

Study on the Influence of Insulation Layer Number and Temperature of Transformer on Rvm Parameters

Li Jingkui

Electrical and Mechanical Engineering College of Wuxi Institute of Commerce, Wuxi, 214153, China

Keywords: Insulation Layer, Temperature, Rvm, Insulation Condition, Oil-Paper

Abstract: Insulation Layer and Temperature Are Two Important Factors That Influence the Rvm Parameters of Oil Paper Insulation. in Order to Study the Influence, the Samples of Different Temperature and Insulation Layer Were Measured and the Results Were Analyzed in the Laboratory; Results Showed That the Return Voltage Maximum Was Increased under the Increase of Temperature, But the Peak Was Decreased; What's More, the Initial Slope and Center Time Constant Were Decrease under the Increase of Insulation Layer and Temperature; the Foundation of Comprehensive Study the Rvm Parameters Influencing Factors and Further Promote the Application of Rvm Method in Insulation Detection Was Laid.

1. Introduction

Oil Paper Insulation System is the Main Insulation Structure of Power Transformer, Which Determines the Economic Life and Operation Stability of Transformer. It is of Great Value to Study It ^[1]. Oil Paper Insulation Will Be Affected by Temperature, Moisture, Acid and Other Factors, and the Insulation Capacity Will Drop Sharply, Which Will Seriously Affect the Safe and Stable Operation of the Transformer ^[2]. Therefore, It is of Great Significance to Strengthen the Monitoring of Oil Paper Insulation Capacity of Transformer to Ensure the Normal Operation of Power Grid and the Life of Residents.

At Present, the Hot Method to Study the Insulation State of Transformer Oil Paper is Based on the Theory of Dielectric Response ^[3] Recovery Voltage Method(Rvm)Polarization Depolarization Current (Pdc) Method and Frequency Domain Dielectric Spectroscopy (Fds) Method ^[4]. Compared with the Traditional Research Methods, These Methods Have the Advantages of Nondestructive, Accurate Measurement and Rich Information. Scholars At Home and Abroad Have Carried out a Lot of Work on the Influence of Temperature, Moisture, Acid and Other Factors on the Parameters of the Three Methods, and Then Deduced the Relationship between Them and the Insulation State and Evaluated the Insulation State ^[5-7].

Based on the Method of Recovery Voltage, This Paper Studies the Maximum Value of Recovery Voltage Caused by the Combination of Insulation Layers and Temperature U_{rmax} , Central Time Constant T_{cdom} and the Effect of the Initial Slope S_i . through the Preparation of Samples, Modeling and Measurement of Control Variables in the Laboratory, the Influence Rules of the Two on Rvm Parameters Are Obtained, the Research Scope of Influencing Factors of Oil Paper Insulation State is Expanded, and the Application of Rvm Method in Diagnosis is Further Extended.

2. Rvm Test Principle

The Recovery Voltage Method is an Electrical Measurement Method to Study the Slow Polarization Process of the Insulating Medium. It Can Check the Insulation State of the Transformer without Damaging the Oil Paper Insulation of the Transformer ^[8]. the Rvm Measurement Schematic is Shown in Figure 1.

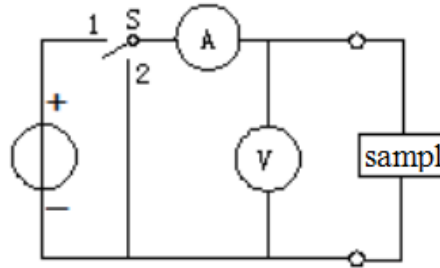


Fig.1 Rvm Measurement Principle

(1) Turn the Switch s to One Place, and Charge the Sample with a Dc Voltage Source. the Voltage is U_0 . the Charged Ions in the Sample Are Arranged According to the Direction of the Electric Field, and the Polarization Process is Carried out. At This Time, Bound Charges Will Appear on the Surface of the Medium;

(2) T_p (2) after the Time, Turn the Switch s to Two Places, the Two Ends of the Sample Are Short Circuited, the Bound Charge in the Medium Begins to Discharge, and the Depolarization Process Begins;

(3) after the Sample is Short Circuited for T_d Time(Generally $T_p/T_d=2$),Turn the Switch s between 1 and 2, and the Depolarization Process is Still in Progress. At This Time, a Voltage Will Be Generated At Both Ends of the Sample. the Recovery Voltage Can Be Obtained by Measuring with a Voltmeter U_r ^[9].

