

## Use and Problems of On-line PD Measurement Technology on Switchgears in Guangzhou Distribution System

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### Abstract:

*On-line PD measurement technology is a useful method to find out insulation defect preventing from power out. A kind of on-line PD measurement technology Ultra TEV plus+ and PDM03 has been introduced in this paper. Principle of the technology has been presented simply. And use in Guangzhou district is also summerized. It is essential to investigate how the PD signals develop and acquire fault presentiment ways, and so, the relationship between PD magnitude and factors such as circumstance temperature and relative humidity should be confirmed. Moreover, PD in different phases also needs to be researched. And basing on works above, early fault presentiment ways suited for practice should be put forward.*

*Keywords: switchgears; partial discharge; radiation character; Fault presentiment*

### INTRODUCTION

By the end of March 2010, there are 6164 power distribution switch rooms and 4708 power distribution integrated rooms in Guangzhou district. Various switch cabinets add up to 67796. Maintainers of power distribution running have high pressure for lacking of corresponding diagnosis means. Base on the statistic these years, electrical insulation fault of switchgear has taken about half part of power equipment fault of power distribution system in Guangzhou. Especially in 2009, the total amount of switchgear fault is 51, and insulation fault is 34, which is about 66.7% of the total one. The number of switchgear fault rises yearly. The operation data indicate that electrical insulation issue of switchgear stands out in Guangzhou district, which has seriously impact on improving the power supply reliability. For

switchgear equipment, diagnosis on insulation situation is mainly through the off-line test. In some situation, the test has not been conducted indeed. With various index evaluation of the power grid operation, trying to detect the insulation situation of switchgear is very important for power supply enterprises at the moment [1-2]. Under the background, the technology on partial discharge detection of switchgear came into being and was used to discover insulation defect. Technology realization was based on ultrasonic waves and radio waves on ground. We could choose corresponding sensor according actual situation. Ultra TEV Plus+ (inspection tour) and PDM03 (diagnose and defect positioning) was used to detect partial discharge of switchgear. At present, the technology was widely adopted in power distribution network of Guangzhou, which had discovered a batch of hidden trouble in safe operation. And it also played a positive role to improve the power supply reliability. This paper would introduce service condition of the technology on partial discharge detection in power distribution network of Guangzhou, and sum up some typical cases in order to provide reference for popularizing the technology in power network of Guangzhou and other places.

### BASIC PRINCIPLE

The system which was used to detect partial discharge of switchgear (Ultra TEV plus+) mainly choose two kinds of patterns, ultrasonic waves and radio waves on ground[3].

Radio waves on ground, when partial discharge occurs, electromagnetic wave propagates in all directions. And a pulsed discharge current is created on the inside surface of metal shell, then it spreads all around. A transient pulsed voltage (radio waves on ground) is created on the

outside surface of metal shell because of skin effect. These pulses could be detected with capacitive probe so that partial discharge would be known. The effective detection band is 3MHz~80MHz. Generally, partial discharge may occur in the switchgear if the detected amplitude exceeds 20dB. PDM03 is updated based on Ultra TEV plus+ system, which could locate partial discharge position with multi-probe according time difference.

Ultrasonic waves, according to the theories of gas discharge, radio sound waves would be created if partial discharge occurs in gas. It is say that a portion of the energy of partial discharge would be propagated in the form of sound waves. These sound pulses would be detected with ultrasonic probe so that partial discharge would be known, too. Generally, partial discharge may occur in the switchgear if the detected amplitude exceeds 7dB.

## APPLICATION

Learn from the experience of power grid companies in Singapore for reference, on-line PD measurement technology was introduced to power grid companies of Guangzhou in 2008, and now has entered popularizing stage. According to preliminary statistics, over 500 switchgears of electric room in power distribution network of Guangzhou have been measured with the technology, and have discovered a batch of hidden trouble in safe operation. Before 10 June 2010, various insulation defects have been detected 12 times in power distribution network of Guangzhou by means of on-line PD measurement technology, which have been verified after being disintegrated. Viewed from the representation pattern of partial discharge, the above defects could fall into two kinds, internal discharge and surface discharge. Internal discharge mainly occurs in semi-insulating switchgear (10 times), while surface discharge occurs in all-insulated switchgear (2 times). Internal discharge could be discovered by detecting radio waves on ground, while surface discharge could be discovered easily by detecting ultrasonic waves. Viewed from the partial discharge characteristic, it could fall into two kinds, continuous discharge (11 times) and intermittent discharge (only 1 time). And it is the same with other

companies according the result of research. In order to illustrate the issue, this paper introduces four typical examples as follow; case one is using ultrasonic waves to detect surface continuous discharge in semi-insulating switchgear. Case two is using radio waves on ground to detect internal continuous discharge in all-insulated switchgear. Case three is using ultrasonic waves as a long-term monitoring to detect surface intermittent discharge in semi-insulating switchgear. Case four is using radio waves on ground as a long-term monitoring to detect internal intermittent discharge in all-insulated switchgear.

