QUANTIFICATION OF CORONA IN POLYMERIC INSULATORS DIAGNOSIS WITH ULTRAVIOLET CAMERA

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Abstract: Scientific literature shows that some cases of tracking in insulators have been started by the action of corona discharges. Aiming to determine which corona intensity is dangerous to the polymeric insulation, experiments have been idealized in order to correlate the Ultraviolet Radiation (UV) and Partial Discharge (DP) emission levels. Polymeric insulators (72.5 kV class) and an electrode were used in this experiment. An UV camera allows video acquisition from the test, and a wideband PD detector allows electric signal acquisition. By varying the applied voltage from corona initiation up to the flashover, it is possible to visualize the proportional growth of UV radiation concentration points and electrode DP levels. In tests using polymeric insulators, some samples with defects were employed: aged, dirty and with different levels of saline pollution (IEC 60507). The UV images and the number of points were used in image processing, aiming to determine the risk of insulation failure.

1 INTRODUCTION

Corona discharges occur when an electric field exceeds the ionization energy of an insulating gas, producing ultrasound, ultraviolet radiation, ozone, superficial mechanical erosion, and Radio Interference Voltage (RIV), among others [1]. These consequences degrade the composition of the polymeric insulation. Since corona can lead to loss of hydrophobicity and also cause degradation it is necessary to evaluate corona performance in polymeric insulators [2].

The technique which utilizes corona measuring by using a UV camera presents simplicity, quickness in corona detection, non-invasive qualities, and field application. However, UV camera inspection provides information only about the place where the discharges are concentrated and an estimative of the quantity of emitted photons. So, quantifying and determining corona levels in a transmission line flashover is essential.

Partial discharge tests and UV camera imaging were used in this work for the characterization of corona discharge patterns in electrodes and polymeric insulators. A correlation between the DP levels, the UV camera data (points/minute) and the UV images (corona pixel concentration) processing was performed.

2 MATERIAL AND METHODS

The tested materials and the corona detection methodology will be presented in this topic.

2.1 Electrodes and polymeric insulators

Initially, rod-plane gap were be tested for system parameterization of electric field radiation. The purpose is to analyze the corona effect and its implications in insulators from the images captured on the UV camera, in order to extract attributes that will make it possible to establish a relation between the captured images and the discharge intensities.

The polymeric insulators used in the tests are projected for 69 kV transmission lines. Three different polymeric insulators: one flawless, one old, and one with a deficient core, were used, as shown in Figure 1.

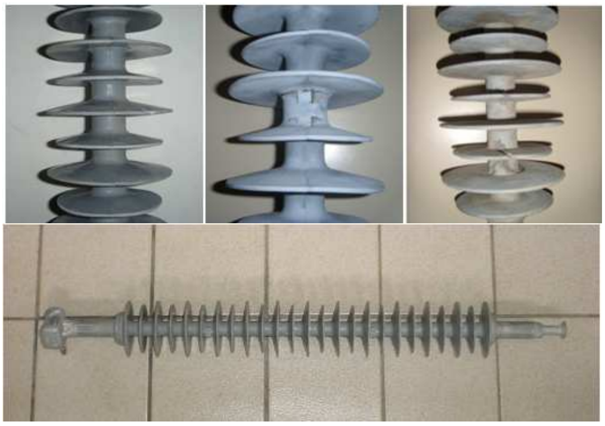


Figure 1: Polymeric insulators, class 72.5 kV

2.2 Methodology

Tests for corona and PD detection according to IEC 60270 [3] were performed simultaneously. The measuring circuit is shown in Figure 2.

The tests with the electrode consist of two parts. The first configuration will be the rod-plane variable gap with a fixed distance from the UV camera. The gap lengths were 40, 50 and 60 mm. In the second configuration, the gap length was 40 mm and the distances between the UV camera and the tested object were 3, 6 and 9 m. In the electrode tests, the applied voltage ranged from the corona discharges until close to the dielectric (air) flashover voltage.

