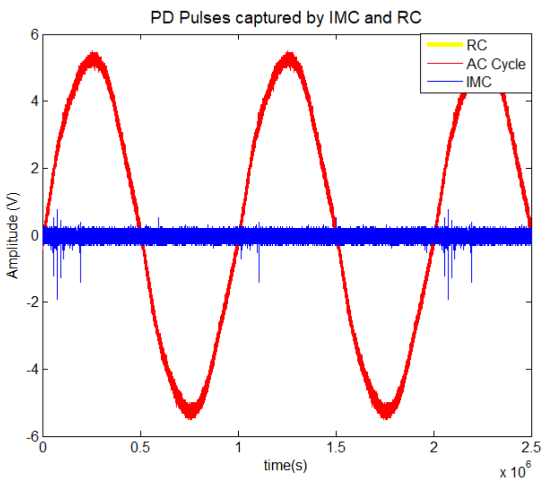
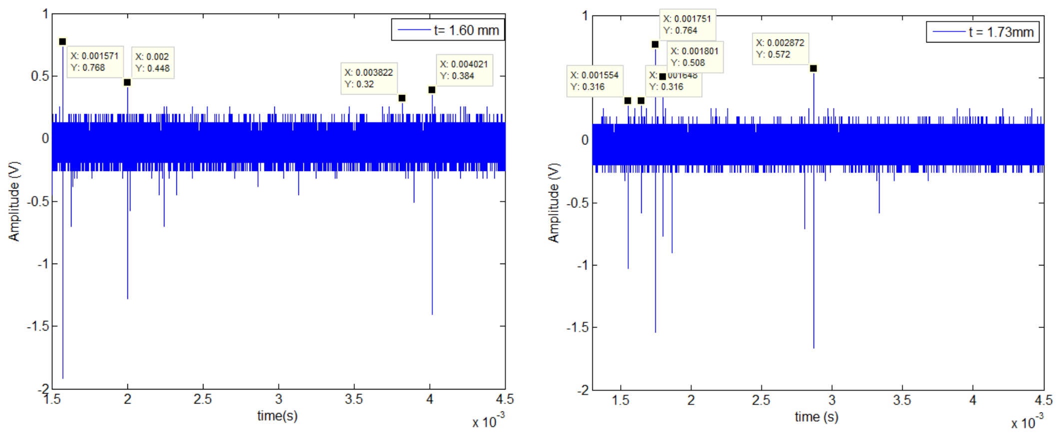


Fig. 4. Partial discharge signal at 8kV supply voltage captured by IMC and RC

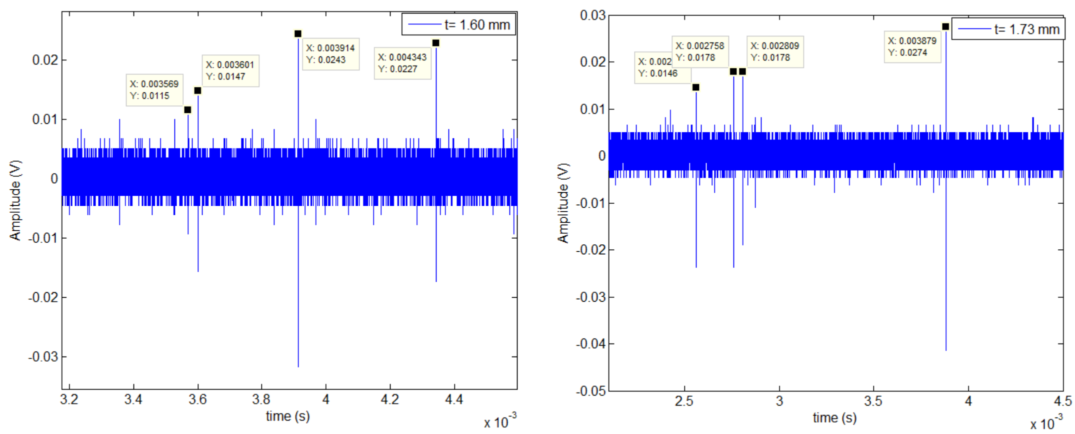
Figure 5 depicts, a PD pulse captured by IMC at the first positive half-cycle of AC voltage for two different sample thicknesses. There are four clearly visible PD pulses that occur when using a 1.60 mm sample thickness and five PD pulses that occur at a 1.73 mm sample thickness.



