Partial Discharge Signal Sensing on Overhead Conductors

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Abstract: - Partial discharge caused by the accumulation of pollutants on the surface of the high voltage insulators has been responsible for many insulation failures in power system. This paper examines the use of signal coupling of partial discharge onto the overhead line as mean to detect signs of degradation on the insulation. The experiment allowed us to study the sensitivity of various commonly-known high voltage measuring methods when it is used to detect very high frequency (VHF) signal such as partial discharge. The results show that the amount of high frequency energy that is coupled onto the overhead conductor ranges from several volts to tens of volts depending on the measuring methods. The coupled signal is expected to travel along the overhead conductor and can be extracted to detect discharge activities on high voltage insulators.

Key-Words: - partial discharges, power distribution reliability, power system monitoring

1 Introduction

Power transmission and distribution lines play a major role in today's society as most modern day devices depend on electricity to function. To prevent unnecessary blackouts that lead to lost in revenue to the industry and the comfort of modern living, this paper explores the possibilities of early fault detection in the power line through partial discharges generated from the point of fault. Partial discharges are usually early indicators that the insulation level has degraded and will very likely lead to the flashover. When partial discharge happens, it produces both small electrical pulses and electromagnetic radiation. In the case of radiation, the electromagnetic energy is coupled back into the transmission line as high frequency (HF) to ultra high frequencies (UHF) pulses traveling in both directions of the transmission line [1, 2].

Over the years, various sensing method has been adopted to detect PD in various HV equipments. The method involves a coupling capacitor that is placed in parallel with the test object and the discharge signals are measured across an external impedance (e.g. resonant circuit) [2]. Apart from capacitive coupling, other known methods used to detect PD signals in HV cables and equipment are inductive, galvanic and directional coupling [3].

Each of these methods has different sensitivity towards high frequency signals. The characteristic of capacitive couplers usually used for detecting PD in rotating machines have been 80pF but it has been found that by increasing the capacitance, higher detection sensitivity could be achieved [4]. Increasing the sensitivity would also expose the sensors to noise, so it is important to get as many PD pulses and still being able to minimize the noise. PD pulses are known to exist between the ranges of high frequency to UHF range. It has been found that UHF pulses travel for only 2m while VHF pulses could be detected 400m to 600m away from the source in shielded cables [2]. Therefore, if the sensor is made to detect the pulses in the higher frequencies, there will be less noise interference but it will only travel a shorter distance compared to the lower frequency pulses.

2 Experimental Set Up

The experiment was carried out in the 100kV high voltage laboratory at RMIT University. As the focus of this test is to detect the partial discharge signal from faulty equipment, the point-to-plane spark gap is used to simulate the PD discharges. As shown in Figure 1, four measurement points were set up for PD pulse measurement. The first monitored point is the 100m transmission line. It is a non-energized cable place 1m away from the point to plane gap. The transmission line is also terminated at both ends with 56 Ohms to prevent reflection. The transmission line is then connected to the oscilloscope using a coaxial cable probe.

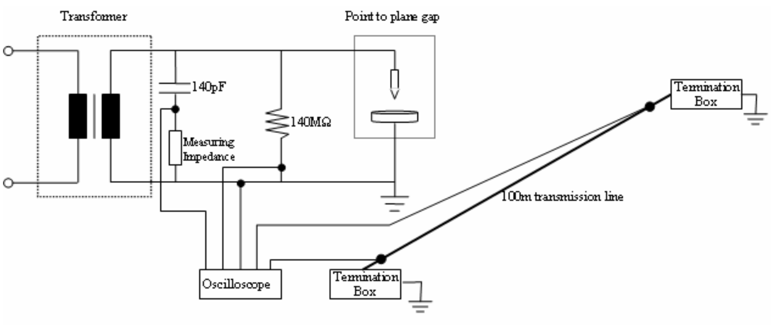

Fig. 1 Experimental Setup

The second monitored point is the ground. The ground is used as a reference point and in the event of partial discharge, PD pulses can be observed on the ground. The next monitored point is from the shunt resistor of 140MΩ. Here a 100x voltage probe was used to connect it to the oscilloscope and the fourth monitored point is from the coupling capacitor of 140pF. To measure this point, a coupling resistor is connected in parallel with measuring impedance shown in Figure 2. The measuring impedance is also used as a high voltage divider and protector in case of a surge.

