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(71) Applicant: **NGK INSULATORS, LTD.**
2-56 Suda-cho, Mizuho-ku
Nagoya-shi, Aichi-ken 467(JP)

(72) Inventor: **Nakayama, Tetsuya**
98 Aza-Iwaishi, Ohaza-Minamiyana
Fuso-cho, Niwa-gun, Aichi-ken 480-01(JP)

(74) Representative: **Stoner, Gerard Patrick et al**
Mewburn Ellis 2 Cursitor Street
London EC4A 1BO(GB)

(54) **Arrestor unit.**

(57) An arrestor unit is disclosed for protecting a power transmission line against lightening surges. The arrestor unit includes a discharge electrode that is electrically separated from the power transmission line by a series air gap. A plurality of non-linear resistors are provided between the discharge electrode and an electrical ground. A container is provided to house the non-linear resistors. The container is arranged to discharge residual electric charges that accumulate in the non-linear resistors. The discharge constant of the container and non-linear resistors is set to a value less than the time interval between voltage surges of a normal multiple surge lightning current.

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The present invention relates to arrester units for power transmission lines. More particularly, the invention relates to an arrester unit container structure that is arranged to discharge residual electrostatic charges that accumulate in the non-linear resistors. The container structure is capable of discharging the resistors during the surge intervals that occur in multiple surge lightening currents.

Japanese Unexamined Patent Publication No. 2-170385 discloses an arrester unit having a series gap as illustrated in Figs. 4 to 6. Fig. 5 shows the equivalent circuit diagram of the arrester unit illustrated in Fig. 4. Fig. 6 shows an arrester unit embodied in accordance with the block diagram illustrated in Fig. 5.

As shown in these figures, the arrester unit of the prior art has a series gap 51 of an electrostatic capacity C_1 and a non-linear resistor 52(R) in an insulating housing 50. A resistor 53(r) for discharging residual electric charge is electrically connected in parallel with the non-linear resistor 52 respectively through seals 54.

The discharge time constant of the arrester unit depends on the electrostatic capacitance C_2 of the resistor 53 and the non-linear resistor 52. The discharge time constant is set to be less than the time interval between voltage surges of a normal multiple surge lightning current. With this arrangement, the residual voltage of a first surge can be discharged before the appearance of the next surge even when the arrester unit interrupts the follow current during the low voltage period between surges in a multiple surge lightning current. Additionally, the flashover voltage of the series gap 51 can be maintained at a constant level.

In the described arrangement, the arrester unit includes an internal series gap 51, within its insulating housing 50. Thus, the operational line voltage is applied to the arrester unit. With this arrangement, it is inevitable that the insulator housing 50 will be subjected to the operational line voltage. For this reason, the insulating housing 50 should have sufficient insulating strength to withstand the continuous use of the arrester unit, without current leakage.

If the resistor 53 is housed in parallel with the non-linear resistor 52 within the insulating housing 50, the resultant arrester unit is too large in diameter and weight to be easily installed on power transmission lines.

It is therefore a main object of the present invention to provide a small and light arrester unit that includes a series gap, and which has good insulating characteristics during multiple surge lightening currents even when the exterior of the insulator is soiled by dirt and/or pollution.

By the invention, an arrester unit is provided for protecting a power transmission line against lightning surges. The arrester unit includes a discharge electrode that is electrically separated from the power transmission line by a series air gap. A plurality of non-linear resistors are provided between the discharge electrode and an electrical ground. A container is provided to house the non-linear resistors. The container is arranged to discharge residual electric charges that accumulate in the non-linear resistors. The discharge constant of the container and non-linear resistors is set to a value less than the time interval between voltage surges of a normal multiple surge lightning current.

The invention, together with the objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

Fig. 1 is a cross sectional view of an arrester unit which embodies the present invention.

Fig. 2 is a front view of the arrester unit shown in Fig. 1.

Fig. 3 is a diagram of the equivalent circuit of the arrester unit shown in Fig. 1.

Fig. 4 is a schematic diagram of an arresting unit of the prior art having a serial gap.

Fig. 5 is a diagram of the equivalent circuit of the arrester unit illustrated in Fig. 4.