### A. Case One

In 11 June 2009, working state of the switchgear in certain electric room was detected. The result showed that partial discharge was over standard (the amplitude exceeded 20dB in the result of radio waves on ground test, the amplitude exceeded 8dB that was nearly 15dB in the result of ultrasonic test), the infrared was normal.

In early July 2009, working state of the switchgear in the electric room was detected again. The result showed that partial discharge was over standard (the amplitude exceeded 20dB in the result of radio waves on ground test, the amplitude exceeded 8dB that was nearly 15dB in the result of ultrasonic test), and it can be identified that power source was in the internal switchgear, the infrared was normal. There was abnormal sound and peculiar smell in the electric room making an inspection tour again.

In 27 June 2009, the switchgear was repaired. Then the working state of the switchgear was normal, and it functions normally.

Afterwards, internal situation of the new switchgear was detected. It was found that inlet wire ditch of the switchgear was damp .There were screws and a mass of waters around trident mouth of electric wire in inlet wire room, as shown in figure1. It is indicated that partial discharge occurred distortion that caused corona discharge due to the existence of screws. A mass of waters would be adsorbed because of the effect of electrostatic field around the screws, which would cause corona discharge, too. The local area would be white finally. There was obvious corrosion in the junction of

bus room electrode and post insulator.

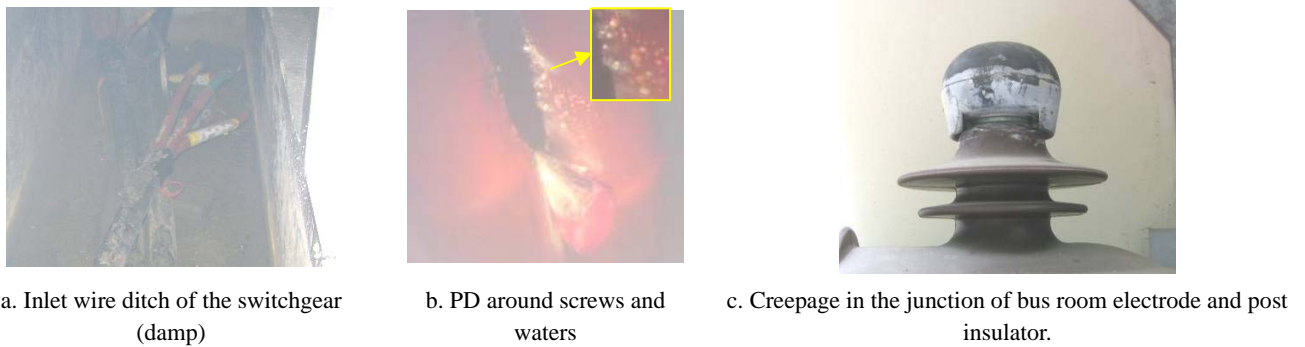


Fig1 the detected switchgear inside the electric room

**B. Case Two**

In 26 April 2010, working state of the switchgear in certain electricity room was detected. The result showed that partial discharge was over standard (the amplitude was 34dB in the result of radio waves on ground test, the amplitude exceeded -5dB in the result of ultrasonic test).

In May 2010, on-line PD measurement was carried out aimed at the above switchgear many times. The result was nearly the same as the first time.

In 2 June 2010, working state of the switchgear in the same electricity room was detected again. The result showed that partial discharge was over standard (the amplitude was nearly 30dB in the result of radio waves on ground test, the amplitude exceeded -6dB in the result of ultrasonic test), the amplitude of ultrasonic waves in the environment background was 20dB, and the amplitude of ultrasonic waves of other switchgears in the same electric room was 20dB, too. Therefore, it can be identified that power source was mainly in the internal switchgear.

In 10 June 2010, the switchgear was repaired. Then working state of the switchgear was normal, and it was functioning correctly.