(a) (b)

Fig. 5. Highlight PD pulses captured by IMC at different sample thickness: (a) 1.60 mm and (b) 1.73 mm

While Figure 6 shows a PD pulse captured by RC at the first positive half-cycle of AC voltage for two different sample thicknesses. Four clearly visible PD pulses occurred at 1.60 mm thickness and 1.73 mm sample thickness. Based on the results, it can be seen that the amplitude of PD pulses captured by RC are smaller than IMC. This is because logically, different devices are created using different components that may have the same functionality but different efficiencies. IMC has a characteristic of a filtering instrument than the RC sensor thus it can amplify the signals detected by it more accurately.



(a) (b)

Fig. 6. Highlight PD pulses captured by RC at different sample thickness: (a) 1.60 mm and (b) 1.73 mm

Some of the parameters of a step response that are related to the times behaviour are overshoot, rise time, peak time and settling time. These parameters could be used as a time domain features in discriminating various types of PD and also can be used to train a classifier, but these are not explored in this paper. The rise time is defined as the time it takes to change from 10% to 90% of the input step height. However, Figure 7 shows a sample of step response which is under-damped system, where the rise time it takes to go from 0% to 100% of the output. While the settling time is defined as the time required for the damped to reach and stay ±2% of the final steady-state value. The time that has the maximum value is called peak time.

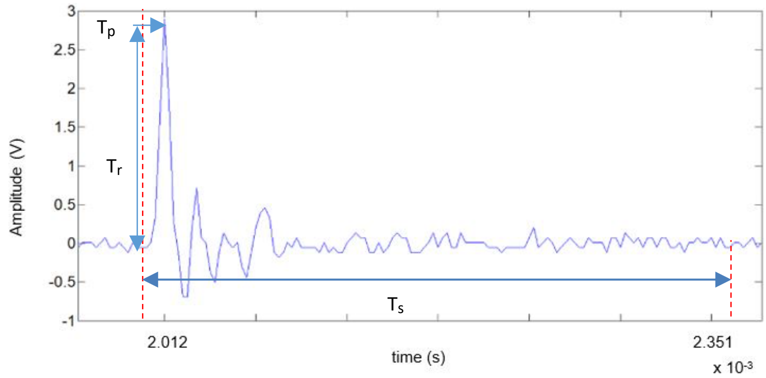
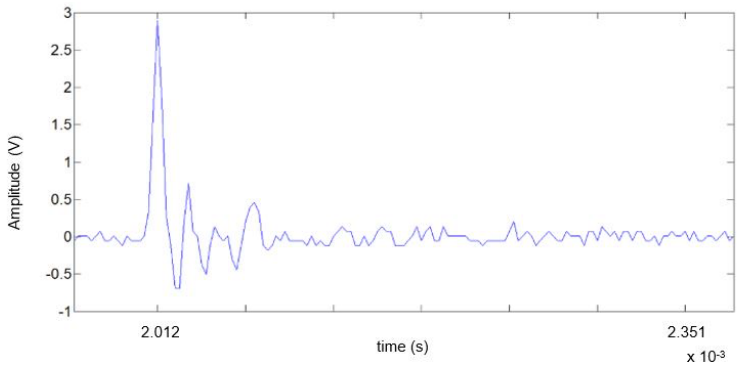
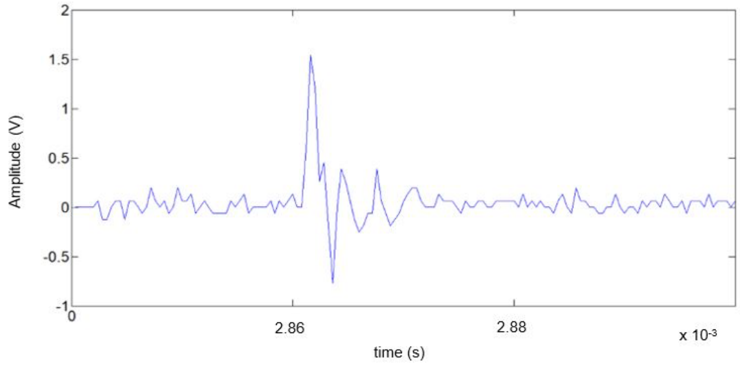


Fig. 7. Sample of step response for PD pulse

Four PD pulses of the first positive half-cycle for each IMC and RC were obtained from the recorded PD data. The average PD pulse of each device at two different thickness is shown in Figure 8 and Figure 9. Based on Figure 8 and Figure 9, it can be seen that IMC was able to detect high PD amplitude of each occurrence and has a small number of false PD occurrences compared to the Rogowski coil. The filtering function in the impedance matching circuit has eliminated or reduced the noise signal. from affecting the measurement value. The amplitude of the PD pulse for thickness 1.60 mm has a high value for both IMC and RC compared to the 1.73 mm.



