Pattern Recognition of Partial Discharge in XLPE Cable Based on Phase Distribution

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Keywords: XLPE cable, partial discharge, the maximum discharge amount distribution, the average discharge amount distribution, the phase distribution of discharge times, *φ-Q-N* distribution

Abstract. In order to analysis the type of XLPE cable partial discharge, and grasp characteristics of partial discharge caused by different defects. In this paper, we use a 10kV 30-meter-long XLPE cable and design different types of defects. Then we collect the PD data of different defect model by PD data acquisition system. To characterize Partial discharge signals generated by different defect model by use of discharge capacity q_s, discharge times n , the average discharge amount q_n and phase distribution function include the maximum discharge amount distribution $H_{Qmax(\varphi)}$, the average discharge amount distribution $H_{Qmean(\varphi)}$, the discharge times phase distribution $H_{N(\varphi)}$ as well as *φ-Q-N* distribution map and so on. The results show that the partial discharge signals produced by different defect model have different statistical characteristics.

Introduction

The partial discharge of power cable is related to the condition of power cable insulation. In some way, the change of partial discharge amount indicates that there are defects which endanger cable safe operation.

Compared to PD amount, the trends of PD have a better response to the degree of electrical equipment insulation aging. Therefore, the current partial discharge analysis mainly based on the assessment of trends of discharge. PD trends analysis mainly includes the maximum discharge amount, the discharge times, the average discharge amount and other numerical trend analysis of basic parameter. In addition to this, there is graphical trends analysis of PD waveform and phase distribution map [1-4].

On the basis of above literature, we designed a variety of defect model for XLPE cables under laboratory conditions. According to the characteristic parameters include discharge amount q_s , discharge times n , the average discharge amount q_n and phase distribution function which is composed of the maximum discharge amount distribution $H_{Qmax(\varphi)}$, the average discharge amount distribution $H_{Qmean(\varphi)}$, the discharge times phase distribution $H_{N(\varphi)}$ as well as φ-Q-N distribution map. We study PD signals produced by different defects and analyze the characteristics of phase distribution [5-6].

Characteristics of statistical parameters. The phase distribution map which is commonly used in analyzing the severity of partial discharge includes a three-dimensional map and five two-dimensional maps. A three-dimensional map is the φ-Q-N map which indicates the distribution of PD times related to phase and discharge amount. The two-dimensional maps include the maximum discharge amount distribution, the average discharge amount distribution, the discharge phase distribution, the discharge amplitude distribution and the discharge energy distribution on the frequency cycle.

Based on the phase distribution information of above parameters, we can compare the different characteristics in phase of PD generated by different discharge model. And then we can distinguish the types of defects. In the time domain, the phase was divided into 360 equal parts. We could obtain the following three statistical parameters by collecting PD data from multiple cycles:

(1) Discharge amount

Discharge amount q_s is the sum of the amount of partial discharge pulse discharge in a phase interval.

$$q_s = \sum q_i \tag{1}$$

(2) Discharge times n

Discharge times n is the sum of the discharge times in a phase interval.

$$n = \sum i \tag{2}$$

(3) The average discharge amount q_n

The average discharge amount q_n is the ratio of discharge and discharge times in a phase interval.

$$q_n = \sum q_s / n \tag{3}$$

q_i is the single PD pulse discharge amount in a phase interval; i is the number of the discharge pulse in a phase interval.

Collecting multiple cycles PD data and according to above three statistical parameters, we can get following phase distribution function in the frequency phase:

(1) The maximum discharge amount distribution $H_{Qmax(\varphi)}$, it means that positive and negative half-cycle amplitude distribution of the maximum discharge capacity in a frequency cycle.

(2) The average discharge distribution $H_{Qmean(\varphi)}$, it means that positive and negative half-cycle amplitude distribution of the average discharge capacity in a frequency cycle.

(3) Discharge times phase distribution $H_{N(\varphi)}$, it means that positive and negative half-cycle discharge times in a frequency cycle.

Test Defects. In order to study the different characteristics of partial discharge signal generated by different models of XLPE cables, we take a 30-meter-long XLPE cable as object and design different defect models under laboratory conditions. We simulated possible defects which appeared on the field operation, then collected PD signal by PD data acquisition system. According to $H_{Qmax(\varphi)}$ distribution, $H_{Qmean(\varphi)}$ distribution, $H_{N(\varphi)}$ distribution and φ-Q-N map, we analyzed characteristic of PD signal of different PD models.

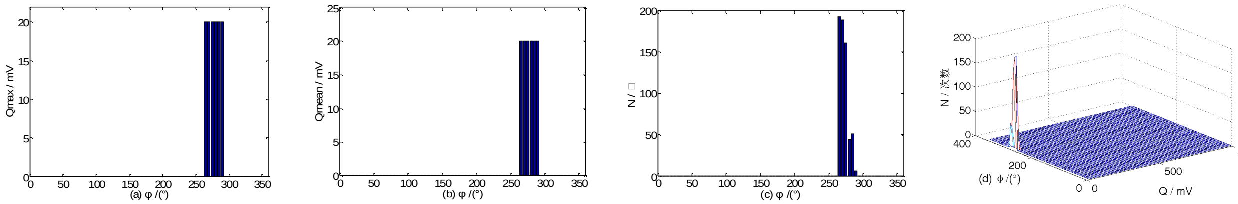
The test system is compose of Step-up transformer, the measured impedance, the coupling capacitor, being tested XLPE cables, amplifiers, and data acquisition system.

In the experiments, we design four types of defects such as Corona needle, suspended electrode, shield scratched and injection after scratched at XLPE cable joints. We made different size of model for each defect. The location and type of the model was shown in Figure 1 respectively.

