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Condition Assessment of High Voltage Instrument Transformer Using Partial Discharge Analysis

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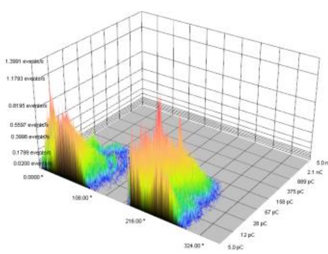
Graphical abstract



Abstract

Determining the incipient faults in high voltage apparatus is important because failure without warning can result in damage to adjacent equipment, personnel injures, customer dissatisfaction and disruption to economic activity. The failure of several high voltage instrument transformers during in-service prompted Tenaga Nasional Berhad (TNB) to identify more effective diagnostic tool to predict insulation breakdowns. The viability of partial discharge (PD) measurements in the field on instrument transformers is investigated. This paper presents the results of partial discharge tests that have been carried out under laboratory experiments and field measurement on high voltage instrument transformers.

Keywords: Partial discharge; instrument transformers; on-site diagnosis

Abstrak

Menentukan kesalahan pada peringkat awal di dalam radas voltan tinggi adalah penting kerana kegagalan tanpa amaran boleh menyebabkan kerosakan kepada peralatan berdekatan, mencederakan kakitangan, rasa tidak puas hati pelanggan dan gangguan kepada aktiviti ekonomi. Kegagalan beberapa alat ubah voltan tinggi semasa dalam perkhidmatan mendorong Tenaga Nasional Berhad (TNB) untuk mengenal pasti alat diagnostik yang lebih berkesan untuk meramalkan kerosakan penebat. Daya maju pelepasan separa (PD) ukuran dalam bidang pada alat ubah di kaji. Kertas kerja ini membentangkan keputusan ujian pelepasan separa yang telah dijalankan di bawah eksperimen makmal dan ukuran lapangan alat ubah voltan tinggi.

Kata kunci: Pelepasan separa; alat ubah; analisis di tapak lapangan

1.0 INTRODUCTION

During in-service, high voltage instrument transformers are exposed to different kinds of stresses namely; electrical, thermal, mechanical and environmental stresses that can cause deterioration of insulation system (oil/paper) and associated with partial discharges (PD) activity.[1,2,3] Catastrophic failures of instrument transformers may result in damages to adjacent equipment, personnel injures and represent high replacement costs. TNB has over 20650 instrument transformers installed in 532 transmission substations operating at 132kV, 275kV and 500kV. The routine method used by TNB to verify the condition of in-service instrument transformers is off-line power factor (or dissipation factor) and capacitance measurement. However, the cost incurred to evaluate each instrument transformer off-line when considering the large amount of units installed on each substation is considerable. Dissolved gas analysis (DGA) is not recommended due to the limited amount of oil contained in the instrument transformer. From year 2001 to 2008, over 30 failures of in-service high voltage instrument transformers were recorded in TNB substation. On-line partial discharge detection technique was currently used by TNB to assess deterioration of insulation in instrument transformers.

In this paper, the partial discharge phenomena in instrument transformer are studied by analysing the PD data from small scale test objects and instrument transformer installed at site. Preliminary results demonstrated that partial discharge analysis can provide useful information about the condition of instrument transformer thus allowing better management of installed instrument transformers in large transmission grid.

2.0 LABORATORY TESTS ON PRESSBOARD PAPER

An insulating pressboard paper was placed between the two electrodes connected to the high voltage source and low voltage or ground terminals. The assemblies were put in an oil-filled vessel and the partial discharge signal is picked up using a high frequency current transformer (HFCT) clamp on the ground connection of the vessel connected to the low voltage terminal of the test object. Different artificial faults were created on the test sampel with the aims to investigate the partial discharge activities and its fault patterns. The test set-up diagram of PD experiment in the laboratory and experimental test vessel are shown in Figure 1 and Figure 2 respectively. MPD600 detection system was used to acquire the PD signals from the laboratory experimental works, as illustrated in Figure 3.

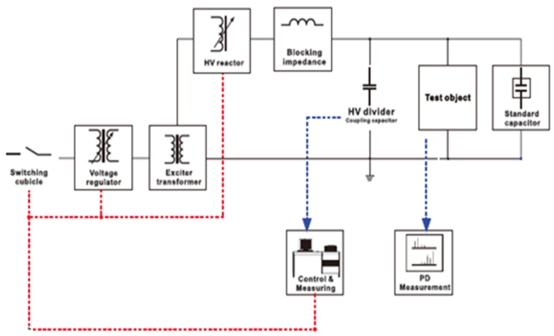


Figure 1 Circuit diagram of PD measurement test set-up

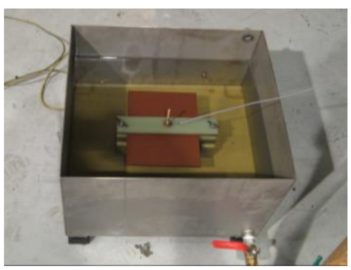


Figure 2 Test vessel with pressboard paper placed between two electrodes immersed in insulating oil

