# Study on Corona Activity using Image Processing Approach

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***Abstract* — In the present work, behavior of corona discharges generated from the multiple needle electrode in the presence of normal air and fog (mist) condition is studied with the aid of an image processing technique. The development of streamers is closely monitored using the high resolution digital single line reflection camera. The digital images obtained are processed in the YCbCr color space to effectively extract corona generated plasma using color thresholding method. Then the streamer spread angle is calculated by applying Hough transform technique. Results indicate that streamer spread angle in the presence of fog to be much lesser than without fog. A physical model has been proposed to explain the observed phenomenon. The paper attempts to highlight the possible application of image processing - as one of the tool in analyzing the corona activity.**

## I. Introduction

Polymeric insulators have gained greater attention in recent years, for the use as outdoor high voltage insulators. The possible attribute could be because of their superior pollution performance, light weight, hydrophobic behavior, in comparison with that of the conventional ceramic or glass insulators [1, 2]. The polymeric insulators being organic in nature, their long term performance in service condition is majorly governed by the electrical and environmental stresses [3]. In this regard CIGRE WG D1.14 [4] has recognized twelve physical parameters which are to be evaluated before using insulators in service. Resistance to corona and ozone is one among them has not been standardized. Literature shows a large number of reported works on corona induced degradation of polymeric insulators [4]-[7]. It is observed that the corona activity will be intensified during foul environmental condition like fog, rain, hoarfrost etc., For 765 kV line; the average corona loss during fair weather condition is about 20 kW/km, whereas during foul weather condition it is 300 kW/km [8]. Thus the study of corona activity in fog environment becomes equally important. Corona activity is associated with the emission of light in the UV spectrum ranging 230-405 nm, as a consequence it difficult to witness this event with an unaided eye [9]. Inspection of corona activity on transmission line involves the usage of day time corona detection cameras. However modern digital single reflection (DSLR) camera can capture the faint corona discharges in darker ambience. Research on application of image processing techniques to study the discharge phenomenon and its quantification is limited in the literature [9, 10]. In the present work, experiments are conducted to study the behavior of corona discharges on the polymer samples. An image processing technique is presented which can be applied to study the corona activity in normal and foggy condition, based on which the streamer spread angle is computed. A physical model which can possibly explain the behavior of corona streamer under fog condition is also presented.

## II. Experimentation

An experimental arrangement consists of 30 cm ×30 cm ×30 cm acrylic chamber which houses corona electrode and the polymeric insulator sample as shown in fig. 1(a). Details of corona electrode (fig. 1(b)) used for the study are presented in [11]. The electrode is energized using 50 Hz high voltage AC source with gap distance between the electrode and sample maintained at 15 mm (fig. 1(c)). Corona behavior is studied at different voltage levels varying from 6 kV to 10 kV. The chamber is provided with a air circulation of 5 l/min using a 1/16 hp portable oil free flow controlled pump. A fog generator indigenously built is used to simulate fog condition inside the chamber, this can spray a constant fog/mist in the region between electrode and the sample at the rate of 0.2 ml/min [11]. Fog is generated using water of conductivity of approximately 220 µS/cm. A Canon DSLR camera (Canon EOS 1200D) with EF-S18-55mm IS II lens is mounted at a distance of 30 cm from the electrode assembly, to capture the discharges. A typical DSLR camera will have following parameters which can be adjusted to get better image [12], (1) exposure time (2) aperture (3) Image sensor optimization (ISO). (1) Effect of exposure time: It is the time period for which camera shutter will be kept open. Increase in exposure time indicates that more number of light photon received by the light sensor and hence increases the image brightness. (2) Effect of Aperture: higher aperture value indicates the larger shutter opening which increases the image intensity. (3) Effect of ISO: ISO defines sensitivity of the camera, with higher ISO value camera will capture lesser intense light. In the present work, camera is operated in manual mode with following settings; exposure time - 30 s, aperture f-number - 5.6, light sensitivity ISO - 6400. Camera setting has significant influence on the images; these settings are maintained same during the course of experimentation. The captured corona image is as shown in fig. 1(d). In digital terminology an image is a two dimensional matrix I(m,n) whose values are corresponding to the pixel intensities. For an 8-bit image, pixel intensities varies from 0 to 255 (2^8-1). Figure 2 (a) show the image of a corona discharge at 12 kV with a reference line (drawn in blue color). The pixel intensity profile along the reference line is shown in fig. 2(b). It is observed that with the increase in voltage, pixel intensities are increasing; signifying that more ionization leading to larger emission of light at higher voltage. Thus image contains factual information which can be extracted suitably to infer associated physical phenomenon. In the present work, images of the corona discharges are taken under normal and the fog condition. Figure 3 (a) and (b) shows the corona plasma spread observed for the case of without and with the application of fog.

