EXPERIMENTAL RESEARCH ON THE TRANSFORMER WINDING INTER-TURN DISCHARGE CAUSED BY CORROSIVE SULPHUR

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Abstract: In order to study transformer winding inter-turn discharge caused by corrosive sulphur,A series of comparative tests were designed.Firstly,a series of accelerated aging tests of transformer oil were completed.All the oil samples were processed by dehydration and degasification ,then divided into three groups,one group samples were added with insulation paper wrapped-copper electrodes and sulphur.while the other group samples were added with electrodes but no sulphur,then aged under 130℃ for 14,24 and 30 days respectively.Next a number of experiments were taken to research the discharge process according to IEC standard methods.The results indicated that the partial discharge inception voltage by corrosive sulfide dropped very significantly compared with the electrodes without sulphur ,and it reduced with the aging time ,but the breakdown voltage variation was much smaller and during the whole developing process, the discharge capacity was increasing with the time until breakdown on the whole,At the same time ,the spark and bubbles.could be seen.Those results are valuable for evaluating the transformer condition order of severity corroded by corrosive sulphur and helpful to evaluating the large transformer life and monitoring the condition of large electrical power transformers.

1 INTRODUCTION

In recent years,the transformer accidents caused by corrosive sulphur have occurred several times ,and caused great loss to the power grid.As the transformer is of great importance to power gird ,people have paid great attention to the problem.

It is generally considered that the source of corrosive sulphur was from the transformer oil and formed Dibenzyl disulfide(DBDS),and it reacted with copper,and resulted in copper-sulfide deposition on the insulation paper, degraded the insulation paper strength and led to transformer accidents finally.[1].The dissolved oxygen and the content of copper have played an important role in the process of generating cuprous sulfide,and cuprous sulfide resulted from Cu-DBDS,and the existence of oxygen could accelerate the cuprous sulfide deposition.[2-3] and some solutions have been suggested to reduce the corrosive sulphur[4-5].But rare papers have reported about the characteristic of insulated paper corroded by sulphur。

In order to study this discharge phenomenon, the transformer winding inter-turn model was designed ,which was called pigtail model[6].shown in figure 1,the model consits of two coil windings,each of size is 16cm length,0.2cm thickness,1.4cm width.Each coil winding is divided into three portions.the straight portion is 10cm，with a bent portion extending to 3cm,and making an angle of about 30° to the horizontal.and the ends were polished in advance.

Figure 1: Pigtail model

2 EXPERIMENTAL PROCEDURE

2.1 Thermal aging tests

Thermal aging tests are done with 25# Kunlun transformer oil ,and each sample with 1500mL and 400mg sulphur to simulate the the real environment in 130℃,The sulphur concentration is 0.3mg/g .Before the thermal aging,the samples were pumping to vacuum under 50 Pa,105℃ for 24 hours,and then immersed in oil for 24 hours.The aging period is for 14 days,24 days and 30 days respectively,and take samples to do experiments regularly.The samples are shown in Figure 2 to Figure 4 after thermal tests.

Figure 2 : Aging for 30 days

Figure 3: Aging for 24 days

Figure 4: Aging for 14 days

2.2 Experiment Research

Transformer is used as the electrical source,which the capacity is 10kVA, rated voltage 120kV.and the whole system discharge is under 5pC when the voltage is 60kV.and the equivalent circuit is shown in Figure 5 and 6.

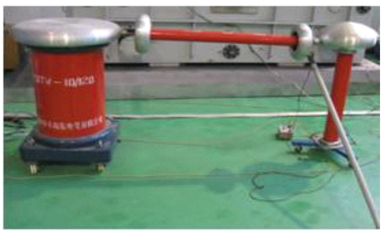

Figure 5: Transformer

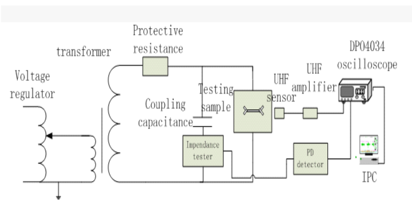

Figure 6: Equivalent circuit

3 EXPERIMENTAL RESULTS

3.1 PDIV and breakdown voltage

Firstly, two samples are selected from different periods to measure the partial discharge inception voltage(PDIV) and breakdown voltage.The results are listed in Table 1

period	PDIV(kV)		Breakdown(kV)	
	With sulphur	No sulphur	With sulphur	No sulphur
14	25	15	41.6	43.1
24	24.5	27	45	44
30	11.2	39	48.25	46

