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BREAKDOWN CHARACTERISTICS OF COMPRESSED NITROGEN UNDER IMPULSE VOLTAGE

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BASINÇLI AZOTUN DARBE GERİLİMİNDE DELİNME KARAKTERİSTİKLERİ

ÖZET

Azotun, düzgün olmayan elektrik alanında standart darbe geriliminde, delinme dayanımı deneysel olarak incelenmiştir. Deneylerde küre-düzlem ve küre-yapay pürüzlü düzlem elektrot sistemleri kullanılmıştır. Elektrot açıklığı 5-25 mm arasında, bağıl gaz basıncı ise 0-4 bar arasında değiştirilmiştir. Her bir elektrot açıklığı ve basınçta, azotun hem pozitif hem de negatif kutbiyette darbe delinme gerilimleri ölçülmüştür. %50 darbe delinme gerilimleri, ölçme sonuçlarından yararlanarak en küçük kareler yöntemi ile elde edilmiştir. Deney sonuçlarından azotun delinme geriliminin, hem elektrot açıklığının büyümesi hem de gaz basıncının artması ile yükseldiği görülmektedir. İncelenen elektrot sisteminde, azotun delinme gerilimleri, pozitif darbede küçük elektrot açıklıklarında, negatif darbedekilerden daha yüksek; büyük açıklıklarda ise çok daha düşük olarak elde edilmiştir. Deneylerde, küre-pürüzlü düzlem elektrot sisteminin delinme gerilimlerinin, her iki kutbiyette, küre-düzlem sistemindekilere göre daha büyük olduğu görülmüştür.

SUMMARY

Breakdown characteristics of nitrogen (N_2) under standard lightning impulse voltages in non-uniform field was experimentally investigated. The experiments were carried out with sphere-plane and sphere-plane with an artificial protrusion electrode systems. The electrode gap spacing and the relative gas pressure were varied within the range of 5-25 mm and of 0-4 bars, respectively. At each gap spacing and gas pressure, impulse breakdown voltages of nitrogen for both negative and positive polarities were measured. The 50% breakdown values were obtained using measured values by the least squares method. The results show that breakdown voltage of N_2 increases either with increasing gap spacing and/or with increasing gas pressure. Breakdown voltages of N_2 in used electrode system under positive impulses, were higher than those of under negative impulses at small gap spacing; but much lower at greater gap spacing. In the experiments, breakdown voltages of sphere-plane with protrusion electrode system were found to be higher than those of sphere-plane electrode system under both polarities.

INTRODUCTION

The characteristics of electrical breakdown in compressed gases are of practical importance for the insulation co-ordination and overvoltage protection of gas insulated apparatus. The breakdown characteristic of gap in pure nitrogen are important, because it serves as a basis against which the characteristics of the same gap in gas mixtures may be compared.

Many studies have been carried out in recent years on the dielectric behaviour of gases under lightning impulse voltages [1-6]. Kuffel and Yializis have studied on the mixtures of SF_6 with air and N_2 in a rod-plane gap at constant electrode spacings [1]. Christopohorou and Pinnaduwage have summarized the basic physical processes of gaseous dielectrics and their electrical insulating properties [2]. Medeiros and Naidu have investigated the breakdown voltages of N_2 in a rod-plane gap with spacing of 5-40 mm [3]. Li, et. al. have reported volt-time characteristics of air and air mixture with SF_6 for a coaxial-cylinder gap [4]. Berger has described investigations on the influence of surface roughness on the onset or breakdown voltage in air and SF_6 under alternating voltage and uniform field with spherical surface protrusion [5].

In this study breakdown characteristics of nitrogen under lightning impulse have been obtained for different discharge parameters, such as gap spacing, gas pressure, polarity of impulse voltage, presence of a protrusion on electrode surface. The positive and negative impulse breakdown voltages of nitrogen for investigated sphere-plane geometry with smooth and rough planes were measured.

