A NEW APPROACH TO THE DETERMINATION OF THE STRIKING DISTANCE FROM THE LIGHTNING CHANNEL PHOTOS

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ABSTRACT

The paper is concerned with the emphasis of the possible influence the stepped leader movement on the value of the striking distance. The numerical values of the striking distances are most frequently verified from the lightning channel photos. There is some explanations for dispersion of the striking distance which appears specilly on the tall structures.Unusualy long striking distance, may be influenced by the positive space charge or prior upward flashes. One more indefiniteness which may have inlfuence in estimation the striking distance is a complex charge motion in the leader channel. Through introduction of two tipes charge motion it is shown possible shortening of the striking distance seen on the lightning channel photos.

INTRODUCTION

In conection with the protecting space of a lightning rod the wide accepted electrogeometric model deals with the striking distance. Thay are more different numerical values of the striking distance from different authors. This different values, results from the different consideration of the critical value of electrical field, distribution of the electrical charge in the leader channel and so on. The numerical values of the striking distances is usualy verify from the photos of the lightning channel, after the sharp bend in channel and simultaneous measurement or estimation of lightning current. Some measurements of the striking disstance trough photos of channel show a significant dispersion [1], wath brought in doubt the relations between crest current and striking distance. Some explanations for dispersion of striking distance includes the space charge by tall structures [2]. It had be shown that periodical inordinate striking distances are, only apparent and that phenomenon could be occur on the tall structures and is influenced by the positive space charge from pont discharge or prior upward flashes [3].

In [4,5] the autors of this paper are introduced the two tipes of movement of the steped leader and pointed out that movement of the stepped leader may have influence on the estimation of the striking distance lenth from the photos of the lightning channel.

STRIKING DISTANCE

They are some definitions of striking distance. But all of them may be represented as: striking distance is the distance between the tip of the downmoving leader and the point on the earth or structure when, under electrical charge deposited in leader channel, electrical field reaches a critical value on the earth or structure. From point on earth or structure,

when electrical field reaches critical value, starts positiv conecting streamer (return stroke), which conects striking point and the tip of the downmoving negative leader. This is the lenght of the last step in the lightning development. It depends, generaly of the electrical charge in the leader channel. The striking pont is not by anything determined in advance, but only by critical electrical field intensity due to downmoving leader. The charges in the leader channel are neutralized during the return stroke process. The crest of the lightning current depends on this charge. It follows that the striking distance could be introduced like function on crest lightning current. The determination of striking distance in function of lightning current was subject of many investigators. For the practical calculations, relation between striking distance r in m and crest value of the lightning current I in kA can be presented in the simplified form

$$r = kI^{p}.$$

Constants k and p have different values, what depends on the authors, and start from 3.3 to 10.6 for k and from 0.51 to 0.85 for p. The different values of the striking distance, for the same crest current, results from the different consideration of critical value of the electrical field, distribution of the charge in the leader channel and so on.

The point where the leader channel and the upward streamer meet, could be see in same photographs according the sharp bend in the lightning channel. From such a photos taken from two directions the striking distance could be determinated-estimated. By simultaneous taking od photographs and current measurement or magnitude current estimation from the lightning current effect, the accuracy of the proposed matematical expression for striking distance in function of lightning current may be examined. Some measurements of striking distance trough photographs of chaneel show a significant dispersion, what brought in doubt the relations between crest current and striking distance.

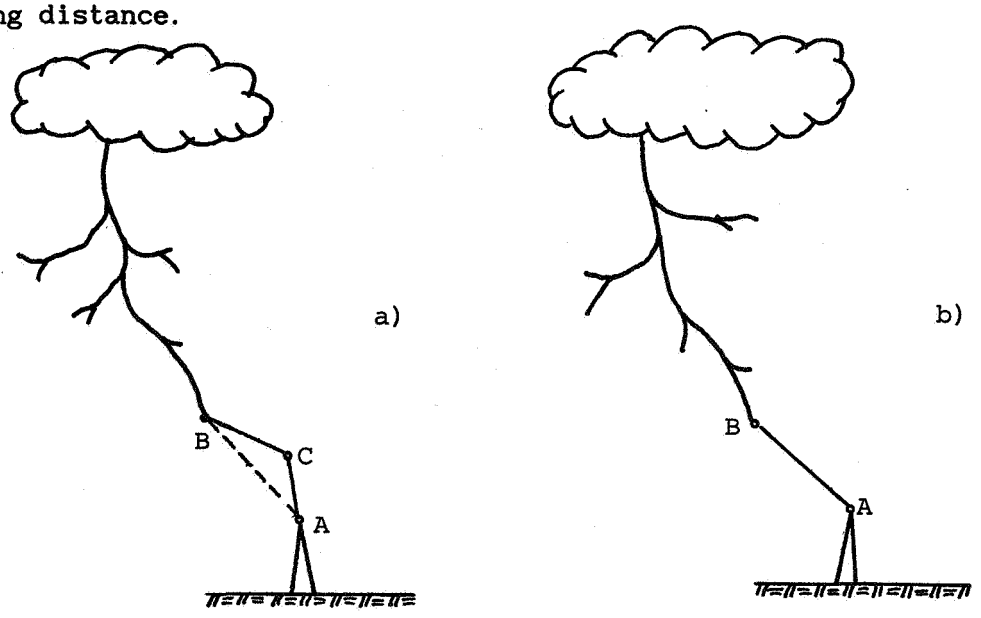

Fig. 1 Paths of the lightning fllash: a) Case of inordinate seen striking distance; b) Normal case

