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THE RELATION BETWEEN THE POLARITY AND EFFECTIVE DISCHARGE REGION OF THE LIGHTNING

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Abstract- Lightning is the largest discharge phenomenon in the nature. The theoretical and the experimental studies about the constitution, development and activity of the lightning discharges have been carried on for lots of years. This study presents the relation between the polarity and the effective discharge region of the lightning determined from experimental simulation studies. Discharges in long air gaps with impulse voltages and sparkover voltages were investigated according to the polarity in the laboratory.

Keywords: Polarity, effective discharge region, lightning.

I. INTRODUCTION

Lightning strokes to the electric power facilities have been the crucial problem for the electric power transmission systems. Power systems are often subjected to overvoltages that have their origin in atmospheric discharges in which case they are called external or lightning overvoltages. Fundamentally, lightning is a manifestation of a very large electric spark and it shows impulse character depending on various factors. Experimental studies about the lightning discharges have been conducted with impulse voltages both in uniform and nonuniform fields in long air gaps [1 -3].

This study presents the relation between the polarity and the effective discharge region of the lightning determined from experimental simulation studies. In this study, the cloud and the earth are simulated by two plane electrodes; the pilot discharge is modeled by a rod electrode and the buildings are replaced by their miniature models. Here, the results of the observations of discharge phenomenon and measured sparkover voltages in long air gaps are reported and the properties of positive and negative impulses under prescribed test conditions are compared.

Lightning discharges are simulated by long air gap discharges in laboratories. However, there are considerable differences between the characteristics of lightning discharges and discharges in long air gaps. The characteristics of a lightning discharge depend on the state of the clouds, the amount and the height of the charges, atmospheric conditions and the geography under the cloud. On the other hand, discharges in large air gaps are effected by the experimental setup, the characteristics of the applied voltage, the gap configuration and the atmospheric conditions as well as the random nature of the discharge itself. Therefore, a great care must be payed while extending the test results of long air gaps for lightning discharges. That is, the adequacy of the results depends on so many parameters mentioned above [1].

II. EXPERIMENTAL

II-1. Experimental Setup

The relation between the 50% sparkover voltage and the polarity of the lightning impulses are experimentally investigated in Fuat Külünk High-Voltage Laboratory of Istanbul Technical University. Experiments are conducted with the standard lightning impulse voltage of 1.2/50 μs both in positive and negative polarities. The impulse voltages are obtained from a six stage impulse generator of 1 MV and 10 kJ.

Lightning cloud and the earth are simulated by two plane electrodes (85 x 185 cm^2, area of 1.5 m^2) spaced by 50.5 cm. The pilot discharge is simulated by a rod electrode of 21.5 cm length located on the middle of the cloud electrode. The distance between the tip of the pilot electrode and the earth electrode is 29 cm. The buildings are simulated by their miniature models (Figure 1). In the experiments, five building model electrodes are used. The heights of building model electrodes are chosen as 13-23-33-43 and 53 mm.

II-2. The Results of the Experiments

The space between the cloud and earth plane electrodes is held fixed. The 50% sparkover voltages corresponding to various horizontal distances between the vertical axis of the pilot electrode and the building model electrode are determined. Tests are carried both for positive and negative impulses until the cease of the discharges between the pilot electrode and the model electrode. That is, the horizontal distance of the model electrode from the pilot electrode axis, corresponding to a discharge either between the pilot electrode and the earth electrode or between the model electrode and the cloud electrode is assumed to be the limit of the effective lightning region.

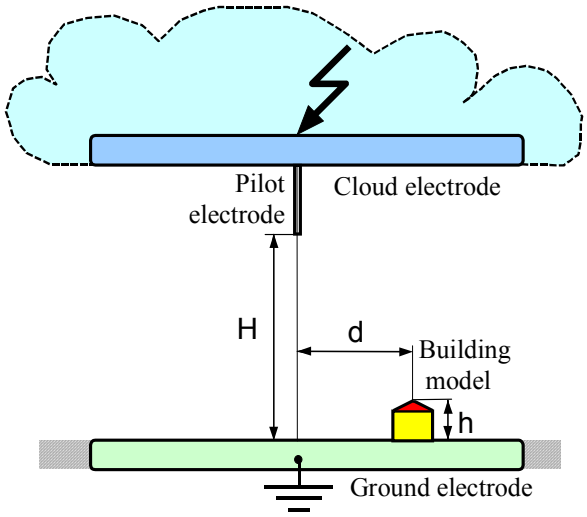

Figure 1: The experimental arrengement. *h*: Building height, *d*: Horizontal distance between the vertical axis of the pilot electrode and the building model electrode

During the experiments temperature, humidity and pressure in the laboratory are measured and relative air density and humidity correction factor are taken into account. 50% sparkover voltage versus the horizontal distance between the building model electrode and the pilot electrode are shown in Figures 2-6. Note that, the figures are titled as $U_d = f(d)$ and the height of the building model electrode is denoted as h.