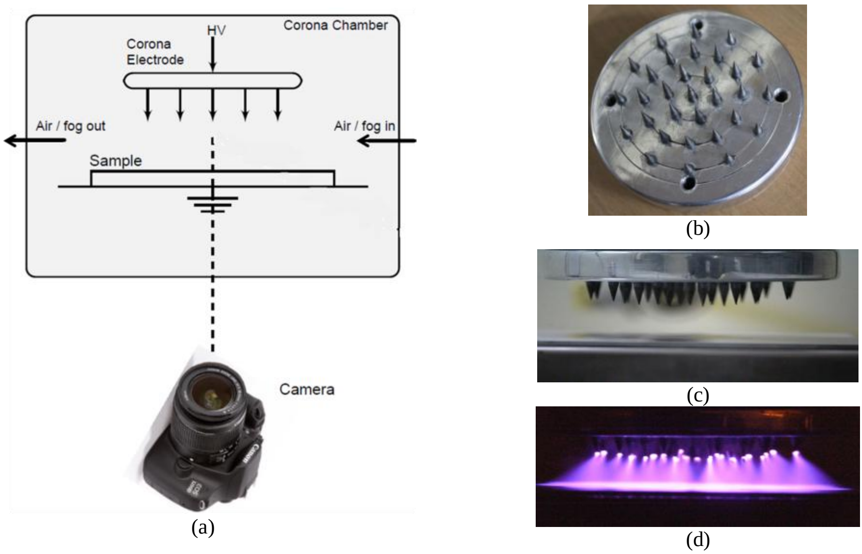



Fig. 1 (a) Block diagram experimental arrangement (b) corona electrode used (c) physical arrangement of electrode (d) image of corona discharge.

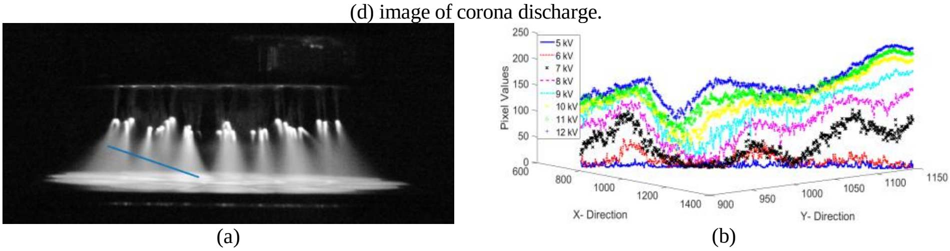



Fig. 2. (a) Corona image at 12 kV with reference line, (b) Intensity profile along the reference line

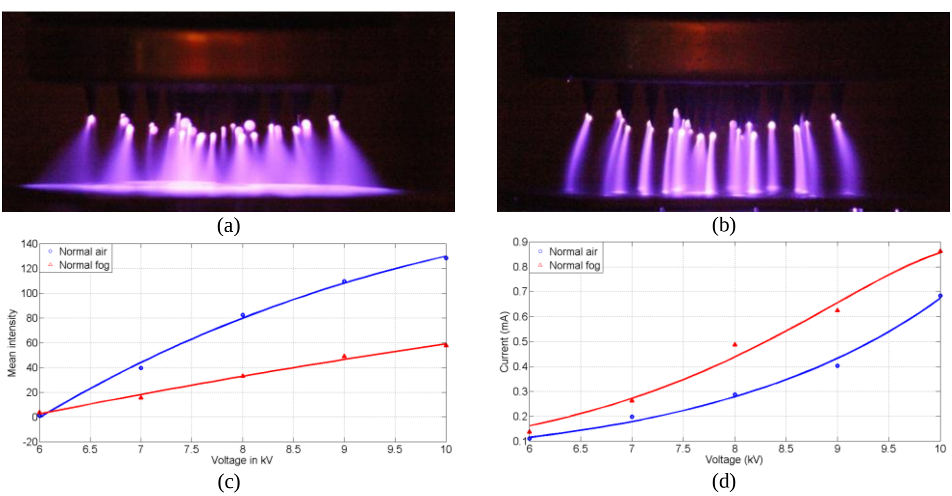



Fig. 3. (a) Corona under normal air condition (b) corona under fog condition (c) Plot of mean pixel intensity with respect to applied voltage. (d) Plot of applied voltage with respect to discharge current

It is noticed that the spread of corona plasma on the sample during normal air application is wider, whereas it is concentrated for normal fog. It is observed from fig. 3(a) and (b) that the corona activity under fog condition is shown to be lesser in comparison with normal air condition. It is further supported by computing the mean pixel intensity ($I_{avg}$) using eq. (1).

$$I_{avg} = \frac{1}{M \times N} \sum_{m=1}^{M} \sum_{n=1}^{N} I(m,n) \quad (1)$$

Figure 3(c) implies that the average pixel intensity of corona images for the case of fog application is below that of normal air. However the measured discharge current indicates other-way-round (as shown in fig.3 (d)). This anomaly can be explained with the aid of a physical model as presented below.