3. Experimental Procedure and Test Model

3.1 Experimental Steps

Experimental materials: 0.25mm Nomex insulating paper, 25[#] mineral oil produced by Karamay;

Measuring instrument: Portable recovery voltage tester RVM5461(Produced by Haefely Instrument in Switzerland);

The specific experimental raw material preparation and measurement steps are as follows:

(1) The Nomex insulating paper shall be cut into 120 pieces of circular paper with a radius of 50 mm. The Nomex insulating paper shall be new insulating paper just delivered from the factory, so as to ensure that the aging degree, moisture and other influencing factors of the tested paper samples are the same, then the measured results can be classified as the influence of insulation layer number or temperature;

(2) Degassing, drying and dehumidifying the new mineral oil to eliminate the influence of insulating oil on the test results;

(3) Take 100 pieces of insulating paper and glue them with insulating glue, and glue them to four samples with insulating paper layers of 2, 4, 6 and 8, each with 5 samples; take the remaining 20 pieces of insulating paper and glue them with insulating glue, and glue them to 5 samples with insulating paper layers of 4. The amount of insulating glue shall be exactly the same as that of the insulating paper, so as to avoid redundant insulating glue to the sample structure After the adhesive is in good condition, hold the sample with heavy objects to ensure the flatness of each sample;

(4) The prepared paper samples with different insulating layers are sandwiched between two copper electrodes with a radius of 45mm and a thickness of 30mm, which are dried and treated. After they are fixed well, they are placed on the insulating base of the test device, and fixed with two lead out conducting rods;

(5) Inject the treated mineral oil into the test device, with the oil surface height above the insulating paper sample; after oil filling, cover the device, seal the device through the control pressing rod, and leave it for 2h to ensure that the mineral oil is fully soaked in the insulating paper;

(6) Connect the two measuring lines of the test device with the tester through the two outgoing lines on the incubator box; after the connection is completed, put the test device with sample into the incubator for standing, and the standing time is set to 3h, and the temperature is set to 25 °C;

(7) Turn on the instrument, set the charging voltage to 300V, and charge discharge time ratio to 2

to measure the sample; take the average value of each 5 samples to draw the curve^[12], and get the influence of different insulation layers on the recovery voltage parameters at the same temperature;

(8) Use the same measurement steps for the remaining four layers of insulating paper samples and put them into the incubator for measurement. Set the incubator temperature to 45°C, 65°C and 85°C respectively and use instruments for measurement. Take the average value of measurement results under different temperatures and draw a curve to study the influence of different temperatures under the same number of insulating layers on the recovery voltage parameters^[14]; before each measurement, the device with samples shall be installed The rest time was 3 hours;

3.2 Test Model

Combined with the actual situation of the sample, the test model^[15] of this experiment is designed, as shown in Figure 2. The model is a rectangular metal box with length, width and height of 400mm, 250mm and 350mm respectively. The device is small in size, and the influence of the box on the test results is avoided through the insulating base. The device is sealed by using the knob to control the pressing rod. The measurement task can be successfully completed by connecting two conducting rods and the instrument.

4. Results and Analysis

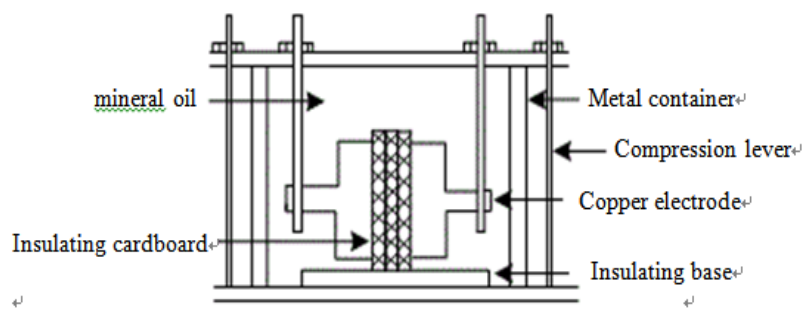


Fig.2 Test Model

4.1 Analysis of Measurement Results of Samples with Different Insulation Layers

This test mainly studies the influence of temperature and insulation layer number on the recovery voltage parameters. Because the temperature and layer number are both variable, and it is not easy to analyze the results in the study, so the control variable method is used for the study. When the temperature is set at 25 °C, the influence of samples with insulation layers of 2, 4, 6 and 8 on the parameters of the recovery voltage is studied. The curve is drawn with the logarithm of time as the abscissa, as shown in Figure 3, figure 4 and Figure 5.