3.2 THE DISCHARGE PROCESS

Three typical experiments were taken to demonstrate the whole process for aging 14 days ,24 days and 30 days,And measured the average discharge magnitude,maximum discharge magnitude ,pulse numbers.

3.2.1 Samples aging for 14 days with sulphur

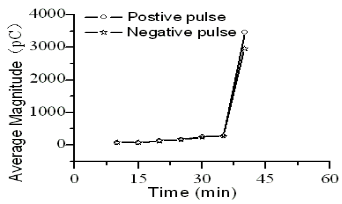

Figure 7: Average magnitude

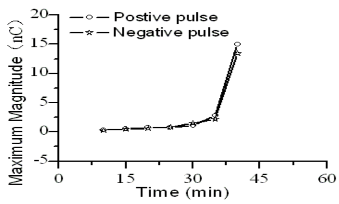

Figure 8: Maximum magnitude

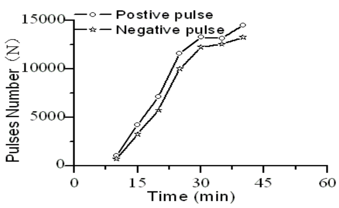

Figure 9: Pulse number

3.2.2 Samples aging for 24 days with sulphur

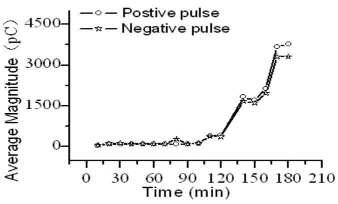

Figure 10: Average magnitude

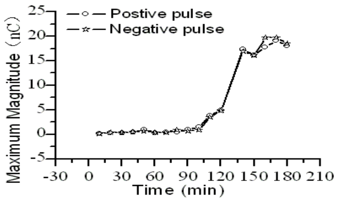

Figure 11: Maximum magnitude

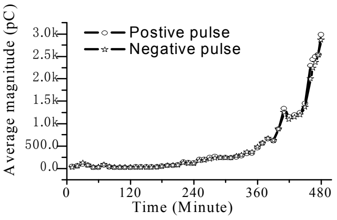

Figure 12: Pulse number

3.2.3 Samples aging for 30 days with sulphur

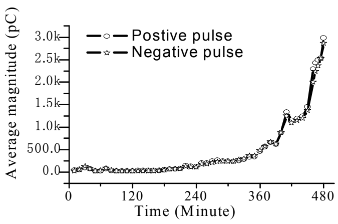

Figure 13: Average magnitude

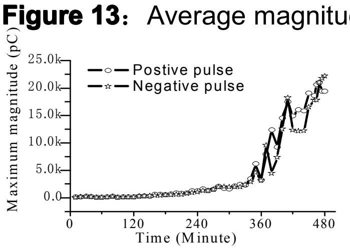

Figure14: Maximum magnitude

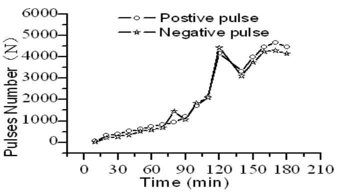

Figure 15: Pulse number

3.2.4 Samples near breakdown

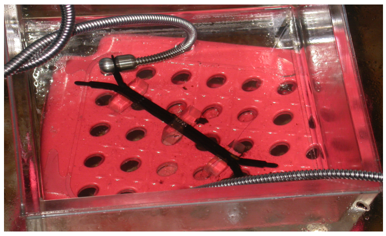

Figure 16: Aging for 30 days

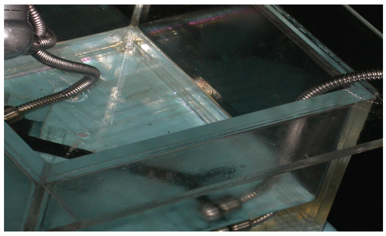

Figure 17: Aging for 24 days

Figure 18: Aging for 14 days

4 CONCLUSION

Three different aging samples have been studied,the experiments have demonstrated that corrosive sulphur has great effect on the transformer winding inter-turn insulation.some salient features of study are:

1) The PDIV variations between different aging periods are obvious,and it dropped very sharply with the aging time.but the breakdown voltage variations are smaller.This is because the outer insulation papers are more likely to suffer from sulphur corrosion,but the inner papers are less.The outer insulation papers became worse with the aging time,and the PDIV also decreased. The breakdown voltage is determined by the inner and outer insulation papers ,but the inner papers are less likely to suffer from sulphur corrosion,the breakdown voltage is almost in the same level.
2) The average magnitude,maximum magnitude pulse number are calculated in 100 cycles every 10 minutes,and all statistical figures are shown in Figure 7 to Figure 15.All calculated parameters are growing in the exponential rule,and grow very quickly near breakdown.In addition, the whole discharge process can be divided into two stages: the stable stage and