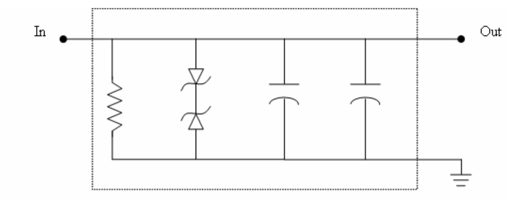

Fig. 2 Measuring Impedance circuit diagram

Here three different gap distances between the point to plane of 20mm, 30mm and 40mm were tested to determine how much partial discharge activity can be measured by the four measurement methods. The model of the oscilloscope used in the test is a TDS 2024 four channel, digital storage oscilloscope with the bandwidth of 200 MHz and the sampling rate of 2 GS/s.

3 Signal Properties

A. Signal strength

The receiving properties of the power transmission line conductor can be determined from the amount and range of energy which is detected. The PD pulses were detected in the three different gaps used and out of the four monitored points; three points captured the PD pulses simultaneously. As shown in Figure 3, the gap of 20mm is used and the voltage from the transformer is 13kV. The resolution for Figure 3 to Figure 5 is set to be 5v/division and 500ns / division. The first channel reading 80V is measured from the shunt resistor. This is the only monitored point that doesn't have any PD pulses but instead when zoomed out, it has a sine wave with saw-tooth signals at its peaks. The second channel is from the coupling capacitor. It has the highest pulse reading compared to the other 2 channels. The third channel monitored is the ground and it has the weakest PD pulses reading. And finally the fourth reading is the from the 100m transmission cable.

Figure 4 is the reading made when the gap is set to 30mm with the voltage given by the transformer at 19kV. In all three different gaps, the reading from both capacitive coupler (channel 2) and transmission line (channel 4) contains a 50Hz sine wave as well. This 50Hz voltage increases with the transformer voltage; hence this 50Hz component is expected to have radiated from the transformer itself. The readings shown in Figure 5 are found when the gap is set to 40mm and the voltage supplied by the transformer at 24kV.

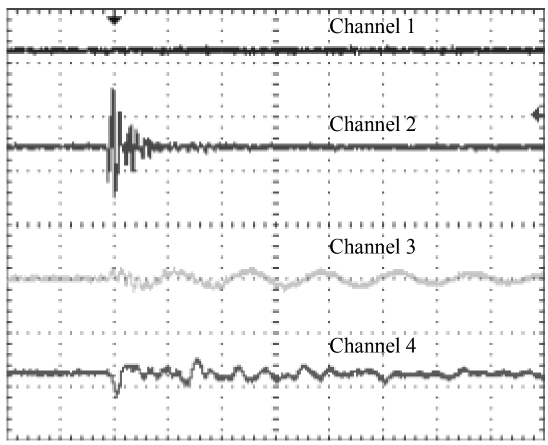

Fig. 3 PD pulses captured from the 20mm gap

Using this setting, the highest PD pulse was captured from the capacitive coupler in channel 2 at 16Vpp. Whereas the other two readings in all 3 gaps are relatively the same without much change in its voltage reading.

