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THE INFLUENCE OF THE CONDUCTIVE RING ON THE EFFECTIVE HEIGHT OF THE LIGHTNING ROD

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Abstract. *In this paper the experimental results of the examination, on the model, the influence of the concentric, conductive circle ring position on the effective height of the vertical lightning rod are given. The effective height is determined in relation to the vertical lightning rod without the ring. The height of the ring is changeable and was, in experiment, changed from zero to the height of the top of the lightning rod. The investigation is performed for a normal discharge case with the negative downward leader and also for a reversed case, the positive discharge coming from the cloud. The results of the experiment pointed out on negative influence of the ring, namely on decreasing of the effective height, and that was expected.*

*" Experiment is materialized doubt"
(S. Djulbabic)*

1. INTRODUCTION

All scientific research requires similar and specific theoretical models for constructive dialogue with the empirical data. For every new physical law, like and new supposition, obliged is the demand for an experimental revision. Only analytical solution has a shortage, because it could not establish the error on the obvious manner. The error which appears by the placed analytical model could be established only by an experiment, which contains also unknown factors, which are not included in the analytical model. The theoretical suppositions are valid only when they are confirmed with the corresponding experiment.

To reconcile some suppositions in connection with the effective height of the vertical

lightning rod with the conductive circle ring [1], was sated the experimental test on physical model. Some experimental researches in connection with atmospheric electrical discharges are very hard to realize. For a really nature of lightning, it should be realized with the length of at least one step of the stepped leader and its length is more than 50m [2]. Some effects are possible to test experimental on model. The effective height of the lightning rod with circle ring is very simple to test experimental on the model. The most interesting and the most numerous (more than 80%) are the downward lightning from the cloud toward earth, which brings negative electrical charges. The electrical discharge across the lightning has its own particularity and first of all it would some wards of its physics [3,4].

2. BRIEFLY ABOUT LIGHTNING AND LIGHTNING ROD

The purpose of the lightning rod, vertical conductive rod, is to protect the disposed surface on the earth from the lightning stroke, so to cause all strikes on its top, was introduced by Franklin in the year 1873. It was quickly accepted. From its appearing, many theories and hundreds of papers were presented in attempt to define the zone protected by the lightning rod. The lightning rod protective zones were generally determined on observations and experience. All these theories are different one from the other and depends on territories, what could be seen from heterogeneous different national regulations in connection with lightning protection. Further research and observation pointed out that the discharge over lightning occurs in successive strikes. Those strikes comes one after another over the same channel which is ionized with the first strike. Strike number in one lightning flash could be over 20, but the most are 3 to 5. The duration of the whole process is about 100 ms. Every strike has its introductory discharge which is named leader. The first introductory discharge, which transports negative electrical charge from cloud to the earth is stepped. The leader spark starts from cloud, crosses some way and stops. After time order of about 30 to 100 ms continues its way crossing distance about 100 m, and so on in the same way. It seems that the lightning with its first leader looks for the most convenient way for the main discharge and therefore curved and broken form the lightning channel. In this stage originates the branches of the spark. The velocity of individual steps is about 5×10^7 m/s and the average stepped leader velocity, together with the standstills is about 1.5×10^5 m/s [2,5].

Striking point of the lightning is not by anything determined in advance, at the beginning leader moving, but on the end when leader approaches to earth on about hundred meters [6]. This distance is called "striking distance" which depends, generally, on the electrical charge in the leader channel. When the leader approaches enough to the object or earth (on striking distance), due to electrical charge deposited in leader channel an electrical field on the object or earth exceeds critical value, starts positive connecting streamer (return stroke) with the velocity of about 5×10^7 m/s, which connects striking point (on object or earth) with the tip of the downmoving negative leader. The charges in the leader channel are neutralized during the return stroke process and this is the main discharge and main current carrier. After completing the first strike with the pause of about 30 ms comes second, third and others strikes. Each of this has also two discharges processes, introductory and the main. The leaders of the second and other strikes are not

stepped but continual and they quickly moves through the already ionized channel with previous strokes. It is very important to know that critical value of electrical field which could initiate the connecting streamer from earth is higher for negative than for the positive polarization [2].

