

Recognition of partial discharge defects in cable terminations

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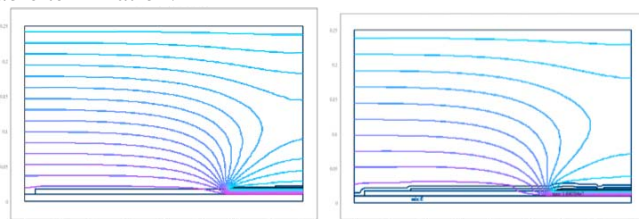
Abstract--As reported in very researches, the majority failure mechanism in cable terminations is predominantly involving partial discharge deterioration caused by voids, contaminants and protrusion. The partial discharge measurement is an effective way to detect such defects. However, no research shows the relation between the magnitude of partial discharge and remaining life of cable termination. Hence, it is hard to make decision to replace the unqualified cable termination immediately or lately for an in-service cable termination, while the partial discharge activities are measured. Based on authors' experiences, different defects have different ageing speed to breakdown. Therefore, recognition of defects is an alternative way to assess the degree of risks. This paper sets up a series test to figure out the properties of partial discharge activities caused by different defects, including wrong position of stress cone, void left, tape left, and needle pricked. Test results show the different properties of different defects, and these characteristics can be used to recognize defects inside cable termination.

Index Terms—partial discharge, recognition, cable insulation

I. INTRODUCTION

As shown in experiences[1][2], the cable accessories have higher failure rate than cable. However, the routine tests in factory do not show such difference. Many inspections of failures show that the root causes of cable accessories failures usually can be attributed to workmanship.

The potential gradient on the end of cable is much higher than on the middle of cable, and the lifetime of cable will be decreased. Therefore, a cable termination is used to restrict the potential gradient into a tolerable rang. The different potential gradients of cables with/without cable terminations are shown in figure 1. In figure 1, the potential gradient of cable with cable termination is much lower than that of cable without cable termination.



(a) without cable termination (b) with cable termination

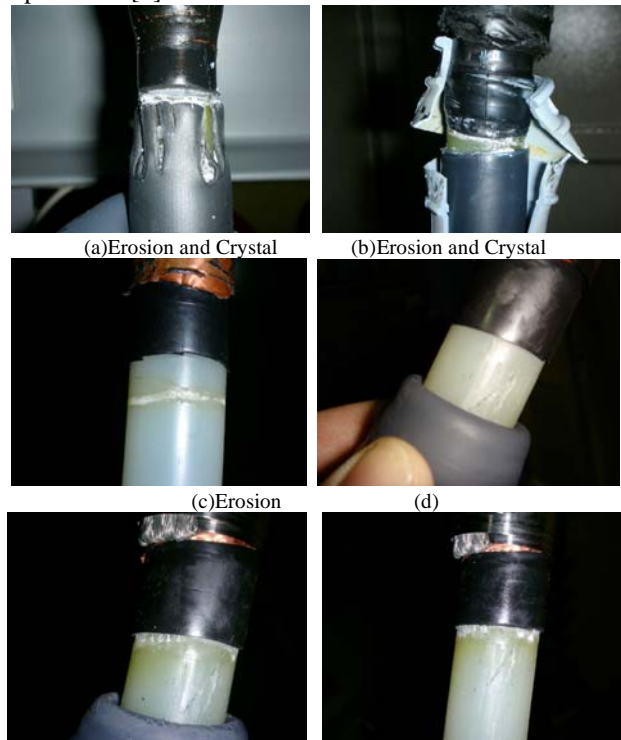
Figure 1 potential gradient distribution

Because cable termination has more parts and is assembled at field, the installation is needed to pay more attention. Hence, cable termination is relative easier to have defects as the workman does not follow installation instruction and casually

assemble it.

Base on authors' experience, the most common defects caused by bad workmanship are wrong position of stress cone, and pollutants left in cable termination. Wrong position of stress cone is usually resulted from not following installation instruction, and this can result in stress cone does not contact well to outer-semiconductor layer, and leaving void inside cable termination. Left pollutants are usually caused by casually attitude, such as rough clearance, irregular edge of out-semiconductor and irregular surface of insulation.

All these defects will enhance potential gradient, and can be detected by partial discharge measurement. Unfortunately, more than half of them can't be detected at commission test except some serious defects, and the defects need time to develop to the degree being detected. Figure 2 shows the ageing procedure caused by wrong position of stress cone, and compare with [3].