### *A. Physical Model*

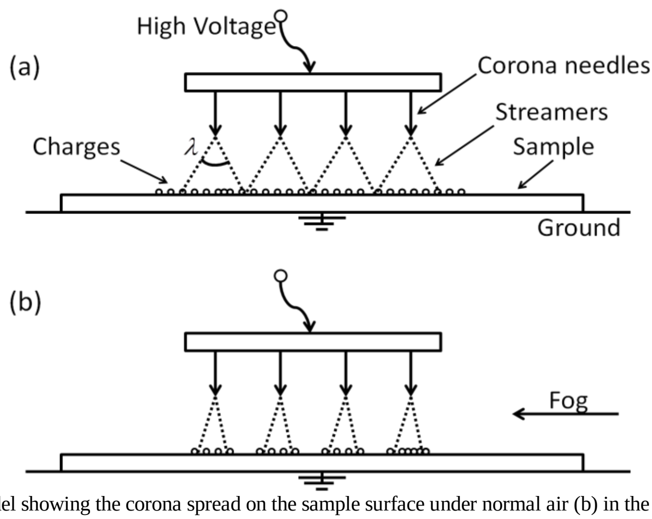



Fig 4. (a) Model showing the corona spread on the sample surface under normal air (b) in the presence of fog

Considering the fig. 4(a), during normal condition discharges originated from the corona needles implant charges on the polymeric surface. The discharge frequencies being high (in terms of kHz) [13] in comparison with that of power frequency (50 Hz), same polarity charge will be deposited in one half of the AC cycle. These pre-deposited charges will try to repel the charges emanating from the corona needle. As a result of which the corona spread angle will be wider as shown in fig. 3(a) and 4(a). The aforementioned process will not significantly change the sample surface resistivity and hence the lesser discharge current. On the other-hand (considering fig. 4(b)) under the application of fog, moisture content will drastically bring down the sample resistivity, whipping away majority of the charges. This will reduce the repulsion of like charges and hence the streamers will concentrate. To substantiate the proposed model it is essential to compute the streamer spread angle for both cases using image processing technique.

## III. IMAGE PROCESSING TECHNIQUE

An image processing technique adopted in the present work is depicted in fig. 5. The flow chart begins with obtaining the corona images using high resolution DSLR camera. The images are stored in .jpeg format, color thresholding base image segmentation is applied on each image to extract the effective corona plasma spread. For segmentation, images are processed in YCbCr (Y-luminance component, Cb and Cr are blue and red difference chroma components respectively) color space. The operation in YCbCr color space gives an advantage of handling the luminosity component (Y) of an image directly [14]. Color thresholding is done as follows; (i) identifying the region apart from corona plasma spread and obtaining range of pixel intensity. (ii) Inverting the threshold levels to get intensity range for the corona plasma. (iii) Filtering out all other intensity level to obtain corona region, (iv) these steps are repeatedly applied to extract the effective corona plasma spread. Color thresholding technique will aid in eliminating noises due to high ISO (6400), other reflections in the image, and to some extent the scattering of the light detected in the image during fog application [9]. In the processed image several portions where streamers are emanating from the corona needle are identified