turkestan increase stage. The stable stage covers the early and middle stage and the turkestan increase stage covers the late stage.The whole discharge process has a turning point.

3) At the early and middle stage,the discharge amplitude is stable,but at the late stage,near breakdown,discharge amplitude is growing very fast,and it can be observed spark and bubbles.

5 ACKNOWLEDGMENTS

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6 REFERENCES

[1] CIGRE TF A2.31: “Copper sulphide in transformer insulation”,ELECTRA, No. 224, pp. 20-23, 2006

[2] H. Kawarai, Y. Fujita, J. Tanimura, S. Toyama, N. Yamada, E. Nagao:"Role of Dissolved Copper and Oxygen on Copper Sulfide Generation in Insulating Oil",IEEE Transactions on Dielectrics and Electrical Insulation Vol.16, No. 5.pp. 1430-1435,October 2009

[3] T.Amimoto:"Identification of Affecting Factors of Copper Sulfide Deposition on insulating Paper in Oil",IEEE Transactions on Dielectrics and Electrical Insulation Vol. 16, No. 1 pp. 265-272, February 2009

[4] Lance R. Lewand:"Corrosive Sulfur Problems in Electric Apparatus: Causes, Prevention,and Mitigation", Doble Collaborative Study, Addendum A,Doble Engineering Company, September 15, 2005

[5] H.-S. Lian,D.-S. Zheng,L.-K. Zhang,R.-W. You:"Causess and Countermeasures for Sulfur Corrosion of Insulation Oil in Transformers", Fujian Electric Power and Electrical Engineering Vol 28,No. 4,pp. 17-20,December 2008

[6] Rudranna N,V.Krishnan,J.Sundara Rajar: "Application of FEM for Understanding the Electric Field Distribution in Copper Sulphide Contaminated Paper-Oil Insulation of Power Transformer",Proceedings of the 9th International Conference on Properties and Applications of Dielectric Materials,pp.73-76,July19-23,2009, Harbin, China

[7] R. Maina, V. Tumiatti,M. Pompili,R. Bartnikas: "Dielectric Loss Characteristics of Copper-Contaminated Transformer Oils",IEEE TRANSACTIONS ON POWER DELIVERYVOL. 25, NO. 3, pp. 1673-1677,JULY 2010

[8] T. Amimoto, N. Hosokawa:"Concentration Dependence of Corrosive Sulfur on Copper-Sulfide Deposition on Insulating Paper Used for Power Transformer Insulation",IEEE Transactions on Dielectrics and Electrical Insulation Vol. 16, No. 5,pp1489-1495,October 2009