(a)



(b)

Fig. 8. Sample of step response for PD pulse

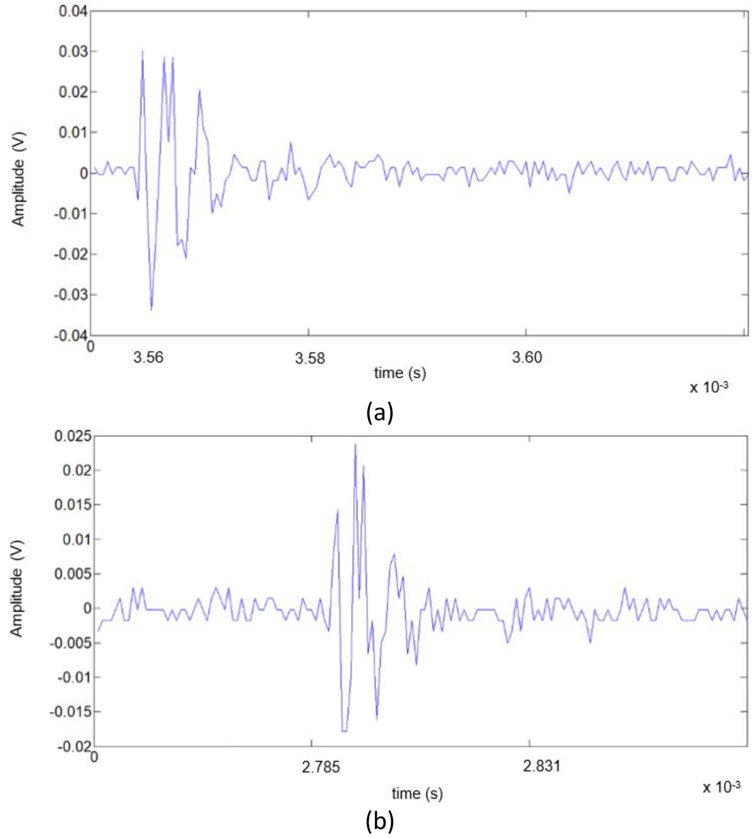


Fig. 9. Average PD pulses captured by RC at sample thickness: (a) 1.60 mm and (b) 1.73 mm

The parameters of step response are calculated from all PD pulses and the averaged for each IMC and RC are provided by MATLAB using a *stepinfo* function and summarized in Table 1. Based on Table 1, the RC has the fastest rise time but has a longer settling time for both thicknesses compared to the IMC. This is because the PD pulses captured by RC have a large number of noises compared to IMC thus, it takes a time to reach and stay ±2% of the final steady-state value. The different thickness of the sample also affects the rise time due to the PD pulse captured having a different amplitude for both devices.

Table 1
Average of step response parameter

Thickness (mm)	Device	Parameters		
		Rise Time, (T_r)	Settling Time (T_s)	Peak Time (T_p)
1.60	IMC	0.16 x 10^{-7}	2.8 x 10^{-7}	0.31 x 10^{-7}
	RC	0.08 x 10^{-7}	4.2 x 10^{-7}	0.15 x 10^{-7}
1.73	IMC	0.24 x 10^{-7}	3.5 x 10^{-7}	0.31 x 10^{-7}
	RC	0.11 x 10^{-7}	5.1 x 10^{-7}	0.15 x 10^{-7}

4. Conclusions

The simultaneous measurement of PD in epoxy resin insulator using IMC and RC has been conducted. The PD pulses have occurred within an AC cycle, between the positive and negative half-cycles, but most of PDs was occurs in the positive half-cycle than in the negative half cycle for both IMC and RC. The step response parameters such as rise time, settling time, and peak time measured by IMC and RC can be used as a time-domain feature to discriminate various types of PD and can be used as targets to train a classifier. Future research is needed especially on how to get the step response parameters without having to analyze every single waveform manually which takes time to complete.

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