On-line measurement of partial discharge at a cable termination

In a cabling system consisting of cables, terminations, and joints, premature failure commonly occurs at the terminations. Mr Lee Wai Meng presents the use of High Frequency Current Transformer (HFCT) sensors, to measure the partial discharge at cable terminations. Partial discharge measurement is a useful assessment tool because it provides an instantaneous measure of the integrity of the cable termination, and also sensitively monitors the deterioration of insulation as a function of time.

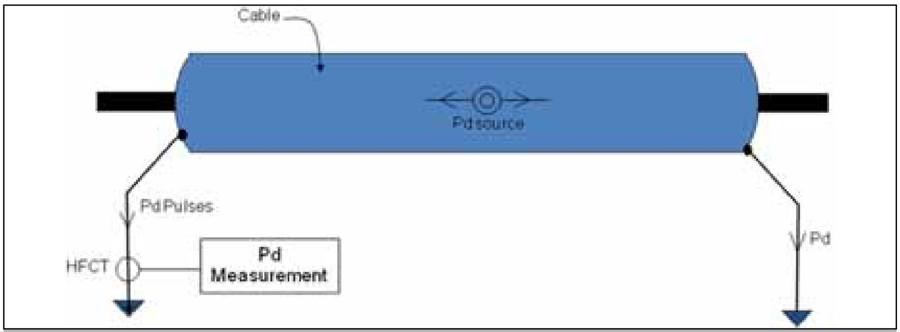

Figure 1: Earthing at both ends.

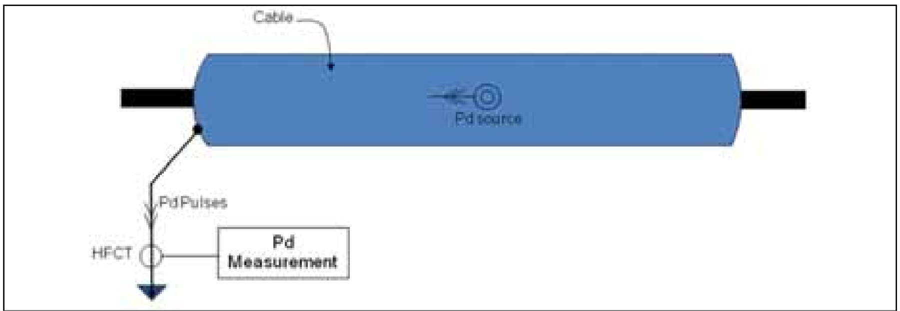

Figure 2: Earthing at single end.

Frequency (kHz)	1	5	10	50	100	500	1000	5000	10 000	13 000
Input (V)	5	5	5	5	5	5	5	5	5	5
Output (mV)	0	1.3	6.7	104	180	222	222	224	218	200

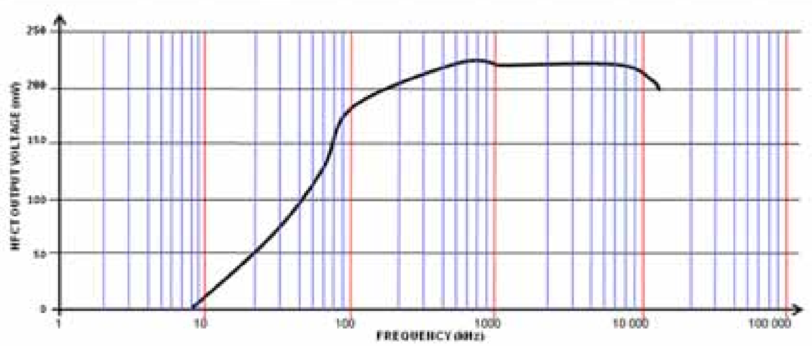

Figure 3: Frequency response of HFCT.

High Frequency Current Transformer

The HFCT sensor has a split core construction, and can be joined to the earth connection for the cable screen, at either end or both ends of the cable termination.

