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MEASUREMENTS OF CORONA DISCHARGE IN NON UNIFORM FIELD FREON GAP

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ABSTRACT: - Corona Discharge have been recorded in pin-to pin electrode at gas pressure gaps with high degree of non-uniformity electric field. For a wide range of experimental applicability the pin to pin electrode was used over pressure range from 1bar to 3bar and gap spacing from 0 to 5mm.

High –pressure dc corona discharge experiments have been carried out in a 16cm long glass chamber with an inner diameter and outer diameter are 16.8cm, and 19cm respectively. Corona onset voltage and breakdown voltages were reached. The design considerations of the setup allow to use pin to pin electrode type geometries.

Electronegative gases such as air, Freon (R22), were separately used for low temperature corona generation. The experiments have been carried out under ambient Laboratory conditions of temperature (19-24 ^{o}C), and humidity. The present experiment were studies the relation between the (V-P) and (V-d), on other hand, we study the relation between the current and applied voltage.

Key word: corona discharge, non-uniform field, electronegative gases

INTRODUCTION

In uniform and quasi-uniform field gaps the onset of measurable ionization usually leads to complete breakdown of the gap. In non-uniform fields various manifestations of luminous and audible discharges are observed long before the complete breakdown occurs. These discharges may be transient or steady state and are known as ‘coronas’. An excellent review of the subject may be found in a book by Loeb. (1) The phenomenon is of particular importance in high voltage engineering where non-uniform fields are unavoidable**.**

Corona discharge is a faint filamentary discharge, invariably generated by strong electric fields associated with small diameter wires, needles, or sharp edges on an electrode, (1) and has a wide range of applications. (1,2) The common electrode configuration of the corona discharge is needle-to-plane electrodes since such setup is simple and easy achieving discharge at atmospheric pressure. A small volume of nonthermal atmospheric discharge generated at the tip of a needle was first studied in 1930s by Trichel. [(3)] Up to now a large number of experimental works [(1, 2, 4–6)] have been conducted on the corona discharge with similar electrode configurations. These results showed that the discharge develops in the region around the needle tip where a high-electric field exists, and that the radius of the needle tip, which determines the non-uniformity of the electric field, has a big effect on the discharge characteristics. [(7)] In the corona discharge, free electrons gain energy from the external electric field near the needle tip, and lose energy primarily by electron-neutral inelastic collisions _namely, excitation and ionization collisions. Each ionization process produces an electron-ion pair; [(8, 9, 10)] the newly generated electron and the old seed electron are accelerated by the electric field, and again ionize neutrals, and create electron-ion pairs. Thus, an avalanche happens. As time advances, electrons leave the cathode needle region and move toward the anode plane, and the electron density in the region away from the needle tip begins to increase gradually**.**

The polarity of the corona is either positive or negative depending on the relative electric potential applied to the discharge electrode with respect to the passive electrode [(11, 12)] Corona is a self-sustained electrical discharge in a gas where the Laplacian electric field confines the primary ionization process to regions close to high field electrodes.

An important application of atmospheric dc corona discharge is the production of unipolar ions for electrostatic charging of various objects. For many decades, photocopiers, laser jet printers, and electrostatic precipitators have relied on the dc corona discharge to charge surfaces or particulates [(13)]. In addition to useful ions, energetic electrons produced in the corona discharge have led to undesirable ozone production [(14, 15)] and deposition of silicon dioxide on the discharge electrode [(16, 17)].

EXPERIMENTAL DETAIL

Although a number of experiments have been carried out to investigate the needle-to-plane discharge, discharge characteristics such as the evolutions of electron energy distribution, electron density, and electric field**.**

Corona and breakdown phenomena in highly insulating gases necessitate a high voltage electrical circuit, gas chamber with adoptable electrode holders, and measuring equipment. The gas is fed into the chamber through the regulating valve to control and set the required pressure valve. Excellent electrical connection must be established at each point in the electrical circuit to avoid any bad contact to experimental eliminate power dissipation.

Careful experimental procedure was proposed to cover the whole required measurements under these corresponding conditions.

Experimental studies have shown that the breakdown-voltage characteristics are strongly dependent on the degree of non-uniformity of the field, the polarity of the highly-stressed electrodes.

A Corona discharges exists only if the electric field is strongly non-uniform, it takes place in the region where the shape of electrodes creates a local field enhancement. The process is controlled by the applied voltage but also by the space charge (ion population) that being formed. A positive corona tends to form filaments called streamers which require an average voltage gradient. The experiment therefore uses a corona source that we limit ourselves to pin-to- pin electrode configuration.

A positive DC voltage is applied to the small diameter and to pin placed in grounded plane. If the applied potential is sufficiently high, an active corona plasma region due to the ionization of Freon. There is increasing interest in the dielectric properties of electron-attaching gases and particularly in those of Freon.

Freons with a suitable boiling point are very well available for this application. Therefore it is significant to investigate the dielectric strength of Freon gaseous, which can be used as insulation in combination with a SF_6 gas.

The whole DC studies with which the present work is concerned were accomplished by using the circuit diagram shown in Fig. (1). Corona and breakdown voltages were record by this circuit arrangement with acceptable precision rate and all observations were essentially justified.

The experiment was conducted using (120kV, 20mA), high voltage dc power supply, it can provide positive and negative polarity. The output was connected to the high voltage terminals of the various test rigs through a R≈10 MΩ oil–impregnated decoupling resistor, and a current viewing resistor (50Ω) was installed in the earth return path.