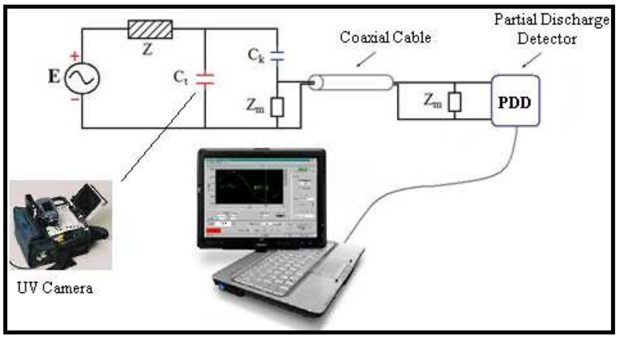


Figure 2: Corona and DP detection circuit, according to IEC 60270

Where: E = 10 kVA / 100 kV transformer;
Z = 282 kΩ resistance;
C_t = testing object;
C_k = 1000 pF coupling capacitor;
Z_m = measuring impedance.

The insulator tests were divided into two parts. In the first one, the nominal voltage (40 kV) was applied in the polymeric insulators and the UV camera gain was varied. In the second part, tests with polymeric insulators were performed with a fixed UV camera gain for different pollution levels, according to EPRI (1975) [4].

Table 1: Pollution level characterization, according to EPRI (1975)

Levels	Classification	ESDD level (mg/cm^2)
1	Clean atmosphere.	0,00 – 0,032
2	Low contamination.	0,038 – 0,056
3	Heavy contamination.	0,056 – 0,123

Where: ESDD = Equivalent Salt Deposit Density (mg / cm^2).

According to Table 1, specific pollution levels were applied according to the procedures of IEC 507 [5]. The pollution composition to be applied on the insulators surfaces was made of 40 g of kaolin, 1000 g of water and a quantity of commercial NaCl to produce the conductivity presented in Table 2.

Table 2: Conductivity values of the solutions.

Levels	ESDD (mg/cm^2)	Suspension Conductivity (mS/cm)
1	Clean atmosphere.	0,00 – 0,032
2	Low contamination	0,038 – 0,056
3	Heavy contamination	0,056 – 0,123

The three insulators were uniformly pulverized on the surface.

All the videos made by the UV camera were divided into several images. These images were processed for attribute extraction, UV pixel concentration, searching to quantify corona intensity.

3 RESULTS AND ANALYSIS

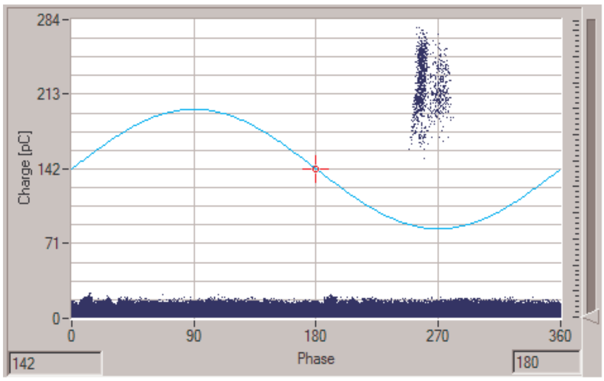
3.1 Rod-plane variable gap with fixed UV camera distance

The distance from the UV camera until the observation point is 3 m. The tests were performed at average air pressure P = 963 mmHg, average temperature T = 27.1 ℃, average relative humidity RH = 65%. The points/min counted by the UV camera increased gradually with the applied voltage. When the gap length became smaller, the flashover voltage also became smaller. In this case, we can observe that the gap length is inversely proportional to the electric field around the energized electrode. Considering the same applied voltage, the greater the gap length, the fewer corona discharges were detected by the UV camera. The tests results are illustrated in Figures 3 and 4, respectively.