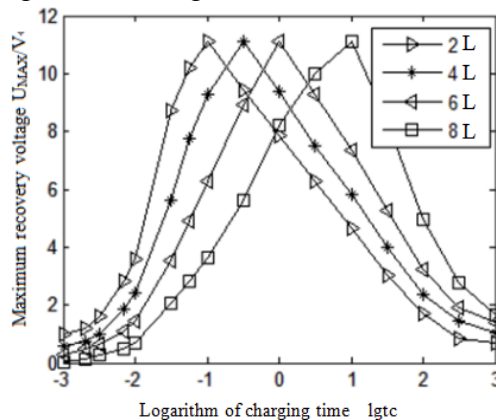


Fig.3 Influence between Insulation Layer and the Maximum Value of Recovery Voltage

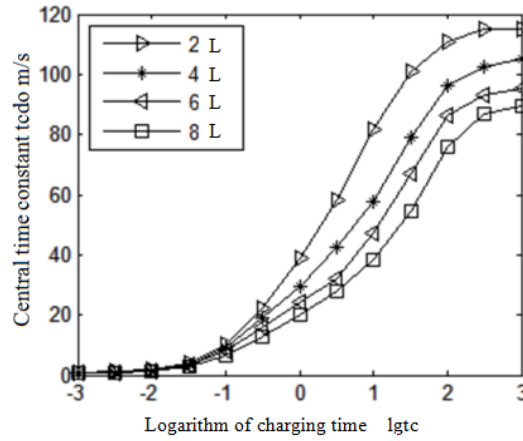


Fig.4 Influence between Insulation Layer and Central Time Constant

It can be seen from the figure that the main time constant increases slowly with the change of insulation layer number, while the peak value of the curve of maximum recovery voltage does not change much, and the trend of curve change keeps the trend of first rising to the maximum value with the increase of charging time, then slowly decreasing and finally becoming stable; the maximum recovery voltage changes slowly before 0.01s, and then increases rapidly. Large, it may be that in the initial stage of charging, the polarization speed of charged ions in the medium does not keep up with the change speed of the electric field, and then there is a certain delay. After that, a large number of charged ions are accumulated at both ends of the sample to discharge to promote the rapid increase of the recovery voltage; in the case of the same amount of mineral oil, the increase of the number of layers of insulating paper will lead to the weakening of the rapid polarization process and the insulation electricity. When the resistance increases, the equivalent capacitance decreases, and the amount of stored charge decreases, resulting in the increase of the main time constant of the curve.

In the figure, when the charging time t_c does not change, the central time constant decreases with the increase of the number of insulation layers^[16]; When the number of insulating layers is constant, the central time constant changes slowly before 0.1s, and then increases sharply; the rapid polarization process is mainly affected by the insulating oil, while with the increase of the number of insulating layers, the amount of insulating oil decreases relatively, the rapid polarization weakens, the slow polarization occupies the main position, and the central time constant increases correspondingly.