EXPERIMENTAL PROCEDURE

Experimental measuring set up in Fig.(1), used to determined corona onset voltage and breakdown of the electrode gap under the application DC voltages from (0 -70 kV), for studies under DC applied voltage , the electrode gap (pin –to –pin) was varied precisely in a range of (1mm to 5mm). Control panel of experimental set up, used for switching DC generation voltage and measurement.

To find DC breakdown voltage values, the voltage was raised gradually till breakdown occurred. To acquire output voltage wave shape and measure its parameters, beside a peak impulse on a digital system oscilloscope, measuring was also used. The breakdown voltage and corona onset measuring from voltage divider are shown in Figs.(1). At present , due to the non –availability of such a system at our laboratory method is only employed with regard to the ground end current it can be conveniently measured indirectly by measuring voltages . The current in indirectly sensed by measuring the voltage a cross as (50 Ω) resistor connected at the ground end.

Freon (R22) as well as air were investigated to evaluate their corona onset voltage and breakdown behavior under the application of DC voltages. The pair of electrodes assembly of each configuration was inserted inside a pressure test vessel as shown in Fig.(1), While the upper end is connected to corona free high voltage ,and input /output ports for gas filling and pressure measurements. The bottom is equipped with outlet connection for corona measurement. In these experiments, the bottom ports was kept connected to the earth.

RESULTS & DISCUSSION

Corona discharge has been used as an ionizer in a wide range of research and industrial fields such as environmental, analytical and atmospheric studies. Corona stabilization and electrical breakdown in electronegative gases (air, Freon (R22)), and their governing parameters are discussed here. Analyses of results involve the effects of gas types and pressure, electrode materials and geometry.

The present experiments have been carried out at ambient conditions over gas pressure ranging from 1bar to 3 bar using the experimental apparatus shown in Figure (1). The chamber consists of a system of stainless steel electrodes possibly even commercial electric appliances .To establish a good understanding of the behavior of the corona discharge.

Subsequently, the behavior of both corona onset voltage and breakdown are fully investigated for pin-to -pin electrode type in the electrical discharge for positive polarity.

The discharge was a achieved by a DC high voltage power supply (DS) at a constant voltage ranging from 0 kV to 120kV,.The positive electrode was connected to a high voltage and the main electrical parameters such as discharge current and voltage were measured using high accuracy (Fluke ,Excel, Aswar M890G) multimeters.

There is relatively little information on corona phenomena in Freon. The positive –point corona in Freon gas was studied to consist of corona stabilization types, depending on gas pressure and gap geometry. With these operation conditions and under slow rising and dc voltages, there is a range of pressure, where breakdown is preceded by a corona discharge from the non-uniform, high –voltage (HV) electrodes.

This (pin-to-pin) electrode configurations were selected to investigate the corona onset voltage and breakdown characteristics, and these are illustrated in figures (2-9), which have given different explanation, for the corona –stabilization phenomena.

Also these figures shows the variation of breakdown voltages and corona onset with gas pressure over range from(1-to-3bar), one can found that the discharge voltage varies depending on pressure, gap length, and electrodes geometry. The corona stabilization region is appeared very well in the (pin to pin), this is small in low pressure and large in high pressure, also increases with gap length. The corona discharge produces a thin plasma is bounded by the high –voltage discharge electrode surface and an imaginary outside boundary where the ionization process balance the electron attachment process. The electron distribution in the corona plasma exhibits a strong spatial non-uniformity especially in the vicinity of the discharge electrode. For a positive point discharge, the electron density is highest near the point and decreases rapidly with increasing distance from the surface, smaller electrodes produce thinner plasma and fewer electrons, but the electrons have a higher mean kinetic energy than those produced with larger points.

The investigations have been carried out on the current – voltage characteristics of positive polarity discharge, (pin to pin). All currents start abruptly and increases of first linearly and then more steeply with voltage, until finally breakdown into a spark occurs. This phenomena observed in the onset region of the (I-V) curves may now be explained. The voltage by the arrival of an ion in the sensitive volume around the tip, which start the stable corona process. This value of voltage for onset depends on the time.

The measurements have determined (I-V) characteristic of the corona as a function of gap geometry, and did not including the voltage at which the corona breaks down into spark.

The corona current voltage curves for various gap distance curves end at voltage at which spark breakdown occurs. The general shape of the current –voltage curve is plotted in figures (9-12), for various gap distance. The essential features are the initial sudden rise of current and the increase which is at first linear with voltage and the becomes steeper until finally breakdown into spark occurs, at which point the curves are ended.

In figures below we can observers that the all current grows exponentially as applied voltage is higher than corona onset voltage in the measurement shown in figures. Fig. (13), represent the corona onset voltage and breakdown in air gap.

CONCLUSION

Pin-to-pin electrode arrangements have been capable of producing a high degree of non-uniformity in the electric field within the gap spacing of the experimental setup. A voltage up to 120kV was applied to the top electrode (HV electrode) over a wide range of gas pressure and gap spacing, when the gap was pressurized by Freon, SF6, and SF6/Freon mixtures. Analysis of all parameters governing the corona – stabilized breakdown were carried out and investigated. The following concluding remarks have been figured out:

