

LIGHTNING PROTECTOR WITH IGNITION DEVICE WITH
SLIDING ELECTRICAL DISCHARGE ALONG A DIELECTRIC

The present invention relates in general to systems for providing protection against lightning, and more particularly to a novel lightning conductor having an initiator device that uses a sliding electrical discharge along a dielectric.

A particularly advantageous application of the invention lies in providing protection against lightning strikes to buildings, private houses, blocks of flats, factories, and in general any zone, any person, any structure or any equipment which it is desired to provide with such protection.

In addition, a particularly advantageous application of the invention lies in providing direct protection against lightning for equipment disposed on conducting metal structures, e.g. telecommunications antennas. It reinforces protection of high tension and medium tension cables on electricity pylons by reinforcing the effectiveness of guard cables and by improving the capture of lightning strikes by the pylons themselves.

A conventional lightning conductor of the Franklin rod or Franklin spike type comprises a metal rod having one end connected to ground and having its other end in the form of a sharp point.

Such a lightning conductor operates as follows. When a storm cloud forms, the atmospheric electric field over the ground increases up to values of about 10 kilovolts per meter (kV/m). A corona effect then occurs at the point of the Franklin rod. Subsequently, a lightning strike begins by a descending leader forming inside the storm cloud and leaping towards the ground. Simultaneously with the cloud leader moving down towards the ground, the ionization of the air in the vicinity of the Franklin point due to the corona effect continues to increase. When the downward-travelling leader reaches an altitude of about 100 meters above the Franklin point, the electric field that it develops in a broad area around the rod exceeds a minimum value of the order of a few hundreds of kilovolts per meter. The corona effect discharge, hitherto localized close to the point suddenly transforms into a rising leader or discharge that is characterized by a succession of waves of ionization separated by rest periods or "dark periods". This phenomenon is also called the "random corona effect". For even greater values of the electric field, the rising leader begins to propagate without discontinuity and subsequently meets the descending leader. The sooner a continuous rising leader is developed, the further the junction point between the two opposite leaders from the Franklin rod.

The main drawback of a lightning conductor of the Franklin rod type lies in the long duration of the start-up period during which the random corona effect takes place. As a result, the continuous rising leader develops late and so the encounter between the two leaders takes place close to the Franklin rod.

A technical solution to this problem is to fit the Franklin rod with an initiator device that is capable of contributing to eliminating the rest periods or dark periods during the development of the rising leader, thereby artificially reducing the length of time required for starting the continuous rising leader.

To this end, Document EP-0 228 984 discloses an air spark-gap lightning conductor comprising a metal rod connected to ground and surrounded by a hollow shell likewise made of metal. The rod has one

of its ends connected to ground and has a point at its opposite end that emerges to the outside through a circular opening provided in the hollow shell. The shell is insulated from the metal rod by air, such that an air gap is defined between the circular opening in the shell and the point of the rod. Furthermore, it is necessary for the shell to be connected to the central rod by an isolating resistance of high impedance.

Thus, when a storm cloud is to be found near the above-mentioned lightning conductor and a descending leader comes near to said lightning conductor, the metal shell charges electrically so as to reach a critical potential above which a spark forms from the shell and propagates across the air gap to the point of the rod. This spark discharges the metal shell.

The operation of the electrical initiator device in that lightning conductor is random. The spark that forms across the gap between the rod and the metal shell arises randomly in time and in space and in "premature manner" at the point of the rod.

Document FR-2 620 581 teaches a lightning conductor installation that includes a hollow rod connected to ground, with an electrical conductor disposed therein and electrically isolated from the rod, the conductor projecting beyond one of the ends thereof for connection to complex means adapted to take up atmospheric potential so as to give rise to spark-over phenomena between the conductor and the rod.

In addition, Document EP-0 096 655 teaches a lightning conductor installation that comprises a rod connected to ground and an electrically conductive member including a first portion that extends radially relative to the rod and that terminates in points that make it easy to take up atmospheric electrical potential, and a second portion forming an electrode that extends away from the first portion towards the rod along a curved path that is disposed at a short distance from the rod so that, in stormy weather, an electrical discharge is established between said electrode and the rod.

Finally, Document FR-2 043 220 discloses a lightning conductor installation that includes a rod connected to ground and a radioactive source of beta radiation that is carried by the rod close to its end.

Those three lightning conductor installations are complex and do not operate in satisfactory manner.

The present invention proposes a novel lightning conductor having an electrical initiator device that seeks to solve the above-mentioned problems of the prior art.