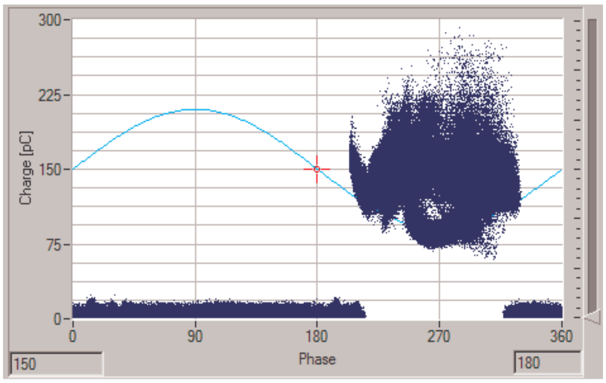
(a)

(b)

Figure 3: Corona discharges detected by the UV camera for a gap length of 40 mm and applied voltages of 10 kV (a) and 22 kV (b)



(a)



(b)

Figure 4: Partial discharges detected for a gap length of 40 mm and applied voltage of 10 kV (a) and 22 kV (b)

Partial discharge results agreed with UV camera results. Discharges always occurred at negative sinusoid semi-cycle of the applied voltage, demonstrating the corona effect in high voltage, more precisely in the energized electrode [6]. When the applied voltage increased, the quantities of detected partial discharges also increased. Figures 5, 6 and 7 show the behavior of the corona discharges captured by the UV camera, the corona concentration and the PD signals versus the applied voltage, respectively.

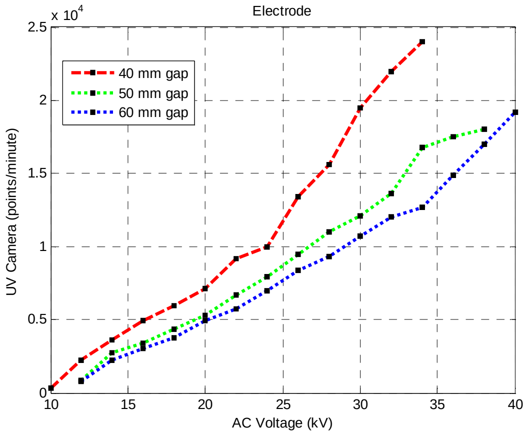


Figure 5: UV points count per minute versus applied voltage

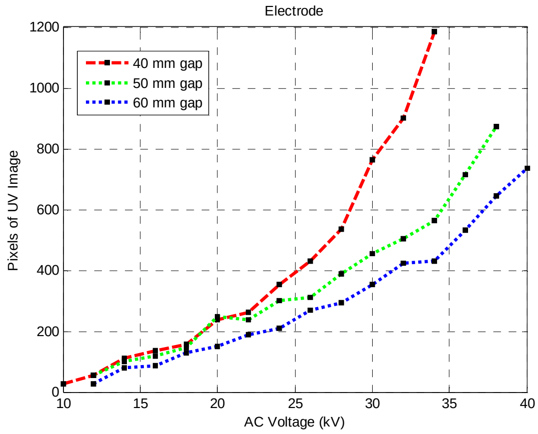


Figure 6: Corona pixels concentration versus applied voltage

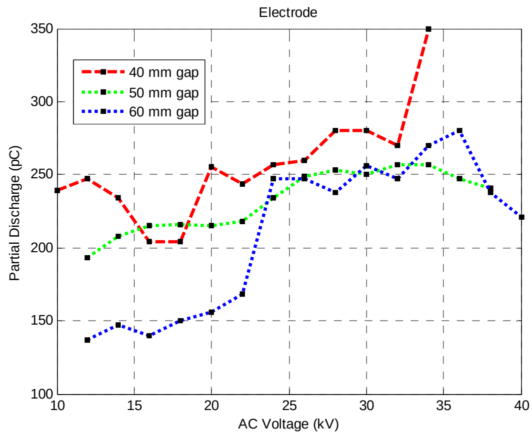


Figure 7: Partial discharge signals (pC) versus the applied voltage

The plotted test data as shown in Figure 8 have a similar behavior independent of the gap length. This shows that even when the gap length varied, each pixel concentration is practically the same as the points/min counted by the UV camera.

