Study on 10kV XLPE Cable with Defects Based on Oscillating Wave Test System

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ABSTRACT

Based on the laboratory test carried out on 351m 10kV XLPE power cable in which there are some typical PD defects, the method of OWTS for detecting PD in XLPE cable and its accessories was introduced. The time domain characters of the OWTS signal is researched in order to distinguish the PD signal from the disturbance. The PD spectrum of q-m was analyzed. The way to locate the PD point was also introduced. The results of the research had proved that the reliability of the PD detection is improved using the method of OWTS.
Keywords: partial discharge; typical PD defects; fault location; oscillating wave; cable accessories

INTRODUCTION

Worldwide, there is a multitude of practical experience regarding partial discharges (PD) measurements [1]. In the direct comparison of different PD measuring systems, OWTS was judged to be the best system for the considered cases of application.
Normally, ground noise levels within the range below 100 pC can be observed in the field so that the requirements for a sufficient measuring sensitivity are given in order to detect PD. The recording, location and evaluation of PD inside the insulation and the accessories of medium voltage cables offer the possibility of an early diagnosis of cable network failures [2, 3, 4], however, there is a need for a clear differentiation between the insulation systems and the accessories.
In order to be able to carry out an evaluation of the risk factor of PD defects as precisely as possible, the applied voltage for a PD diagnosis should be within the range of the operating frequency. This is because the typical PD parameters, such as inception and extinction voltage [5, 6], PD levels and PD patterns, correspond to the relevant values under operating conditions.
On the other hand, to avoid emerging or exacerbating other types of defects, thevoltage should be limited to the extent that no irreversible damage takes place.

OWTS TESTING SYSTEM

The Oscillating Wave Test System (OWTS) described hereinafter unites all advantages of a non-destructive PD diagnosis system[7,8]. The principle of high voltage generation and the measuring circuit are shown in Fig. 1.
The test object is charged within a few seconds to the desired voltage and then discharged via the electronic high-voltage switch and the specially designed inductor.

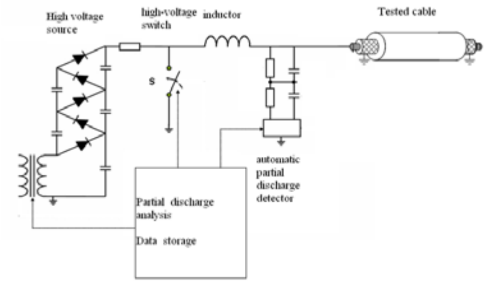

Fig.1 OWTS testing system schematic diagram

This creates an oscillating decay voltage, the oscillation frequency of which is determined by the inductance of the inductor and the capacity of the test object according to equation 1.

$$f_0 = \frac{1}{2\pi\sqrt{LC}} \quad (1)$$

The attenuation of the decaying voltage amplitude corresponds to the dielectric losses within the test object, because the ohmic line losses in the test circuit can be neglected. This way, the dielectric characteristics (tan δ) of the test object can be characterized.
During the oscillation, the travelling wave location is used to locate the points of PD. Fig.2 illustrates the process.

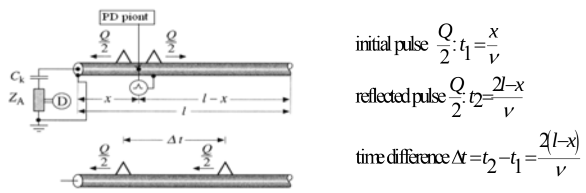

Fig.2 Partial discharge located by pulse reflection

PROCESS OF THE EXPERIMENT

Before the test, a 351m long 10kV power cable was used in the experiment. During the experiment, terminals were defined as A and B, the location of the joint was 242m from terminal A. The location of the defects in the cable itself was 68m from terminal A. Fig.3 illustrates the connection and location of the cable.

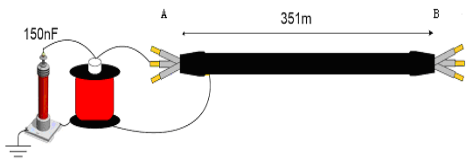

Fig.3 Experimental equipment and its connection

In the experiment, the test was carried out 13 times.