More particularly, the present invention provides a lightning conductor having an electric discharge initiator device, the conductor comprising:

- a central electrode having a free end and an end connected to ground;

- a part made of insulating material, surrounding the central electrode, and having an outer surface that touches the free end of the central electrode continuously;

- an electrically conductive outer electrode partially covering said outer surface of the insulating part in such a manner that a non-covered portion of said outer surface that connects to the free end of the central electrode defines a bridge of insulating material

between said outer electrode and the free end of the central electrode.

said bridge being suitable, during discharge of said outer electrode, for guiding a spark between the electrically conductive outer electrode that is electrically charged under appropriate atmospheric conditions, and the free end of the central electrode.

Thus, when a descending leader coming from a storm cloud approaches the lightning conductor of the invention, the electrically conductive outer electrode charges by electrical induction until its electrical potential reaches a critical value above which a spark forms between the electrically conductive outer electrode and the free end of the central electrode which is advantageously in the form of a point, thereby enabling plasma to be created in the vicinity of the point of the central electrode. This plasma associated with the intense electric field that extends in the vicinity of the end of the central electrode constitutes the first step in developing a rising leader. The discharge spark from the outer electrode is intense and vigorous since it slides along the outside surface of the insulating part, and more particularly over the bridge between the outer electrode and the point of the central electrode, said bridge forming a springboard for the spark between the outer electrode and the free end of the central electrode.

In the lightning conductor of the invention, the value of the electric field required for self-propagation of the trigger spark can be as little as ten times smaller than the corresponding field value in the lightning conductors of the above-mentioned prior art techniques.

Preferably, according to the invention, said outer surface of the insulating part includes at least one portion whose shape is essentially convex towards the outside, and the electrically conductive outer electrode rests on said convex portion of the outer surface.

It should be specified that it is advantageous for said outer electrode to have no projecting portions that could favor the formation of parasitic sparks at locations other than between the free end of the central electrode and the outer electrode. The shape and the disposition of the insulating part and of the electrically conductive outer electrode are designed so that the spark forms from the edge of said outer electrode, adjacent to the springboard-forming bridge of insulating material, to the free end of the central electrode, and propagates over said bridge to the central electrode.

In a preferred embodiment of the lightning conductor of the invention, the insulating part is in the form of a hemisphere whose outer surface is essentially convex towards the outside and which supports the electrically conductive outer electrode, and the portion of the outer surface that is not covered by the outer electrode and that forms the bridge between said electrode and the central electrode is in the form of a ramp that is generally concave towards the outside.

In addition, in the above specified embodiment, said outer electrode is in the form of a hollow spherical cap.

In an embodiment of the invention, the outer electrode and/or the central electrode is/are made of copper or of a copper-based alloy.

In a second embodiment of the invention, the outer electrode and/or the central electrode is/are made of iron or of an iron-based alloy.

In a third embodiment of the invention, the outer electrode and/or the central electrode is/are made of aluminum or an aluminum-based alloy.

In another embodiment of the invention, the outer electrode is a metal deposit on a fraction of the outer surface of the insulating part.

In an embodiment of the invention, the insulating part is a dielectric constituted by a polymer material.

In another embodiment of the invention, the insulating part is a dielectric constituted by a ceramic material.

The following description made with reference to the accompanying drawings relates to non-limiting embodiments of the invention and serves to show clearly what the invention consists in and how it may be implemented. In the drawings:

Figure 1 is a vertical section view through a first embodiment of a lightning conductor of the invention;

Figure 2 is a vertical section view through a second embodiment of a lightning conductor of the invention;

Figure 3 is a vertical section view through a third embodiment of a lightning conductor of the invention;

Figure 4 is a vertical section view through a fourth embodiment of a lightning conductor of the invention;

Figure 5 is a vertical section view through a fifth embodiment of a lightning conductor of the invention;

Figure 6 is a curve showing variations in predischage current as a function of time for a conventional Franklin rod type lightning conductor put under electrical conditions appropriate for being struck by lightning;

Figure 7 is a curve showing variations in predischage current as a function of time for a lightning conductor having an air spark-gap and subjected to conditions identical to those of Figure 6; and

Figure 8 is a curve showing variations in predischage current as a function of time for a lightning conductor of the invention subjected to the same electrical conditions as Figure 6.

As a preliminary point, it should be observed that from one Figure to another, elements that are identical or similar are designated, whenever possible, by the same reference symbols, and they are not described again every time.

Figure 1 shows a lightning conductor 100 having an initiator device using a sliding electrical discharge. This lightning conductor 100 comprises a vertical central electrode 110 made of metal having an end 112 for connection to ground and a free end 111 that forms a point that points towards the sky. In addition, the lightning conductor 100 comprises both an insulating part 121 surrounding the central electrode 110 and having a circularly symmetrical outside surface 121a adjacent to the free end 111 of the central electrode 110, and also an electrically conductive outer electrode 122 that covers a portion of the outer surface 121a of the insulating part 121.