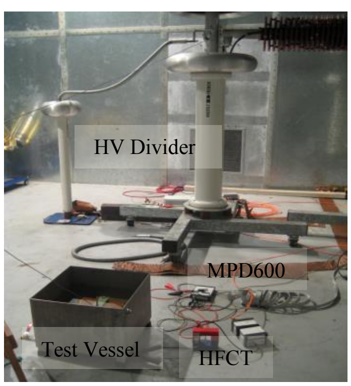


Figure 3 Actual picture of experimental test set-up

2.1 Void in Pressboard Sampel

Voids within the dielectric system is probably the most technologically important source of partial dicharges. Detection of such defect frequently uses partial discharge analysis. In this experiment, a void with diameter of 2mm was created by assembling three pressbord sample (3mm thick) after having carved an hole in the central sheet, and high voltage was applied to the upper electrode to generate PD activities. The electromagnetic signals produced by the partial discharges were measured using the HFCT placed on the ground connection of the test vessel.

Figure 4 shows the phase resolved PD pattern of the void inside the pressboard sampel. The typical behaviour of the void PD was observed where the PD activities concentrated at the first quadrant and third quadrant of the 50Hz cycles. By means of this kind of measurements, it was figured out that the partial dicharge activity level was around 80pC.

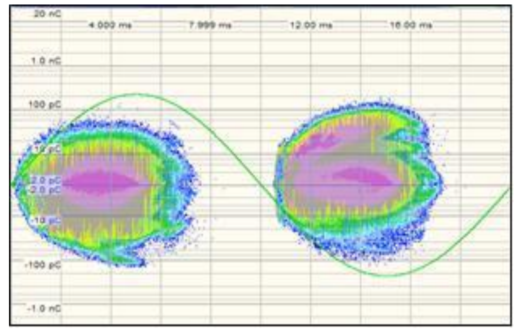


Figure 4 Phase resolved PD pattern of void inside the pressboard sample

The frequency spectrum of the partial discharge activities is shown in Figure 5. It was found that PD is easily detected at the frequency of 2-5 MHz while lower PD amplitude was observed at higher frequency range where the characteristic of the presence of partial discharge was not easily distinguishable.

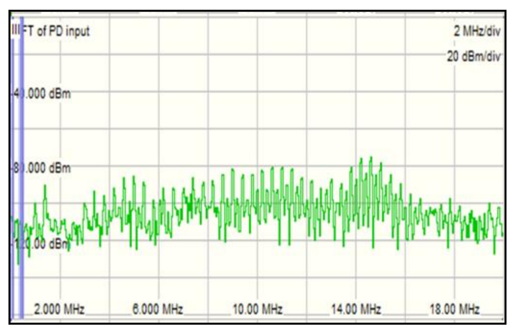


Figure 5 Frequency spectrum recorded for pressboard sample with artificial void measured using HFCT applied to the ground conductor, frequency range 2MHz -20MHz.

2.2 Shorted Laminated Insulation

The shorting of laminated insulation could occur on capacitive graded insulation type of high voltage equipment such as high voltage bushing and instrument transformer. The aluminium foil was shorted between pressboard sample through thin hole of diameter 0.5mm and high voltage was applied to generate PD activities. The phase resolved PD pattern is shown in Figure 6. It can be seen that the results obtained are substantially similar to those observed on void in pressboard sample. However, the magnitude of partial discharge activity recorded is only 40pC. Figure 7 shows the frequency spectrum of the partial dicharge activities with shorted laminated insulation. It can be explained that shorted insulation has created a puncture or small hole between the laminated insulation of the overall insulation system thus giving a similar PD characteristic with void in insulation but has a lower magnitude PD level.