(e) after one year (f)after two year
Figure 2 ageing procedure of wrong position of stress cone

Now a day, the defects can be detected by partial discharge measurement, but the relation of remaining lifetime and the degree of partial discharge activity does not be built yet.

According to authors' observation at field, the accelerating

ageing rates of different defects are quite different. Generally speaking, the wrong position of stress cone have relative slower ageing rate than left pollutants.

Hence, the recognition of partial discharge can aim to assess the degree of dangerous caused by the defects, and help operator can make relate strategy according to the recognition of defects even though the exact ageing degree still can't be assessed.

Therefore, this paper addresses the recognition of defects in cable terminations. Authors made cable terminations with four different defects, and then do partial discharge measurement. According to the test results, the four kinds of defects have different partial discharge properties, which can help operator to recognize the defects. The future research will be done by the observation of ageing speed, and the assessment of dangerous degree in cable terminations can be carried out.

II. TEST METHODOLOGY

A. Partial discharge measurement

The purpose of this paper is to measure the partial discharge activities resulting from different defects, and then classifies these results to assess the kinds of defects. Therefore, authors do partial discharge measurement according to IEC 60270[1], and measure the spectrums. The test arrangement is shown in figure 3. The applied voltage is rated phase-to-ground voltage rather than phase-to-phase voltage.

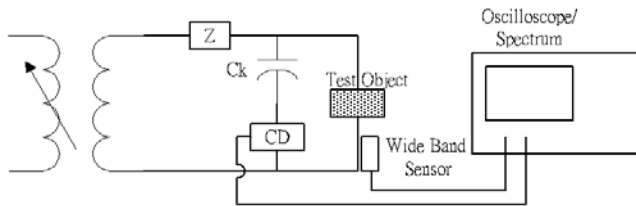


Figure 3 test arrangement

B. Specimen

According to authors' experiences, the defects in cable terminations are usually caused by workmanship[2], as shown in figure 4. Hence, the defects simulated in the test are wrong position of stress cone and left pollutants including void, tape, and metal particle, and the detail are shown as follows.

- Wrong position of stress cone: stress cone and out-semiconductor are 2 mm apart, as shown in figure 5a.
- Void left: insulation are dug by a small part, and is not filled by silicone, as shown in figure 5b.
- Tape left: before installing cable termination, a hairlike semiconductor tape is put on the surface of insulation, as shown in figure 5c.
- Metal particle left: a 2 mm length needle is pricked into insulation, as shown in figure 5d.