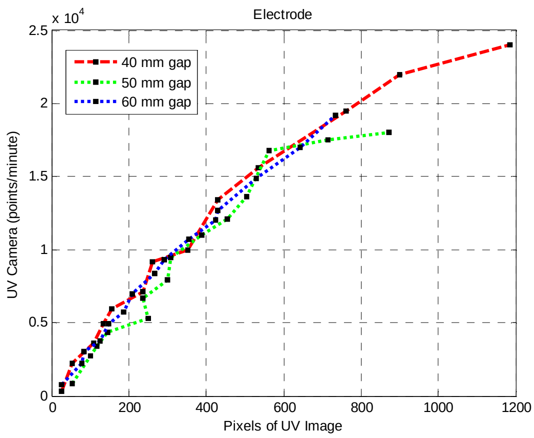


Figure 8: Relation between the UV camera (points/min) and the pixel concentration from the image processing

3.2 Rod-plane fixed gap with variable UV camera distance

In this case, the gap length was 40 mm and the distance between the UV camera and the electrodes was varied. The chosen distances were 3, 6 and 9 m, considering the laboratory dimensions. The tests were performed at average air pressure P = 963 mmHg, average temperature T = 28.3 ℃, average relative humidity RH = 55%.

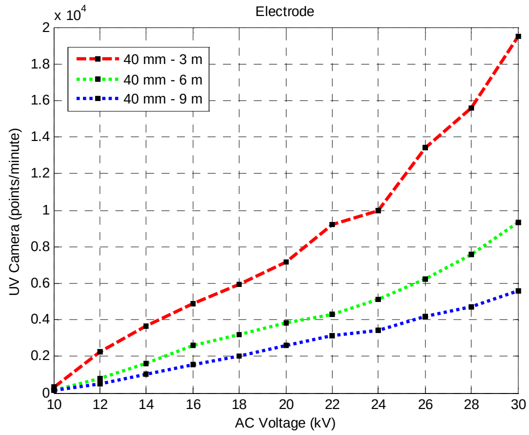


Figure 9: UV points count per minute versus applied voltage

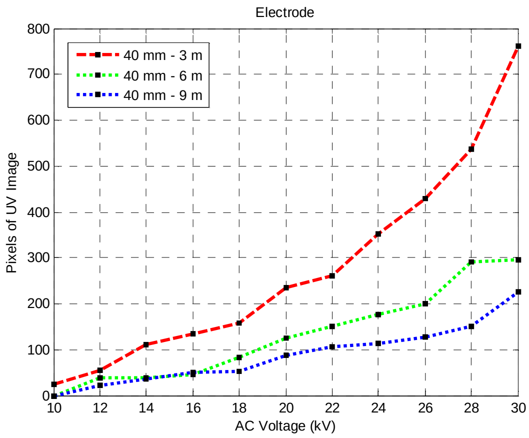


Figure 10: Corona pixels concentration versus applied voltage

3.3 Tests in polymeric insulators by varying the UV camera gain.

This test had the objective of verifying the UV camera sensitivity gain. The counting of points shown in Figure 11 is the noise from the laboratory. Noises are amplified when the UV camera gain is increased, reaching approximately 14,000 points/min for a 250 gain. The linear behavior of the UV camera is situated between gains of 120 and 160, as also shown in Figure 11. In this stretch, the counting of points has a bigger independence with the gain variation.

