RISK EVALUATION OF PARTIAL DISCHARGE DEFECT ON OIL-IMPREGNATED PAPER

Yangchun Cheng, Ming Chen, Yang Xue, Chengrong Li, Wei Wang
State Key Laboratory of Alternate Electrical Power System with Renewable Energy Sources, Beijing Area Major Laboratory of High Voltage and EMC, North China Electric Power University, Beijing, China
*Email: chych@ncepu.edu.cn

Abstract: High voltage partial discharge experiments on ball-plate models were carried out with step raised high voltage. Partial discharge signals were sampled and stated. Summarizing the information from the partial discharge signals, the development process of the partial discharge defect was divided into three stages. The criteria of the stages can be extracted to predict the failure and assess the failure risk. By the criteria, the risk of the transformers is divided into low risk, moderate risk and high risk. When the defect is in the destructive stage, the pulse rate of partial discharge signals becomes steady at a certain level for a considerably long time. Afterwards it increases exponentially, with pulses covering a wide range of phase angles towards to zero degree. The PD amplitude is not stable and decreases for a considerably long time, but significantly increases just before breakdown.

1 INTRODUCTION

Power transformers are the key equipment of electric power system. A fault in a power transformer could lead to a serious electric power failure. Under the global trend of IntelliGrid, condition assessment and failure prognosis of power apparatus are required by the worldwide electrical power utilities. The majority of power transformers adopt mineral oil and oil-impregnated paper and pressboard in their insulation system. Partial discharge (PD) is one of the main reasons for insulation failure of transformers, at the same time it is also one of the important indications for local defects of the oil-paper insulation system. Therefore detection of PD signals is powerful tool to assess the insulation condition and to predict the insulation of a transformer[1-3].

PDs erode paper insulation and produce carbonized traces, which reduce the insulation ability of the paper. When the carbon trace grows big enough, an electrical fault is inevitable. The key of failure prognosis is to understand the scale of the carbon trace through PD signals or DGA signals.

In this paper, AC high voltage PD tests on oil wedge models with oil-impregnated paper were carried out. The voltage applied was step increased. In order to study the developing process of carbonized traces in the paper, PD signals were continuously measured. Furthermore, the features of the PD signals were calculated, including the pulse rate, the average amplitude, the maximum amplitude and the phase distribution. The trends of the PD signals were analyzed to extract criteria to predict the failure and assess the failure risk.

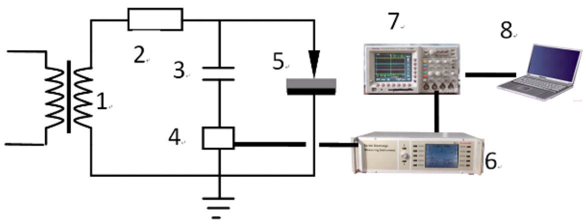
2 INSTRUCTIONS OF HIGH VOLTAGE EXPERIMENTS

The high voltage experiment platform, oil-impregnated paper samples, ball-plate electric field model, PD measurement system and data process were introduced in this paragraph.

2.1 High voltage experiment platform

The high voltage PD experiment platform was shown in Figure.1. It consisted of a high voltage transformer, high voltage conductor, capacitive high voltage divider, oil-impregnated paper, PD measurement device, oscilloscope and computer.

This platform was free of PD. Its background noise was about 8pc when the high voltage was 45kV. The PD signals were measured by a PD device, which eliminated noise and enlarged the PD signals. Then the PD signals were transmitted from the PD measurement device to the oscilloscope to be sampled. At last, the PD signals were transferred to the computer through a USB connective line.



1-high voltage transformer, 2-protective resistance (10kΩ), 3-capacitive divider (800pF), 4-measuring impedance, 5-PD model, 6-PD measurement device, 7-oscilloscope, 8-computer

Figure.1 Experiment platform

2.2 Partial Discharge Model

The PD phenomena were researched through a PD model with a ball-plate electrode structure, shown in Figure.2. The copper ball was the high voltage electrode, with 40mm diameter. The copper plate was the earth electrode, with 75mm diameter.