1. Upon having gas pressures up to 3bar , gap spacing between 1mm and 5mm, and curvature, radii of the high – voltage electrode from 0.025mm to 0.05mm, both corona and breakdown mechanisms were analyzed and justified accordingly.
2. It has been observed experimentally that in non-uniform field gaps for electronegative gases, corona onset voltage is much lower than the complete breakdown voltage. The corona appears at high voltage with the increases of gas pressure and gap spacing for many electrodes, arrangements. In the region of stabilized corona, breakdown occurs first positive crest and in the region of direct breakdown, the event is reversed. The transition between direct breakdown and corona breakdown depends on field non-uniformity and gap spacing.
3. The electron distribution in the corona plasma exhibits a strong spatial non-uniformity especially in the vicinity of the discharge electrode. For a positive point discharge, the electron density is high near the point and decreases rapidly with increasing distance from the surface, smaller electrodes produce thinner plasma and fewer electrons, but the electrons have a higher mean kinetic energy than those produced with larger points.
4. The results suggest that the V/p, and (I-V) characteristics are high in (pin –to-pin) electrode, this might be due to the area of the electrode when the gap spacing is varied. However, the ratio (electric field / pressure) is of prime importance for all experimental condition, in particular, when the electric field may show a uniform feature under certain values of d and electrode tip radius.
5. Both current level and Trichel affect the electron distribution in the corona plasma. When a low voltage is applied, small current flow between electrodes and the insulation retains its electrical properties .If the applied voltage is sufficiently high the current flowing through the insulation, increases very sharply resulting in a complete breakdown as a result of the insulation collapse.

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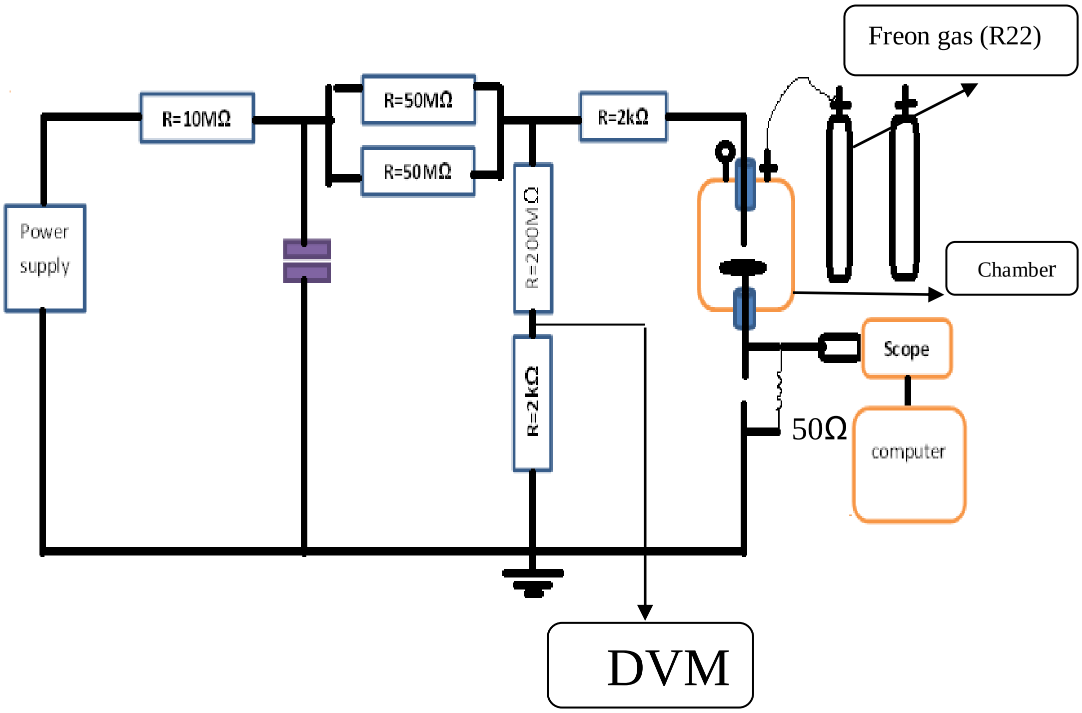

Fig. (1): The schematic of the diagram for electric circuit.

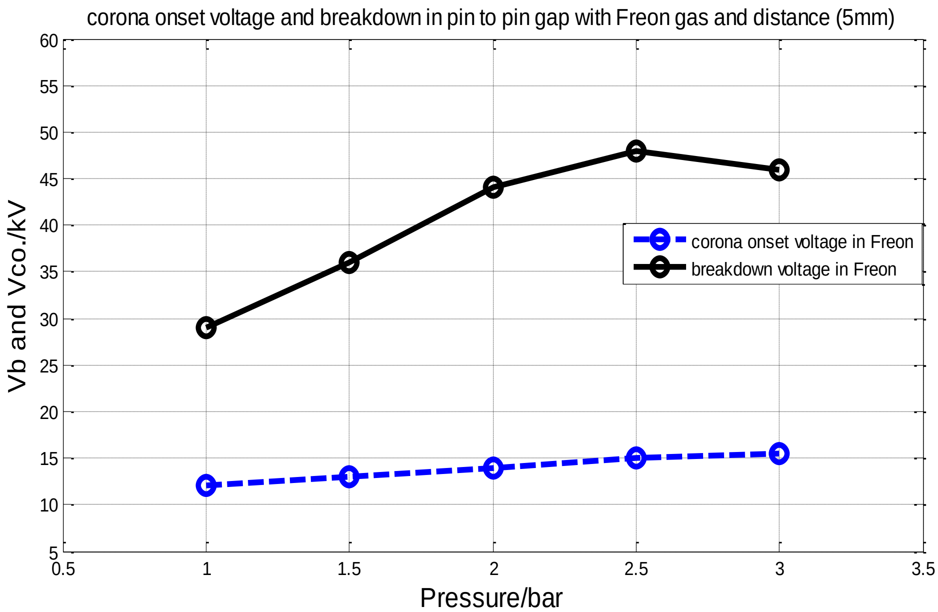

Figure (2): shows the functional relationship between the breakdown and corona onset voltage with gas pressure in pin to pin for Freon gas with distance 5mm.

