PDS100 Application Note:
The use of Transient Earth Voltage probe as sensor for Switchgear diagnostics

CASE STUDY 2 (Doble Client Conference 2011, ACCA committee meeting)

A high percentage of 11/33kV switchboards have an installed age that exceeds 25 years. During their operation they are subjected to various types of duty plus a varied level of maintenance. The trend is to extend the maintenance period for medium-voltage (MV) switchgear bringing with it a need for interim non-intrusive condition monitoring techniques to give confidence in the continuing safety and reliability of the equipment [11].

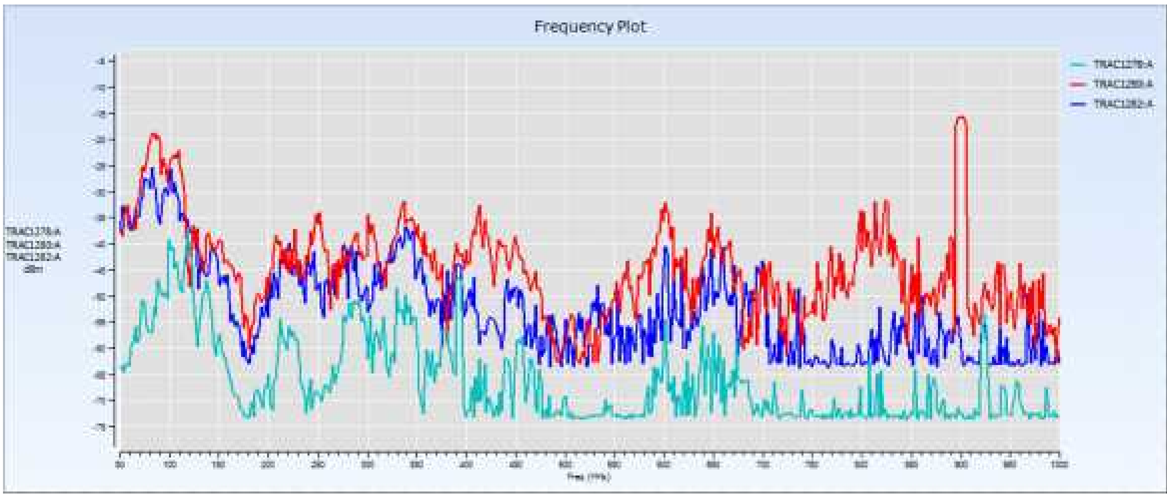
FIGURE 1 shows a Reyrolle LMT, 440A, oil-filled circuit breaker making up a typical 11kV distribution switchboard configuration commonly found in the UK.

(a) Front of Switchboard **(b) Rear of Switchboard**

Front and Rear Views of Reyrolle 11kV 400A Oil-Insulated Circuit Breaker
FIGURE 1

RFI Measurements

At a distribution substation RFI measurements were undertaken to survey the condition of each of the circuit breakers in the switchboard shown in FIGURE 1. A baseline RFI scan was captured in an adjacent room away from the surveyed switchboard (TRAC1278). Further measurements at the rear of each of the circuit breakers were captured and compared with the baseline. There is clear evidence in the observed uplift of frequencies that a discharge source is located in the vicinity (TRAC1280). An uplift of up to 40dB can be observed at, for example, 800MHz. The source of RFI emissions can be triangulated to one particular circuit breaker by comparing the uplift in higher frequencies as the receiving antenna is moved along the rear of the switchboard.



