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The Ultraviolet Detection of Corona Discharge in Power Transmission Lines

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ABSTRACT

Corona discharge is a common phenomenon in power transmission lines external insulation, and it may cause serious defect if without effective detection. The ultraviolet (UV) imagery technology has been widely used to detect the corona discharge in industry in recent years, but some influence factors' functions are not definite. In this paper, the fracture aluminum strands which is common in power transmission lines were used as the electrode model while a SuperB ultraviolet imager were utilized to detect, the photon count rate was detected with different detect distance, electric field, aluminum strands length and UV gain were applied. Then the multivariate regression analysis (MRA) was taken to calculate the function between the photon count and the factors.

Keywords: Corona Discharge; Transmission Lines; Defect Detection; UV Imager; Multivariate Regression Analysis

1. Introduction

With the development of Extra High Voltage (EHV) and Ultra High Voltage (UHV), the electromagnetic environment problem caused by corona discharge of conductor was paid attention increased [1-3]. The corona discharge could generate the negative phenomenon such as radio interference, audible noise, ozone-forming, electrochemical reaction [4-6]. The detection of the defect of the corona discharge has been added to the daily inspect in transmission lines in recently years [7].

The corona discharge in the transmission lines often occurred at the high voltage terminal of amour clamp, split clamp, conductor surface and the end of fractured aluminum strands caused by lightning stroke or conductor galloping. And the influence of fractured aluminum strands is extra clear, it not only generate corona discharge by distort the electric field at the end of the strands, but also make a bad influence on the mechanical behavior of the conductor, the defect would make serious harm to transmission security if without fix timely [8]. So it is important to find and fix fractured aluminum strands at the early stage in transmission lines patrol.

The traditional ovular estimate and infrared thermography technology don't have well effect on the fractured aluminum strands detection. For the ovular estimate, people may have different vision disparity and the corona discharge could be find nearly only in intensity at night [9]. While the infrared thermograph technology is able to detect the defect with consecutive electrothermal effect, but the corona discharge must be serious, so it is not promptly for detection of little heat at the early corona stage [10, 11]. So the infrared thermograph technology is not widely used in the outdoor corona detection in transmission lines.

The ultraviolent imaging technology is able to catch the specific wavelengths photon of UV signal, and then combine with the visible light to decide the corona discharge point. And the strength of discharge is judge by the photon counting rate.

The UV imager was researched and developed to detect the discharge phenomenon by occident at the earliest. It can find the discharge point with small temperature rise at the early discharge stage, is currently one of main methods of discharge detection in the world [12]. From 1980s, the EPRI attempted to utilize the UV imager to test the discharge in the transmission lines [13-15], and have got good achievements. In china it is also have convinced performance in actual use.

The ref [16, 17] take the research of corona discharge performance of insulator at different applied voltage, the UV imager was used to measure the discharge. In ref [18], several influence factor of UV imager was studied, such as photon counting rate, detect distance, discharge capacity. Refs [19, 20] have discussed the principle of UV imager, and then the UV imager of SuperB was used to detect the corona of electrical equipment in the transmis- sion lines. In ref [21], the UV imager was used to decide the corona inception voltage of the conductor under dry or rainy conditions.

In this paper, the UV imager type of SuperB, which designed by Ofil company, was used to detect the corona discharge at the top of fractured aluminum strands. And the electric field, length of the strand, detection distance and gain level were researched. Then the MRA was taken to calculate the function between the photon count and the factors.

2. Introduce of Experiment

2.1. Test System

The experiment was carried out in a shielding hall with a size of 66 m × 30 m × 18 m, and the test model was 4×LGJ300/40, bundle space was 45 cm, height was 6.8 m, the model picture was showed in **Figure 1**. And the temperature was 8.4℃~10.8℃，relative humidity was 35%~43%.

The UV imager with type of DayCor SuperB was showed in **Figure 2**. And the 50 Hz source with maximum of 1000 kV and 1000 kVA was showed in **Figure 3**.

And the measurement system schematic diagram was showed in **Figure 4**.

2.2. Fractured Aluminum Strands Information

The fractured aluminum strands (see **Figure 5**), was set at one of the LGJ300/40 conductor, with different length (see **Figure 6**).

Figure 1. Picture of test model.

Figure 2. UV imager of SuperB.

And the different strand length, detection distance, applied voltage, UV gain level were show in **Table 1**. The electric field of the conductor surface (not the top of strand) was calculated by ANSOFT for applied voltage as 10.7 kV/cm, 13.6 kV/cm, 16.4 kV/cm, 19.3 kV/cm, and respectively.

Figure 3. 1000kV transformer.