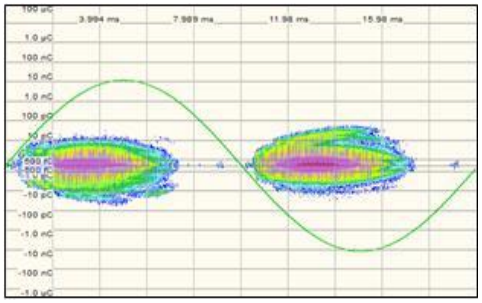


Figure 6 Phase resolved PD pattern of shorted laminated insulation

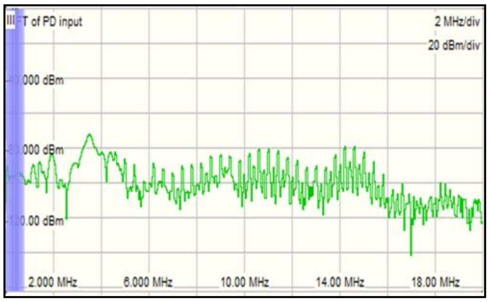


Figure 7 Frequency spectrum recorded for shorted laminated insulation measured using HFCT applied to the ground conductor, frequency range 2MHz -20MHz

■3.0 PARTIAL DISCHARGE MEASUREMENTS PERFORMED IN THE FIELD–HIGH VOLTAGE CURRENT TRANSFORMERS

Partial discharge measurement was carried out on in-service 132kV oil-filled high voltage current transformer. The HFCT was coupled to the earth lead of the current transformer. The acquired PD signals were then amplified and conditioned before they were sent to the PD detector.[4,5] An external hardware gating was used for detecting external disturbance pulses not correlated to the PD activities in the current transformer. Phase reference sensor is used to synchronise the PD signals with the 50Hz phase voltage signal to allow parameters such as PD repetition rate, PD magnitude, and phase angle where PD's occur at each cycle to be characterised. The field measurement set-up is shown in Figure 8.

Figure 8 On-line PD measurement for in-service 132kV oil-filled high voltage current transformer

The results of PD measurement on new current transformer installed at the substation are shown in Figure 9. The phase resolved PD pattern indicated that the PD amplitude level recorded is 60pC.

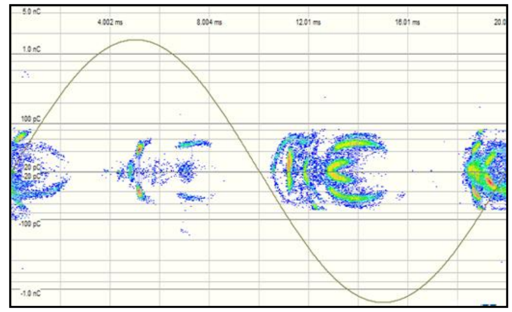


Figure 9 Phase resolved PD pattern of new current transformer

The frequency spectrum of the partial discharge activities on the new current transformer is shown in Figure 10.

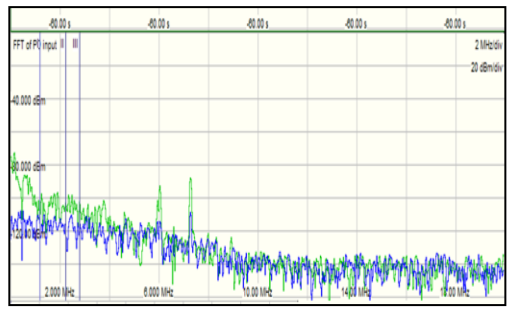


Figure 10 Frequency spectrum of new installed current transformer

The PD measurement was carried out on one of the suspected problematic current transformer. The phase resolved PD pattern of the unit was shown in Figure 11 indicated that the amplitude PD level recorded is 650pC, , and the frequency spectrum of the partial discharge activities is illustrated in Figure 12.

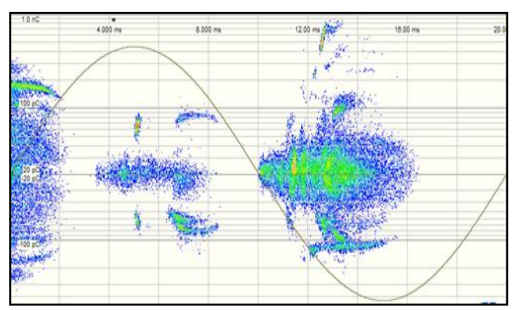


Figure 11 Phase resolved PD pattern of problematic surrent transformer

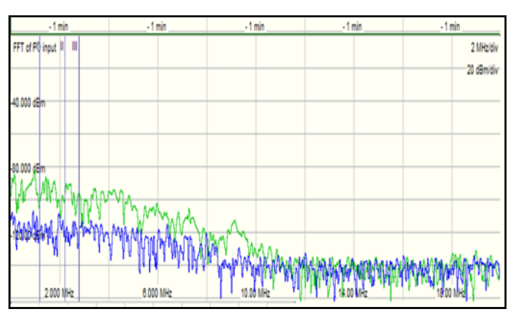


Figure 12 Frequency spectrum of problematic current transformer

Interpretation of the acquired PD data is a challenging task especially handling with noise or external disturbance during on-site PD measurement. For example, the result of new and problematic current transformer shows quite similar PD pattern but different amplitude PD level. The results are sometimes affected by external disturbance such as corona from nearby systems. The next part of this paper will discuss on the evaluation method used to distinguish between different PD faults and noise pulses.