(1)Defects in cable terminals

L1: cable terminals outer semi-conducting layer non-smoothing (Fig. 4a)

L2: cable terminals outer semi-conducting layer too long (Fig. 4b)

L3: cable terminal main insulation layer non-smoothing (Fig. 4c)

(2) Defects in cable terminals

L1: impurities in cable terminal (Fig. 4d)

L3: scratches in cable terminal main insulation layer (Fig. 4e)

(3) Combination of defects

L1: winding cable joints pressing joint pipe with insulating tape (Fig. 4f) & impurities in cable terminal

L2: flash in pressing joint pipe (Fig. 4g) & cable terminal's outer semi-conducting layer too long

L3: salty water in joint (Fig. 4h) & scratches in cable terminal main insulation layer

(4)Defects in joints

L1: winding cable joints pressing joint pipe with insulating tape

L2: flash in pressing joint pipe

L3: salty water in joint

(5) Combination of defects

L2: flash in pressing joint pipe+ saw traces in outer insulation (Fig. 4i)

L3: salty water in joint+ squeezing cable (Fig. 4j)

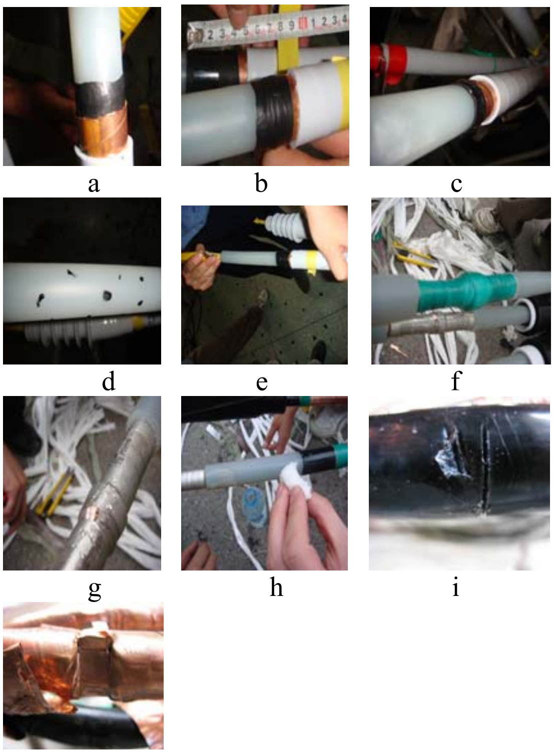

Fig.4 the pictures of kinds of defects

RESULTS

According to the reports from the automatic analyzer, there was some PD caused by defects that was invisible. The following figures are the various PD. The left pictures show the relationships between partial discharge and the voltage, right ones illustrate the partial discharge and location of the PD.