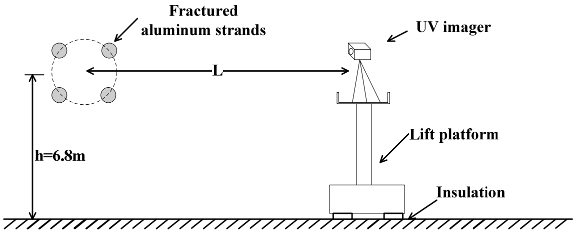


Figure 4. Measurement system schematic diagram.

Figure 5. The top of the fractured aluminum strands.

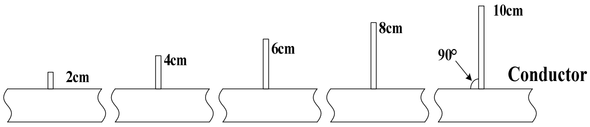


Figure 6. Schematic diagram of fractured aluminum strands.

Table 1. Information of the factor.

Influence factor	content				
Length of strand (cm)	2	4	6	8	10
Applied voltage (kV)	150	190	230	270	
Detection distance (m)	7	9	11	13	
UV gain	60	80	100	120	

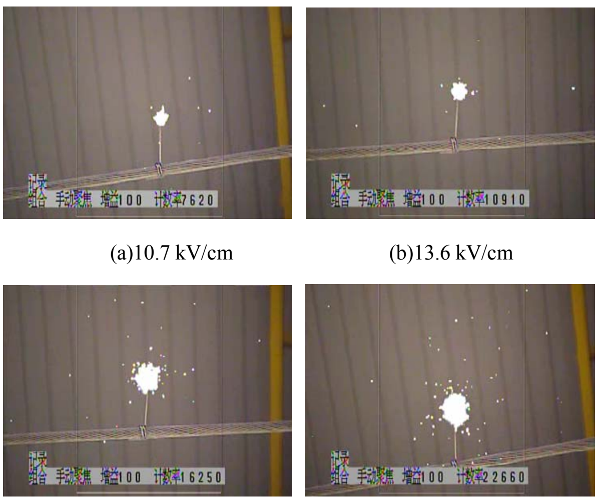
3. Results and Analysis

With the different influence factor applied on the strands, the corona phenomenon was detected by the UV imager. Limited by the paper length, one of them was showed in **Figure 7**.

We noticed in **Figure 7** that the photon counting rate would increase with the rise of the applied voltage, such as applied voltage was 150 kV (with conductor surface electric field is 10.7 kV/cm) while the photon counting was 7620, with the voltage increased to 270 kV (with field 19.3 kV/cm) the photon counting rise at 22660.

3.1. Influence of Voltage (Electric Field)

With the applied voltage of 150kV, 190kV, 230kV, 270kV, the electric field was 10.7kV/cm, 13.6kV/cm, 16.4kV/cm, 19.3kV/cm, respectively, one part of result of experiment was show in **Figure 8**.



(a)10.7 kV/cm (b)13.6 kV/cm

(c)16.4 kV/cm (d) 19.3 kV/cm

Figure 7. Corona discharge at the top of fractured strand with different voltage applied (length of strand is 10cm, detection distance is 9 m, UV gain is 100).

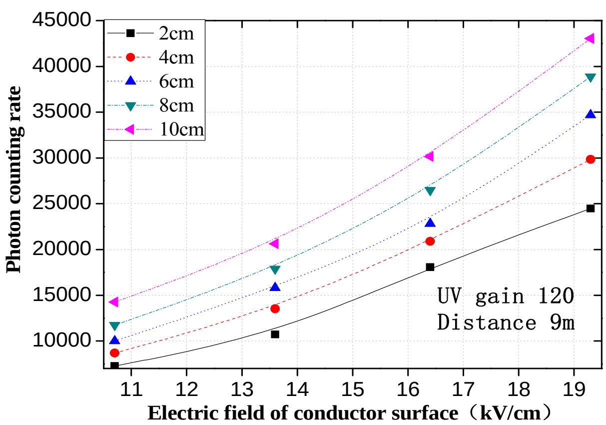


Figure 8. Influence of electric field.

3.2. Influence of Detection Distance

With the different detection distance of 7 m, 9 m, 11 m, 13 m, the results were partly showed in **Figure 9**.

3.3. Influence of UV Gain

With the different UV gain was set in the experiment, the results were partly showed in **Figure 10**. However, the UV gain character is most related to the signal processing module of the UV imager designer, so it may different from other UV imager.

3.4. Influence of Length of the Strand

With the different length of strand applied on the conductor, the results were partly showed in **Figure 11**.

4. Multivariate Regression Analysis

MRA was developed from one dimension regression analysis and used to investigate the connection between dependent variable and several independent variables. MRA is considered as an effective mathematical method to solve practical engineering problem.

