Experience of On-site Partial Discharge Measurement on EHV Power Transformer by UHF Method

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***Abstract*—In authors' experience, the majority of power transformer failure can be classified as heat aging by poor contact, and electric aging by insulation defects. Dissolved gas analysis (DGA) is the main diagnostics for the preventive maintenance (PM) of power transformer. The breakdown caused by heat aging can be prevented by DGA. However, the failure caused by electric ageing is hard to prevent due to the short period from gas detected to ultimate breakdown. Hence, partial discharge measurement (PDM) is the alternative way and is effective way to detect electric ageing resulted from defects.**

The common methods of PDM on power transformer are acoustic emission (AE) method and electromagnetic (EM) method . The AE method has good immunity to electric noise interference, and the EM method has good sensitivity to partial discharge signals.

This paper adopted the EM method, and built-in coupler/valve-probe were utilized to do on-stie PDM.In the field, the background noise will enter into the tank along the conductors though the metal tank forms a shield, and will interfere the PDM. The frequency band selection is also adopted for solving this problem. This paper takes several transformers as examples to show how to do on-site PDM on power transformer in acceptance test and routine test.In the final, the PD source location method were also illustrated to locate the fault position.

Keywords – on-site; partial discharge measurement; UHF method

I. INTRODUCTION (HEADING 1)

Conventional diagnostics of insulation condition can only estimate the insulation degree rather than detect defects. The majority of failure is the defects accelerating the insulation aging causing facilities insulation breakdown. Heat aging, such as poor contact, takes longer period to make insulation system failure, and the electric aging, such as defects inside epoxy resin, usually takes shorter period to make the insulation system failure.

Partial discharge measurement (PDM) is the most effective method detecting defects inside insulation system. There are many PDM methods by detecting one or more of electrical, chemical, acoustic and RF phenomena associated with partial discharge (PD) activities. Because the power transformer is metal enclosed, most partial discharge signal cannot transfer into external and also external noise cannot enter the tank.

Metal enclosed transformer forms a faraday cage, by which the sensors are screened from external interference. In the same manner, the metal enclosure also traps the radiated signal, and the pulse is reflected around inside. Therefore, the built-in sensor is suitable for the partial discharge measurement in power transformer.

As the PDM is applied in the field, the background noise, such as corona at insulator of other equipment, can propagate along the conductors into the tank, and interfere the PDM though the metal enclosure screened most interference. Nonetheless, the internal partial discharge activities contain higher frequency components, such as ultra high frequency (UHF), and the interference/external signals usually has relatively lower frequency components vary high frequency (VHF). Therefore, the VHF/UHF sensor is possible to discriminate between interference signals and partial discharge signals by frequency selection.

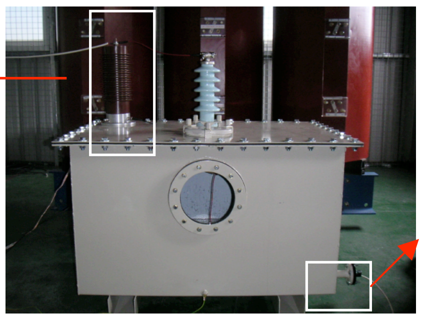
In this paper, the authors adopted the electrical method of built-in sensors for on-site PDM on power transformer. An on-site acceptance test and an on-site routine test were illustrated to demonstrate on-site PDM on power transformers.

II. UHF METHOD

A. *Configuration of UHF method*

In order to understand the difference between standard method (IEC 60270) and UHF method, an experiment was set up for the comparison between coupling capacitor and oil valve type sensor of UHF method, as shown in figure 1.

Coupling capacitor



VHF/UHF Sensor

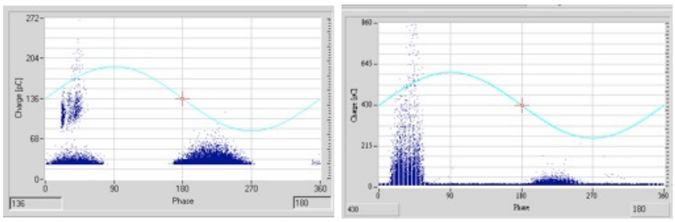
Fig. 1 Configuration of comparison between coupling capacitor and VHF/UHF sensor.

The objects under test are pinpoint and pool insulation paper with moisture, as shown in figure 2. The objects under test are put inside a tank, and covered by oil.