Figures 1 and 2 illustrate the two methods of earthing the cable screen. When a cable has earthing at both ends of the cable screen, there will be a current with a power frequency of 50 hertz, circulating in the earth cable connected to the cable screen. The magnitude of the 50 hertz current is proportional to the length of the cable and the magnitude of the current in the phase conductor of the cable. However, the HFCT will not detect the 50 hertz current in the earth cable connected to the cable screen, because it has a soft ferrite core whose frequency response is constant at 1 MHz to 10 MHz.

Figure 3 shows the frequency characteristics of the HFCT. This frequency range is consistent with that of other capacitive and inductive sensors, at about 10 MHz, and will achieve the best 'signal to noise' ratio. The HFCT sensor is easy to use because it can easily be connected to the earth cable connected to the cable screen and there is no need to de-energise the cable system for partial discharge measurement. In addition, the split core construction does not require the disconnection of the earth cable, in order to insert the HFCT sensor. Figure 4 shows an HFCT.

Figure 4: High Frequency Current Transformer (HFCT).

The Measurement System

The output of the HFCT sensor is connected to a typical digital oscilloscope with 100 MHz bandwidth and a sampling rate of 1 Giga sample per sample. The oscilloscope has four input channels with three of the input channels connected to the L1, L2 and L3 phases of a 3-phase cable system. The last input channel is connected to an antenna to detect external noise. The oscilloscope is interfaced to a partial discharge software using a standard GPIB (General Purpose Interface Board).

The software will detect and display partial discharge activity in the 'phase resolved' mode, on the vertical axis, with the horizontal axis showing the phase angle of the line voltage, from 0˚ to 360˚. This will provide real time information on the partial discharge across the phases of the 50 hertz AC line voltage. When the AC line voltage is zero, there will be no partial discharge activity. Partial discharge can happen only when there is voltage whose magnitude exceeds the partial discharge inception voltage. This basic behaviour will allow recognition of real partial discharge activity patterns.

The partial discharge software can be used to set up the oscilloscope which will have the following characteristics:

- The trigger source of the oscilloscope will be on AC line voltage.
- The measurement is set to peak detection.
- The input channel will detect only the AC component of the measured signal. Any DC component will be ignored.

Figure 5 shows the basic block diagram of the measurement system. The duration of measurement can be as short as 5 minutes or as long as 60 minutes. The typical duration is 10 minutes.

Case History

A short length of new 230 kV XLPE cable connects an existing 230 kV GIS to a new 230/66 kV, 150 MVA transformer. The transformer was successfully energised to the 230 kV line voltage of the utility supply. Partial discharge activity was detected at the cable termination at the transformer, by the utility company, and it was measured, using HFCT sensors. Figure 6 shows the measurement for phase L1, which shows partial discharge activity near the positive and negative peaks of the line voltage.

The termination at the transformer comprised a 230 kV XLPE cable in an oil-filled box. The cable was unplugged from the oil-filled box, cleaned, plugged back into the oil filled box, and re-energised to the utility line voltage. Figure 7 shows the re-measurement for phase L1. The previous 'double hump' did not appear and the re-measurement was relatively constant across the phase angle of the utility line voltage. This indicates absence of partial discharge activity.

Conclusion

The partial discharge activity was measured using the actual utility line voltage, and hence will represent the insulation condition at the actual operating voltage. The split core construction of the HFCT sensor allows easy connection to the cable termination. These two factors make the partial discharge measurement of cable terminations useful and easy to perform.

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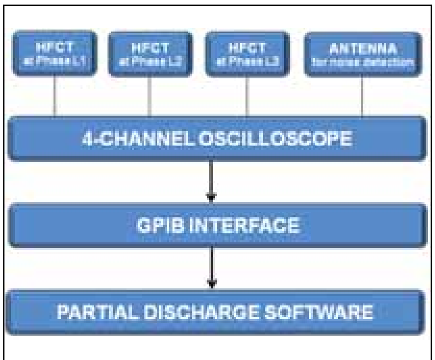

Figure 5: Measurement system.

