

APPARATUS FOR LIGHTNING PROTECTION WITH SPRING-TYPE ELECTRODES AND AN ELECTRIC POWER LINE PROVIDED WITH SUCH AN APPARATUS

Technical field

5 The present invention relates to apparatuses for lightning protection of electrical equipment and supporting structures. The invention can be used for protection of, for example, high-voltage apparatuses, insulators and other elements of high-voltage electric power lines, electrical equipment and other constructions and devices requiring lightning protection.

Prior art

10 The patent RU2299508 discloses a current-shunting apparatus for lightning protection of electrical equipment or electric power line elements. The apparatus comprises an insulating body made of a solid dielectric, at least two main electrodes
15 mechanically coupled with the insulating body, a rod-shaped electrode set inside the insulating body along its axis and electrically connected to one of the main electrodes, and several intermediate electrodes set on the insulating body between the main electrodes with a mutual displacement along at least a longitudinal axis of the insulating body.

20 The said patent has an assumption that the intermediate electrodes are made as rings allowing to be put on the insulating body having preferably a circular section. Such intermediate electrodes are sufficiently easily set on the insulating body, for example, by putting the rings on the said body. At the same time a disadvantage of this intermediate electrode's type is that fastening of the rings on the insulating body requires additional actions such as, for example, a ring crimping.

25 Another variant of the intermediate electrode is a clamp which could be substantially easily fixated on the insulating body in a prescribed position, however clamp usage stipulates for increased labor expenditures for their arrangement along with increased complexity of the intermediate electrode resulting in increased cost.

Summary of the invention

30 Embodiments of the present invention seek to provide a simple structure of the intermediate electrode having low manufacturing and operating costs and providing reliable fixation of the intermediate electrode on the insulating body without additional actions.

35 According to an aspect of the present invention, there is provided an apparatus for lightning protection of electrical equipment or electric power line elements. The apparatus

comprises an insulating body made of a dielectric, at least two main electrodes mechanically coupled with the insulating body, a rod-shaped electrode set inside the insulating body along its axis and electrically connected to one of the main electrodes, and two or more intermediate electrodes set on the insulating body between the main electrodes with mutual displacement along at least a longitudinal axis of the insulating body, characterized in that at least part of the intermediate electrodes is made as wire springs settable on the insulating body. An inner size of the springs is advantageously smaller than an outer size of the insulating body. In this case the inner size of the spring is determined when the spring is unstrained.

In an embodiment of the present invention at least one intermediate electrode made as the wire spring comprises at least two projections formed by ends of the wire used for the spring fabrication, wherein a length of each projection is less than a distance between an end plane of the spring and an adjacent intermediate electrode. The springs are considered to be wound (coil), wherein wire material is chosen or treated in such a way that the spring being strained takes or tend to take a shape of the spring before deformation.

The said projections are preferably disposed at opposite end sides of the spring and advantageously mutually displaced along its circumference at least at 90° . The mutual displacement of the projections along the spring circumference is optimally equal to 180° .

A surface of each intermediate electrode excluding the projections or end surfaces of the wire used for the spring manufacturing can be covered with insulation layer.

In one of the embodiments the insulating body is made of a solid dielectric. The insulating body and the rod-shaped electrode preferably have a circular cross-section.

According to another aspect of the present invention, there is provided an electric power line as well. The electric power line comprises towers provided with insulators, at least one current-carrying wire coupled with the insulators by fastening devices and at least one apparatus for lightning protection of electric power line elements. At least one main electrode of the said apparatus connected to the protected element directly or via spark gap, and at least one other main electrode connected to ground directly or via spark gap, characterized in that the apparatus for lightning protection is made as the apparatus according to the above mentioned variants.

A technical result of the embodiments of the present invention is providing the simple structure of the intermediate electrode having low manufacturing and operating costs and providing reliable fixation of the intermediate electrode on the insulating body without any additional actions. This results in increased reliability and the simplified structure of the lightning

stroke protecting means. Embodiments of the present invention provide with the electric power line having reliable lightning protection due to the fact that the line is equipped with the reliable and low-cost apparatuses for lightning protection operable at low discharge voltage.

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Brief description of drawings

Fig. 1 schematically shows the apparatus according to the invention.

Fig. 2 shows the intermediate electrode according to the invention.

Fig. 3 shows the preferable embodiment of the intermediate electrode according to
10 the invention.