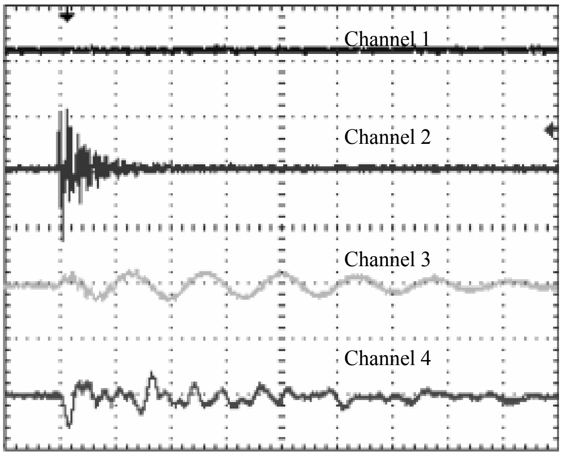

Fig. 4 PD pulses captured from the 30mm gap

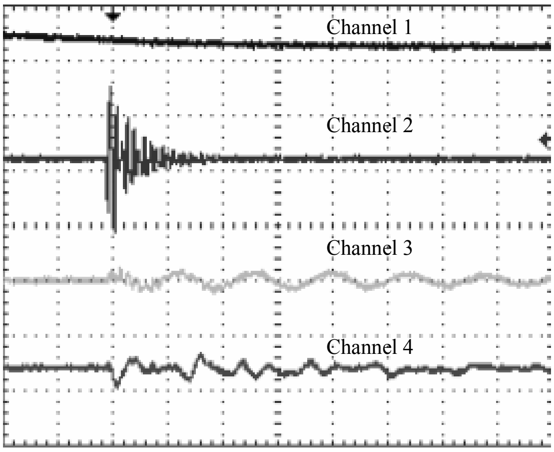

Fig. 5 PD pulses captured from the 40mm gap

4. Discussions

As this testing was done in a laboratory, the noise disturbance faced by the power transmission lines faced indoor is definitely much less then outdoors. Since there isn't much noise, it could be considered as an ideal condition to do testing, but when this is to be properly implemented, filters would be required to only allow the desired frequency to come through.

Using a spectrum analyser, frequencies was detected up to 100MHz. The pulses currently detected are only around 5MHz. According to the Nyquist theory, there is a 5 times rule that the required oscilloscope bandwidth should be the highest frequency component of measured signal be multiplied by 5. So in essence, a 500MHz oscilloscope is required to fully detect the range of the radiated partial discharge pulses. This is probably the reason for when the gap is bigger than 40mm; no more pulses are detected because of the pulse frequency increase with the gap distance.

To accurately pin point the fault location along the power transmission line, the traveling speed of the pulses are required. The proposed method is to measure both end of the 100m line and calculate the delay. This will require the other end of the line to be pulled back for monitoring by the same oscilloscope but this will expose it to the original partial discharge signal. So in order to do this, a pulse generator would be required to simulate a PD pulse and calculate the delay using this method.

Another observed incident is that the signal strength varies every time. The captured pulses from the coupling capacitor range from 8Vpp to 16Vpp. Whereas the pulses captured from the ground and power transmission line is around 1Vpp to 4Vpp.

5. Conclusion

This work investigates the possibility of utilizing existing power line conductor as partial discharge sensors or receivers. The receiving properties of power line conductors have been considered in this paper through a series of experimental investigation. The results from this work strongly indicate that the power line conductor is capable of receiving a broadband signal results from a nearby electricity discharge activity. A point-plane flashover gap is used to simulate the partial discharge event to couple electrical and electromagnetic power into the power line to verify the concept.

This opens the possibility for developing a condition monitoring system for power transmission networks without the use of individual sensors for each transmission tower. For an actual implementation, the partial discharge signals can be extracted at high voltage metering point or busbar. The extracted signals can provide valuable information on the health of the line insulation and the location of any defect based on time-of-flight information.

Simulations have shown that a faulty insulator will couple a small signal onto the line which can theoretically be observed at the line terminals. In fact, similar receiving properties can be explored in equipments such as Gas Insulated Substations (GIS) and power transformer. However, as the transmission voltage is reduced, it is anticipated that the ability to detect these discharges will decrease. Specifically, lower voltage feeders behave less like lossless lines due to the increase number of insulators, structures, conductor resistance and the increased likelihood of tee'd circuits and tapped loads.

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