■4.0 EVALUATION METHOD

The PD data and fault separation in real time were analysed using evaluation method[6] known as 3-Center Frequency Relation Diagram (3CFRD) graph. A signal output of three filters with different center frequencies are compared and plotted into a single diagram to form separable clusters. This refers to the fact that due to the discharge physics, different PD types or noise pulses generate different but characteristic energy frequency spectra. By selecting only the relevant 3CFRD cluster, the PD activity can be isolated from the environmental noise.

Figure 13 shows a complete PRPD pattern generated in real time during PD measurement on high voltage current transformer. It can be seen in (a) that the pattern consists of background noise and PD activity. The actual PD activity and the disturbance sources can be differentiated by selecting a single 3CFRD clusters and a real time back transformation will result in clear and de-noised PRPD patterns of single PD sources as shown in Figure 12 (b), (c) and (d).

■5.0 CONCLUSIONS

The PD measurement has provide effective tool to monitor the condition of in-service instrument transformers. The use of inductice sensor, high frequenct CT clamped on the grounding conductor has allowed the PD measurements to be performed without the need for outage of the instrument transformer and in a safe manner. The successful trials of the technique in instrument transformer condition assessment show the potential and economic benefits in management of installed instrument transformer in large transmission grid.

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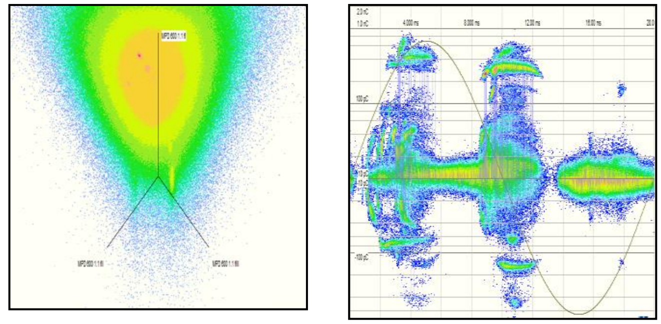
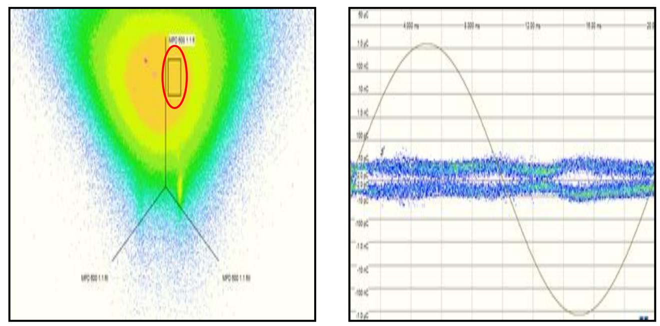


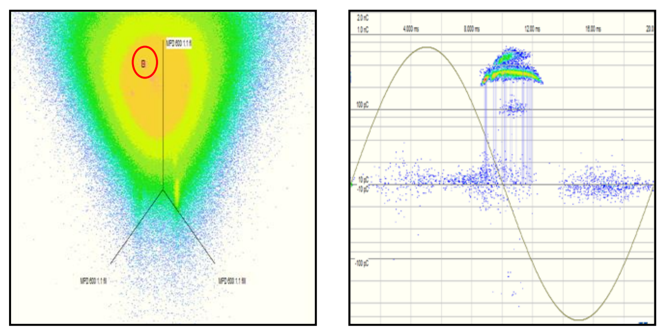
3CFRD Phase Resolved PD Pattern

(a) Superposed pattern



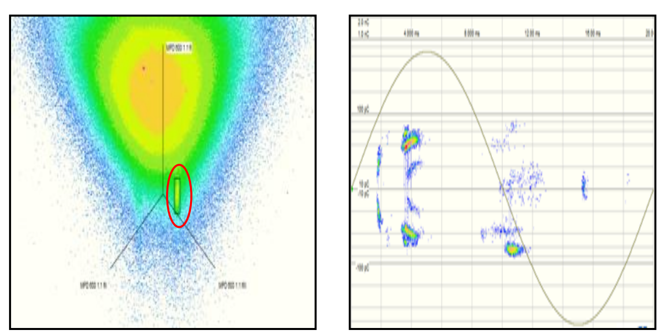
3CFRD Phase Resolved PD Pattern

(b) Ambient noise



3CFRD Phase Resolved PD Pattern

(c) Noise pulses



3CFRD Phase Resolved PD Pattern

(d) PD activity

Figure 13 PD data evaluation using 3CFRD graph

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