More precisely, the insulating part 121 is a solid dielectric that, in this case, is in the form of a hemisphere whose said outer surface 121a is essentially convex towards the outside and that

includes a portion 121'a in the form of an outwardly concave ramp that touches said free end 111 of the central electrode 110 continuously, i.e. without leaving any gaps. This dielectric may advantageously be made of a polymer material or of a ceramic material, or even of a juxtaposition of both types of material. It should be specified that the dielectric material constituting the insulating part advantageously has very high electrical resistivity, good mechanical stiffness, and characteristics of non-wettability and of resistance to environmental conditions.

Furthermore, said convex outer surface 121a is partially covered by a hollow spherical cap made of metal that forms an electrically conductive outer electrode 122 fitting the convex shape of the outer surface 121a of the dielectric 121. The outer electrode 122 does not cover the ramp-shaped portion 121'a of the said outer surface 121. Said outer electrode 122 includes a circular top opening 122a such that said portion 121'a emerges through said opening 122a towards the outside, thus forming a bridge of insulating material that extends between the circular edge 122'a of the top circular opening 122a in the outer electrode 122 and the free end 111 of the central electrode 110. The outer electrode 122 may be made of iron, copper, or aluminum, or of an alloy based on iron, copper, or aluminum. In a variant embodiment, the outer electrode 122 is constituted by a deposit of metal formed directly on that portion of the outer surface 121a of the insulating part 121 that is to be covered.

In a typical example, the metal central electrode 110 has a diameter of about 10 mm to 20 mm, the hemispherical insulating part 121 has a maximum diameter of 25 cm, and the bridge of insulating material 121'a has a length lying in the range 1 mm to 50 mm. It should be observed that the outer electrode 122 may be of several different thicknesses. Furthermore, it advantageously includes no projecting portions since that would impede proper operation of the lightning conductor as explained below.

Figure 2 shows a first variant embodiment of the Figure 1 lightning conductor. In this variant, the part 121 of insulating material is in the form of a body of revolution that flares away from the bottom of the central electrode 110 towards the top of said electrode and that then runs into the point 111. The insulating part 121 has a rounded top portion 121" whose outer surface is convex towards the outside. This top portion 121" extends to the point 111 by means of a frustoconical connection portion 121' whose outer surface 121'a is in the form of a ramp that is concave towards the outside. The conductive outer electrode 122 in the form of a hollow spherical cap partially overlies the insulating part 121, bearing against the rounded portion 121" of the insulating part 121 so that a portion of the outer surface of said rounded portion 121" is the only contact surface between the outer electrode 122 and the insulating part 121. The outer surface 121'a of the frustoconical portion 121' of the insulating part 121 is not covered by the outer electrode, and it extends between said outer electrode and the point 111 of the central electrode 110.

In a variant embodiment shown in Figure 3, the outer electrode 122 is in the form of a torus 124 that surrounds the insulating part 121. This torus has a connection skirt 124a that partially overlies

the outer surface of the rounded top portion 121" of the part 121 made of insulating material.

In another variant embodiment, as shown in Figure 4, the outer electrode 122 is a spherical zone that partially overlies the rounded top portion 121" of the insulating part 121. This spherical zone is connected by electrical wires 131 to metal spheres 130 that are secured to the insulating part 121. More precisely, the insulating part 121 has arms that project radially, with a metal sphere 130 being mounted at the end of each arm.

In Figure 5, there can be seen another variant embodiment of the lightning conductor of Figure 1, which is more suitable for being installed on horizontal conductors, such as the guard cables of electricity lines or the horizontal conductors of mesh cages. In this variant, the insulating part 121 extends beneath the outer electrode 122 in the form of an insulating portion 123 which is generally in the form of a rectangular block in this case. This extension portion 123 may be added on to the insulating part 121 or it may be formed integrally therewith. In addition, as can be seen in Figure 5, the insulation extending portion 123 includes a horizontal passage 140 for receiving a horizontal conductor perpendicularly to the vertical central electrode 110. It may be observed that the horizontal passage 140 is disposed at a distance d from the outer electrode 122 that is about twice as great as the distance between the edge 122'a of the outer electrode 122 and the point 111 of the central electrode 110. The central electrode 110 is connected to the conductor disposed inside the passage 140 by connection means 150 (in this case a metal tab). The conductor is itself connected to ground.