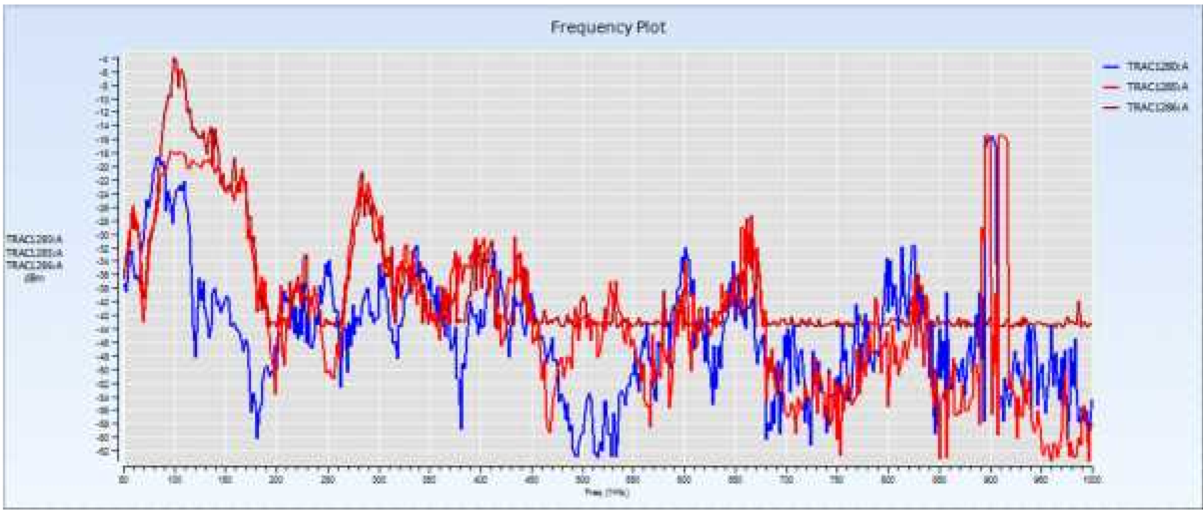
RFI Peak Measurements
Legend: TRAC1278, TRAC1280, TRAC1282
FIGURE 2

Further RFI measurements were captured at the front of the switchboard. Each measurement location required the circuit breaker cubicle door to be opened to provide increased accessibility to the RFI emissions, FIGURE 3. Comparison of the front and rear RFI measurements for the circuit breaker identified that the uplift in the lower frequencies was strongest to the front of the unit, FIGURE 4.

Time-resolved measurements taken at a number of spot frequencies further characterise the source of RFI emissions in terms of its pulsed behaviour. Selecting the spot frequencies at which to observe and capture the time-resolved pulses allow the signal-to-noise ratio of the detected pulses to be optimised. Selected traces at various frequencies of the received RFI spectrum are plotted in FIGURE 9. The observed discharge pattern is strongly correlated to the power cycle, repeatable in behaviour and having a symmetry over both half power cycles. Multiple pulses are evident in each half cycle exhibiting a high discharge rate. The pattern of pulses provides further evidence of a potential PD source. The observed pulsed behaviour is consistent across frequency bands.

As a surveillance technique the captured RFI measurements provide an assessment of the state of insulation deterioration in the switchboard and a clear identification of the presence of a possible fault condition. However, deploying other complementary EMI measurements can provide more information and also possible location.

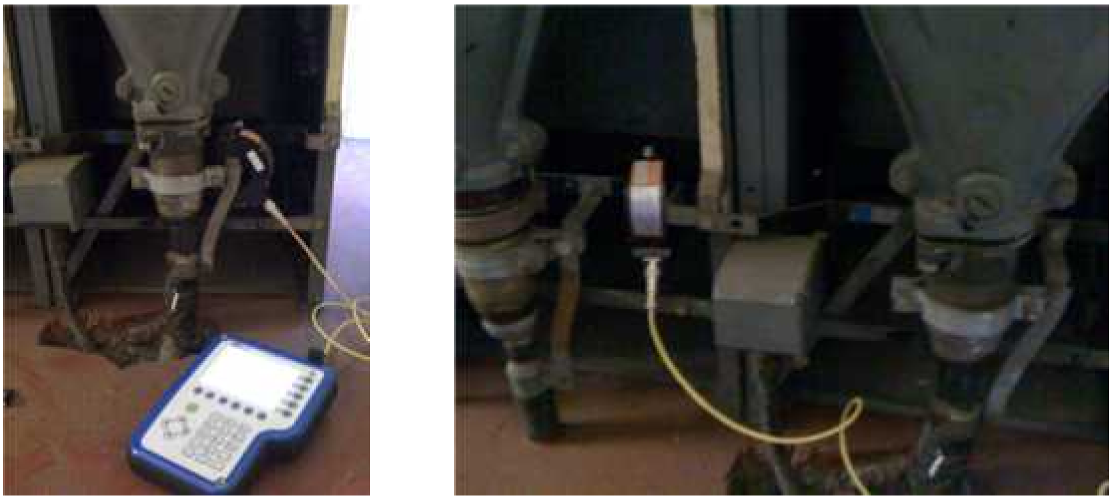
Recording RFI Emissions from the Front of the Circuit Breaker
FIGURE 3