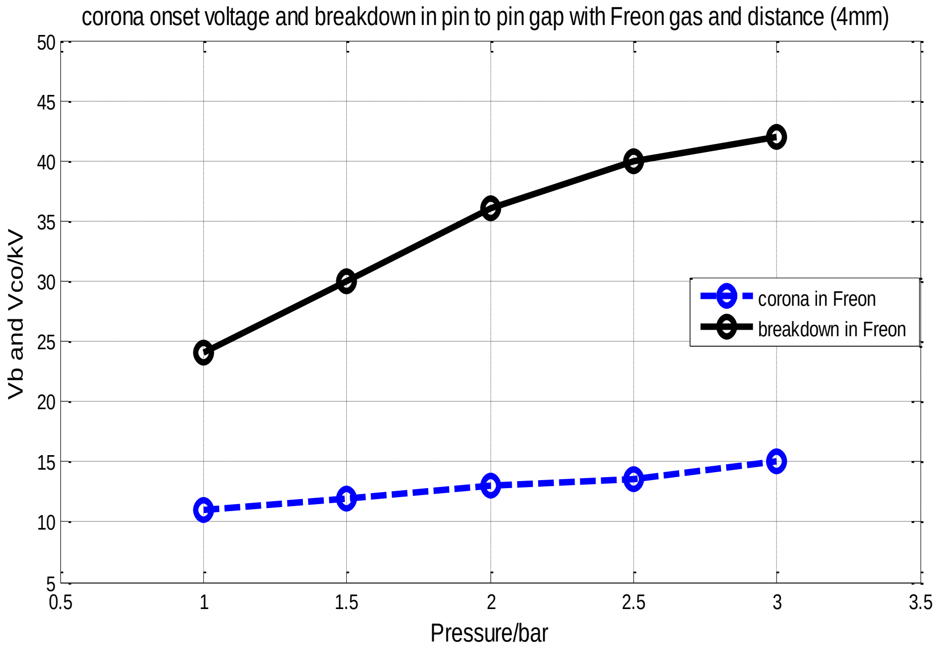

Figure (3): shows the functional relationship between the breakdown and corona onset voltage with gas pressure in pin to pin for Freon gas with distance 4mm.

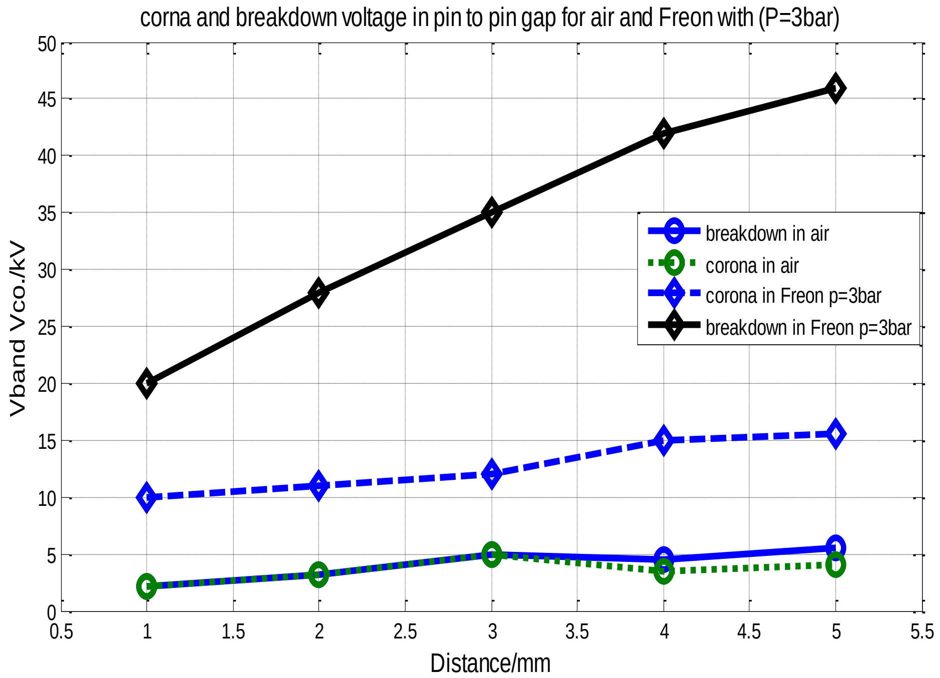

Figure (4): shows the functional relationship between the breakdown and corona onset voltage with gap spacing in pin to pin for Freon gas (P=3bar) and air.