It will be observed that in another variant (not shown), it is possible to envisage the end 112 of the electrode projecting towards the inside of the passage 140 so that the horizontal conductor installed in said passage comes into contact with the vertical electrode. In addition, it would also be observed that the outer surface of the insulating extension portion 123 is not covered by the outer electrode.

The operation of the lightning conductor, e.g. as shown in Figure 1, is now described.

When a descending leader comes close to a lightning conductor as shown in Figure 1 and having an initiator device, then the external electric field increases and the electrically conductive outer electrode 122 charges electrically until it reaches a critical potential above which a spark forms going from the circular edge 122'a of the opening 122a of said outer electrode 122 and slides over the bridge of insulating material 121'a until it reaches the point 111 of the metal central electrode 110.

This spark makes it possible to create a plasma in the vicinity of the point 111 of the central electrode 110, and said plasma (which is associated with the intense electric field that exists in the vicinity of the point 111 of the central electrode 110) causes a rising leader to be formed that travels to meet the descending leader. When the two opposite leaders meet, a conductive channel is established between the cloud and ground. The lightning current then flows to ground via the metal central electrode.

It should be specified that the bridge 121'a serves to guide the discharge spark between the outer electrode 122 and the central

electrode 110, said spark then being much more vigorous than in other lightning conductors of the prior art that use an air spark-gap.

In addition, the electric field required for causing the trigger spark to propagate can be as little as ten times smaller than the field required in lightning conductors that use an air spark-gap.

Furthermore, the fact that the outer electrode 122 has no projecting portions advantageously serves to avoid parasitic sparks forming at locations other than the circular edge 122'a of said outer electrode.

Figures 6, 7, and 8 relate to three different lightning conductors put under identical electrical and lightning conditions, and they comprise, respectively, a conventional Franklin rod (not shown), a lightning conductor having an air spark-gap (not shown), and a lightning conductor having an initiator device of the invention, with the experimental curves reproducing variations in the predischage current at the point of the various devices as a function of time.

More precisely, all three lightning conductors were tested in the laboratory using a test procedure that simulates lightning conditions. That is to say an ambient electric field was created simulating the fields produced by the distribution of charge in a storm cloud, and a pulse field was created representing the field induced by the approach of the descending leader in the vicinity of the ground. These two fields were superposed and applied to a plate (not shown in the figures) situated above the lightning conductor in question. The ambient field is represented by a DC field of the order of 10 kV/m to 20 kV/m between ground and the plate, and the pulse field was created by a Marx impulse generator that delivered a driving wave having a long rise time lying in the range 200 microseconds to 1,000 microseconds.

Under the above-specified conditions, variation in the predischage current at the point of each of the lightning conductors was observed as a function of time until a rising discharge was formed and caused to propagate from the point of the lightning conductor to the top plate.

When using a conventional Franklin rod, as can be seen in Figure 6, the curve shows changes in the predischage current as a function of time from the instants at which pulse voltages were applied at $t=0$ and $t=250$ microseconds, in the form of random pulses A corresponding to unsuccessful attempts at starting the rising discharge. The discharge leaves the point of the Franklin rod at a time close to 250 microseconds and then travels through the space from the point towards the plate.

For a lightning conductor having an air spark-gap, as shown in Figure 7, the rising discharge propagates from the point at an instant lying in the range 250 microseconds to 300 microseconds, which is later than for the conventional Franklin rod (see Figure 6). As in Figure 6, it may be observed that random pulses of type A are recorded. The three observed fine B-type pulses correspond to initiation of the air spark-gap, with the first two corresponding to premature operation of the air spark-gap, too soon for starting the rising discharge.

In contrast, as shown in Figure 8, with a lightning conductor having an initiator device using a sliding electrical discharge along a dielectric of the invention (as shown in Figure 1), discharge takes

place much sooner, between 150 microseconds and 200 microseconds. Firing of the initiator system as marked by a large fine pulse C at 160 microseconds enables a rising discharge to be started immediately. A statistical study of this lightning conductor has shown that the anticipated triggering of the rising discharge is regular and reliable compared with the Franklin rod type conductor or with the above-mentioned conductor having an air spark-gap.

By comparing Figures 6 and 8, it can be seen that there is a very significant reduction in the time required for the capture discharge to be developed, due to its initiation being anticipated, said capture discharge taking place from a lightning conductor of the invention earlier than would the capture discharge from a conventional Franklin type lightning conductor put under identical lighting conditions. The lightning conductor of the invention thus makes it possible to trigger capture discharge for initiation field intensities that are much smaller than those which initiate a conventional Franklin type rod.

It should be observed that the various embodiments shown in the figures described can be combined with one another.