Fig. 6 is a cross sectional view of an arrester unit of the prior art having a series gap as shown in Fig. 4.

In the following paragraphs, a detailed description is given of one embodiment of the present invention. As seen in Fig. 2, a suspension insulator 9 is suspended from the end of a support arm 2 that extends from a transmission tower 1. A power transmission line 5 is supported by the bottom part of the suspension insulator 3 via a support 4. Arc horns 6 and 7 are attached to the top and bottom ends of the suspension insulator 3 respectively to protect the suspension insulator 3 in the event of a flashover. A discharge electrode 9 is supported by the support 4.

An arresting insulator 8 is supported by the intermediate part of the support arm 2 via an adapter. A discharge electrode 10 is mounted to the bottom part of the arresting insulator 8, such that it is opposite to the discharge electrode 9 with a series air gap G existing therebetween. Arc horns 6A and 7A are mounted to the top and bottom end parts of the arresting insulator 8 respectively to protect the arresting insulator 8 from damage in the event of flashover.

In Fig. 1, the arresting insulator 8 includes a plurality of non-linear resistors 13 housed in a container 20. The container 20 further includes an inner wall 11 and an outer wall 21. The inner wall 11 is a cylindrical glass cloth made of fiberglass reinforced plastics impregnated with, for example, epoxy resin with carbon

black. The resistance of the container 20 can be controlled by adjusting the content of the carbon black in the epoxy resin of which the inner wall 11 is made. The outside circumference of the inner wall 11 is provided with a plurality of pressure release holes 12.

A plurality of non-linear resistors 13 are housed within the inner wall 11. The top and bottom ends of the inner wall 11 are sealed with end caps 14 and 15. The non-linear resistors are designed to pass a large current at lightening surge voltages, but only small currents at operational voltages. Thus, they can cut off follow currents in order to prevent a ground fault in the affected line. That is, they prevent the normal operational line currents (referred to as follow currents) from being grounded (i.e. a ground fault) through the arrestor unit after the lightening surge has past. In a preferred embodiment, the main material of the non-linear resistors 13 is zinc oxide (ZnO).

An upper seal 16 and a lower seal 17 are adhesively attached to the upper and lower ends of the inner wall 11 respectively by using adhesive 18. A coil spring 19 is set between the end cap 15 and the lower seal 17 at the bottom part of the non-linear resistors 13 in such a way that the end cap 15 and the lower seal 17 are electrically connected with a low impedance. A conductive foil shunt 100 extends between the top and bottom ends of the spring.

The outer wall 21 is fit airtight about the inner wall 11 and over the side walls of the upper seal 16 and the lower seal 17 by means of rubber molding. A plurality of sheds 21a are formed on the outer side of the outer wall 21.

In order to ensure long-time reliability, the same rubber material as that of the outer wall 21 is filled into the clearance between the non-linear resistors 13 and the inner wall 11 from the pressure release holes 12 at the time of molding.

A method suitable for determining the minimum allowable resistance R_{min} and maximum allowable resistance R_{max} of the container 20 is described hereafter. Fig. 3, shows the equivalent circuit of the arrestor unit in this preferred embodiment. In this equivalent circuit, the electrostatic capacity C_1 of the series air gap G, the total resistance r of the non-linear resistors 13, and the total resistance R of the container 20 are indicated. These should be set so that the discharge constant $C_2 \cdot R$ of the container 20 is smaller than the expected time interval τ between surges of a multiple surge lightning current. That is, $R < \tau / C_2$ in mathematical terms.

It is generally understood that the interval τ between surges of a multiple lightning surge, (i.e. the available discharge time) is in the range of 1ms to 10ms. Assuming that the interval τ is 1ms, the maximum allowable resistance R_{max} is obtained from an equation expressing the time constant ($\tau = C_2 \cdot R$). Table 1 shows R_{max} for several representative power transmission voltage ratings.

In Table 1, the minimum allowable resistance R_{min} is an experimentally determined resistance that is necessary to insure that the follow current will be interrupted. The experiment was based on an assumed maximum value of the allowable current of 5A (whereas the effective value is 3.5A).