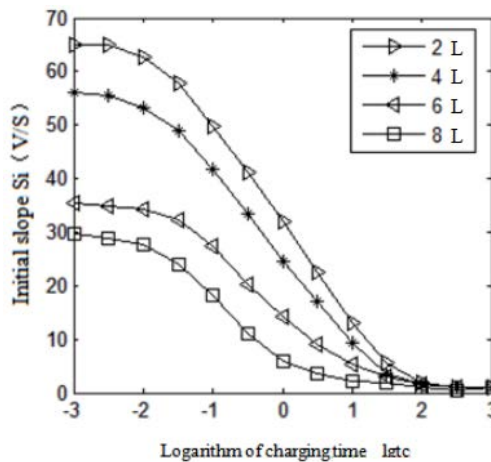


Fig.5 Influence between Insulation Layer and Initial Slope

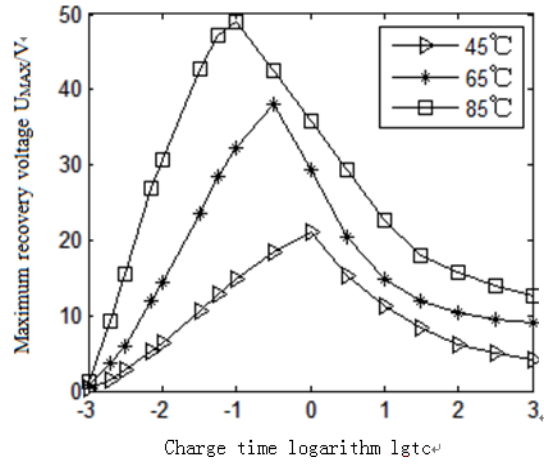


Fig.6 Influence between Temperature and the Maximum Value of Recovery Voltage

With the extension of charging time, the initial slope curves corresponding to different insulation layers show a decreasing trend and remain stable eventually; comparing the curves with the number of insulation layers of 2 and 6, we can see that the smaller the number of insulation layers, the greater the corresponding initial slope; oil paper insulation is the main insulation system of transformer, the more the number of insulation layers, the stronger the corresponding insulation capacity, and the initial slope and oil paper The insulation state is closely related. The larger the initial slope is, the lower the corresponding insulation capacity is. This is why the smaller the number of insulation layers is, the larger the initial slope is^[17].

4.2 Analysis of Measurement Results of Samples At Different Temperatures

The number of insulation layers is taken as 4, and the effects of samples at 45 °C, 65 °C and 85 °C on the parameters of recovery voltage are studied. The results are shown in Fig. 6, Fig. 7 and Fig. 8.

Comparing the measurement results at 25 °C, it can be seen that under the same insulation layer, the increase of temperature will speed up the polarization movement of charged ions in the medium, and can accumulate a large amount of charges at both ends of the sample in a very short time. The charge discharge will cause the rapid increase of the recovery voltage, which is the reason why the curve of the maximum value of the recovery voltage increases faster with the higher temperature at the initial stage of charging in the figure Under the condition of temperature, the curve changes slowly, and the measurement error is smaller than that under the condition of high temperature; after adjusting the switch to enter the depolarization process, a large amount of charge accumulated at both ends of the sample is discharged, resulting in the maximum recovery voltage gradually becoming smaller.

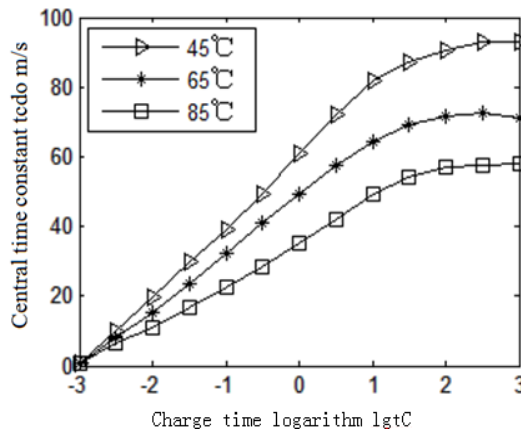


Fig.7 Influence between Temperature and Central Time Constant

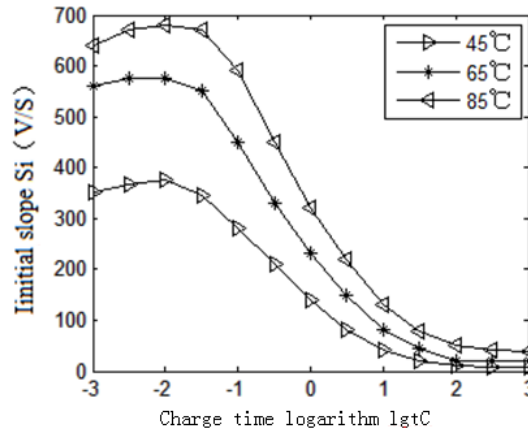


Fig.8 Influence between Temperature and Initial Slope

In Figure 7, with the increase of charging time, the central time constant curves of samples at different temperatures are increasing, and the higher the temperature is, the smaller the central time constant value corresponding to the curve is; the higher the temperature is, the faster the polarization movement in the medium is, and the shorter the time when the recovery voltage reaches the maximum value is. Comparing Fig. 5 and Fig. 8, it can be seen that the central time constant changes faster under the influence of temperature than the number of insulation layers, that is, it is more affected by temperature.

In the figure, before the charging time of 0.1s, the initial slope has a trend of slowly increasing, and it drops sharply after 0.1s, and remains stable after 100s; under the same charging time, the lower the temperature is, the larger the corresponding initial slope is; compared with the curve in Figure 5, it can be seen that the initial slope in Figure 8 changes slowly, that is, the temperature has little impact on the initial slope.