For example, it may be envisaged that the insulating part has a facettted outer surface that is partially covered by the outer electrode. Such an insulating part would also include an essentially frustoconical top portion that extends the facettted portion to the top end of the central electrode.

CLAIMS

1/ A lightning conductor (100) having an electric discharge initiator device, for providing protection against lightning, the conductor comprising:

a central electrode (110) having a free end (111) and an end (112) connected to ground;

a part (121) made of insulating material, surrounding the central electrode (110), and having an outer surface (121a) that touches the free end (111) of the central electrode (110) continuously;

an electrically conductive outer electrode (122) partially covering said outer surface (121a) of the insulating part (121) in such a manner that a non-covered portion (121'a) of said outer surface (121a) that connects to the free end (111) of the central electrode defines a bridge of insulating material between said outer electrode (122) and the free end (111) of the central electrode (110),

said bridge being suitable, during discharge of said outer electrode (122), for guiding a spark between the electrically conductive outer electrode (122) that is electrically charged under appropriate atmospheric conditions, and the free end (111) of the central electrode (110).

2/ A lightning conductor according to claim 1, characterized in that said outer surface (121a) of the insulating part (121) includes at least one portion whose shape is essentially convex towards the outside, and in that the electrically conductive outer electrode (122) rests on said convex portion of the outer surface (121a).

3/ A lightning conductor according to claim 1 or 2, characterized in that the insulating part (121) is in the form of a hemisphere whose outer surface (121a) is essentially convex towards the outside and which supports the electrically conductive outer electrode (122), and in that the portion (121'a) of the outer surface (121a) that is not covered by the outer electrode (122) and that forms the bridge between said electrode and the central electrode (110) is in the form of a ramp that is generally concave towards the outside.

4/ A lightning conductor according to claim 3, characterized in that the insulating part (121) is a hemisphere having a maximum diameter equal to about 25 centimeters, and in that the bridge of insulating material has a length lying in the range 1 mm to 50 mm.

5/ A lightning conductor according to claim 1 or 2, characterized in that the insulating part (121) is of a shape that flares upwards going away from the central electrode (110), and that includes a rounded top portion (121'') having an outer surface that is convex towards the outside and that supports the conductive outer electrode (122), and a connection portion between the outer electrode (122) and the free end (111) of the central electrode, which connection portion is frustoconical in shape.

6/ A lightning conductor according to any one of claims 1 to 5, characterized in that said outer electrode (122) is in the form of a hollow spherical cap.

7/ A lightning conductor according to claim 5, characterized in that the outer electrode (122) is in the form of a spherical zone (123) covering at least a portion of the outer surface of the rounded top portion (121") of the insulating part (121), and is electrically associated with metal spheres (130) secured to the insulating part (121).

8/ A lightning conductor according to claim 5, characterized in that the outer electrode (122) is in the form of a torus (124) that surrounds the insulating part (121) and that includes a connecting skirt (124a) which partially covers the outer surface (121a) of the rounded top portion (121") of the part (121) made of insulating material.

9/ A lightning conductor according to any one of claims 1 to 8, characterized in that the part (121) of insulating material extends beneath the outer electrode (122) in the form of an insulating portion (123), said extension portion (123) comprising a horizontal passage (140) for receiving a horizontal conductor, and in that it includes connection means (150) between the central electrode (110) and the horizontal conductor placed in said passage (140).

10/ A lightning conductor according to any one of claims 1 to 9, characterized in that the outer electrode (122) is made of copper or of a copper-based alloy.

11/ A lightning conductor according to any one of claims 1 to 9, characterized in that the outer electrode (122) is made of iron or of an iron-based alloy.

12/ A lightning conductor according to any one of claims 1 to 9, characterized in that the outer electrode (122) is made of aluminum or of an aluminum-based alloy.

13/ A lightning conductor according to any one of claims 1 to 9, characterized in that the outer electrode (122) is a metal deposit formed on a portion of the outer surface (121a) of the insulating part (121).

14/ A lightning conductor according to any one of claims 1 to 13, characterized in that the central electrode (110) is made of iron or of an iron-based alloy.

15/ A lightning conductor according to any one of claims 1 to 13, characterized in that the central electrode (110) is made of copper or of a copper-based alloy.

16/ A lightning conductor according to any one of claims 1 to 13, characterized in that the central electrode (110) is made of aluminum or of an aluminum-based alloy.

17/ A lightning conductor according to any one of claims 1 to 16, characterized in that the insulating part (121) is made of a dielectric constituted by a polymer material.

18/ A lightning conductor according to any one of claims 1 to 16, characterized in that the insulating part (121) is made of a dielectric constituted by a ceramic material.