Some explanations for dispersion of striking distance includes the space charge by tall structures. It had be shown that periodical inordinate striking distance are, only apparent and that phenomenon could be occur on the tall structures and is influenced by the positive space charge from point discharge or prior upward flaches. For the mechanism proposed by Mousa [3], photos of the lightning channel show two deviation points in the path of the lightning channel befor it terminates on the structure. In Fig. 1 are given two possible cases. Fig. 1a shows the situation when last step of downmoving leader conects structure over spark (AC) from prior upward flash and Fig. 1b when is this spark extinguished. In the first case striking distance is not AB but BC like in case b (BA). Posibility for the first case is greater for the short-time rate (flashes/minute). According Erikson, for the first case (Fig. 1a) the striking distance would be doted line (AB).

INFLUENCE OF THE STEPPED LEADER

According to the photographs from the Bays cammera and measuring the electrical field on the earth, the cloud-ground discharge is initiated by streamer that develops downwords in a series of steps. Each of this steps observed as a sudden increase in luminosity of the channel of the ionized air at the tip of the streamer. This streamer is called stepped leader. The spark in its moving toward ground get over some distance, stops and after short time interval continue to move. The lenght of each step is about 50 m. After completing a step the tip of the streamers appears to pause for a time of the order 50 μs, and the new step being much brighter then the rest of the streamer. When stepped leader in its moving, approaches the ground, starts the positive conecting streamer from the earth to the stepped leader. This conecting streamer, which is initiated by the critical electrical field, from the electrical sharge in the channel of the downmoving stepped leader, conects striking point with the leader channel. The stepped leader approaches the ground at the average velosity at about $1,5 \times 10^5$ m/s. The second one ist velosity of the individual step motion value of about 5×10^7 m/s.

They are more theory of the stepped leader, but it could be concluded that all of them includes that the average velosity for a negatively charged downmoving stepped leader is about $1,5 \times 10^5$ m/s, like the velosity of the pilot streamer. The pilot streamer, which prepares the way for the step proces by ionizing the air, moves continualy. The mean velosity of individual steps is about 5×10^7 m/s, much higher then average velosity of the stepped leader. Time intervals between individual steps is about 50 μs. Velocity of the conecting streamer is about 5×10^7 m/s, like velosity of individual steps. Let us denote: V_1 - velocity of the pilot streamer propagation also average velocity of the stepped leader, V_2 - the velosity of the individual steps trough the already prepared channel by the pilot streamer and V_s - the velosity of the conecting streamer. The mean values of velocities are: $V_1=1,5 \times 10^5$ m/s; $V_2=5 \times 10^7$ m/s; $V_s=5 \times 10^7$ m/s.

Now we have to distinguish two tipes: tip of the pilot streamer moving

with the velocity V_1 and tip of the individual step in the stepped leader moving with velocity V_2. It is possible that position of both tipes may initiate the conecting streamer from the striking point because the both of them bears the charge. It is not the same which tip and from which position due the critical field on the striking point. If it is a tip of the individual step we have to take in consideration that it has the velocity like conecting streamer and it has already prepared way for its motion.

