Research on Typical Discharge Mode of Power Transformer

Wu Peng, Chen Zhiyong, Li Ruihua, et al

HIMALAYAL - SHANGHAI - CHINA

Abstract: Five kinds of oil-paper insulation models are designed and produced to simulate typical defects of power transformer. Plenty of discharge spectrogram and discharge impulse waveform are obtained by using digital PD measuring system. PD features of different defects are analyzed, which will be helpful for further research on PD pattern recognition and insulation aging of power transformer.

Key words: Transformer, partial discharge(PD), oil-paper insulation, discharge model

1. Introduction

In recent years, large quantities of research into partial discharge mechanism and monitoring technologies of power transformer has been undertaken at home and abroad. Much progress has been made on the on-line monitoring method and instrument. However, its stability and reliability still needs to be improved. Features of transformer oil-paper insulation defect discharge are thoroughly studied, which can lay a solid foundation for the design of PD monitoring system, anti-interference and pattern recognition.

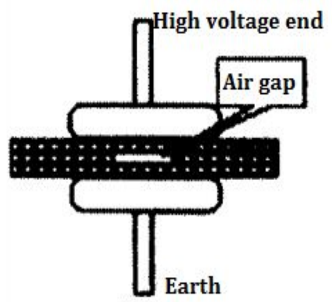
Based on typical PD types existing in power transformer, the author designed five typical discharge models and conducted PD tests in the simulated transformer oil tank. Moreover, high-precision digital system was adopted to observe the process of different kinds of discharges. Discharge atlas and discharge impulse waveform per time were obtained. Discharge features of different kinds of discharges are obtained by means of analysis of atlas and waveform in order to get a deeper understanding for PD features and provide scientific basis for further diagnosis of power transformer aging.

2. Design of Typical PD Models for Power Transformer

The Power transformer in operation has seven kinds of partial discharges: ①Oil gap discharge of oil bulkhead insulation in the middle of winding; ② Oil gap discharge of winding terminal; ③ Oil gap discharge of insulation wire and electric paper(lead insulation and bonding jumper) ; ④ Partial discharge in oil-paper; ⑤ Oil gap discharge between coils (longitudinal insulation) ; ⑥turn insulation partial breakdown; ⑦ Sliding discharge of electric paper. The discharge mostly occurs at some oil gap, oil wedge, air gap, metal conductor with floating potential, conductor protrusion and solid surface. According to above-mentioned discharges, five discharge models are designed. All used insulation paste-boards are dried at a temperate of 65℃ for three days; then do it again at a temperate of 105 ℃ for three days in order to guarantee complete dried. They are immersed into the oil for over five days and polished. Structures of discharge models are as follows in details.

(1) Internal air-gap discharge model

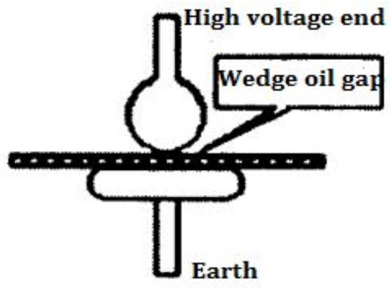
The internal air-gap discharge model of insulation paste-board is shown in Fig.1 (a). The medium in the model is two layers of oil-immersed insulation paste-boards. The thickness is 2.0mm. One layer of paste-board with the thickness of 1.0mm and hole (the diameter is 20.0mm) is pasted between two paste-boards. Moreover, In order to prevent transformer oil from entering air gap and affecting measuring results, insulation paste-boards are bonded via a layer of thin epoxy resin.



(a)

(2) Wedge oil-gap discharge model

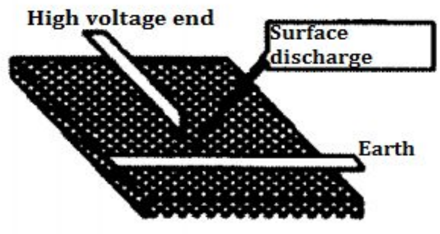
The discharge model of wedge oil gap is shown in Fig.1 (b). The copper ball is placed on insulation paste-board with the thickness of 2.0mm, forming wedge oil gap. The thickness of copper ball is 25.0mm.



