SENSITIVITY ANALYSIS OF CABLE OSCILLATING WAVE TEST SYSTEM ON MULTI-SOURCE DEFECTS DIAGNOSTICS

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ABSTRACT

In this article, the author introduces the successful application cases of multi-source defect diagnosis, by using the cable partial discharge detection and location under oscillation wave test system (OWTS). By using OWTS, the existence of partial discharge defects simultaneously among the three intermediate cabling connectors was discovered. Statistics to the relationship among discharge frequency characteristic and test voltage for the 3 positions respectively found that the discharge pulse number presented terraced rising trend with the increase of test voltage, which is exactly the characteristics of typical discharge. To reveal the cause of concentrated discharge, a variety of advanced state detection technology were applied on the second defective intermediate joint. Partial discharge type identification with pulse current method suggested that: When phase A was at U0, recognition showed two discharge types, surface discharge and internal discharge .But when the voltage came to 1.73U0, surface discharge gradually disappeared, left surface discharge only. These two discharge types always existed in phase B. And the signal in phase C was weak, with intermittent and 180° phase characteristics. The subsequent disintegration of the second defective joint revealed that: the existence of the defect inside the joint partial discharge risks, and this is due to the obvious result of making bad process. At the same time, this case also shows that the oscillation detection technology effectively, as well as field testers judged entirely correct.

INTRODUCTION

Oscillatory wave voltage method had gain more and more attention in the field of middle and low voltage cable partial discharge detection, for its advantages of non-injurious , easy for operating and so on. Oscillation wave Voltage method, namely the Oscillating waveform or Damping AC Voltage, was developed about twenty years ago. Meanwhile, E.Gulski et al. from Netherlands had carried out a lot of work for the development of oscillation wave method test apparatus. Yang Rongkai from China, Katsumi Uchida from japan et al. made a deep exploration in the equivalence of oscillatory wave voltage method and the other three methods.

Recently, with the solving of some key problems such as fast switch, the power sector of America, Netherlands, Japan, and China's Beijing, Suzhou, Shanghai and other places began to introduce this method, and has proved its effectiveness in the detection of power cable, especially in the detection of state of insulation for the low voltage cable.

This article introduced a successful application case that oscillatory wave partial discharge detection and location technology used in middle and low voltage power cable. The tester found three concentrated discharge defects mainly in the middle joint position of a Particularly important power lines(10kV Fengnan No.1 cable) with this method. To analysis the causes of concentrated discharge, a variety of advanced state detection technology and disintegrated check was applied. The results showed that the bad craftsmanship lead to several concentrated discharge hidden danger area, which suggests that the oscillation wave detection and positioning results and the judgment of field staff were right.

FIELD DATA

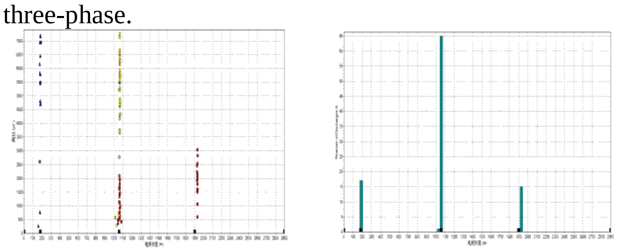
Basic parameters of line

Fig1 is the Diagram for 10kV Feng Nan Ⅰ lines. The line length of this cable is 2883 meters, the product type is YJV22-8.7/15kV-3×300. The intermediate connector supplier is Chang Yuan Electric Power Co., Ltd. Electric Power Technology Co., Ltd, type is CYG-#4, contraction connector. The operation time of this cable is unknown, the installation time of the intermediate connector is April 2013. The connector location of concentrated discharge defects is 180 meters, 1060 meters and 1900 meters from the FengLing station, respectively (labelled ①、②、③ in Fig for convenience). These basic parameters are the field test setting value in the partial discharge detection (wave velocity is 170m/μs), and they may have deviation with the actual location.