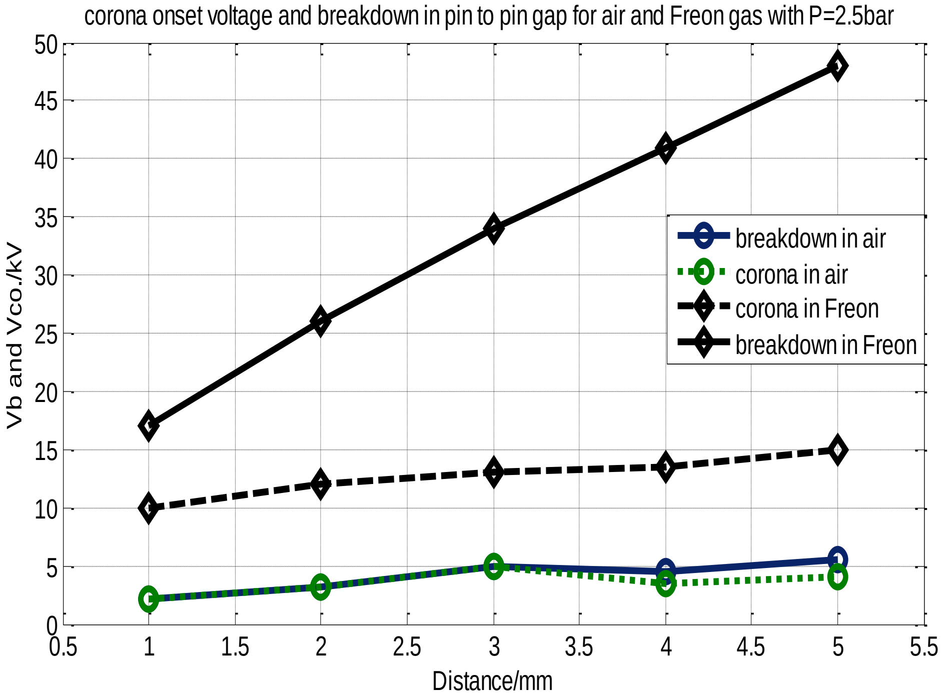

Figure (5): shows the functional relationship between the breakdown and corona onset voltage with gap spacing in pin to pin for Freon gas (P=2.5bar) and air.

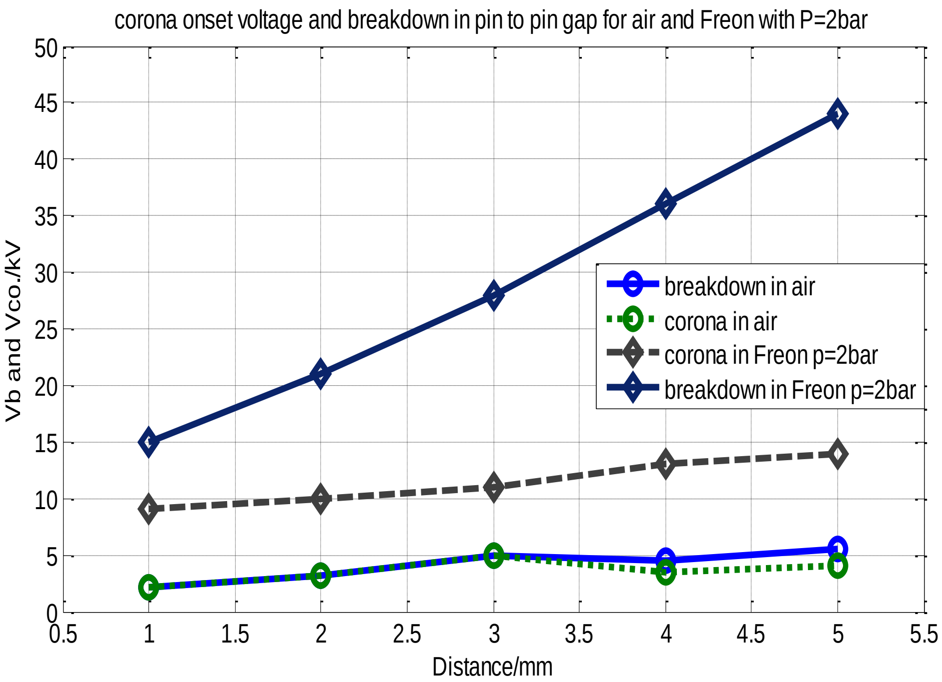

Figure (6): shows the functional relationship between the breakdown and corona onset voltage with gap spacing in pin to pin for Freon gas (P=2bar) and air.

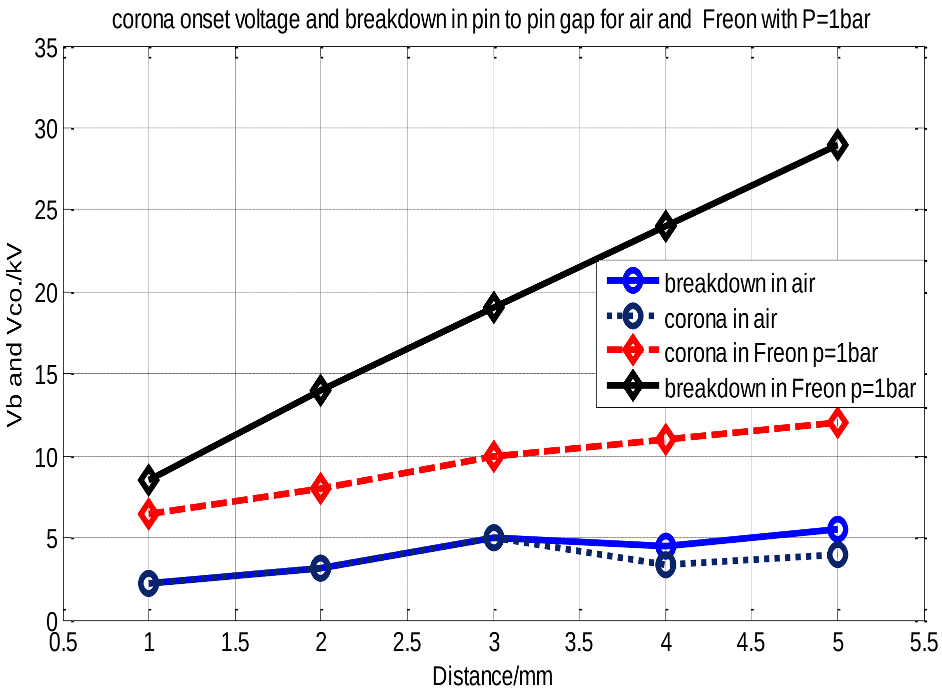

Figure (7): shows the functional relationship between the breakdown and corona onset voltage with gap spacing in pin to pin for Freon gas (P=1bar) and air.