EXPERIMENTAL

In the experiments, sphere-plane electrode system was used to simulate and study the effects of field non-uniformities in practical systems which usually have a relatively lower utilization factor (Fig. 1). The sphere electrode had a diameter of 4 mm.

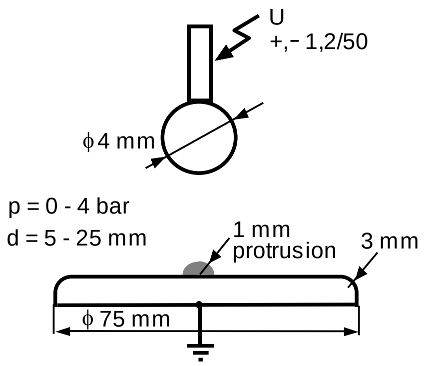

Figure 1. The electrode system used in the tests.

The plane electrode was a 75 mm diameter circular plate with a well-rounded edge. The electrodes were made of brass. The electrodes were mounted in a transparent plexiglass pressure vessel 550 mm high and 120 mm in diameter which is capable of withstanding pressure up to 6 bar. The electrode spacing and the relative gas pressure were varied within the range of 5-25 mm with an increment of 5 mm and of 0-4 bars with an increment of 0.5 bar, respectively. The gap spacing was set under high pressure from outside the pressure vessel. The gap spacing was measured with an accuracy of ± 10 μm using special measuring scales.

In order to simulate a distortion of the highly inhomogeneous field between sphere-plane electrode, a metallic hemispherical protrusion with 1 mm radius was fixed to the center of the plane electrode as shown in Fig. 1.

The sphere electrode was connected to a 2 stage impulse generator which was adjusted to generate 1.2/50 μs standard impulse. The plane electrode was earthed. Before each series of tests, the electrodes were thoroughly polished and cleaned. The pressure vessel was first evacuated at $\sim 10^{-1}$ torr for about half an hour before introducing the gas and then filled slowly with commercial grade nitrogen without any further treatment, up to desired relative pressure. Nitrogen was left for at least thirty minutes before test, to obtain an uniform pressure grading. The pressure was measured with a pressure gauge with an uncertainty of $\pm 1\%$. All experiments were made at room temperature, and the small deviations in room temperature have been corrected by adjusting the gas pressure. Before each series of measurements, at least ten unrecorded shots, resulted with breakdown were applied to the electrodes, for conditioning. In all cases a time interval about thirty seconds was allowed between successive shots. The crest value of the applied impulse voltage was measured by a digital peak voltmeter, using a capacitive divider.

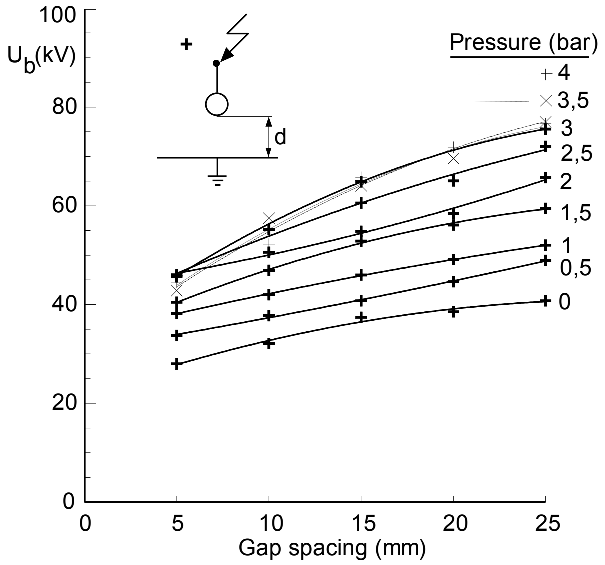

Figure 2. Positive impulse breakdown voltages of sphere-plane gap in N_2.

At each pressure and gap spacing, impulse breakdown voltages for both negative and positive polarities were measured. The 50% breakdown values were obtained using measured values by curve fitting method of first order, based on the least squares [7]. For each breakdown value, at least 20 impulses were applied at a voltage close to the 50% breakdown level. The standard deviation of 50% impulse breakdown voltages was less than 10%. The voltage measurement error was less than 1%.