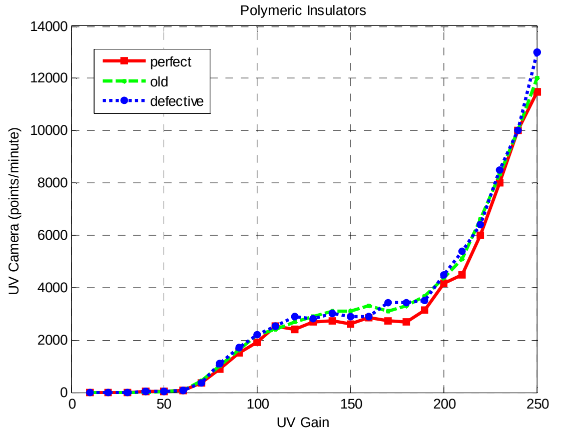


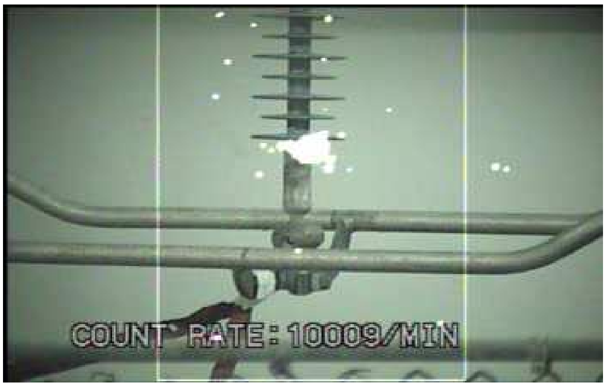
Figure 11: Discharges per minute count versus UV camera gain.

3.4 Tests with polymeric insulators with different levels of pollution

At pollution level 1 (clean atmosphere), the discharges increased gradually according to the state of degradation of the insulator. The tests with the defective insulator presented corona discharges from UV radiation of 18,700 points/min. The defective insulator has internal defects and the PD detected signals which reached levels 14 times greater than the aged insulator, while UV camera count reached levels two times higher.

Figure 12: Result of the laboratory test with UV camera for perfect insulator with pollution level 1

Figure 13: Result of the laboratory test with UV camera for aged insulator with pollution level 1



(a)

(b)

Figure 14: Result of the laboratory test with UV camera for defective insulator with pollution level 1

The perfect insulator presented greater discharges due to the higher pollution level, except in the case of pollution level 3 where the number of discharges was smaller due to the low relative humidity (62%).

In the case of the aged insulator, the discharge levels increased for the heavy pollution levels, while the level of discharges decreased suddenly with the fall of the relative humidity in the case of pollution level 3.

Comparing the tests with the defective insulator, the corona measures were consistent. The corona levels and the average of the partial discharges increased according to the pollution level, even with great humidity variations. In this case, the insulator presented large core degradation and also on the external insulation, causing lots of discharges even with decreases of 14% of the relative humidity between the tests with the different pollution levels.

Table 3: Summary of the results with polymer insulators for different levels of pollution

Levels	Insulators	UV Camera	Pixels	PD (pC)	RH (%)
1	Perfect.	6.000	289	316	76
	Old.	10.300	672	620	76
	Defective.	18.700	676	9.232	76
2	Perfect.	14.000	356	3.232	72
	Old.	15.000	659	1.152	72
	Defective.	9.100	327	8.352	72
3	Perfect.	930	23	20	62
	Old.	230	0	30	62
	Defective.	15.250	701	10.912	62

4 CONCLUSIONS

A UV image processing technique was proposed, still in optimization process, with promising results. It was proven that the concentration of pixels on the corona increased proportionally according to the increase of the points/min of UV camera. The advantage of the UV image processing method is the elimination of ambient noise, allowing more efficient outdoor corona inspections.

The results with three samples of polymeric insulators (perfect, aged and defective) show increased discharges detected with increasing of their degradation state, when maintaining the relative humidity at variations of less than 5%. The experiments implemented in the laboratory for the three insulators with different levels of pollution documented the increase of discharges detected with the increasing of pollution, as ESDD applied. However, large variations in humidity affected the results for the case of pollution level 3, which showed a decrease in discharges in relation to pollution levels 1 and 2. The variation of relative humidity can induce errors in the analysis of insulator defects.

5 ACKNOWLEDGMENTS

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6 REFERENCES

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