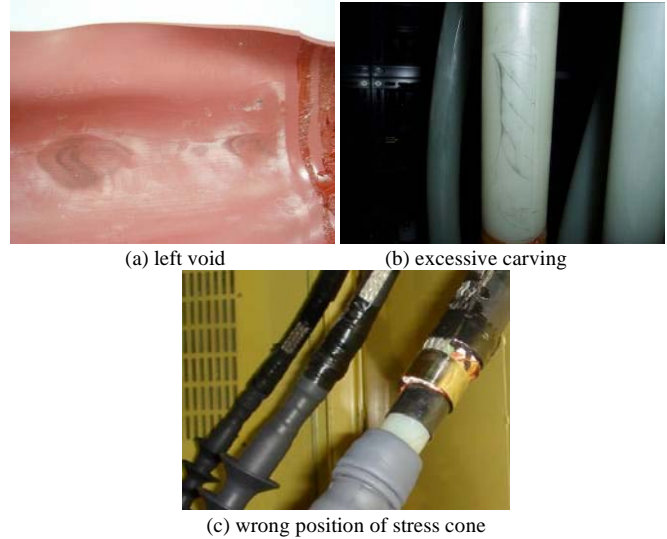


Figure 4 common defects caused by workmanship

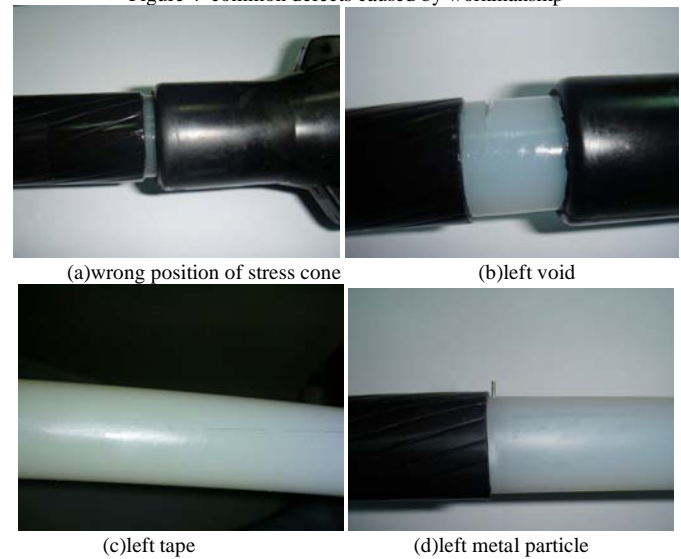


Figure 5 artificial defects

III. TEST RESULTS

Partial discharge measurements were done in laboratory, and figure 6 to figure 9 show the phase-resolved patterns of the measurement results.

All measurements have similar partial discharge areas: $0^\circ \sim 90^\circ$ and $180^\circ \sim 270^\circ$, and similar spectrum: wide frequency range up to 800 MHz.

The phase-resolved pattern with left void is the only one with asymmetry, and its peak magnitude of partial discharge locate close to the peak of reference voltage. The phase-resolved pattern with left tape is corona-like pattern. The phase-resolved patterns with wrong position of stress cone and pricked needle are quite similar, and can only be distinguished by their envelope. Table 1 summarize the properties of these defects.

Table 1 partial discharge properties of different defects

	Partial discharge area	Symmetry	Location of peak magnitude	Shape look like	
Wrong position of stress cone	0~90, 180~270	Sym.	Center of quarter	Typical pattern	PD
Void left	0~90, 180~270	Asym.	Peak of voltage	External pattern	PD
Tape left	0~90, 180~270	Sym.	Center of quarter, Peak of voltage	Corona	
Needle pricked	0~90, 180~270	Sym.	Peak of voltage	Typical pattern	PD

A. Wrong position of stress cone

Figure 6 shows the partial discharge pattern of specimen with wrong position of stress cone. The ranges of partial discharge distribution are 0° to 90° and 180° to 270° , and the patterns of partial discharges of both half cycles are very close. And the peak magnitudes of both half cycles locate close to the middle of the first and third quarters.

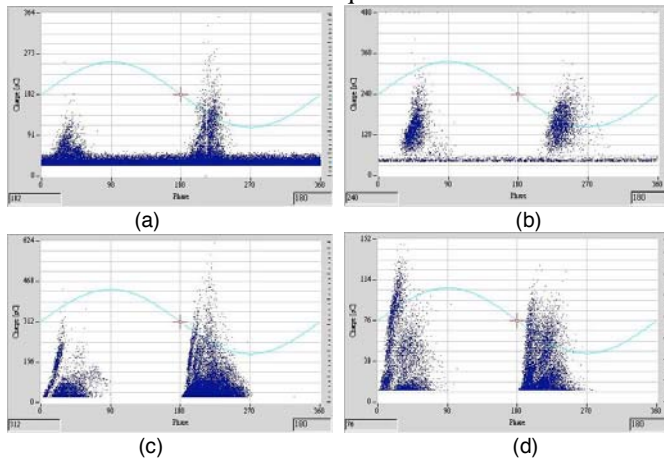


Figure 6 phase-resolved pattern

B. Void left

Figure 7 shows the partial discharge pattern of specimen with left void. The areas of partial discharge are 0° to 90° and 180° to 270° , and the magnitude of partial discharge in negative half cycle is larger than that of positive half cycle. The characteristics of these partial discharge patterns are alike to external partial discharge due to their peak partial discharge appears near the peak of applied AC voltage.