(a) pinpoint (b) poor insulation paper

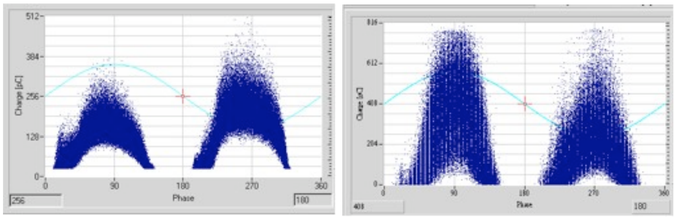
Fig. 2 Test specimen with artificial

The coupling capacitor is made for off-line partial discharge measurement, and the oil valve type is made for on-line partial discharge measurement. The test voltage was gradually increased till the partial discharge activities occurring, and the phase-resolved patterns and spectrums were also recorded as shown in Fig. 3 and Fig 4.



(a) Coupling capacitor (b) VHF/UHF sensor

Fig. 3 Phase-resolved pattern of pinpoint defect



(a) Coupling capacitor (b) VHF/UHF sensor

Fig. 4 Phase-resolved pattern of poor insulation paper

As shown in Fig. 3 and 4, the phase-resolved patterns show good agreement but slightly difference in detail. This is due to the different measuring frequency band. Moreover, the readings of these patterns are also different. This is resulted from the different measuring methods: the coupling capacitor calculates the amount of charges, and the VHF/UHF sensor detects the peak of partial discharge signals.

B. *Types of built-in sensor*

While selection built-in sensors for power transformer, the purpose of PDM is the most concern. For permanent using, the hatch type sensor will be adopted as it could be an integral part of the transformer tank. However, it should be installed in the manufactory. For temporary diagnostics, the oil valve type sensor will be utilized as it could be installed on-line. However, it can only be installed in gate-type-valve, and fewer oil valves can be adopted.

III. Acceptance Test

A. *Configuration*

A new transformer with four built-in sensors of hatch plant, as shown in Fig. 5, is installed, and the acceptance test was also carried out on site. A truck with step-up transformer, which is powered by 440 V, was utilized as the voltage source. The four built-in sensors were connected into a multiplexer, and the output of the multiplexer was connected to the measurement instrument, LDS-6, as shown in Fig. 6.

Fig. 5 Hatch type of UHF sensor

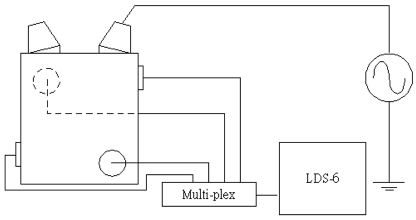


Fig. 6 Configuration of on-site PDM by hatch type sensors

B. *Performance check*

Before the acceptance test, a performance test should be done to insure that all built-in sensors work normally. Therefore, a calibration signal of 3 V pulse was injected into #1 built-in sensor, and the measurement system was wired to the #4 built-in sensor. The measurement result is shown in Fig. 7. All built-in sensors should be tested in sequence.

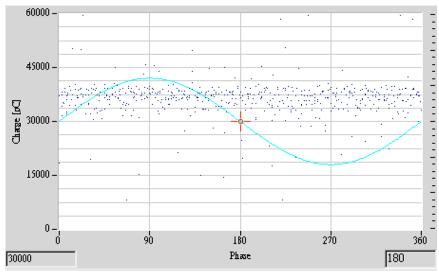
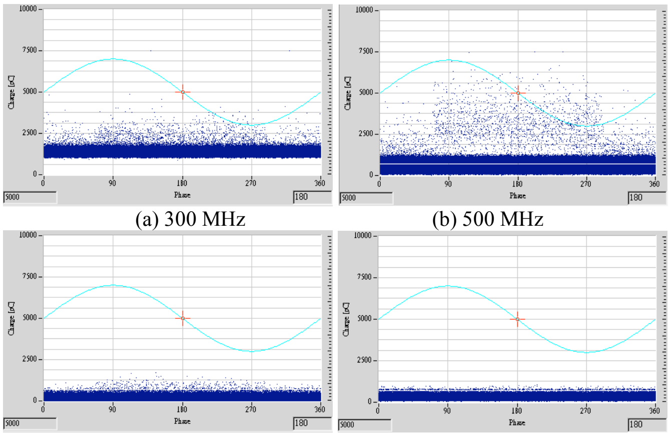


Fig. 7 Phase resolved pattern measured at #4 built-in sensor as the calibration signal was injected into #1 built-in sensor.

Note: The reading is not calibrated due to the different qualities of pC and mV

Beside performance check, the background signals measurement was also carried out to search a clear frequency band. The background signals measurement results are shown in fig. 8. In Fig. 8, the lower frequency bands showed more background noises, especially the frequency band of 500 MHz.