Best mode for carrying out the invention

Fig. 1 partly shows a 10 kV electric power line lightning-proofed with use of the lightning protection apparatus according to the invention. In this embodiment the lightning
15 protection apparatus is made as a cable segment having an insulation forming the insulating body 1 and a metallic strand used as the rod-shaped electrode 6. A metallic tube used as the second main electrode 2 is set in the middle part of the cable segment over the insulating body 1 and end terminals of the cable are used as the first main electrodes 2. Ends of the cable strand (i.e. the rod-shaped electrode 6) are fastened to a
20 wire 4 of the electric power line by means of clamps. The second main electrode 3 is fastened to an insulator set at the tower 13 of the electric power line by means of a bracket and a wire. An electrode 14 forming a spark gap with the second main electrode 3 (a length of the gap is 2 cm for the 10 kV electric power line) is set at the tower 13 as well. Metallic springs forming the intermediate electrodes 5 are set on the cable segment.

25 When the wire 4 of the electric power line is loaded with overvoltage, an electric potential of the cable strand (i.e. the rod-shaped electrode 6) connected to the wire 4 becomes high via the end terminals. Due to strong capacitive coupling of the rod-shaped electrode 6 and the metallic tube, an electric potential of this tube becomes high as well. An electric potential of the tower 13 of the electric power line and the electrode 14
30 connected to it is equal to zero since the tower 13 is grounded. A potential difference (high voltage) arises between the second main electrode 3 (the metallic tube) and the electrode 14 and the air spark gap is disrupted under the influence of the potential difference. After that the overvoltage is applied between the cable strand and the second main electrode 3. Under the influence of this overvoltage, channels of creeping discharge run on a cable
35 surface in one or both directions depending on an overvoltage value and sequentially arc over gaps between the springs, i.e. between the intermediate electrodes 5. Once the overvoltage passed, a follow current of industrial frequency flows through the channels,

heats this bridging channels and converts spark discharge into an arc. Due to dividing the arc into separate sections (small arcs) by the intermediate electrodes 5, the small arcs are cooled by the cool metallic intermediate electrodes. Owing to this fact, a current-shunting apparatus with intermediate electrodes quenches a sufficiently greater current than a
 5 current-shunting apparatus without intermediate electrodes. In other words the current-shunting apparatus according to the invention is more arc-suppressive while a structure is simple (and low-cost, accordingly).

When the current-shunting apparatus is loaded with overvoltage U , a disruption of the solid insulation between the intermediate electrodes 5 and the rod-shaped electrode 6
 10 is not acceptable, i.e. discharge between the main electrodes should run only through the intermediate electrodes and air gaps. Thus, a discharge voltage of the current-shunting apparatus (spark gaps disposed on its surface) should be less than a disruption voltage of the solid insulation $U_d < U_{dr}$. The disruption voltage can be expresses in terms of an insulation thickness Δ (i.e. a thickness of a insulating body layer) and a disruptive strength
 15 E_{dr} of a material used for insulating body manufacturing: $U_{dr} = \Delta \cdot E_{dr}$. Therefore, the insulation thickness should meet the requirement

$$\Delta > \frac{U_d}{E_{dr}}.$$

Hence, to provide necessary electrical strength of the insulation, a thickness Δ_i of the insulating body 1 between the rod-shaped electrode 6 and an i intermediate electrode
 20 5 ($i=1,2,\dots,m$) should be selected on the basis of the following requirement:

$$\Delta_i > \frac{U_{d,i}}{E_{dr}},$$

where $U_{d,i}$ is a discharge voltage between the i intermediate electrode and the second main electrode; and E_{dr} is the disruptive strength of the insulation material used for insulating body 1 manufacturing.

To decrease production costs of the apparatus and to additionally decrease the discharge voltages, the insulation thickness between the intermediate electrodes 5 and the rod-shaped electrode 6 can be different for different intermediate electrodes. The further the i intermediate electrode is from the second main electrode 3, the larger the discharge voltage $U_{d,i}$ between them should be and therefore the thicker the insulation
 30 layer Δ_i should be. In other words, the insulation thickness between the rod-shaped electrode 6 and the i intermediate electrode 5 should directly relate to a distance between the i intermediate electrode and the second main electrode (in a general case, a main electrode electrically connected to the rod-shaped electrode).

The closer the rod-shaped electrode 6 is to the intermediate electrode 5, the larger
 35 capacity C_0 between the electrodes 5 and 6 is and the lower the discharge voltages of the

current-shunting apparatus are. Therefore, to decrease the discharge voltages, it is expedient to dispose the rod-shaped electrode 6 along the whole length of the insulating body 1 in such a way where each intermediate electrode 5 is opposite to the rod-shaped electrode 6. However there could be cases, where assurance of insulation disruption elimination is more important than lowering of discharge voltages. Along with this the rod-shaped electrode can be disposed not along the whole length of the insulating body 1 but spans only a part of it. In this variant a part of the intermediate electrodes 5 disposed closer to the second main electrode is opposite to the rod-shaped electrode 6 and another part of the intermediate electrodes is disposed with displacement along a longitudinal axis of the rod-shaped electrode. At the same time distances between these intermediate electrodes 5 and an end of the rod-shaped electrode 6 (insulation thicknesses) are much larger than if the rod-shaped electrode was disposed along the whole length of the insulating body 1. In such a case the discharge voltages of the apparatus according to the invention are lower as compared with analogous apparatuses but not to such an extent as in the case of the rod-shaped electrode 6 disposed along the whole length of the insulating body 1. Apparently, the maximal increase of the thicknesses of the insulation between the intermediate electrodes 5 and the rod-shaped electrode 6 along with decrease of the discharge voltages is achieved by disposing the rod-shaped electrode opposite to the only intermediate electrode 5 closest to the second main electrode 3.