Fig.1 Diagram for Feng Nan Ⅰ lines

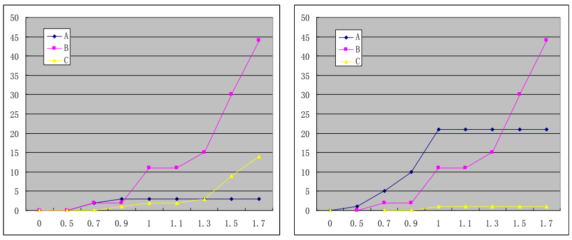
Field test results

The relative positions of the concentrated discharge were showed as the figures below. Abscissa represents the length of the cable, ordinate represents the discharge pulse amplitude distribution and discharge frequency accumulation for tests under different oscillating voltage. Red, yellow, and blue, respectively, on behalf of A, B, C three-phase.

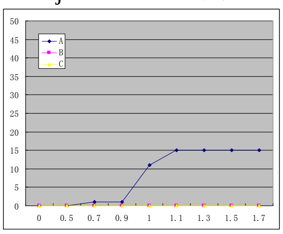


（a）Discharge amplitude distribution （b）Discharge frequency cumulative

Fig.2 the Results of Partial Discharge Detection and Locations



（a）No. 1 joint （b）No. 2 joint



（c）No. 3 joint

Fig.3 the Relationship between Partial Discharge and Test voltages

Statistical analysis the three-phase starting discharge characteristics of No. 1, No.2, No.3 joints, the results show that: No.1 middle joint discharge phase C existed concentration discharge, initial discharge voltage is 13 kV (1.5 U0 ,U0 for rated voltage 8.7 kV), the amplitude distribution ranges from 4600 pC to 7000 pC. No.2 middle joint discharge phase A and B existed concentration discharge. Initial discharge voltage for phase A is 6.2 kV (0.7 U0), the amplitude distribution ranges from 800 pC to 2000 pC. Initial discharge voltage for phase B is 8.7 kV (1.0 U0), the amplitude distribution ranges from 2700pC to 7250pC.Phase C existed accidental discharge, low frequency, happened in 1.7 U0, amplitude is less than 500 pC. No.3 middle joint discharge phase A existed concentration discharge. Initial discharge voltage for phase A is 8.7 kV (1.0 U0), the amplitude distribution ranges from 1000 pC to 3000 pC .

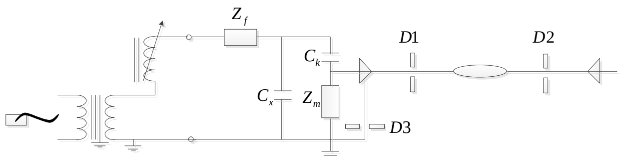
Figure 3 shows the statistical analysis of the relationship between three middle joints ' discharge frequency characteristics and test voltage. Abscissa is applied voltage ratio (U0), while ordinate is pulse accumulation number. The result shows that discharge pulse accumulation number increased with the increase of applied voltage, had a stepped up trend, and matched the typical discharge characteristics. The three-phase insulation resistances before and after test are above 1 G Ω, qualified. To further analyze the causes the middle joint discharge , we applied power frequency voltage withstand test under laboratory conditions for No.2 defective Joint.

EXPERIMENTAL VERIFICATION

Platform construction

Experiment was done in cable shielding room located at the Distribution network quality inspection center of Guangzhou power supply bureau. Test power supply used Isolation transformer, high pressure filter, adjustable reactance, three level interference isolation measures. We also used coupling capacitance discharge test method and optical fiber transmission to make the background interference less than 3 pC.

Test circuit is as follows:



L for Adjustable inductance device,Z_f for high pressure filter,Cx for equivalent capacitance,C_k for coupling capacitance,Zm for measured impedance,D1/D2/D3 for high frequency CT