Afterwards, internal situation of the new switchgear was detected. It was found that in the interface between DIN causing of inlet wire cabinet of the switchgear and waterproof insulating sheath was dried up. The electric field in air gap concentrated, which caused partial discharge finally.

**C. Case Three**

In 2 February 2010, working state of the switchgear in certain electric room was detected. The result indicated

that partial discharge may exist in the switchgear (the amplitude was 20dB in the result of ultrasonic test; the amplitude was less than 10dB in the result of radio waves on ground test). Not only the radio wave on ground detecting was so insensitive, but also the partial discharge was so weak that power source could not be located.

In 12 February 2010, working state of the switchgear in the same electric room was detected for the second time. The result showed that partial discharge of some switchgear in the electric room was over standard (the amplitude was 10dB in the result of ultrasonic test).

In 29 March 2010, working state of the switchgear in the same electric room was detected for the third time. The result showed that working state of the switchgear was normal, which did not exceeded standard.

In order to locate the position of partial discharge in the switchgear, and compare detected results in different times, each side of the switchgear and gap on each side of the switchgear has been detected. The amplitude of partial discharge on each side of the switchgear was analyzed by means of statistic average. The number was in order of cabinet1, cabinet2, cabinet3, cabinet4, cabinet5 and cabinet6 from left to right, as shown in figure2. The detected value of gap on each side of the switchgear was averaged, which should be the amplitude of partial discharge on each side of the switchgear.



Fig2 detection schematic

Maximum average values of partial discharge on each side

of the switchgear from three tests are shown as figure3. In 2 February 2010, 12 February 2010 and 29 March 2010, the amplitude was 20dB, 10dB and 3dB in the result of ultrasonic test. In 29 March 2010, the results showed partial discharge was disappeared temporarily

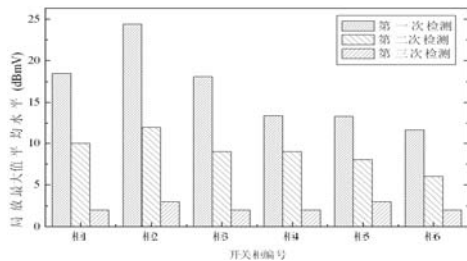


Fig3 Maximum average values of partial discharge on each side of the switchgear

**D. Case Four**

In 1 March 2010, working state of the switchgear in certain electricity room was detected. The result indicated that partial discharge may exist in the switchgear (the amplitude was 29dB in the result of radio waves on ground test; the amplitude was less than 3dB in the result of ultrasonic test).

In 30 March 2010, working state of the same switchgear in the electric room was detected for the second time. The amplitude was 30dB in the result of radio waves on ground test; the amplitude was less than 5dB in the result of ultrasonic test.

In 5 April 2010, working state of the switchgear in the same electric room was detected for the third time. The amplitude was 19dB in the result of radio waves on ground test; the amplitude was less than 3dB in the result of ultrasonic test. In 26 April 2010, working state of the switchgear in the same electric room was detected for the fourth time. Paradoxical discharge was detected and located by using PDM03. Detected time continued for about 3 days, results are shown as figure4 and figure5. The green curve and the red curve are the amplitude of two of different sides of the switchgear. As a matter of judgment experience, partial discharge occurred close to number6 channel and number7 channel on certain period of time in three days. And it is intermittent discharge.

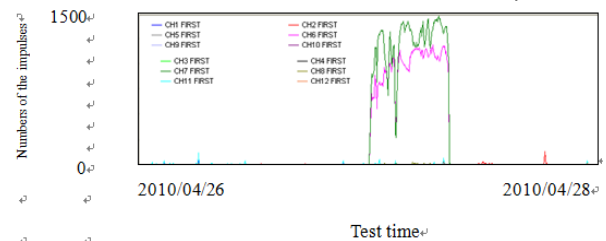


Fig4 the relationship between numbers of the impulses and test time

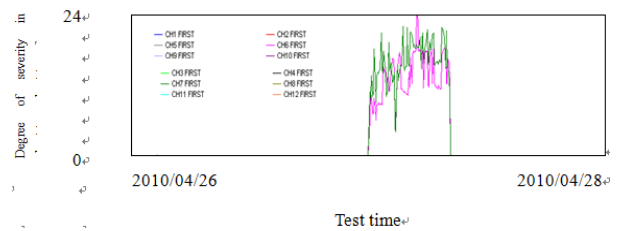


Fig5 the relationship between degree of severity in short-term and test time

**DISCUSSION**

This paper has described the above cases in the third quarter, case one is using ultrasonic waves to detect surface continuous discharge in semi-insulating switchgear, case two is using radio waves on ground to detect internal continuous discharge in all-insulated switchgear, case three is using ultrasonic waves as a long-term monitoring to detect surface intermittent discharge in semi-insulating switchgear, case four is using radio waves on ground as a long-term monitoring to detect internal intermittent discharge in all-insulated switchgear.