(a) (b) (c)

Fig 1. Defect model. (a) Corona needle, (b) suspended electrode, (c) The cable outer semicon layer is scratched

Test results. XLPE cable needle model, The radius of curvature of the needle is 50um, Vertical tip toward the ground and fixed to the cable conductor at high voltage. It's shown as fig 1(a). Discharge occurs when pressurized to 2.5kV, the discharge capacity is 21pC. Pattern Analysis was shown as figure 2.



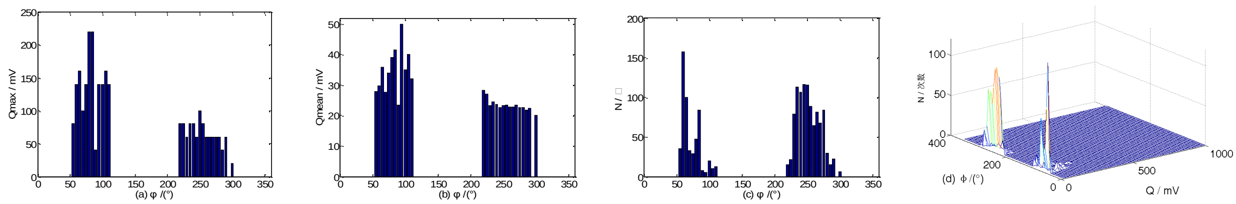
(a) (b) (c) (d)

Fig 2. Two-dimensional distribution and φ-Q-N map of corona needle model

The two-dimensional distribution of cable high-voltage conductor tip and φ-Q-N map was shown in fig 2. Among them, (a) is $H_{Qmax(\varphi)}$ distribution, (b) is $H_{Qmean(\varphi)}$ distribution, (c) is $H_{N(\varphi)}$ distribution, (d) is φ-Q-N three-dimensional map.

As can be seen from the two-dimensional and three-dimensional map, Tip model belongs to a single point in the air corona discharge, Its distribution is mainly concentrated in the negative half-cycle.

XLPE cable suspended electrode model, we simulate floating electrode by picking a copper cylinder at high voltage conductor in the cable terminal. The diameter and length of cylinder is 3mm, 10mm; 4mm, 12mm; 5mm, 15mm respectively. Discharge occurs when pressurized to 20kV. Pattern Analysis was shown as figure3.



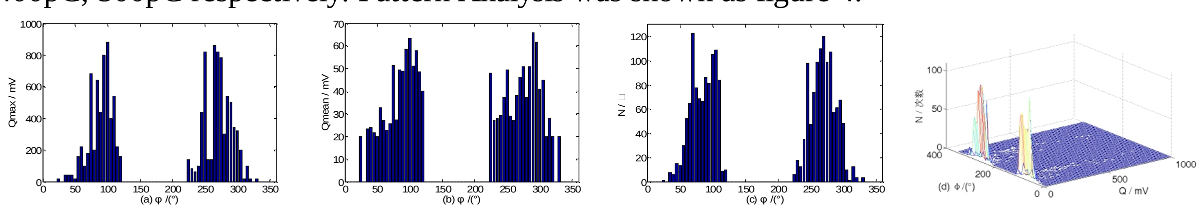
(a) (b) (c) (d)

Fig 3.Two-dimensional distribution and φ-Q-N map of electrode model

The two-dimensional distribution of cable conductor tip model and φ-Q-N map was shown in fig 3. Among them, (a) is $H_{Qmax(\varphi)}$ distribution, (b) is $H_{Qmean(\varphi)}$ distribution, (c) is $H_{N(\varphi)}$ distribution, (d) is φ-Q-N three-dimensional map.

As can be seen from the two-dimensional and three-dimensional map, suspended electrode model PD occurs both in positive and negative half cycle. The discharge amount of positive half cycle is more than negative half cycle. but its difference is small and it's mainly concentrated in the vicinity of the peak.

XLPE cable outer semiconductor layer scratched model, we draw irregular shape of insulation damage on the semiconductor layer out of cable. The scratched shapes were deep 1.3mm, length 12.1mm, width 11.3mm;deep 2.1mm, length 12.8mm, width 12.4mm and deep 3mm, length 18.8mm, width 14.8mm. The initial discharge voltage is 8kV, 7kV and 4kV. The discharge amount is 200pC, 400pC, 500pC respectively. Pattern Analysis was shown as figure 4.



(a) (b) (c) (d)

Fig 4.Two-dimensional distribution and φ-Q-N map

The two-dimensional distribution of cable outer semiconductor layer scratched model and φ-Q-N map was shown in fig 4. Among them, (a) is $H_{Qmax(\varphi)}$ distribution, (b) is $H_{Qmean(\varphi)}$ distribution, (c) is HN(φ) distribution, (d) is φ-Q-N three-dimensional map.

As can be seen from the two-dimensional and three-dimensional map, due to the model for insulation damage is more serious, a large amount of discharge appeared in positive and negative half cycle. In addition, the discharge amount and discharge times distributions are uniform.

Conclusion. Through four types of defects in the cable terminal, we take partial discharge detection by use of PD acquisition system. According to discharge capacity q_s , discharge times n , the average discharge amount q_n and phase distribution function include the maximum discharge amount distribution $H_{Qmax(\varphi)}$, the average discharge amount distribution $H_{Qmean(\varphi)}$, the discharge times phase distribution $H_{N(\varphi)}$ as well as φ-Q-N distribution map, we analyzed different defect model.

The results show that high voltage conductor tip model is a typical needle corona discharge, the discharge amount is mainly concentrated in the negative half cycle. The discharge amount and discharge times of suspended electrode model and cable outer semiconducting layer scratch model is uniform both in positive and negative half cycle. But due to the cable insulation was badly damaged for scratch mode, the discharge amount and discharge amplitude is larger than suspended electrode model.

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