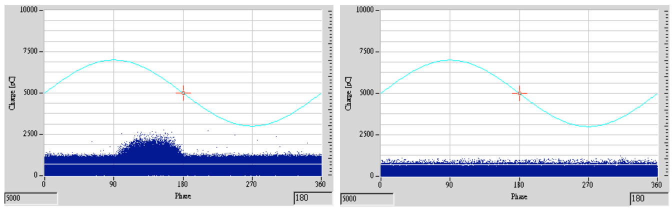
(a) 300 MHz (b) 500 MHz

(c) 700 MHz (d) 1100 MHz

Fig. 8 Background noise measurement result before energizing the power transformer.

C. *On-site PDM*

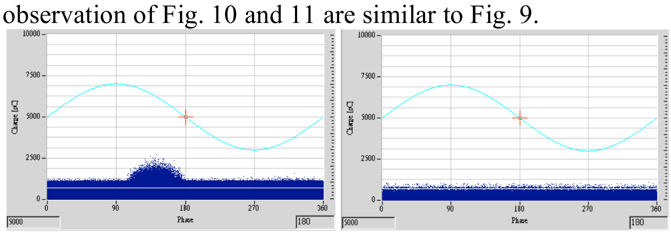
The applied voltage was gradually increased from 0 V to 345 kV, and held for 10 minutes. Fig. 9 shows the phase-resolved patterns of #1 built-in sensor at 500 MHz and 700 MHz frequency band. Figure 9(a) shows that there is interference at 500 MHz band as indicated in Fig. 8(b). Fig. 9(b) shows no PDs.



(a) 500 MHz (b) 700 MHz

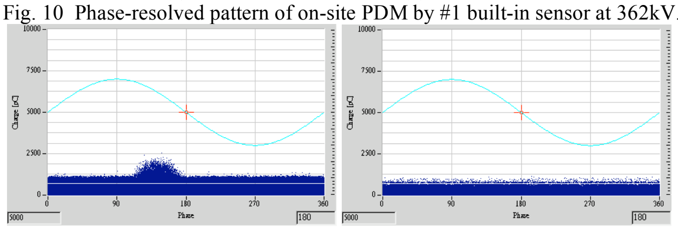
Fig. 9 Phase-resolved pattern of on-site PDM by #1 built-in sensor at 345kV as voltage increasing.

After 10 minutes, the test voltage rose to 362 kV, and held for 10 minutes. Then, the test voltage decreased to 345 kV again, and held for 10 minutes. Finally, the test voltage decreased to 0 V. Figure 10 and 11 show the phase-resolved patterns of ##1 built-in sensor at 500 MHz and 700 MHz frequency band. The observation of Fig. 10 and 11 are similar to Fig. 9.



(c) 500 MHz (d) 700 MHz

Fig. 10 Phase-resolved pattern of on-site PDM by #1 built-in sensor at 362kV.



(e) 500 MHz (f) 700 MHz

Fig. 11 Phase-resolved pattern of on-site PDM by #1 built-in sensor at 345kV as voltage decreasing.

IV. Routine Test

A. *Configuration*

The routine test was carried out after the maintenance of the power transformer, and a diesel generator was used for the voltage source. The PDM instruments consist of LDIC LDS-6, LDS-5, and Lecroy WaveRunner 64Xi, and the wiring diagram is shown in fig. 12.

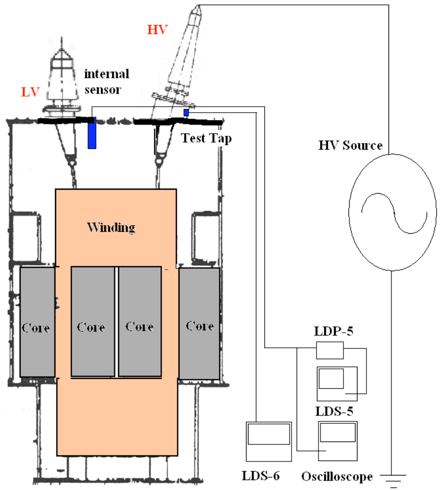


Fig. 12 Configuration of routine test

Because the transformer was in-service, it is difficult to install the built-in sensor of hatch type. As shown in fig. 13, the UHF sensors of oil-valve type are installed through the oil-valve.

Fig. 13. internal sensor installed in oil valve.

B. *Performance check*

The performance check of internal sensors was done by means of one internal sensor sending signals and another internal sensor receiving signal, as shown in fig. 14. As shown in fig. 14, the calibrator sent a 10 V pulse, and the peak of calibration signal at sending end was 2.6 V and at receiving end was 0.2 V.