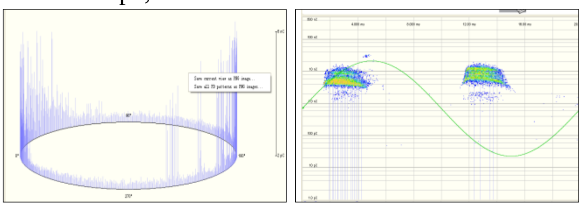
Fig.4 Schematic Diagram of Test Circuit

Basis of judgment

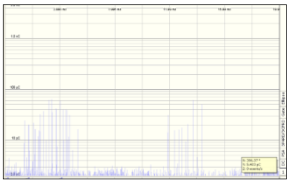
For the new cable accessories, national standard of "GB - 12706.4 T - 2008 rated voltage 1 kV (Um = 1.2 kV) to 35 kV (Um = 40.5 kV) insulated power cables and accessories Part 4 6 kV rated voltage (Um = 7.2 kV) to 35 kV (Um = 40.5 kV) power cable accessories test requirements" : 1.73 U0 partial discharge should be 10 pC or less, while the standard of the southern power grid is not larger than 5 pC. The middle middle joints are after the operation, while the partial discharge amplitudes in national standard are used only for analysis reference.

Experimental result

We re-identified the phase for three phases of No. 2 defective joint after installing terminal. Based on the process of national standard, applied a test voltage 1.73 U0, the apparent discharge respectively: Phase A more than 8 npC, frequent; Phase B more than 5npC, phase C is about 105 pc, intermittent.



（a）phase A （b）phase B



（c）phase C

Fig.5 the Amplitude of the Discharge under different test voltages

By using ladder booster method (voltage from zero, in turn keep 5 mins in 0.5 U0, U0, 1.2 U0, 1.5 U0, 1.73 U0 for partial discharge measure), tracking the relationship between discharge amplitude and the test voltage, as shown in figure 6 below. Ordinate is discharge value(pC), while abscissa is the multiples (U0) of test voltage.

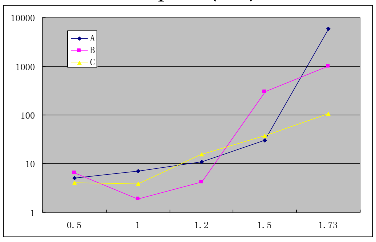


Fig6 relationship between Three-phase discharge value and test voltage

Source of signal

To exclude the introduction of discharge defects due to the new joint, we set up a partial discharge source location test. Double frequency CT clamp was use to put at both sides of the No.2 defect joint, between the new joint and the defect one. When discharge pulses have the same signal polarity, the signal is derived from the outside of double frequency CT. When discharge pulses have opposite signal polarities, the signal is derived among the double frequency CT.

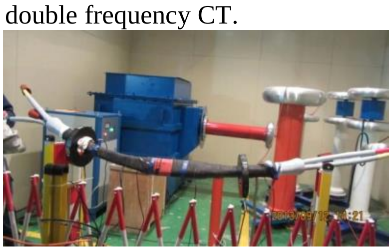
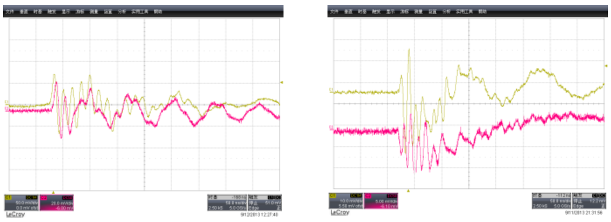


Fig.7 Schematic Diagram of Test Circuit



（a）standard signal （b）reality signal

Fig.8 Simulated and Measured Results

The result of the partial discharge diagnosis test shows that the discharge signals detected had reverse polarity and repetition characteristics, which proved that signals were from No.2 defective joint, excluding the introduction of discharge defects due to the new joint.

Discharge type

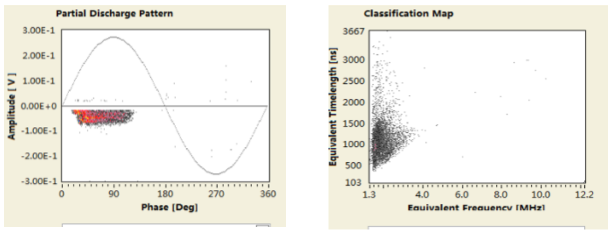
According to the previous question processing experience, this paper carried out a partial discharge type diagnostic test, to point out the focus for the subsequent disintegrated checking.