As shown on the Fig. 2, the intermediate electrodes 5 in the form of wire springs are put on the insulating body 1, which can be made of both a solid dielectric and dielectric being elastic to some extent. The springs 5 are disposed at the insulating body 1 with mutual displacement along the longitudinal axis of the insulating body 1.

The said spring can have inner size being less than outer size of the insulating body 1, i.e. in a case where the insulating body is made as cylinder (as well as the rod-shaped electrode) and the springs are round, an inner diameter of the springs is advantageously less than an outer diameter of the insulating body. As a result, the springs 5 can be put on the insulating body tightly, wherein a positioning of the spring 5 along the insulating body can be made easily if the spring is deformed, for example, by a facilitating device gripping spring ends and the inner diameter of the spring is increased in such a way.

In order to facilitate operations with springs during their positioning along the insulating body, a spring 15 comprises two projections 16 formed by ends of a wire used for the spring 15 manufacturing, wherein a length of each projection 16 is chosen to be less than a distance between an end plane of the spring and an adjacent intermediate electrode. Due to these projections, the spring deformation directed to diameter increase

can be carried out much easier through gripping the spring projections by the device facilitating its deformation.

The said projections 16 are preferable arranged at opposite end sides of the spring 15, as it is shown on Fig. 3, and advantageously mutually displaced along its circumference at least at 90° . In the optimal variant the mutual displacement of the projections along the spring circumference is 180° , this case is shown on Fig. 3.

A surface of each intermediate electrode can be covered with insulation layer with the exception of the projections or end surfaces of the wire.

Owing to changeability of the inner size of the intermediate electrode made as a spring, the electrode can be located on the insulating body without any obstacles if the inner size of the spring is increased through its deformation up to a size larger than the outer size of the insulating body. Having the spring located at a desired position on the insulating body, the spring deformation can be terminated and the spring's inner size becomes smaller than the outer size of the insulating body resulting in reliable fixation of the intermediate electrode.

If the projections of the intermediate electrodes are arranged with the mutual displacement along the spring circumference, spark discharges can be located at different sides of the insulating body, which prevents joining of the spark discharges into one and thus facilitates arc suppression.

CLAIMS:

1. An apparatus for lightning protection of elements of an electrical equipment or an electric power line, the apparatus comprises an insulating body made of a dielectric, at least two main electrodes mechanically coupled with the insulating body, a rod-shaped electrode set inside the insulating body along its axis and electrically connected to one of the main electrodes, and two or more intermediate electrodes set on the insulating body between the main electrodes with a mutual displacement along at least a longitudinal axis of the insulating body, **characterized** in that at least a part of the intermediate electrodes is made as wire springs.
2. The apparatus of claim 1, wherein an inner size of the springs is smaller than an outer size of the insulating body.
3. The apparatus of claim 1, wherein at least one intermediate electrode made as the wire spring comprises at least two projections formed by ends of the wire used for the spring manufacturing, wherein a length of each projection is less than a distance between an end plane of the spring and an adjacent intermediate electrode.
4. The apparatus of claim 3, wherein the projections are disposed at opposite end sides of the spring.
5. The apparatus of claim 4, wherein the projections are mutually displaced along a spring circumference at least at 90°.
6. The apparatus of claim 4, wherein the mutual displacement of the projections along a spring circumference is equal to 180°.
7. The apparatus of claim 3, wherein a surface of each intermediate electrode excluding the projections or end surfaces of the wire is covered with insulation layer.
8. The apparatus of claim 1, wherein the insulating body is made of a solid dielectric.
9. The apparatus of claim 1, wherein the insulating body and the rod-shaped electrode have a circular cross-section.
10. An electric power line comprising towers provided with insulators, at least one current-carrying wire coupled with the insulators by fastening devices and at least one apparatus for lightning protection of elements of the electric power line, wherein at least one main electrode of the apparatus connected to the protected element directly or via spark gap, and at least one other main electrode connected to ground directly or via spark gap, **characterized** in that the apparatus for lightning protection is made according to any of claims 1 to 9.