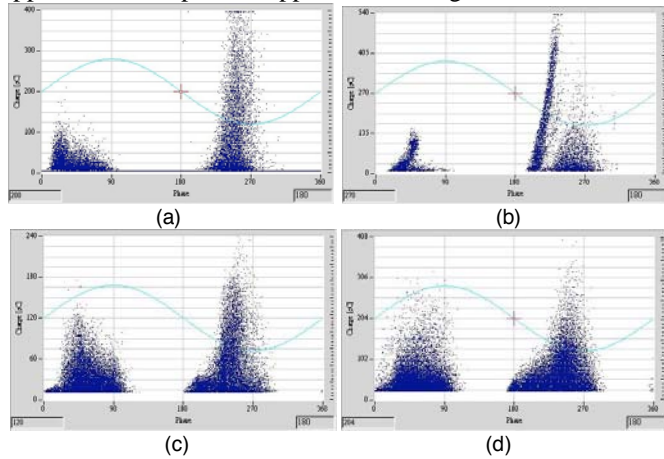


Figure 7 phase-resolved pattern

C. Tape left

Figure 8 shows the partial discharge pattern of specimen with left tape on the insulation. The areas of partial discharge are 0° to 90° and 180° to 270° . The intensities of partial discharge activities in both half cycles are similar to each other. One of peak magnitudes locates at the center of first/third quarter, and the other locates at the positive/negative peak of reference voltage. The characteristics of these partial discharge patterns are alike to corona due to the cloud like pattern.

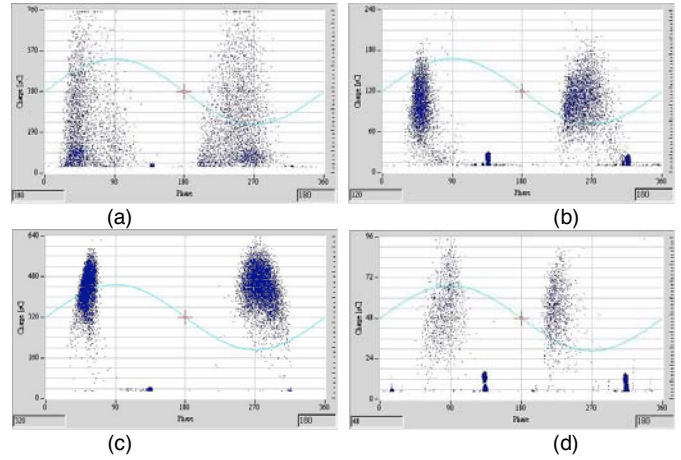


Figure 8 phase-resolved pattern

D. Metal particle left

Figure 9 shows the partial discharge pattern of specimen with needle pricked into the insulation. The areas of partial discharge are 0° to 90° and 180° to 270° . The patterns of partial discharges of both half cycles are very close. These patterns like those shown in figure 6, and the difference between them is the envelope of figure 9 are wide and the envelope of figure 6 are steep.

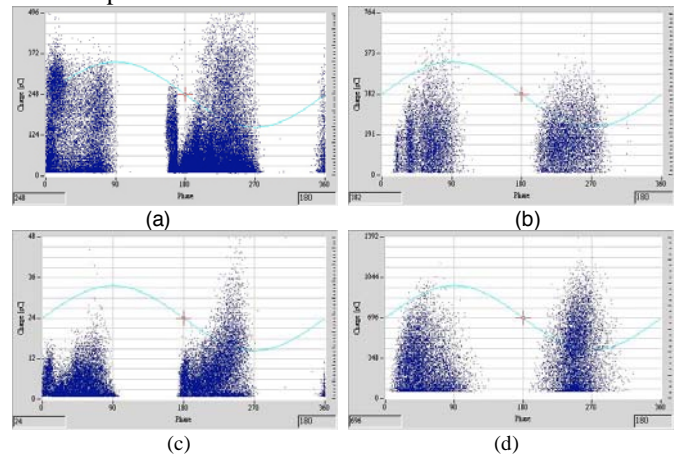


Figure 9 phase-resolved pattern

IV. CONCLUSION

Experience shows cable terminations have higher failure rates than cable, and the majority cause is workmanship. Such small defects usually can't be detected by commission test.

Till to now, no relation between the magnitude of partial discharge and the remaining life of cable system is built. Therefore, if the partial discharge activities are measured and the cable system is in-service, it is hard to make decision to

replace unqualified cable termination immediately or lately.

According to authors' experiences, different defects have different failure time. Hence, the recognition of defects can be helpful to assess the degree of risk.

The laboratory tests show that phase-resolve pattern can be used to distinguish between defects caused by workmanship, as shown in table 1, and figure 6 to figure 9.

This recognition of defects is valid by this paper, and the future efforts will focus on the comparison of ageing speed of different defects.

V. REFERENCES

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