RFI Peak Measurements: Front and Rear of Circuit Breaker
Legend: Front (TRAC1285, TRAC1286), Rear (TRAC1280)
FIGURE 4

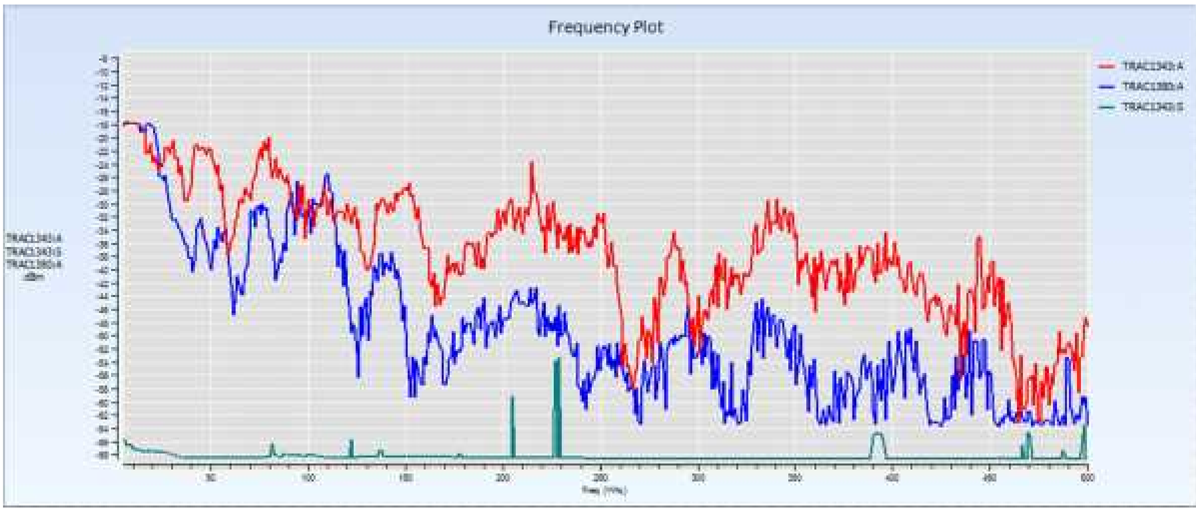
Accompanying HFCT Measurements

The HFCT uses inductive coupling to detect PD pulses flowing to earth. The HFCT is capable of picking up both local PD in the cable end box and also the lower frequency PD pulses coming from down the cable. FIGURE 5 illustrates the deployment of a 300MHz split-core HFCT placed around the cable earth strap. To be effective there should be insulation between the cable earth strap and the circuit break earth at the cable end box of the circuit breaker, i.e. maintaining zonal isolation.



(a) On the Cable Earth Strap **(b) Earth Strap of the Adjacent Circuit Breaker**

Placement of the HFCT
FIGURE 5



Measurements of Conducted EMI using the HFCT
Legend: Cable Earth Strap (TRAC1343), Adjacent Circuit Breaker (TRAC1380)
FIGURE 6

The uplift in frequencies observed in the measurements of conducted EMI confirm the observations from the RFI survey, FIGURE 6. Uplifts of up to approximately 50dB at 75MHz and 40dB at 200MHz can be observed. Time-resolved measurements show pulse behaviour that is similar to and confirm those that were obtained from RFI measurements, FIGURE 9.