Next, the function of the described arrestor unit will be explained in the following paragraphs. A lightning surge (which is caused by lightning striking the power transmission line 5) flows from the support 4 and the discharge electrode 9 and flashes over to the discharge electrode 10 through the series air gap G. This begins the discharge. Then, the lightning surge flows through the lower seal 17, the non-linear resistors 13, the upper seal 16, the adaptor and the support arm 2 and is discharged to the tower 1, which is grounded.

After the lightening surge has past, the normal line current would typically try to act as a follow current (i.e. following the lightening surge to ground). However, the resistance of the non-linear resistors 13 recovers after the lightening surge passes. Therefore, the follow current is interrupted by the recovered resistance of the non-linear resistors 13 and the series air gap G. This prevents a ground fault in the line.

After the lightning surge is applied to and discharged from the non-linear resistors 13, a residual electric charge will remain in the non-linear resistors 13. Since the arresting insulator 8 is insulated from the applied voltage side by the series air gap G, the residual charge cannot flow towards the applied voltage side. However, the resistance R of the container 20 is set so that the discharge constant $C_2 \cdot R$ of the container 20 is smaller than the surge interval τ . Therefore, the residual charge in the non-linear resistors 13 will drain through the container 20 within the specified time and is then discharged to the ground.

It is noted that if the residual charge is not drained, the arrestor unit will have a residual voltage. In this event, the voltage at the support 4 must be higher by a corresponding amount in order to reinitiate the flashover through the air gap G. On the other hand, in the present invention, since the residual voltage of the non-linear resistors 13 is discharged, when the next lightning surge occurs, the voltage differential necessary to initiate a flashover through the series air gap G is very similar to the voltage required to initiate the original flashover. Therefore, even if a multiple surge lightning current is encountered, the residual charge in the non-linear resistors 13 will be reduced sufficiently such that they appear substantially negligible. Thus the described arrestor unit has improved discharge characteristics.

Since the container 20 is electrically conductive, it equally distributes the voltage between the applied voltage side and to the grounded side. Because of this characteristic, the distributed voltage can be improved when the creeping surface of the container 20 has been soiled or otherwise polluted. Thus, the creeping flashover voltage characteristic can be improved. From a different point of view, when pollution withstand voltage is considered, the arresting insulator 8 can be decreased in size and weight from the existing arresting insulators by minimizing the increase in the creeping leak distance of the container 20. Furthermore, due to the same function, the creeping flashover voltage against the discharge voltage in the event of lightning surge can be improved, and the series air gap G of the arresting insulator 8 can be short-circuited.

In the present invention, the impedance of the arresting insulator 8 connected in series to the series air gap G is much smaller than that of the existing arresting insulators because of the fact that the container acts as a resistor R. As a result, the distributed voltage of the serial air gap is much larger and the lightning flashover voltage at the initial lightning surge application is lower in comparison with existing arrestor units. This means that, in comparison with the existing arrestor units, flashover at the arresting insulator side is easier because the flashover voltage of the arresting insulator is lower than that against lightning surge of the suspension insulator 3. In addition to the improvement in the arresting characteristic, the impedance of the arresting insulator falls as describe above. Furthermore, the electrostatic induction voltage caused by the operational line voltage falls, and thereby safety can be improved.

The present invention is not limited to the previously described embodiment and may be embodied in many other forms as well. Specific modifications include as follows:

(1) The inside circumference of the inner wall 11 and/or outer wall 21 can be coated with conductive paint. As a result, existing materials or parts can be used, saving the cost.

(2) The inner wall 11 is used in the afore-mentioned preferred embodiment. By dispensing with the inner wall 11 and reducing the resistance of the outer wall 21, an insulating tube made of a material which has the required mechanical strength, such as epoxy resin, can be applied to the arrestor unit of the present invention.

Therefore, the present examples and embodiments are to be considered as illustrative and not restrictive and the invention is not limited to the details given herein.

TABLE 1

Line voltage (kv)	33	66	77	110	154	187	220	275
Line voltage max. (kv)	36	72	84	120	168	204	240	300
Rmin. (k Ω)	11	21	24	35	48	44	52	65
Rmax (m Ω)	16	34	40	50	67	67	100	100
Electrostatic Capacity C2 (PF)	65	30	25	20	15	15	10	10

Claims

1. An arresting unit having a series air gap comprising a container housing a plurality of non-linear resistors and having the function of a resistor at least in its part to enable the discharge of residual electric charge, and said plurality of non-linear resistors being housed in said container, wherein the discharge constant which is dependent on the electrostatic capacity of said container and non-linear resistors is set to be not more than the rising up interval of the multiple lightning surge.