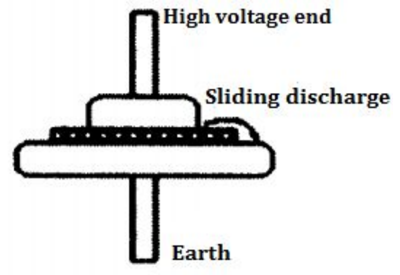
(b)

(3) Surface discharge model

The surface discharge model has two designs (surface discharge and sliding discharge). The surface discharge is shown in Fig.1 (c) while sliding discharge is shown in Fig.1 (d). In the Fig.1 (c), both high-voltage electrode and earthing electrode are copper sheet, the thickness of which is 0.4mm. The place around the copper sheet is polished, and chamfer. Two electrodes are fixed on the insulation paste-board with the thickness of 2.0mm by means of epoxy resin glue. The distance between two electrodes is 10mm. In the Fig.1(d), the diameter of upper electrode is 15.0mm while that of lower electrode is 75.0mm. The diameter of middle insulation paste-board is 45.0mm, and the thickness is 2.0mm. When the voltage rises to certain value, sliding discharge will generate.



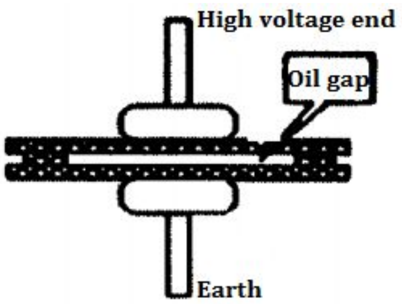
(c)



(d)

(4) Oil-paper bulkhead structure discharge model

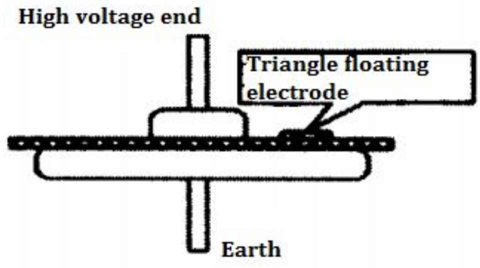
The model is shown in Fig.1 (e). The medium in the model is two layers of oil-immersed insulation paste-boards. The thickness is 2.0mm. Two layers of rectangle paste-boards with the thickness of 2.0mm are pasted between two paste-boards. The insulation paste-boards are bonded via a layer of thin epoxy resin.



(e)

(5) Floating electrode discharge model

The floating electrode discharge model is shown in Fig.1 (f). The high voltage electrode and earthing electrode are plate electrodes. The floating electrode is triangle copper sheet, and the thickness is 0.4mm. It is fixed on the insulation paste-board with the thickness of 2.0mm via epoxy resin glue. The distance between floating electrode and high voltage electrode is 7.0mm. One protrusion of triangle floating electrode is against high-voltage electrode.



(f)

3. Test and Result Analysis

Based on impulse current shunt measuring method, the test adopts TE571 digital PD measuring system to measure PD spectrogram of all discharge models. At the same time, broad frequency-band current sensor and digital oscilloscope are used to obtain single discharge impulse. The system diagram is shown in Fig.2. LVF is used for filtering high-frequency interference from power source while HVF for reducing power frequency interference of high voltage end. The part represented in dotted line in the Fig.2 is placed in the shielding room. Without connecting discharge model, test transformer is on. The measured background noise is less than 0.25pC, which meets the requirement of test.