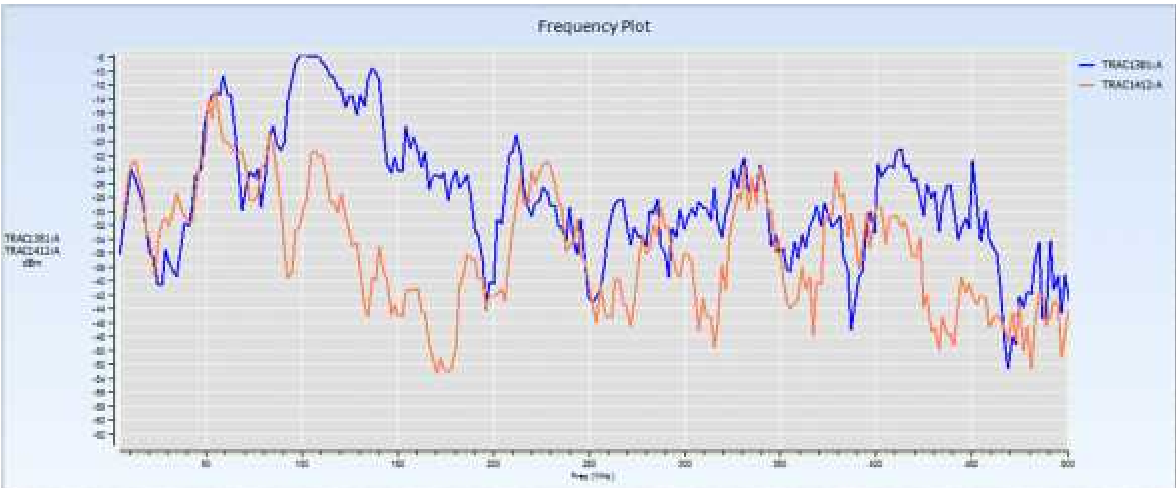
The placement of HFCTs provide a means to trace the likely source of the signals by comparing the uplift in frequencies. Traces TRAC1343 and TRAC1380 show that the uplift reduces significantly as the location of the HFCT is moved away from the suspect circuit breaker. Repeated measurements on earth straps placed on adjacent circuit breakers indicate the circuit breaker identified is the source of the measured discharge activity.

Accompanying TEV Measurements

The most advantageous setup for metal-clad switchgear is to use an HFCT sensor in conjunction with a TEV sensor. Transient Earth Voltage (TEV) measurements work on the principle that if a PD occurs within metal clad switchgear, electromagnetic waves escape through openings in the metal casing. The electromagnetic wave propagates along the outside of the casing generating a transient earth voltage on the metal surface. TEV sensors are “capacitive couplers”, which when placed on the surface of metal cladding can detect TEV pulses as a result of PD internal to the switchgear. Bandwidths of >100MHz are needed to capture pulse rise-times of the order of nanoseconds that are typical of such pulses [12].

(a) Cable End Box **(b) Main Circuit Breaker Tank**

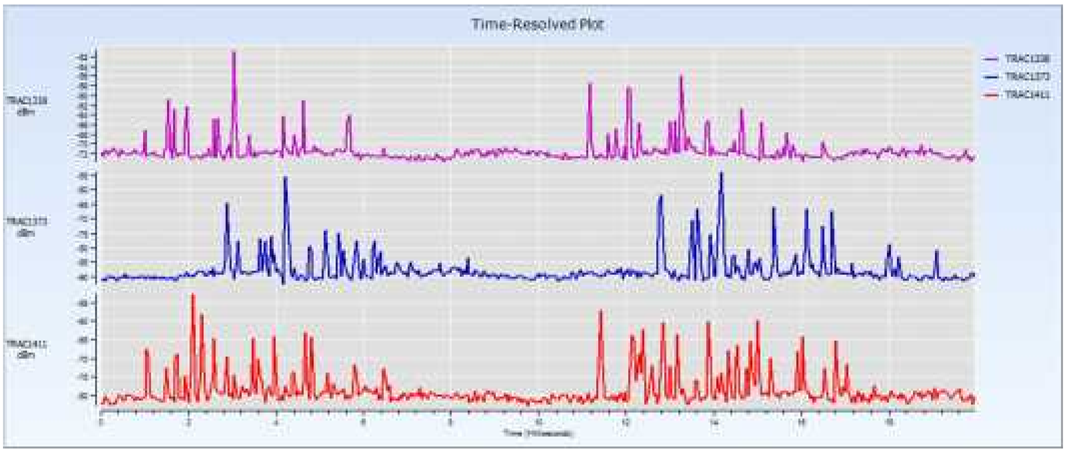
Placement of Transient Earth Voltage (TEV) couplers
FIGURE 7