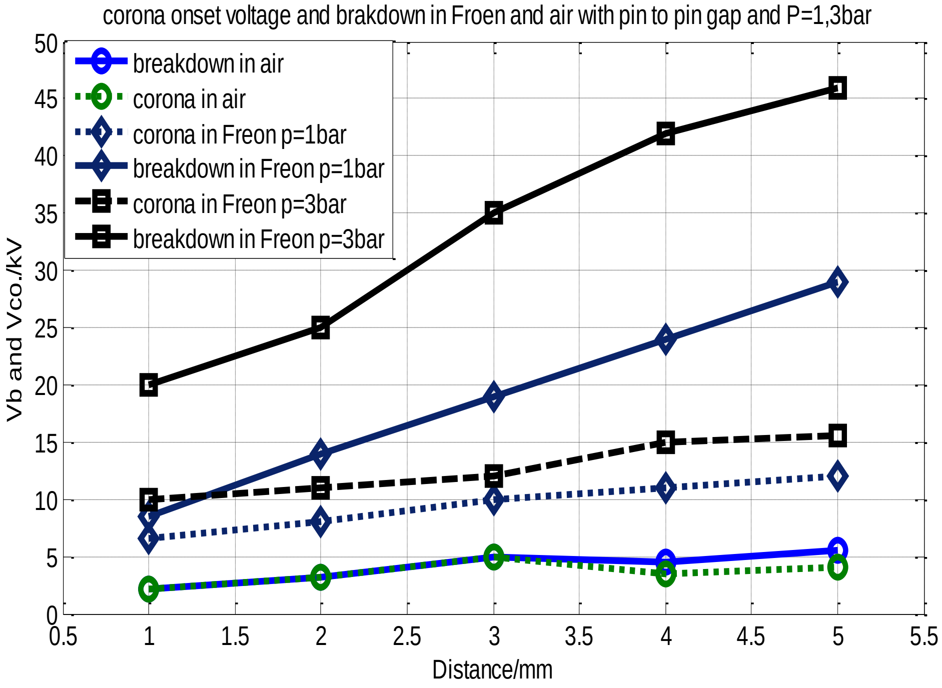

Figure (8): shows the functional relationship between the breakdown and corona onset voltage with gap spacing in pin to pin for Freon gas (P=1,3bar) and air.

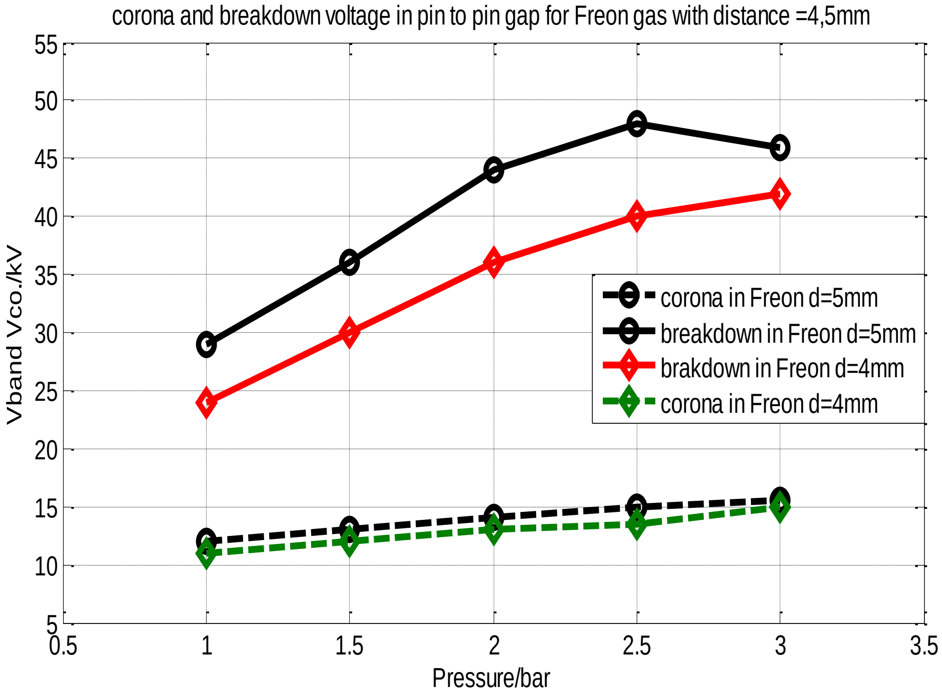

Figure (9): shows the functional relationship between the breakdown and corona onset voltage with gas pressure in pin to pin for Freon gas with distance (4, 5) mm.