Figure.2 Partial discharge model

Considered of the developing process of the PD defect in the oil-impregnated paper, pressboards with 2mm or 3mm thickness were chosen. Their ideal electric stress was above 35kV/mm. According to the IEC60641-2, the pressboards were dried and degassed under 105℃ and 100pa vacuum oven for 24 hours. Then, the pressboards were impregnated by new mine oil in vacuum condition and put 24 hours.

The humidity, electric stress, dielectric loss of the mine oil was detected to control the quality of the oil. The oil was filtered to eliminate gas, water and particles. It was 8.6 ug/mL of humidity, 80kV of withstand voltage, 0.008% of dielectric loss and 0.1% of gas content.

2.3 Partial Discharge Measurement

The PD signals were measured by a DST-4 PD device. It was 40kHz-80kHz, with 5pC of sensitivity. The PD signals were filtered and enlarged by this device. Before each experiment, the text circuit was calibrated to assure the accuracy.

The PD signals were sampled with speed of 500kSps. Each data of 20ms was one fragment. The data were sampled and stored one by one fragment. Because of the transfer speed limit, one fragment need about two seconds. Data of 100 cycles need about 3.3 minutes.

3 RESULTS OF HIGH VOLTAGE TESTS

3.1 Applied High Voltage

In order to reduce the time of the PD development process, step raised high voltage was used, shown in Figure.3. The high voltage started at the PD inception voltage of the specimen, and raised 1kV within each 30 minutes, until the specimen was broken down.

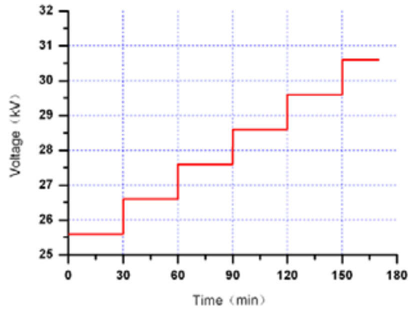


Figure.3 Applied high voltage

3.2 The Phase Related Pulse Distribution

About 20 specimens were used to research the development process of PD defect. The phase related pulse distribution (PRPD) of the PD signals was stated at first. Along with the raised high voltage and the time, the PD signals were appeared at the positive semi-cycle of the high voltage at first. Then, PD pulses also appeared at the negative semi-cycle. PD pulses expend their phase range to 0 degree and 180 degree. Finally, negative PD pulse appeared from 150 degree to 300degree, positive PD pulses appeared from -30 degree to 100 degree. In Figure.4, Figure.5 and Figure.6 there are typical PRPD graphs.