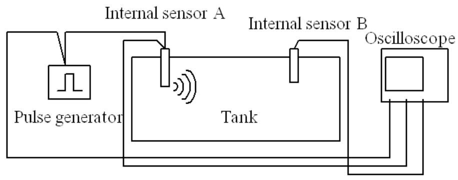
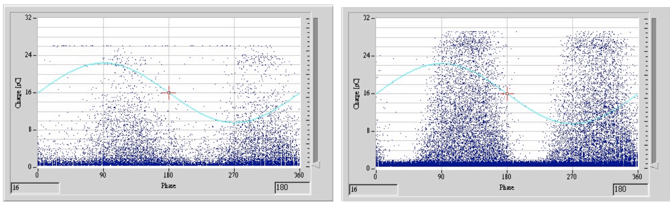


Fig. 14. performance of internal sensors

C. On-site PDM

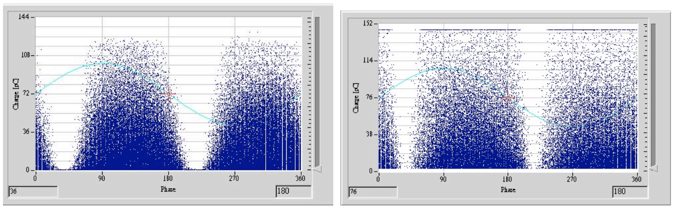
The reading of PDs measured by internal sensors were quite stable as the applied voltage higher than 5.7 kV, and were increasing with applied voltage rising. Fig. 15 showed the measured PD pattern of these sensors.



(a) internal sensor A (b) internal sensor B

Fig. 15. Measured partial discharge patterns at 5.7 kV

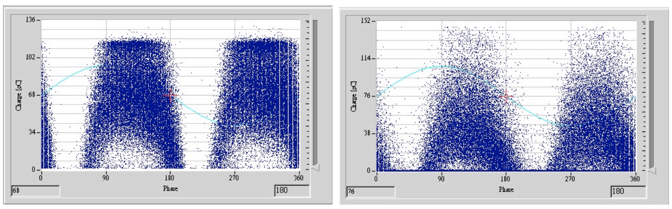
As the test voltage increased to 8.9 kV, the PD patterns measured by internal sensors were also recorded as shown in fig. 16.



(a) internal sensor A (b) internal sensor B

Fig. 16. Measured partial discharge pattern at 8.9 kV

While the applied voltage was rose to 9.8 kV, the PD patterns measured by internal sensors were shown in fig. 17. According to experiences, this type of PD pattern is usually measured at the poor insulation of paper as shown in fig.4.

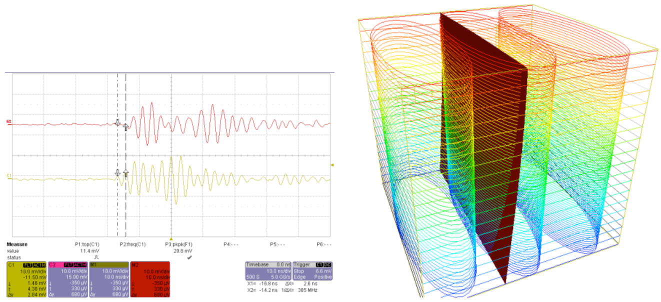


(a) internal sensor A (b) internal sensor B

Fig. 17. Measured partial discharge pattern at 9.7 kV

D. Partial discharge source location

Because the location of PD source needs three internal sensors at least, the amount of internal PD sensors in this case was only two, which is too few to locate the PD source in a point. Therefore, only intersection of a parabolic surfaceof PD source can be pointed out. Fig. 18 shows the recorded waveforms of internal sensor 1 and 2, and the time difference is 2.4 ns. Assuming that the velocity of electromagnetic wave in oil equals to that of light, $3*10^8$ m/s, the difference of the distances from PD source to each internal sensors is 72 cm. The PD source was located at the middle position of the transformer, S phase.



(a) Arriving Time by different sensors (b) 3D location

Fig. 18. PD source location

The measurement results show that the winding of S-phase would have insulation paper problem with moisture. Because the bushing of the power transformer was cracked and a water track was discovered at the iron core below S phase, the measurement results and the field observations shows good agreement.

V. CONCLUSION

The built-in sensor of UHF type shows good capability of the application on the metal enclosure equipments, especially for gas-insulated switchgear. The application of built-in sensor is extended to the power transformer. Two applications of built-in sensor on power transformer are presented in this paper.

The acceptance test of power transformer shows that the wider frequency band is helpful for the field application of measuring frequency selection to prevent the interference from external.

The routine test of in-service power transformer shows the feasibility of on-site PDM with built-in sensor of oil-valve type. Moreover, more than one built-in sensor can locate the PD source to help the operator estimating the insulation situation.

The two cases of acceptance test and routine test show that the built-in sensor of UHF type can also have good performance as applying to the power transformer.

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