Detection method was pulse current method. Equivalent time-frequency processing technology was applied as data analysis method, which can achieve the separation and reconstruction of different signal, and thus realized pattern recognition. Pattern recognition accuracy relies mainly on knowledge accumulation. The high voltage cable partial discharge charged tester used in the experiment can classify the discharge signals into three types, corona discharge (tip), surface discharge (surface), and internal discharge three (internal, such as the air gap).

Voltage applied process for discharge type diagnostic test: the ladder booster method (voltage from zero, in turn keep 5 mins at 0.5 U0, U0, 1.2 U0, 1.5 U0, 1.73 U0 for partial discharge measure), the same as before

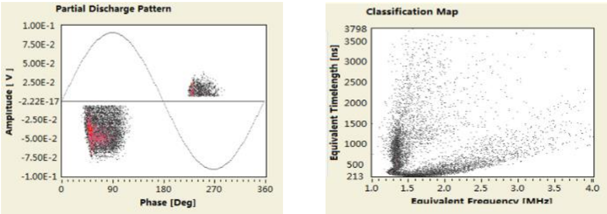
Results shows that: when phase A was applied Uo, pattern recognition reflected two types dignals, surface discharge and, internal discharge. When voltage raised to 1.73Uo, surface discharge disappeared, left internal discharge only. For phase B, there were surface discharge and internal discharge from beginning to end. Signals of phase C were weak and intermittent, and the discharge has 180 °phase characteristics, but cannot be recognized for lack of data.

This partial discharge type diagnosis result can provide certain guidance for subsequent disintegrated checking. For example, for surface discharge type, focusing on wheather the main insulation surface is clean, or if there is a possible creepage channel, etc. For corona discharge (tip), focusing on whether semi-conducting layer take surplus, stripping is round without spikes, pressing duct has burr or not. For internal discharge type, focusing whether there is a bubble in the main internal insulation, whether there is a scratch on the surface or air gap formed in semi conductive layer for lack of chamfering and so on.



（a）power frequency phase map （b）equivalent time-frequency characteristics

Fig.9 A Phase PRPD Map under 1.73U$_0$



(a) power frequency phase map (b) equivalent time-frequency characteristics

Fig.10 B Phase PRPD Map under 1.03U$_0$

DISINTEGRATED CHECKING

No.2 defective middle joint

Base on installation process requirement from the suppliers, applied disintegrated checking for 1No.2 defective middle joint. The production process problems found are as follows:

1) Surface of the three phase pressing duct did not grind, and had burrs, with Semi conductive tape on it (technology does not demand). Phase B had too much semi conductive tape winding on it , causing not enough contact with the main insulation surface, and thus leaving air gap.

2) Semi-conducting layer between shrink tubing and the main insulation surface did not match the demand, existing taking surplus phenomenon. For phase A, lap between shrink tubing and the main insulation surface were respectively 47mm,35mm. For phase B, lap between shrink tubing and the main insulation surface were respectively 45mm,50mm. For phase C, lap between shrink tubing and the main insulation surface were respectively 48mm,35mm. The technological requirements of lap is 20mm.

3) The lap between semi-conducting layer of the shrink tubing and pressing duct did not satisfied the technological requirement, existing cooperate with dislocation phenomenon. One side of phase A was less fit about 10mm,the other side was interference fit about 50mm. One side of phase B was less fit about 7mm,the other side was interference fit about 46mm. One side of phase C was less fit about 10mm,the other side was interference fit about 49mm.

4) Obvious scratch ,with the length of 70mm,was found on the main insulation surface of Phase A.

5) The insulation distance of the main insulation surface was not enough. For example, in disintegrated checking of phase A, although the main insulation surface length of one side satisfied the demand, effective insulation distance is only 70 mm due to stress cone interference, which was inadequate. The insulation distance of the main insulation surface of one side was 73mm, also inadequate. For phase B, although the main insulation surface length of one side satisfied the demand, effective insulation distance is only 73 mm due to stress cone interference, which was inadequate. The insulation distance of the main insulation surface of one side was 58mm, also inadequate. For phase C, the main insulation surface of one side meet the demand basically, while the insulation distance of the other side was only 70mm, inadequate. Technical requirements: generally range from 110 mm to 120 mm.