3. EXPERIMENTAL TEST

Because we could not attain so high voltages, which can create so long spark to correspond at least one step of the stepped leader ($D \sim 100\text{m}$), it is not possible fully to achieve the nature of lightning. But there is possible some effects and behaviors experimental to check. Here belongs and effective hight of the vertical lightning rod with conductive ring. The experiments realized on the theory similarity have generally admitted scientific basis and the results are common valid.

For the experimental test the vertical lightning rod effective height, was made the model of the lightning rod with the conductive ring, which can move along the whole length of the lightning rod. The lightning rod model is placed on the conductive plate, which substitutes earth plane. Above lightning rod, in axis, was placed the downcoming leader electrode of which distance from the top of the lightning rod could be regulated. For effective height experiment the leader electrode must be in axis with the lightning rod electrode.

Idea for experiment is that for one determined distance (D) between tops of leader electrode and lightning rod electrode without ring to realize breakdown voltage U_0 . Further, with the same distance (D), only by lifting the conductive ring to achieve the breakdown with voltages U_1, U_2, U_3, \dots for different ring hights H_1, H_2, H_3, \dots . If the breakdown voltages are smaller than U_0 , it mean that the effective height such a lightning rod is increased and reverse if the voltages increased the effective height such a lightning rod decreases. First would be realized experimental measurement, which corresponds to the most numerous occurrences, when the leader electrode is negative and lightning rod electrode on positive potential and afterwards measuring with the reverse polarization.

The lightning rod electrode, length of 65 mm, was mounted on the large conductive plate, which approximated earth. Along the whole rod it was possible to move the concentric conductive ring the diameter of 32 mm. The leader electrode of large length was in axis with the rod electrode and it was possible to change the distance of its top from the lightning rod top. The distance, for the case of lightning rod without ring was $D_0 = 50$ mm and was not changed through the whole experiment. At this distance (D_0) and with the negative leader and positive lightning rod electrodes, the discharges realized at the voltage $U_0 = 45$ kV. Afterwards the ring was slowly moved higher and higher from zero to the lightning rod height. For every new height of the ring (H_1, H_2, H_3, \dots) was realized the discharge and was measured voltage of the discharge (U_1, U_2, U_3, \dots). The measuring results are given in Table 1.

Table 1.

Ring height H(mm)	0	40	55	60	65
Breakdown voltage U(kV)	45	47	52	57	66

On the Fig.1 - left, is shown electrodes position on the physical model for case the lightning rod without ring and right, the model of rod with ring. On the Fig.1 are also shown designation of dimensions.

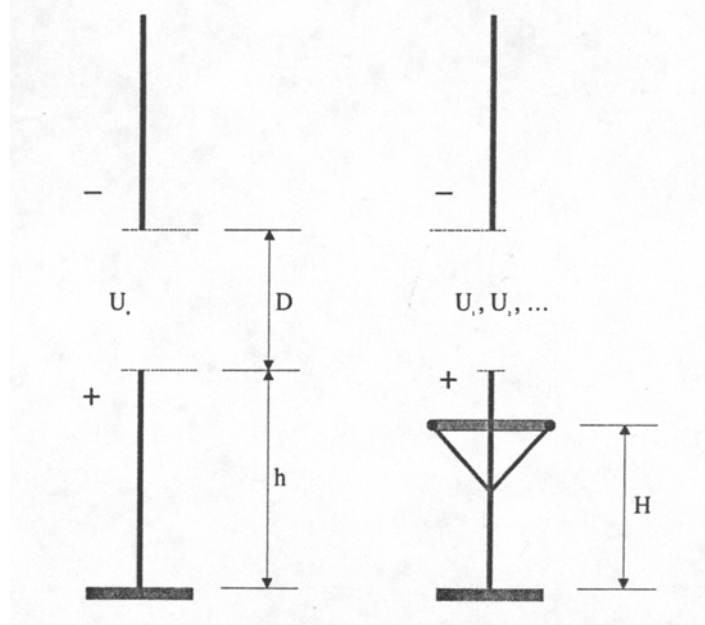


Fig.1. Position leader and lightning rod electrodes on experimental model.
Left lightning rod without and right with conductive ring.