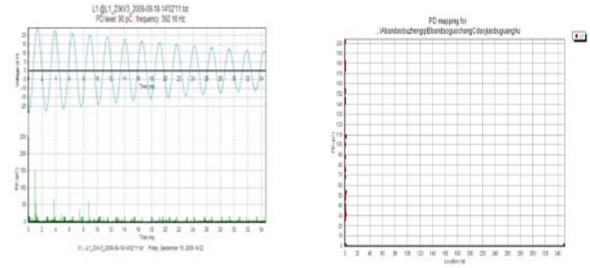

Fig. 5a Cable terminals outer semi-conducting layer non-smoothing

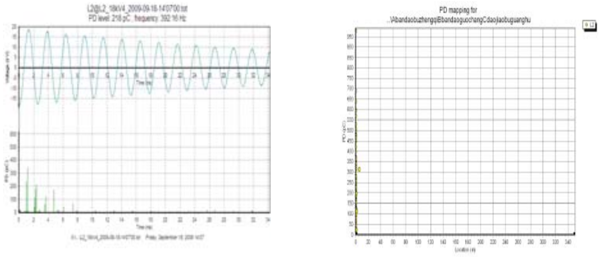

Fig.5b Cable terminals outer semi-conducting layer too long

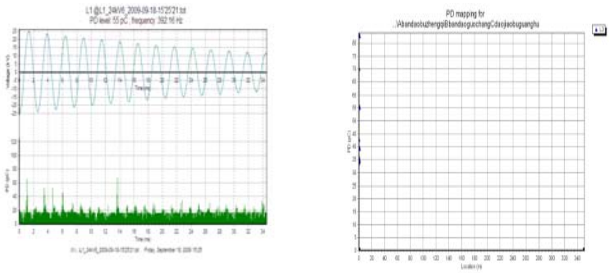

Fig. 5c Cable terminal main insulation layer non-smoothing

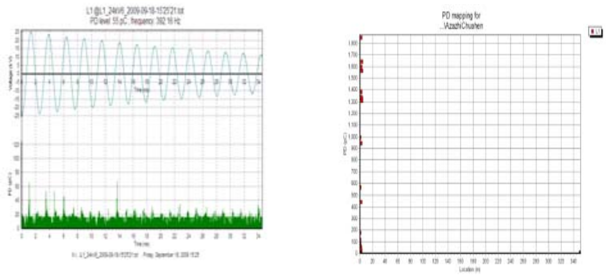

Fig. 5d Impurities in cable terminal

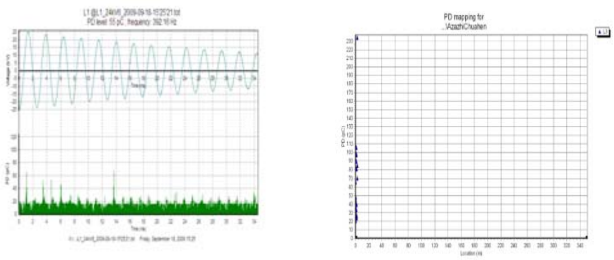

Fig.5e Scratches in cable terminal main insulation layer

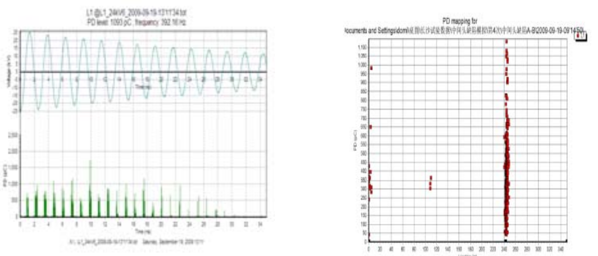

Fig.5f Winding cable joints' pressing joint pipe with insulating tape& impurities in cable terminal

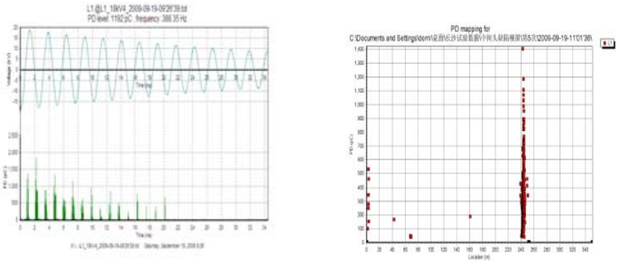

Fig.5g Winding cable joints' pressing joint pipe with insulating tape

Fig.5 The pictures of typical PD and wave of voltage defects

During the experiment, characters of the PD were recorded under different defects. The height stands for the altitude of PD. The length stands for the location of PD. The pictures show that some PD caused by different defects can be distinguished by OWTS. But others couldn't. Table I can figure out the characters of PD under different defects, and show the accuracy of location with OWTS.

TABLE I

RELATIONSHIPS BETWEEN CHARACTERSS OF PD AND DEFECTS IN CABLE

Defects	**PDIV (kV)**	**PD (pC)**	**Noise (pC)**	**Location**
Cable terminal's outer semi-conducting layer non-smoothing	22	69	28	good
Cable terminal's outer semi-conducting layer too long	18	347	40	good
Cable terminal main insulation layer non-smoothing	24	66	20	good
Impurities in cable terminal	15	100	22	good
Scratches in cable terminal main insulation layer	20	95	20	good
Winding cable joints' pressing joint pipe with insulating tape & impurities in cable terminal	15 /11	252/289	19	good
Flash in pressing joint pipe& cable terminal's outer semi-conducting layer too long	18/23	107	20	good
Salty water in joint& scratches in cable terminal main insulation layer	8/25	85	20	good
Winding cable joints' pressing joint pipe with insulating tape	9	91	23	good
Flash in pressing joint pipe	27	49	22	invisible
Salty water in joint	20	60	26	invisible
Flash in pressing joint pipe& saw traces in outer insulation	28	100	20	general
Salty water in joint& squeezing cable	28	44	20	general

CONCLUSIONS

1) According the figures and tables in the experiment, the corresponding relationships between PD and the kinds of defects can be built initially. OWTS is effective in detecting defects in terminals and joints. Some defects in cable itself were hard to be detected by the OWTS even under 2U0.
2) The noise level was low because the experiment was carried out in the high-voltage laboratory. Extracting the PD signal from the noise would seem difficult in a field situation.
3) The traveling wave location is the key in the OWTS test, which detects incident wave and reflective wave. The cable used in experiment was short distance and contains only one joint. The validity of location of the OWTS is still worthy to prove.

ACKNOWLEDGMENTS

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