5. Conclusion

Through the experiments of oil paper insulation samples at different temperatures and insulation layers, the influence rules of various parameters of recovery voltage are studied, and the following conclusions are drawn:

- (1) When the temperature is constant, the main time constant increases slowly with the increase of the number of insulation layers, while the peak value of the maximum recovery voltage curve does not change much, and the central time constant decreases. With the increase of charging time, the smaller the number of insulation layers, the larger the initial slope;
- (2) With a certain number of insulation layers, the maximum value curve of recovery voltage increases faster with the increase of temperature, and the peak value of the curve decreases;
- (3) The experiments of temperature and insulation layer number make up the blank of their influence on the parameters of recovery voltage, and expand the research scope of evaluating the insulation ability of transformer by the parameters of recovery voltage.

References

- [1] LIAO Ruijin,HAO Jian,YANG Lijun etal.Study on frequency domain dielectric spectrum of transformer oil paper insulation[C].Proceedings of the 2010 academic conference of the Electrical Engineering Society of Chongqing. 2010.
- [2] SANG Fumin.Study on Thermal Analysis Kinetic Parameters of Oil-paper Insulation in Power Transformer[D].Chongqing University,2009.
- [3] LIAO Ruijin,HAO Jian,YANG Lijun etal.Simulation and Experimental Study on Frequency-domain Dielectric Spectroscopy of Oil-paper Insulation for Transformers[J].Proceedings of the CSEE,2010,30 (22):113-119.

- [4] GAN Lu,CAI Jinding,ZHANG Konglin.Study on parameters identification for equivalent circuit of oil-paper insulation system based on RVM[J].Journal of Electric Power Science and Technology,2013,28(3):71-76.
- [5] WANG Xiaojian,WU Guangning,LI Xianlang et al.Influence of acid value on recovery voltage parameters of transformer oil-paper insulation system[J].Electric Power Automation Equipment, 2013,33(12):133-139.
- [6] Ma Zhiqin,Liao Ruijin,Hao Jian et al.Influence of Temperature on Polarization and Depolarization Current of Oil-Paper Insulation[J].Transactions of CHINA Electrical technical Society,2014, 29(4):290-297.
- [7] LIAO Ruijin,GUO Pei,ZHOU Nianrong et al.Influence of Water Content and Aging on Temperature Domain Dielectric Spectroscopy and Activation Energy of the Transformer Oil Impregnated Papers[J].High Voltage Engineering,2014,40(5):1407-1415.
- [8] JIANG Xiubo,ZHANG Tao,HUANG Yanjie.Simulation of transformer insulation polarization spectrum[J]. Electric Power Automation Equipment,2011,31(2):31-35.
- [9] PENG Huadong,DONG Ming,LIU Yuan et al.Transformer Oil-Paper Insulation Ageing Condition Assessment Using Return Voltage Measurements[J].Power System and Clean Energy,2012,28 (9):06-12.
- [10] LIAO Ruijin,SUN Huigang,YUAN Quan et al.[J].High Voltage Engineering,2011,37(1): 136-142.
- [11] WEN Hua,MA Zhiqin,WANG Yaolong et al.Experimental Investigation and XY Model Simulation on the Frequency Domain Spectroscopy Characteristics of Transformer Oil-paper Insulation [J]. High Voltage Engineering,2012,38(8):1956-1964.
- [12] ZHANG Aiyun,ZENG Wei,GAO Wai et al.Key Driving Circuit of Piezoelectric Injector for High-pressure Common Rail System[J].Vehicle Engine,2013,(2):6-9.
- [13] GAO Zongbao,WU Guangning,ZHOU Lijun et al.Influence of Moisture Content on Parameters of Return Voltage Measurement in Oil-paper Insulation System of Transformer[J].High Voltage Apparatus,2011,47(4):37-41.
- [14] LIU Gang,LIAO Rui-jin,FENG Yun et al.Temperature Influence on Parameters of Return Voltage Measurement of Oil-paper Insulation System in Transformer[J].High Voltage Apparatus,2010,46 (1):80-84.
- [15] CHEN Chao,ZHOU Dongyang,LI Qun et al.Study on Simulation Model Testion Based on SMP2 [J].Journal of System Simulation,2007,19(10): 2300-2303.
- [16] WANG Lin,PENG Qian,ZHOU Lijun et al.Analysis on return voltage of Oil-paper Insulation aging characteristics[J].Insulating Materials,2012,(5):42-45.
- [17] WANG Kai,CAI Jinding.Research on air gap influence on return voltage parameters for oil-paper insulation system[J].Journal of Electric Power Science and Technology,2013,28(4): 37-42.