Because, in experiment, the position of the electrodes remained the same and the voltage increased with the increasing the height (H) of the ring, it follows that the effective striking distance increases and effective height of the lightning rod with the ring decreases. In the Table 2 are given, on the base of measuring results in experiment, the effective height (h_{eff}) of the lightning rod in function of the ring height (H) on the base the taking the linear dependence on

$$D + h = D_{\text{caf}} + h_{\text{eff}} = 115 \text{ mm.}$$

Table 2.

Ring height	$H(\text{mm})$	0	40	55	60	65
Breakdown voltage	$U(\text{kV})$	45	47	52	57	66
Eff.striking distance	$D_{\text{eff}}(\text{mm})$	50	53	58	63	70
Eff.height lightn.rod	$h_{\text{eff}}(\text{mm})$	65	62	57	52	45

On Fig 2 is given the diagram effective height of the lightning rod with the conductive ring in function of the conductive ring height. There is also performed an experiment with the reversed polarization, namely the leader electrode was positive and

lightning rod with ring on negative potential. Experiment shows that, in this case, the height of the conductive ring does not influence on the break voltage so does not influence on the effective height of the lightning rod. During the whole experiment, in this case, the voltage was not remarkably changed and it was about 45 kV.

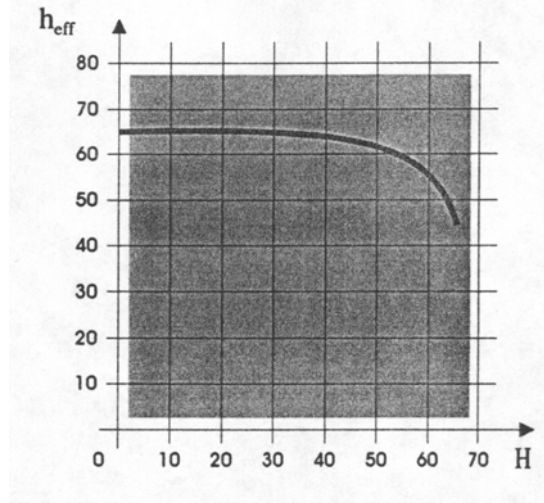


Fig.2. Diagram effective height of the vertical lightning rod in function of the conductive ring high H.

4. COMMENT AND CONCLUSION

The experimental results are expected. Namely, the electrical discharge always starts from the positive electrode, for which we need smaller critical electrical field in comparison with the critical field for discharge from negative electrode. In case of the positive lightning rod, from its top starts connecting streamer (discharge) when on its top electrical field reaches the critical value. As much the ring height increases and approaches the lightning rod top so much the electrical field on its top decreases, so it is necessary greater and greater voltage between electrodes, to create critical electrical field on the lightning rod top, from which starts connecting streamer (discharge). This is quite obvious, because by set up the conductive ring near the top of the lightning rod, the peak effect sinks and stops, because then comes to the deformity the equipotential surfaces its rarefing and decreasing the electrical field.

In the case when the leader electrode is positive and lightning rod electrode on a large plate is negative, the measuring results show that ring position on the rod has no influence on the discharge voltages, because in a general configuration, the ring which is near plate (earth) does not influence on electrical field on remote positive leader electrode from which now starts discharge.

The results of the experiment pointed out on negative influence of the ring, namely on decreasing the effective height of such a lightning rod with the conductive ring.

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UTICAJ PROVODNOG PRSTENA NA EFEKTIVNU VISINU GROMOBRANA

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U radu su dati eksperimentalni rezultati istraživanja, na modelu, uticaja visine postavljanja koncentričnog provodnog kružnog prstena na efektivnu visinu gromobrana. Efektivna visina je određivana u odnosu na visinu gromobranske hvataljke bez prstena. Visina prstena je promenljiva i menjana je od nule do visine vrha gromobranske hvataljke. Istraživanja su vršena za uglavnom normalna pražnjenja sa negativnim silaznim liderom kao i za obrnut slučaj pozitivnog dolazećeg pražnjenja iz oblaka. Rezultati eksperimenta ukazuju na negativan uticaj prstena tj. na smanjenje efektivne visine, što se i očekivalo.