No.3 defective middle joint

Base on installation process requirement from the suppliers, applied disintegrated checking for 1No.3 defective middle joint. The production process problems found is as follows:

1) Pressing duct of phase A used the wrong insulating tape, which was not meet the demands.

2) The lap between shrink tubing and the main insulation surface was Inadequate. Laps for each side of phase A were 8mm,14mm respectively. Laps for each side of phase B were 8mm,14mm respectively. But the demand is 20mm.

DISCHARGE CAUSE ANALYSIS

No.2 defective middle joint

To reflect the construction process problems found in disintegrated checking more intuitively, we recovered the three-phase actual size measured of No.2 defective middle joint.

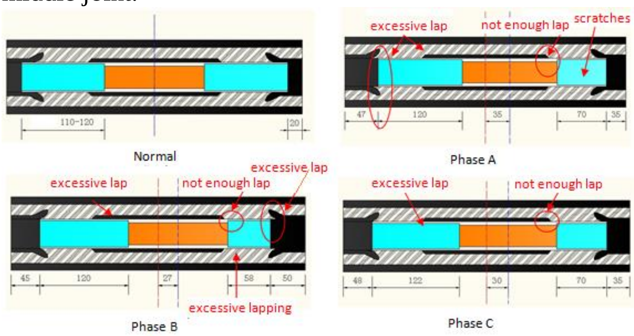


Fig.11 the Relative Size of the Intermediate Joint

According to the experiment result above, when phase A was applied Uo, pattern recognition reflected two types signals, surface discharge and, internal discharge. When voltage raised to 1.73Uo, surface discharge disappeared, left internal discharge only. Disintegrated checking exposes the causes. For one thing, the cold tube surface not fully contact with the main insulation surface due to scratches on surface of the main insulation. When silicon grease dry or daub is inadequate, it would formed an air gap in the Insulation composite material interface, and thus lead to Internal discharge. For the other thing, lap joint between cold pipe and semi-conducting layer was excessive, making the electric field concentrated at the semi-conducting layer, and thus lead to Internal discharge under the oscillating voltage. When the test voltages rise gradually, discharge defects disappear gradually, because the partial discharge charge short-term accumulation eased the local concentration of the electric field. Additionally, insulation distance of the main insulation surface was not too short, increasing the electric strength

of the defect.
For phase B, there were surface discharge and internal discharge from beginning to end. For one thing, the cold tube surface not fully contact with the main insulation surface due to too much lapping of semi-conducting electrical tape, forming an air gap in the Insulation composite material interface, and thus lead to Internal discharge.For the other thing, lap joint between cold pipe and semi-conducting layer was excessive, making the electric field concentrated at the semi-conducting layer, and thus lead to Internal discharge under the oscillating voltage.

With the raise of test voltage, phase B present the different discharge trend with phase A, and the main insulation surface discharge type persisted. Because insulation distance of phase B is more insufficient and the air gap discharge and surface discharge in the same side, making the insufficient of electric strength for discharge defect, and thus the discharge persisted with the increase of test voltage.

No.3 defective middle joint

Obvious concentration discharge phenomenon was observed at phase A through field oscillation wave testing. Winding insulation tape was found outside the pressing duct through disintegrated checking. For this type of discharge defects, we have a lot of experimental research. With Winding insulation tape outside the pressing duct, suspended discharge defects would form for the unequal potential of pressing duct and shrink tubing stress cone. A lot of experimental research and field application experience has proved that oscillation wave method is very sensitive and effective for the type of defect.

CONCLUSIONS

In this article, the author introduces the successful application cases of multi-source defect diagnosis. By using OWTS, the existence of partial discharge defects simultaneously among the three intermediate cabling connectors was discovered. To analysis the causes of concentrated discharge, a variety of advanced state detection technology and disintegrated check was applied. the existence of the defect inside the joint partial discharge risks, and this is due to the obvious result of making bad process. At the same time, this case also shows that the oscillation detection technology effectively, as well as field testers judged entirely correct.

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