EXPERIMENTAL RESULTS AND DISCUSSION

The breakdown voltage-gap spacing characteristics of nitrogen for a sphere-smooth plane gap, sphere electrode of 4 mm diameter, at different gas pressures, are shown in Figures 2 and 3. It can be seen from Figure 2 for positive sphere-plane electrode system, the breakdown voltage increase with pressure and gap spacing, as expected.

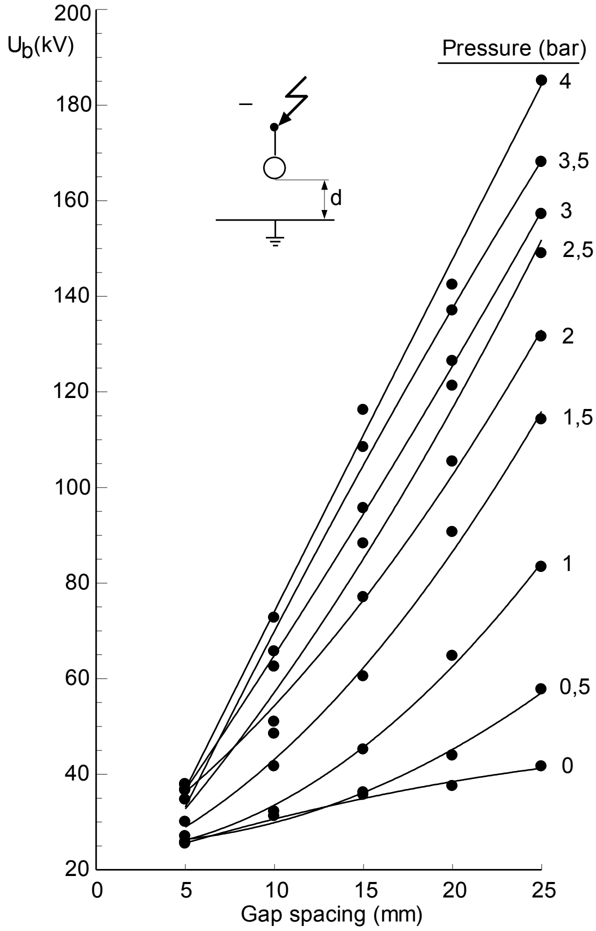

Figure 3. Negative impulse breakdown voltages of sphere-plane gap in N_2.

The negative polarity breakdown characteristics shown in Figure 3 exhibit a different trend. These breakdown voltages are in general higher than those of positive polarity breakdown voltages (Fig. 2). Moreover, both of the electrode systems show a rapid increase in the negative polarity breakdown voltages. A similar behaviour may be noticed in the experimental results of Kuffel and Yializis for the 1.59 mm diameter rod-plane gap with a spacing of 10 mm [1] and Medeiros and Naidu for different diameters (5-20 mm) rod-plane gap with spacing of 5-40 mm [3].

Figures 4 and 5 show the breakdown voltage-gap spacing characteristics of nitrogen, under different gas pressure (0-4 bars), with a fixed metallic hemispherical protrusion of radius 1 mm on the center of the plane electrode, for positive and negative polarities, respectively. Its clear that at higher pressures the breakdown voltages under negative polarity are greater than those at lower pressures; but vice versa for positive polarity. This fact can be attributed to the field divergence and gap irradiation.