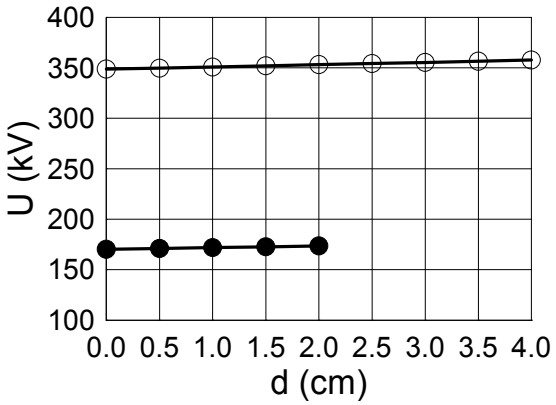

Figure 2: $U_d = f(d)$ for h = 13 mm.
•: positive impulse
o: negative impulse

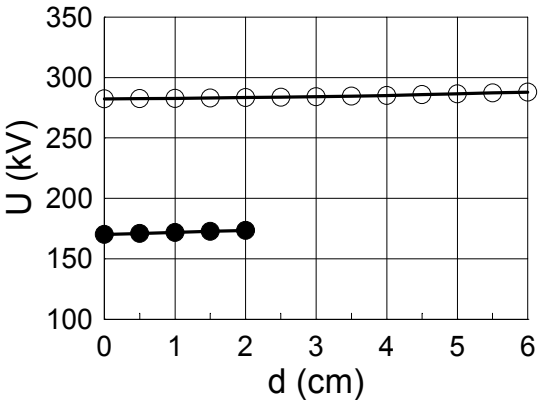

Figure 3: $U_d = f(d)$ for h = 23 mm.
•: positive impulse
o: negative impulse

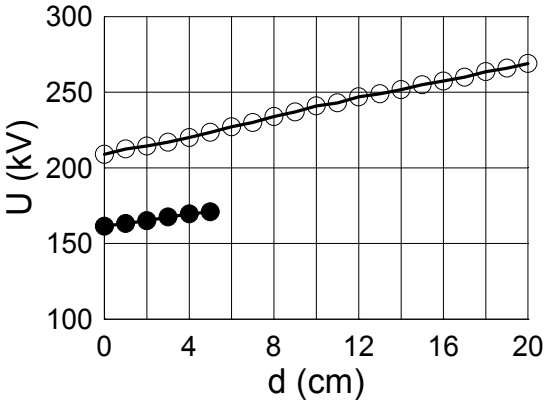

Figure 4: $U_d = f(d)$ for h = 33 mm
•: positive impulse
o: negative impulse

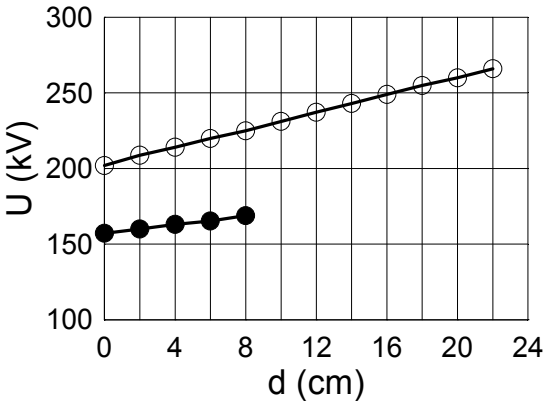

Figure 5: $U_d = f(d)$ for h = 43 mm.
•: positive impulse
o: negative impulse

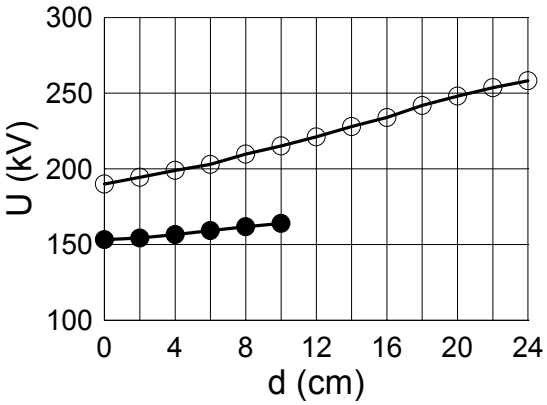

Figure 6: $U_d = f(d)$ for h = 53 mm.
•: positive impulse
o: negative impulse

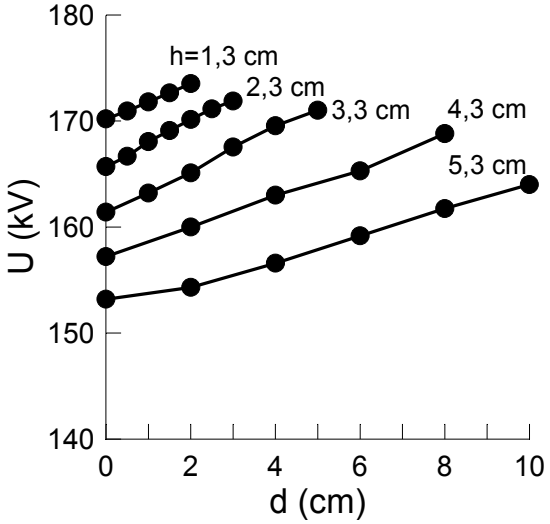

Figure 7: $U_d = f(d)$ for various h at positive impulse.

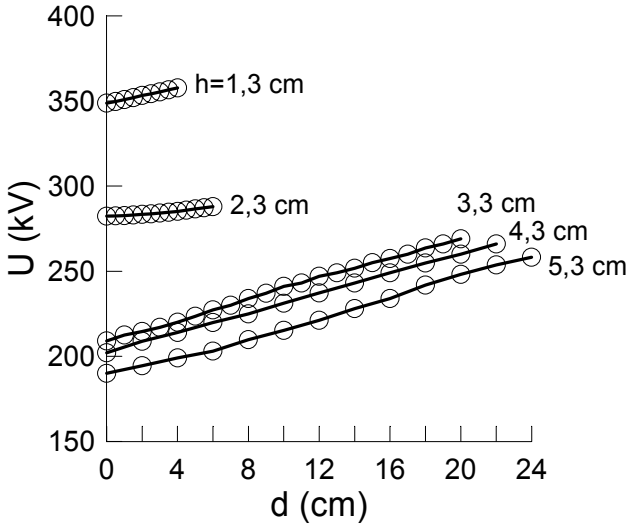

Figure 8: $U_d = f(d)$ for various h at negative impulse.

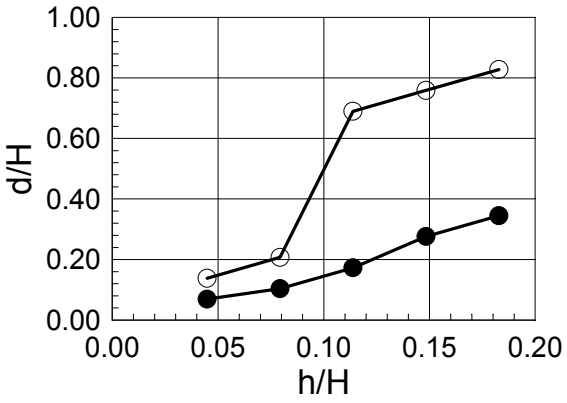

Figure 9: Variation of d/H with h/H
•: positive impulse
o: negative impulse

III. CONCLUSION

From an overview of the test results together with the associated observations the following conclusions can be emphasized.

1. The 50% sparkover voltage increases with the horizontal distance from the axis of pilot electrode in both polarities.
2. After a certain critical horizontal distance, the discharge occurs between the cloud electrode and the building model electrode for positive impulse voltages while between the cloud electrode and the building model electrode for negative impulse voltages.
3. If the buildings are distant enough from the pilot discharge, the possibility of the lightning discharge is very small, even zero for the both polarity of impulses.
4. 50% sparkover voltages for the negative polarity is higher than those for positive voltages for fixed distances.
5. For a fixed building height the sparkover region of a negative discharge is wider than of a positive discharge.

It would be author's great gratitudes if this paper helps to improve the understandings of the relation between the polarity and effective region of the lightning.

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