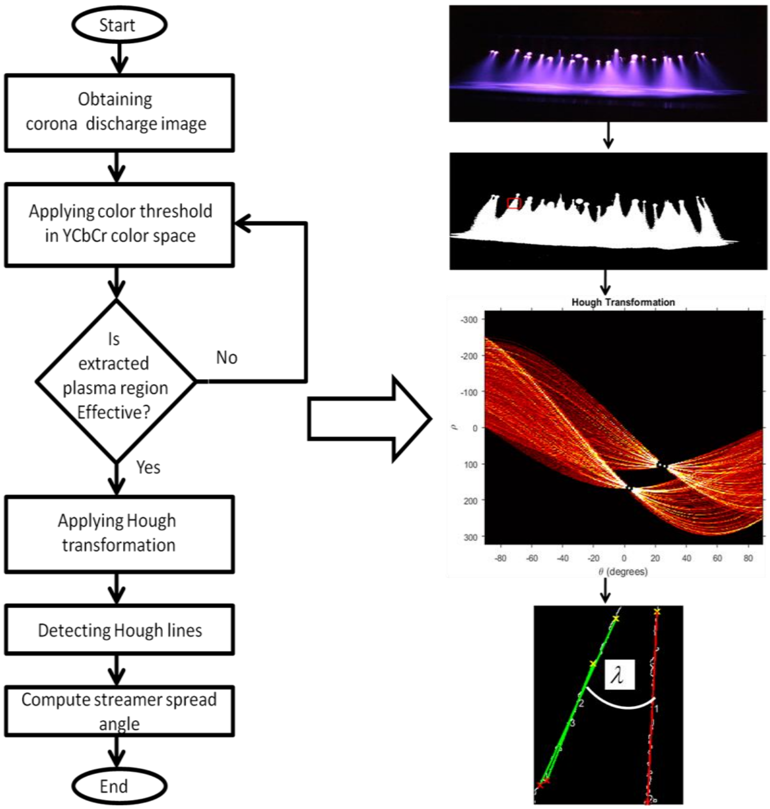
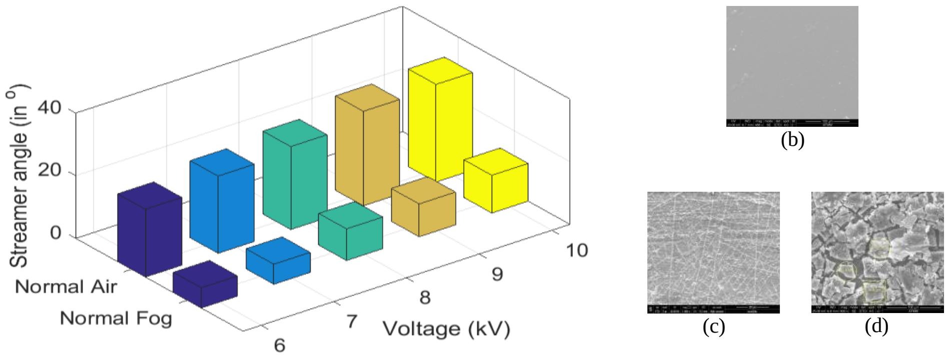



Fig. 5 Flowchart for obtaining the corona spread angle.

and Hough transformation is applied to the same portion. Hough transformation is extensively used in the image processing to detect the lines in an image [14]. Once the Hough lines are detected, the angle between the lines are computed using the formulation shown in eq. (2)

$$\lambda = \tan^{-1}\left|\frac{m_1 - m_2}{1 + m_1 \times m_2}\right| \tag{2}$$

Where, $m_1$, and $m_2$ are the slope of the two lines respectively. The codes to implement the above mentioned flowchart are developed in MATLAB [15].The bar graph given in




(a)

Fig.6 (a) Plot of corona streamer spread angle (b) SEM image of Fresh polymer sample (c) sample treated under normal air condition (d) sample treated under fog condition.

fig. 6(a) shows the computed streamer spread angle for normal air and fog condition, at different voltage values.

Following observations are made; (i) the spread angle is increasing with the applied voltage indicating that the higher the voltage, more the ionization and hence large amount of charges reaching the surface resulting in larger spread angle. (ii) The spread angle observed during the fog application is found to be lesser than that of normal air application, a reduction of 60% (on an average) is observed for the present case. To assess the effect of corona under normal air and the normal fog, samples are treated with 30 hours adopting the methodology described in [11]. The treated samples are analyzed using scanning electron microscopy (SEM). Figure 6(a)-(c) shows the SEM images of fresh, normal air treated, and normal fog treated sample respectively. It is evident from the SEM images that the sample treated under fog condition developed the fragmentation (fig. 6(b)) whereas the treatment with normal air resulted into crack formation (fig.6(c)). Thus severity of damage is more in case of fog treatment, which is in agreement with that of the increased discharge current (fig. 3(d)). These concentrated streamers observed during fog treatment are believed to damage the sample locally and largely.

## IV. Conclusions

Following are the conclusions drawn from the present study

- The behavior of corona discharges under normal air and fog condition is studied in regard to the polymeric degradation. The corona plasma spread is found to be different during fog application, wherein streamers are concentrated.
- Color thresholding based image segmentation is adopted to extract the effective corona plasma spread. The corona spread angle is computed on the processed image using Hough transformation. The spread angle during fog application is found to be lesser (in the present study it is 60%) than during the normal air application.
- A physical model is presented which explains the underlying mechanism of development of concentrated streamers during fog application. Further it has been substantiated by the computation of streamer spread angle.
- The concentrated streamers are believed to damage the polymeric material locally and intensely, which was confirmed from the SEM analysis.

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