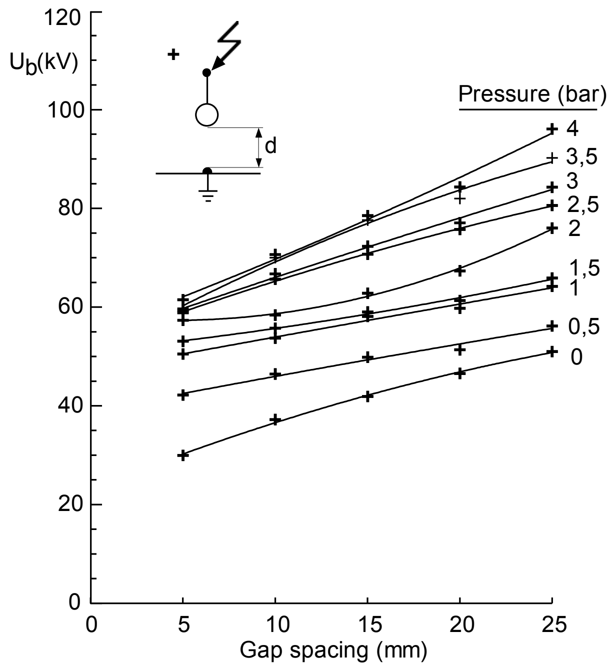

Figure 4. Positive impulse breakdown voltages of sphere-plane with protrusion gap in N_2.

It can be seen also that the values of positive breakdown voltage with metallic protrusion are higher than those in the case of the smooth plane. The protrusion effect in negative polarity was observed to be reversed, especially at greater gap spacing and higher gas pressure.

It is seen that the increase in the breakdown strength of nitrogen is accompanied by a movement of the initiation point of discharge around the tip of the sphere electrode. Generally, the discharges followed the shortest distance between electrodes. But, at the high pressure and large gap spacing, the discharges developed into different directions from the sphere electrode. This means that space charges increase the radial field strength and introduce sparks in those directions. So, the discharge path doesn't follow the shortest path between electrodes. These cause to get higher breakdown voltages.

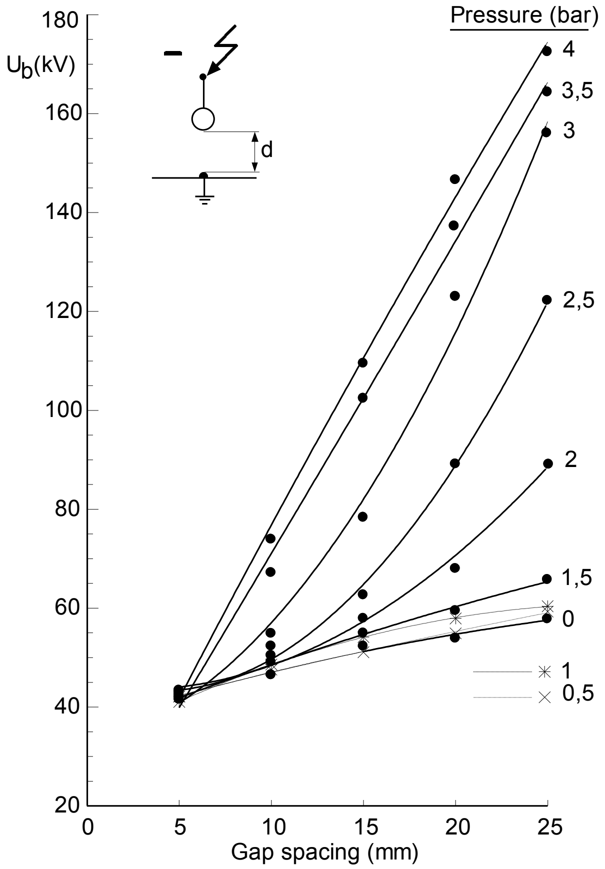

Figure 5. Negative impulse breakdown voltages of sphere-plane with protrusion gap in N_2.

CONCLUSIONS

In this study breakdown characteristics of nitrogen under lightning impulses have been examined at different gap spacings, gas pressures, polarities and presence and absence electrode roughness. Generally, breakdown voltages are higher at negative polarity than those at positive polarity. This trend is more distinct in higher pressure.

The experimental results show that the presence of protrusion on plane electrode has no significant effect on the breakdown voltage. This result has been attributed to the little effect on non uniformity field and discharge path.

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