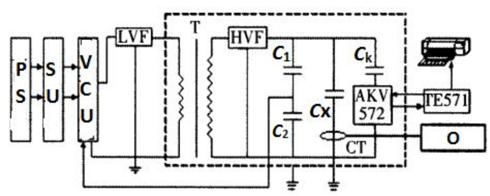


Fig.2 Test system of PD

PS--Power supply

SU--Stable unit

VCU--Voltage control unit

LVF--Low-voltage filter

T--Test transformer without PD (discharge quantity < 5pC under 1000kV rated voltage)

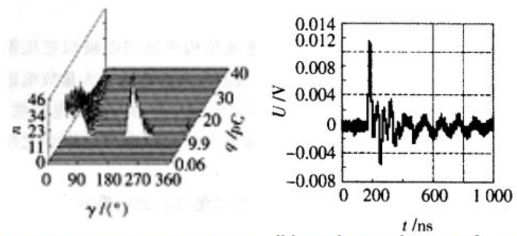
HVF--High-voltage filter

Cx--Test object of transformer discharge model

CT--Broad frequency-band current sensor

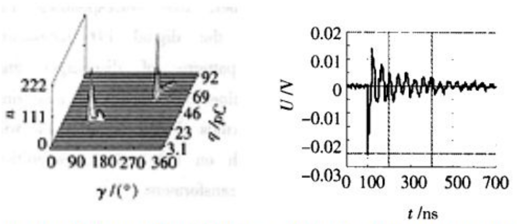
AKV572--detected impedance

As for each discharge model, ten test objects are used to conduct PD test. The discharge 3D distribution spectrogram and single discharge impulse waveform are obtained. Typical discharges are shown in Fig.3-8.



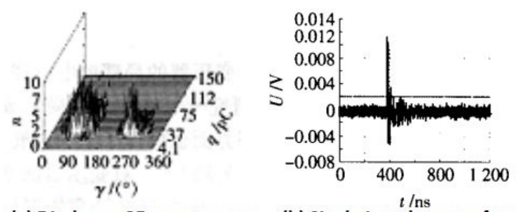
(a) Discharge 3D spectrogram (b) Single impulse waveform

Fig.3 Internal air-gap discharge spectrogram



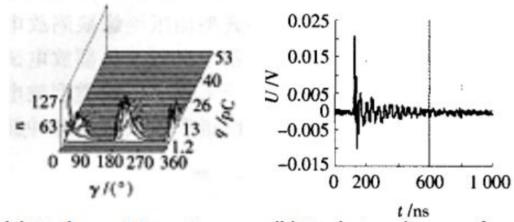
(a) Discharge 3D spectrogram (b) Single impulse waveform

Fig.4 Wedge oil-gap discharge spectrogram



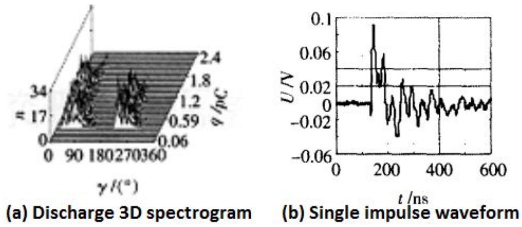
(a) Discharge 3D spectrogram (b) Single impulse waveform

Fig.5 Surface discharge spectrogram



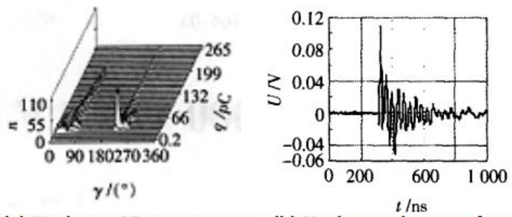
(a) Discharge 3D spectrogram (b) Single impulse waveform

Fig.6 Sliding discharge spectrogram



(6) (a) Discharge 3D spectrogram (b) Single impulse waveform

Fig.7 Oil-paper bulkhead structure discharge spectrogram



(a) Discharge 3D spectrogram (b) Single impulse waveform

Fig.8 Floating electrode discharge spectrogram

According to the test, as the voltage rises, spectrogram of each kind of discharge tends to broaden while the shape of discharge impulse varies a little. Within typical discharge phases (from 1.2 times of initial discharge voltage to 2.0 times of initial discharge voltage), spectrogram distribution features of five models are measured, and parameters of corresponding waveform are calculated. Features of five typical models are summarized in Tab.1. As the voltage rises, the quantity of each discharge impulse increases, and the amplitude of single discharge impulse also increases. However, the waveform feature parameter changes a little.