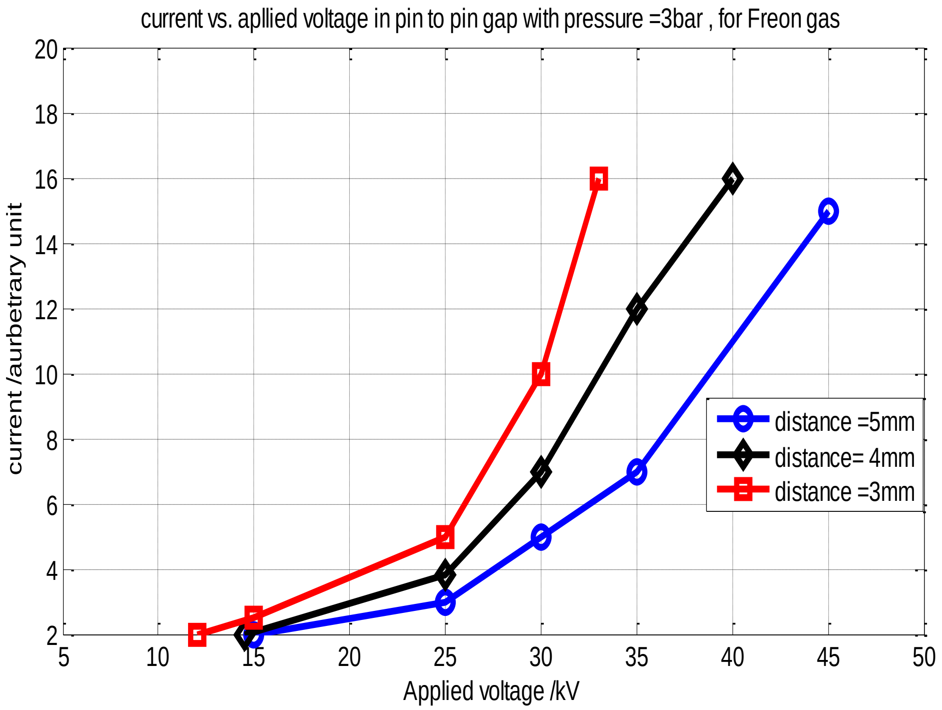

Figure (10): Relationship between current and applied voltages in Freon for pin to pin with gap length (3, 4, 5mm) and gas pressure =3bar.

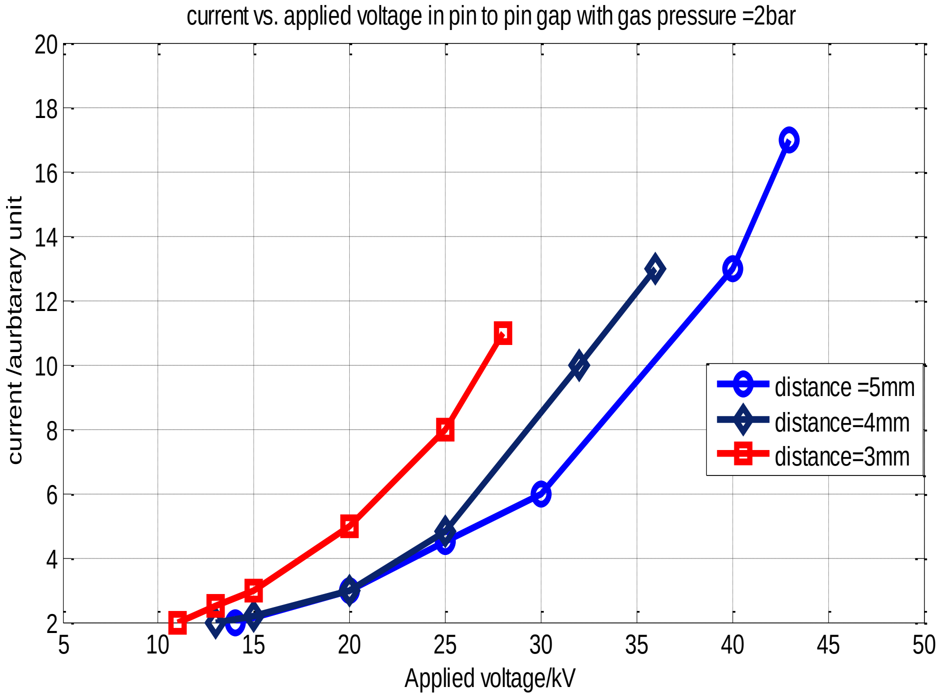

Figure (11): Relationship between current and applied voltages in Freon for pin to pin with gap length (3, 4, 5mm) and gas pressure=2bar.

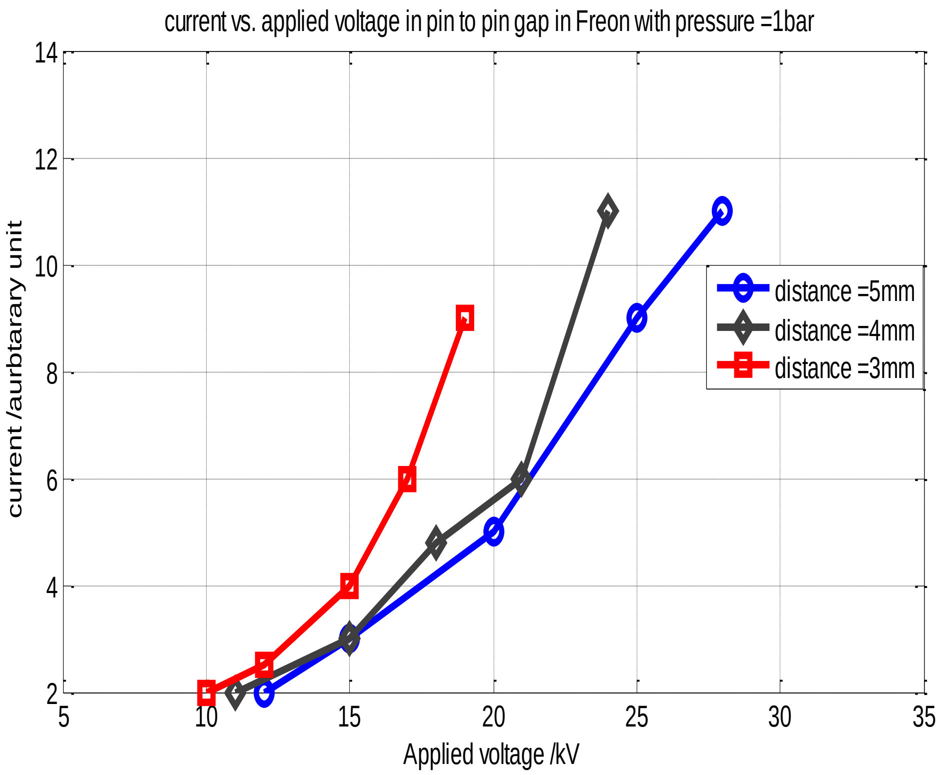

Figure (12): Relationship between current and applied voltages in Freon for pin to pin with gap length (3, 4,5mm) and gas pressure =1bar.