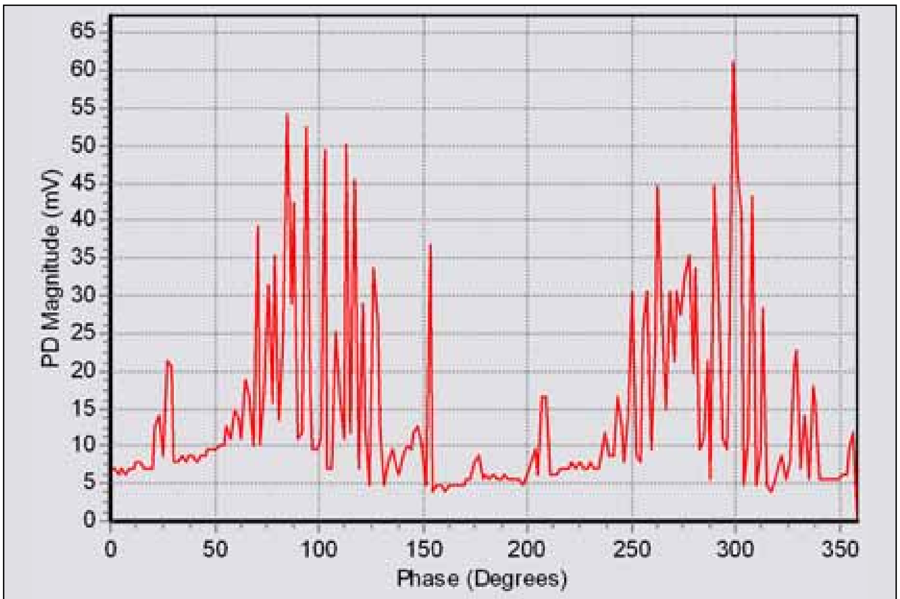

Figure 6: Measurement before repair for phase L1.

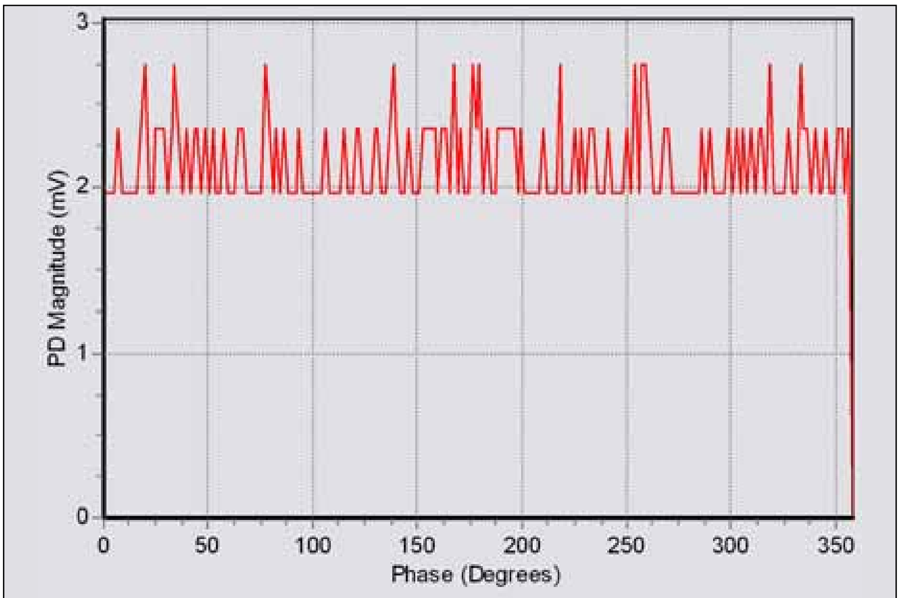

Figure 7: Measurement after repair for phase L1.