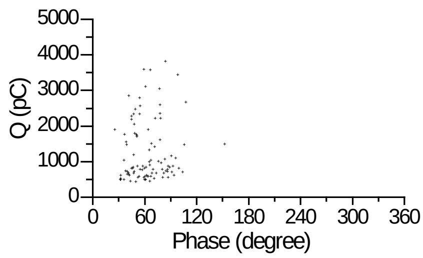


Figure.4 The PRPD at the beginning of the process

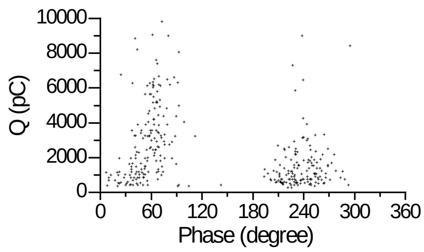


Figure.5 The PRPD at the middle of the process

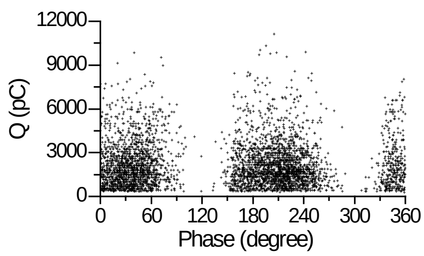


Figure.6 The PRPD at the end of the process

3.3 The Pulse Number and Total Charge

The pulse number and total charge (the summary of the charge with every PD pulse) in 100 cycles was stated at every 5 minutes. The results were shown in Figure.7, Figure. 8. In these figures, the horizontal axis was the time to the breakdown. In Figure.9 the curves were plot again with logarithm vertical axis. From the curves, the PD number and total charge of the PD pulses experienced a stable fragment for a long time, then a quickly enlarged fragment with a exponential rule.

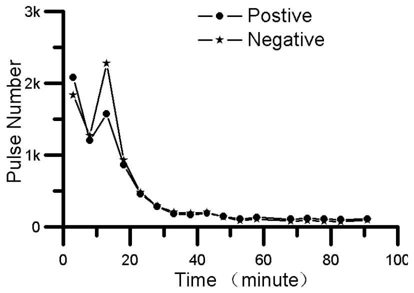


Figure.7 the developing process of pulse number

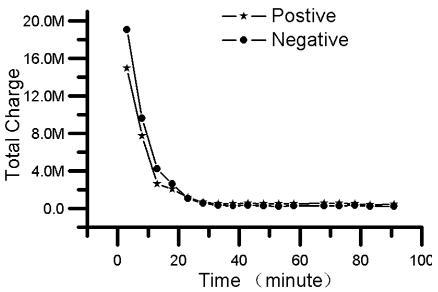


Figure.8 the developing process of total charge

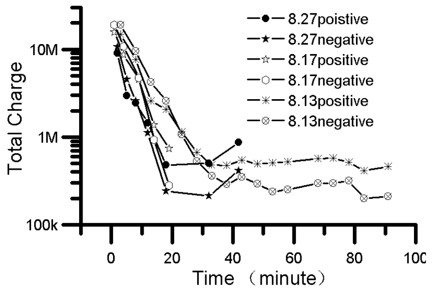


Figure.9 the developing process of total charge

3.4 The Magnitude of the PD Pulses

The average amplitude and maximum amplitude of the PD pulse 100 cycles was stated at every 5 minutes. The results were shown in Figure.10 and Figure.11. In these figures, the horizontal axis was the time to the breakdown. From the curves, the PD pulses experienced an unstable fragment for a long time, then a quickly increased fragment. The average amplitude had a reduced tend in its unstable fragment, because of the appearance of many small pulses.

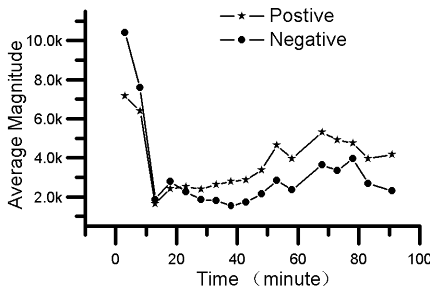


Figure.10 the developing process of average magnitude

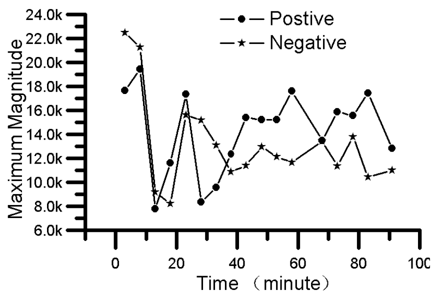


Figure.11 the developing process of maximum magnitude

3.5 The PD Pulses in One Cycle

In Figure.12, Figure.13 and Figure.14, there are the typical PD pulses in one power frequency cycle. The figures were coincident with the three stage in Figure4 ~Figure.6. It is very clear that the PD pulses are seldom for a very long time. Before the breakdown, the PD pulses are very dense in one cycle.