Tab.1 Summary of five discharge features

Type of discharge	Quad	Phase	Spectro-gram Shape	Main impulse shape	Rising edge time/ns	Falling edge time/ns	Impulse width	Notes
Internal air-gap	1&3	Focus on 45° and 225°	Peak	Single peak	8-9	16-17	12-13	
Wedge oil-gap	2&4	Close to 90° and 270°	Protrusion	Double peaks	4-5	10-11	12-13	8ns between two peaks
Surface discharge	1&2&3&4	Focus on 90° and 270°	Bun	Single peak	1.4-1.6	4.4-4.6	6-7	
Sliding discharge	1&3	Close to 0° and 180°	Peak	Double peaks	2-3	4-5	10-11	8ns between two peaks
Oil-paper structure	1&3	Focus on 45° and 225°	Peak	Double peaks	14-15	4-5	48-50	36ns between two peaks
Floating electrode	1&3	Close to 45° and 225°	Protrusion	Single peak	7-8	6-7	6-7	

Comparing features of five kinds of discharges in Tab.1, no matter what 3D distribution spectrogram or single discharge impulse waveform is, each kind of discharge has obvious features, and there is a great discrepancy between waveform feature parameter of one kind of discharge and the other. The waveform feature parameters of all kinds of discharges are extracted as recognition samples.

In addition, impulse rising edge time of surface discharge and sliding discharge is short, only 1-2ns. The generated transient current is high. Black trace remains on the insulation paste-board after the discharge, which illustrates that it can cause great damage to transformer insulation and pose a threat to PD monitoring equipment. Based on discharge spectrogram, discharge spectrogram of wedge oil gap and floating electrode look like protrusion. The phase concentrates, and the discharge quantity is large. It also poses great damage to oil-paper insulation of transformer. These kinds of defects should be avoided in the actual operation.

4. Conclusions

(1) If the defects are different, their discharge attributes and single impulse waveform are also different, and have repeatability.

(2) As for different discharge impulse, the difference in waveform rising edge, decreasing edge and impulse duration makes it possible to distinguish discharge pattern by means of discharge impulse. Feature parameters are extracted from discharge spectrogram and discharge waveform. Pattern recognition via the combination of discharge spectrogram and waveform will be helpful for the diagnosis of transformer insulation faults.

(3) The impulse rising edge time of surface discharge and sliding discharge is the shortest. The generated transient current is high. It also poses great damage to insulation. Hence, these kinds of defects should be avoided in the design of transformer insulation and actual operation.

REFERENCES

[1] K Raja, F Devaux, S Lelaidier. Recognition of Discharge Sources Using UHF PD Signature [J]. IEEE Electrical Insulation Magazine, 2002, 18(5):8-14.

[2] J Unswoerth, J Kurusingal, R E James. On-line Partial Discharge Monitor for High Voltage Power Transformers [A]. Proceeding of the 4th International Conference on Properties and Applications of Dielectric Materials [C], 1994.

[3] Zhang Guanjun, Quan Yusheng, et al. Discharge Signal Spectrogram of Typical PD Models about Power Transformer[J]. High Voltage Techniques, 1999, 25(2): 13-15.

[4] Fang Qiong, Xu Yang, et al. Digital PD on-line Monitoring System of Power Transformer [J]. High Voltage Techniques, 2002, 28(7): 25-27.

[5] Wang Guoli, Hao Yanpeng, Li Yanming. Study on Pulse Current of Typical PD Models in Power Transformer [A]. International Symposium on Electrical Insulating Materials (ISEIM)[C], Himeji, Japan, 2001.

[6] Jin Xianhe, Wang Changchang, et al. Partial Discharge Pattern Recognition of Power Transformer with Neural Network Applications [A]. Conference on Electrical Insulation and Dielectric Phenomena [C], Austin Texas, USA, 1999.