For case one and case three, the defects could be effectively checked by ultrasonic test, and it showed that corona or creepage on surface was the main defect after being disintegrated. The electrochemical corrosion could be found easily in most partial discharge position. The same case is common in power distribution network of Guangzhou district. Insulation situation of semi-insulating switchgear is strongly associated with environmental temperature and humidity. It is indicated that frequency of induced pulse signal on surface of the metal cabinet caused by partial discharge in the air was inferior to 1MHz usually, while frequency band that could be detected was higher (over 3MHz at least). The degree of superposition between two frequency bands is low, and it is the main reason that radio wave on ground detecting was so insensitive.

For case two and case four, the defects in switchgear could be effectively checked by radio waves on ground test. The kind of cases was common in all-insulated switchgear. And the detected defects were mainly in inlet wire room, and they were mostly insulation discharge on interface. The frequency of partial discharge was higher, and it propagated in the form of electromagnetic waves. Therefore, instantaneous changes of ground potential could be induced on surface of the metal cabinet. The signal could be easily detected through the instrument.

For case three, the amplitude was 20dB, 10dB and 3dB in the result of ultrasonic test three times. The switchgear should be repaired according to the first detection, while the switchgear was normal that did not need any reparation according to the third detection. Obviously, single threshold standard is not suitable for this situation. Instead, the development trend of amplitude was more significant for the operation of switchgear. During the test, temperature of electric room was 11.5°C, 16°C and 23.6°C respectively, and relative humidity of electric room was 89%, 69% and 46.4% respectively, the relationship with amplitude in the result of ultrasonic test was showed as figure6. From figure6, the indicator value of partial discharge increased positively with temperature and negatively with relative humidity. Intensity of partial discharge was changed with external environment. According to operation experience, the partial discharge was possibly corona or creepage on surface of switchgear. And it is the most common in semi-insulating switchgear.

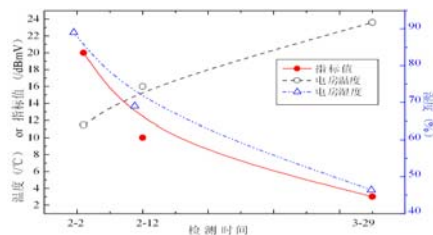


Fig6 the relationships between circumstance temperature (relative humidity)

and amplitude in the result of ultrasonic test

For case four, the amplitude was 29dB, 30dB and 19dB in the result of radio waves on ground test three times. Partial discharge may exist in switchgear according to the first detection and the second detection, while the switchgear was normal that did not need any reparation according to the third detection. Obviously, single threshold standard is

not suitable for this situation, too. Instead, the development trend of amplitude was more significant for the operation of switchgear.

After the technology was put into use for a long time, operation unit would have interruption maintenance or replace directly if partial discharge is over standard. With power distribution reliability developing and detecting ideas based on the concept of risk assessment building, decision layer has begun to consider the optimal maintenance schedule now. Therefore, to provide the optimal maintenance schedule for maintainer, on-line partial discharge test in switchgear should need further study. It is essential to investigate how the PD signals develop and acquire fault presentiment ways, and so, the relationship between PD magnitude and factors such as circumstance temperature and relative humidity should be confirmed. Moreover, PD in different phases also needs to be researched. And basing on works above, early fault presentiment ways suited for practice should be put forward.

## CONCLUSION

On-line PD measurement technology is a useful method to find out insulation defect preventing from power out. And it is an effective method to improve life-cycle management. At present, on-line PD measurement technology is widely used in Guangzhou power supply. The development of defects has become a mutually concerned issue already. To provide the optimal maintenance schedule for maintainer, on-line partial discharge test in switchgear should need further study. It is essential to investigate how the PD signals develop and acquire fault presentiment ways, and so, the relationship between PD magnitude and factors such as circumstance temperature and relative humidity should be confirmed. Moreover, PD in different phases also needs to be researched. And base on works above, early fault presentiment ways suited for practice should be put forward. In addition, the previous experiences should not be copied completely. Instead, maintenance rules and standards should be put forward according to practical conditions.

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