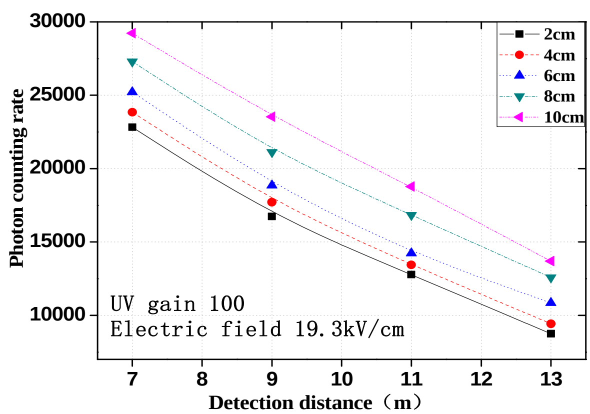


Figure 9. Influence of detection distance.

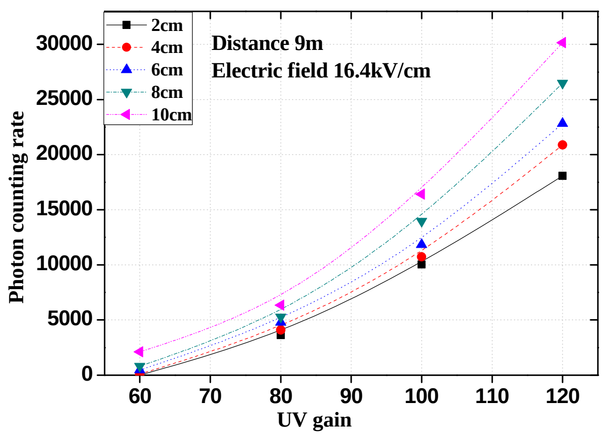


Figure 10. Influence of UV gain.

The multiple regression prediction equation about the photon counting rate was:

$$P = \beta_0 + \beta_1 \cdot E^2 + \beta_2 / L + \beta_3 \cdot K + \beta_4 \cdot s \quad (1)$$

In the equation, electric field was set as E, kV/cm; detection distance was set as L, m; UV gain was set as K; length of strand was set as s, cm.

And the significance test was taken, including R, F and T test , showed in Equation (2) ,(3) and (4).

$$R = \sqrt{\sum_{i=1}^{n}(\hat{y}_i - \bar{y})^2 \Big/ \sum_{i=1}^{n}(y_i - \bar{y})^2} \quad (2)$$

$$F = \frac{\sum_{i=1}^{n}(\hat{y}_i - \bar{y})^2 \Big/ m}{\sum_{i=1}^{n}(\hat{y}_i - y_i)^2 \Big/ (n-m-1)} \sim F(m, n-m-1) \quad (3)$$

$$T_j = \frac{(b_j - \beta_j) \Big/ \sqrt{c_{jj}}}{\sqrt{\sum_{i=1}^{n}(\hat{y}_i - y_i)^2 \Big/ (n-m-1)}} \sim t(n-m-1) \quad (4)$$

The results of MRA and significance test were display in **Table 2**.

The result of significance test is well, so the regression equation about photon counting rate is:

$$P = -57980 + 49.29E^2 + 101230 / L + 347.7K + 754.4s \quad (5)$$

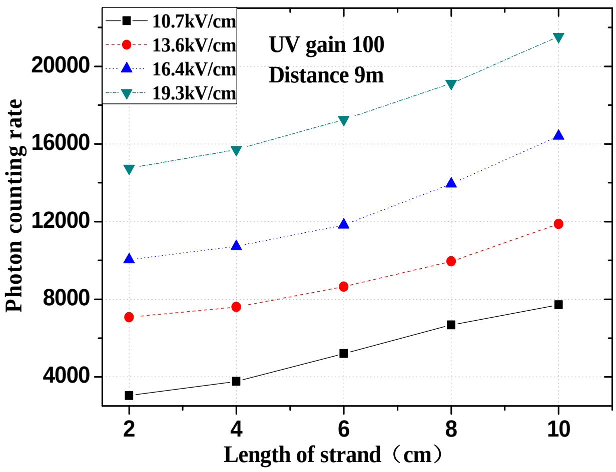


Figure 11. Influence of strand length.

Table 2. Mra about photon counting rate and significance test.

	R	F	T				
	R	F	β0	β1	β2	β3	β4
Value	0.934	1080	-57980	49.29	101230	347.7	754.4
α	---	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

5. Conclusions

In this work, the fractured aluminum strands was taken for the test model to research the corona discharge detection of UV imager. The influence detect distance, electric field, strands length and UV gain were investigated while the MRA was utilized to summarize the regression equation about the photon counting rate. These conclusions have good contribute to expand UV imaging technology in practical transmission lines patrol of corona discharge.

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