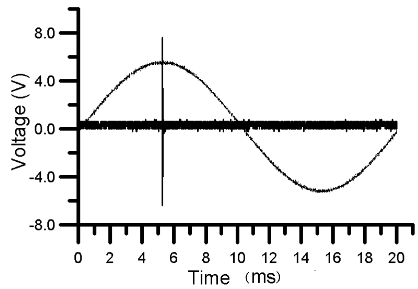


Figure.12 The PD pulses at the beginning of the process

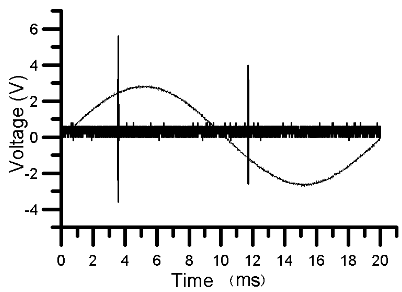


Figure.13 The PD pulses at the middle of the process

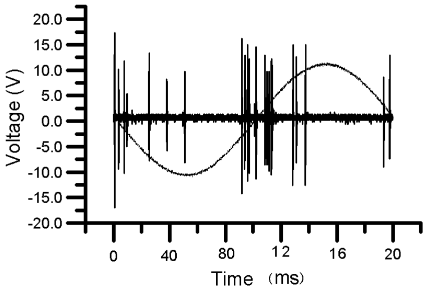


Figure.14 The PD pulses at the end of the process

4 ANALYSE OF THE PD DEVELOPING PROCESS

From the PRPD figures, the pulse number curves, the pulse magnitude and pulse in one cycle, we can get some information about the developing PD defect. At the beginning of the development, the PD pulse bring very small destroy to the pressboard. Even the high voltage was increased, the number, total charge, magnitude of the PD pulses did not increase. At this stage, we think that the PD pulses occurred at the oil gap between the ball and the plate electrode. The pulses were so seldom that they did not generate defect on the pressboard.

When the applied electric field was continue increased, two or more PD pulses appeared in one cycle. At this stage, the power of the PD pulses accumulated to a great value that the carbon defect appeared on the pressboard. Since then the developing process entered into a recycle that the PD pulses enlarge the carbon defect and the carbon defect bring out more PD pulses. So, the PD pulses number and the total charge increased with exponent rule. The inception voltage of the pressboard was reducing gradually. So that the phase distribution of the PD pulses was extending gradually.

Just before breakdown, the defect did accelerate to develop. The remainder dielectric stress of the pressboard was very weak. Then, the magnitude of the PD pulses was very big. Small PD pulses disappeared. The defect had a great scale that many PD pulse can appear in one cycle.

5 CONCLUSION

Through high voltage experiments of PD on ball-plate model, the development process of PD defect on oil-impregnated paper was obtained. From the development rule we can get the criteria to diagnose the risk level of PD defects on oil-impregnated paper. The development process can be divided into three stages, which coincides in three levels of transformer risk.

At the first stage, the PD signals was seldom, appeared only at the positive cycle of the high voltage. At this stage, the oil-impregnated paper was not destroyed, and it can withstand the high voltage for a long time. The transformer has low risk.

At the second stage, the two or more PD signals appeared at one power frequency cycle of the high voltage, including the positive semi-cycle and the negative semi-cycle. The phase rang of the PD pulses is extending to 0 degree and 180 degree. The pulse number and the total charge are increasing with exponent rule. At this stage, the oil-impregnated paper was destroyed, and the defect accelerates to develop. The transformer has moderate risk.

At the third stage, many PD signals appeared at one power frequency cycle of the high voltage, including the positive semi-cycle and the negative semi-cycle. The phase rang of the PD pulses across 0 degree and 180 degree. The pulse number and the total charge are increasing with exponent rule, and the magnitude of the pulses is increased suddenly. At this stage, the oil-impregnated paper was losing its insulation and will be broken down soon. The transformer has high risk.

6 ACKNOWLEDGMENTS

This research supported by National Basic Research Program of China(973 Program).(2009CB724508).

7 REFERENCES

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