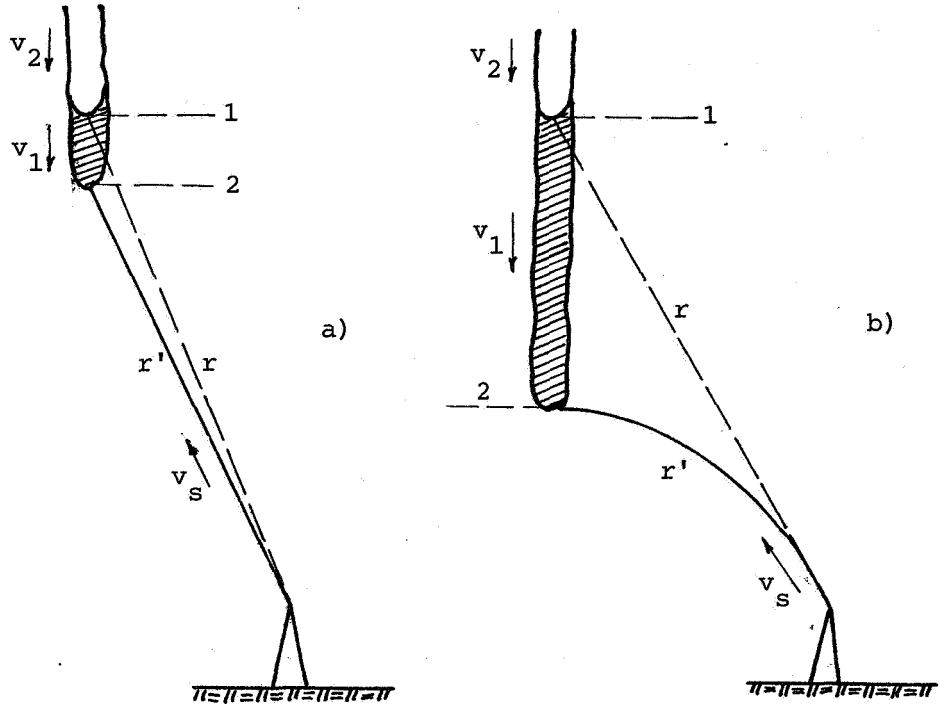

Fig. 2. Tip positions of stepped leader when starts conecting streamer: a) Case r≅r; b) Case r'>r

Fig. 2a shows position of individual step near to end of prepared way by pilot streamer, when is conected streamer iniciated. Bending of channel could be much sooner and there is not big difference between r and r'.

Fig. 2b shows position of individual step tip iniciating conecting streamer, when the tip is in begining of its motion. The both, step and conecting streamer moves with equal velocities ($V_2=V_s$). The way of downmoving leader is determinated. Meeting point "2" of two streamers, which is seen on the photographs like bend of channel is nearer to the striking point and the striking distance on the photographs is r'instead r. It is possible to see this channel with two deviation.

Dispersion of the striking distance are in both directions. Greater striking distances then expected, got from photos of the channel, are explained with the positive space charge and could be seen on photos with two deviation points. Our suggestion is that shorter striking distances could be explained with two tipes with different velocities in the stepped leader (shown in Fig. 2).

In Fig. 3 are given two known examples of the lightning channel photos. If they are very strong strokes it could be taken that from point D the

downmowing leader initiates the conecting streamer which in beginning has direction toward point D (part AC). Step of the stepped leader moves along prepared channel (DB) by pilot streamer. The conecting streamer from A turn over C to B. But the some shape of the lightning channel could be in more way interpreted. Above metioned striking distance could be AD. According to Erikson definition striking distance is AB, according Mousa is BC and classical definition is AC.

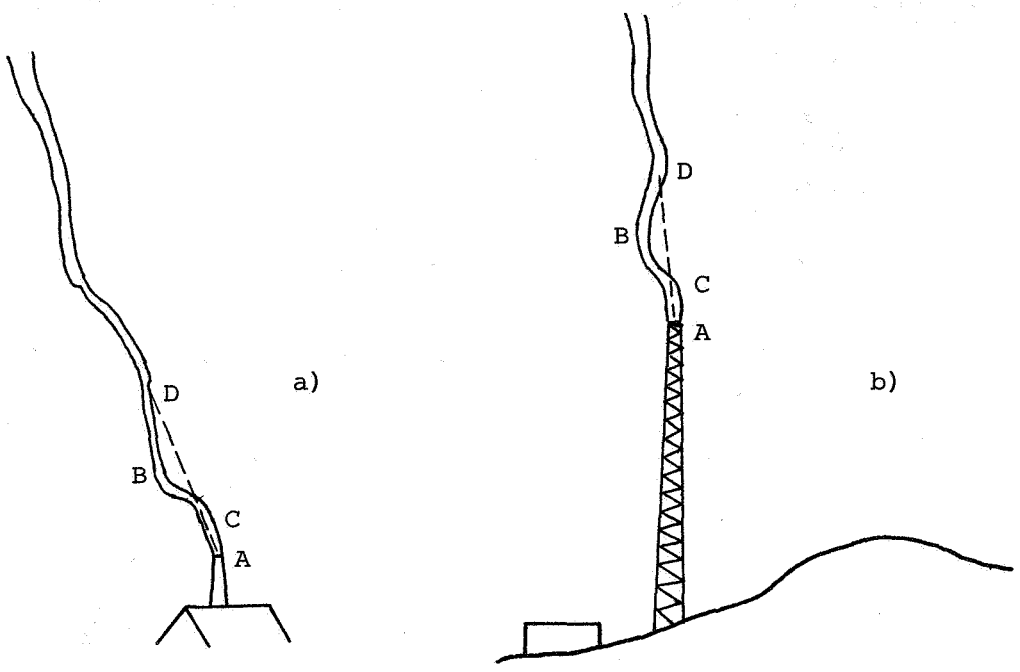

Fig. 3. The striking stroke in a) Chiminey in Britain and b) tower in Monte Orsa.

CONCLUSION

Some estimation or measurement the striking distance from the photos of the lightning channel shows a significant dispersion in both directions from established relations. Approaching to the more correct estimation in some cases is taking in accont the remainder sparc of prior upward flashes as an extension of the structure. This could be seen on the lightning channel photos with two deviation points. Trough the introduction of two tipes with different velocities in the stepped leader is shown possible influence of its movement in estimation the striking distance. The movement the step of the stepped leader along the channel already prepared by the pilot streamer could be seen on the photos like shorter striking distance. To get more precisely striking distance from the lightning channel photos it must be taken in consideration all effects including also the shape of the channel and intensity of the lightning current.

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