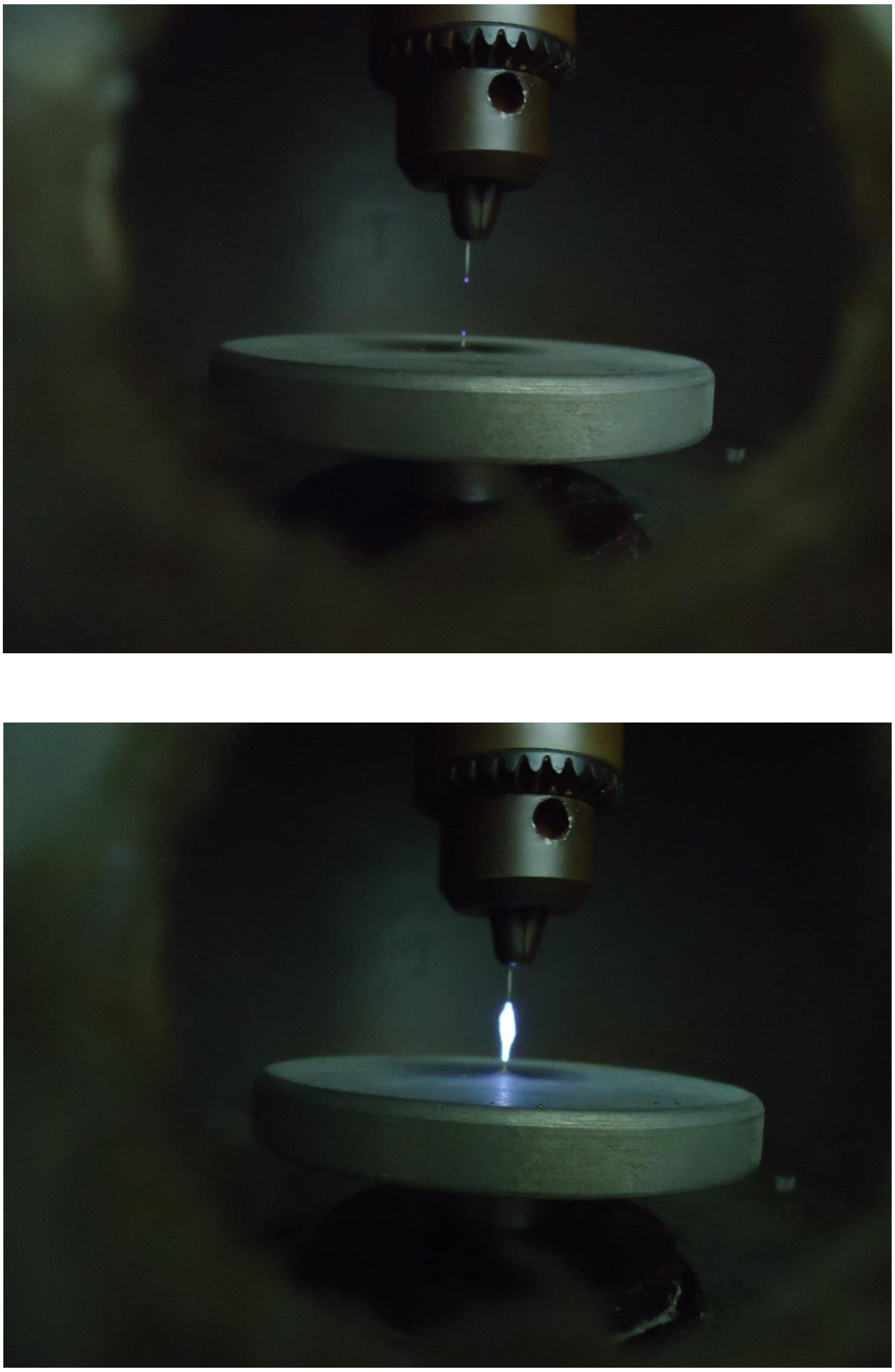

Figure (13): Photograph represent the corona and breakdown voltages in pin to pin Electrode geometry.

قياسات تفريغ الهاله في مجال كهربائي غير منتظم باستخدام غاز الفريون

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الخلاصة

لغرض توليد ودراسة فولتية الهالة الكهربائية وفولتية انهيار الغازات، سمحت معطيات التصميم وبناء المنظومة لاستخدام الاقطاب (pin to pin) وتحت ضغوط الغاز في مجال كهربائي غير منتظم. التجربة انجزت لمدى ضغط غاز من (1بار الى 3بار) ولحيز فجوة من (1ملم الى 5 ملم).

اجريت مجموعة من تجارب توليد الهاله الكهربائية في اسطوانة زجاجية (غرفة تفريغ) طولها (16سم) وقطرها الداخلي (16,8 سم) والخارجي (19سم) تحت ضغوط غازات عالية.

استخدمت غازات كهروسالبية في التجربة مثلا: الهواء، وغاز الفريون، لتوليد هاله ذو درجة حرارة منخفضة. انجزت التجربة عند درجة حرارة ورطوبة المختبر.

تم دراسة العلاقة بين الفولتية كعلاقة الضغوط وبين الفولتية كعلاقة لحيز الفجوة وكذلك درسة العلاقة بين الفولتية والمسلطة وبين التيار.