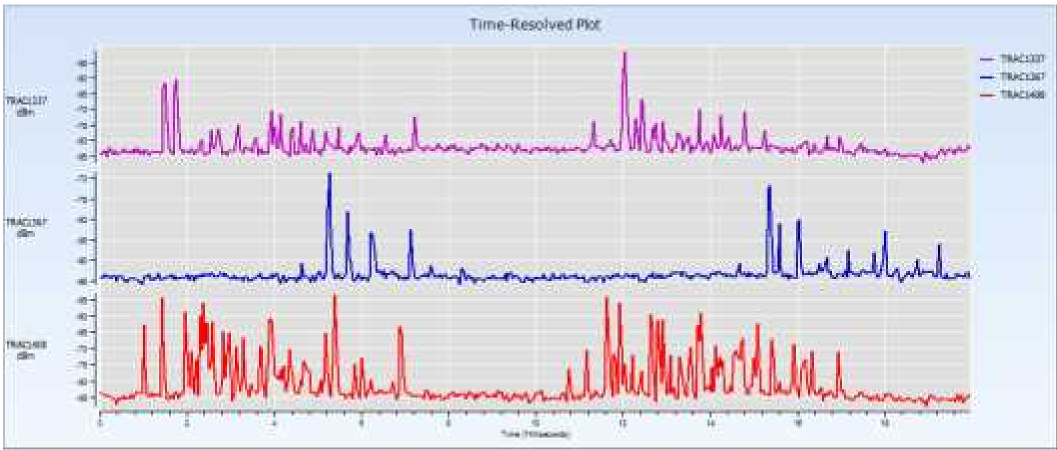
Comparison of TEV Measurements
Legend: Main Breaker Tank (TRAC1381), Cable End Box (TRAC1412)
FIGURE 8

Observed peak TEV measurements on the main circuit breaker tank (TRAC1381) reach 0dBm at a frequency of 100MHz. Comparative measurements taken with the TEV sensor located on the cable end box show a reduction in uplift of approximately 20dB. The main circuit breaker tank is identified as the likely source of the discharge. Time-resolved measurements show pulse behaviour which confirm the results obtained from both RFI and HFCT measurements, FIGURE 9.

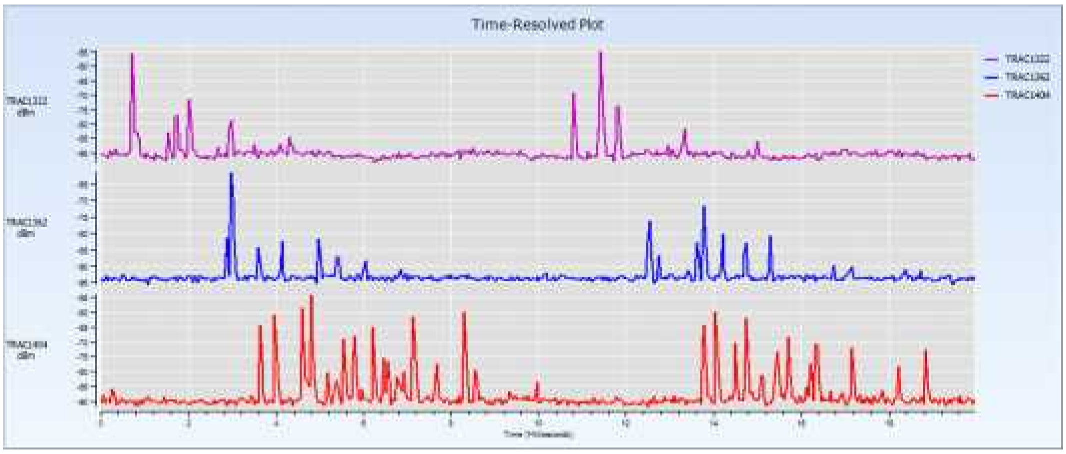
The power utility was prompted to open up the circuit breaker and found signs of carbon at the cable end in the main tank of the switchgear. This confirms that deploying frequency spectra measurements and time-resolved patterns from RFI, HFCT and TEV probes provides a surveillance tool which facilitates the pinpointing of PD issues within switchgear.



(a) Lower Frequency (circa 50MHz)
Legend: RFI, HFCT, TEV



(b) Mid Frequency (circa 150MHz)
Legend: RFI, HFCT, TEV



(c) Higher Frequency (circa 200MHz)
Legend: RFI, HFCT, TEV

Comparison of Time Resolved Measurements for RFI, HFCT and TEV Couplers
FIGURE 9

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