2. An arrestor unit according to claim 1, wherein said container comprises an inner wall made of electrically conductive synthetic resin and an outer wall airtightly formed with a plurality of sheds around the outside circumference of said inner wall by means of rubber molding.

3. An arrestor unit according to claim 1, wherein the resistance of said container is controlled by changing the carbon black content in said synthetic resin composing said inner wall.

4. An arrestor unit according to claim 1, wherein the resistance of said container is controlled by changing the carbon black content in said synthetic resin composing said outer wall.

5. An arrestor unit according to claim 3, wherein the resistance of said container is controlled by changing

the carbon black content in said synthetic resin composing said outer wall.

5

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Fig. 1

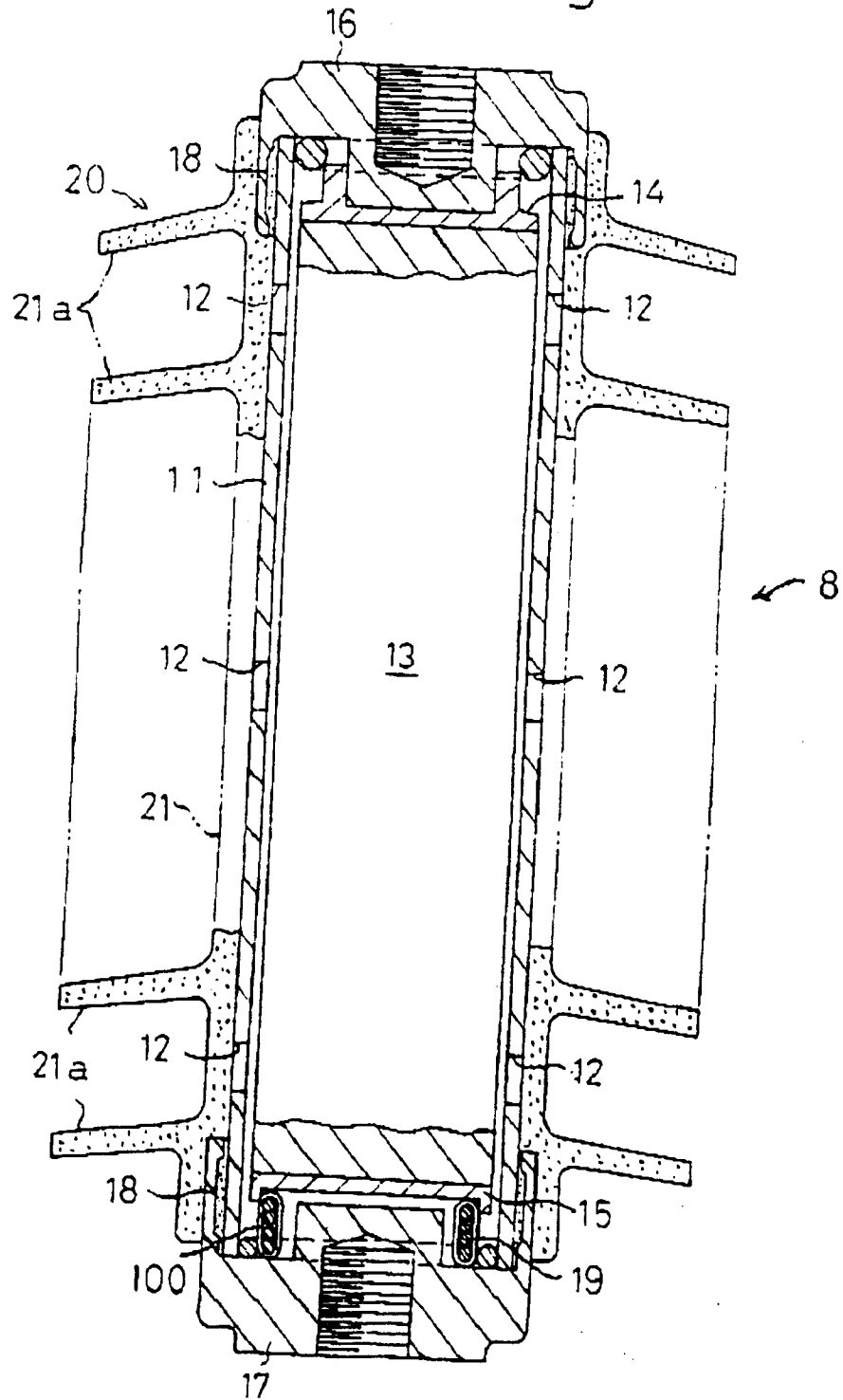


Fig. 2

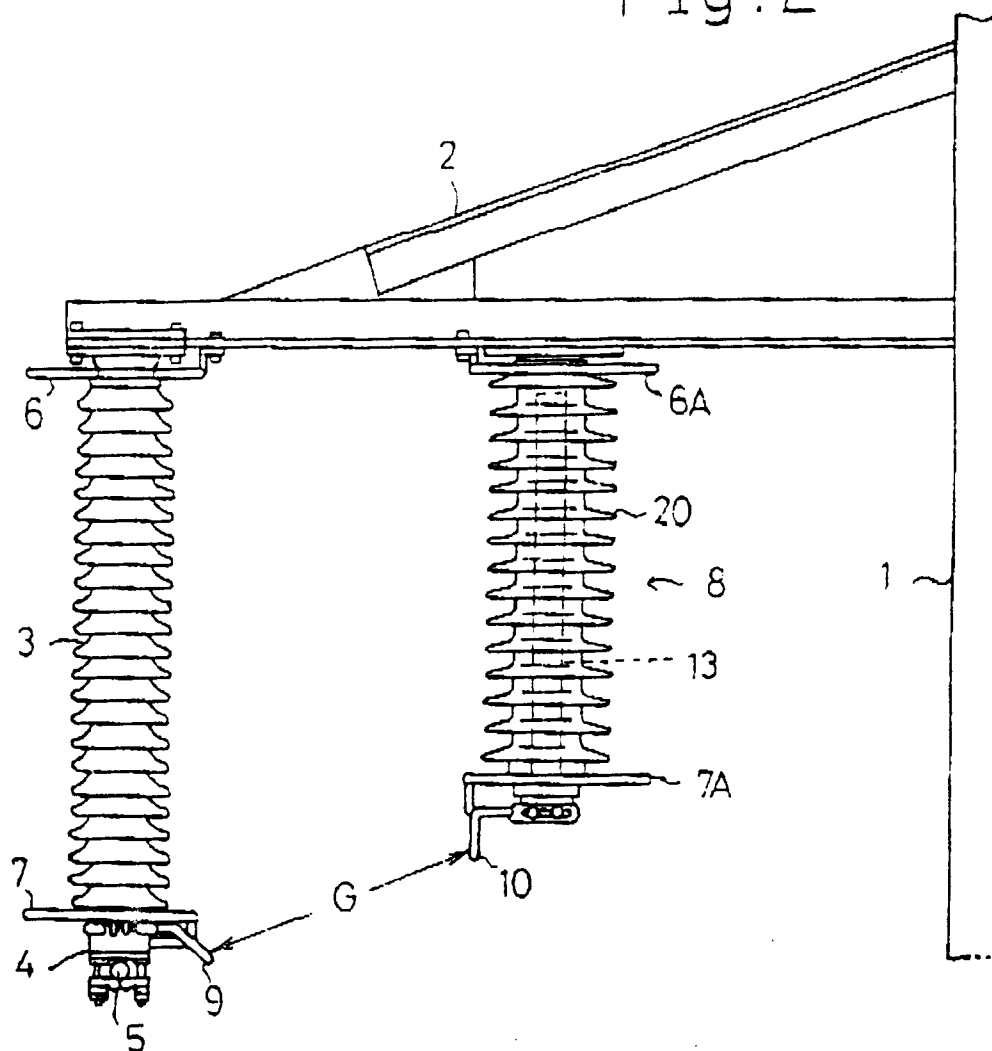


Fig. 3

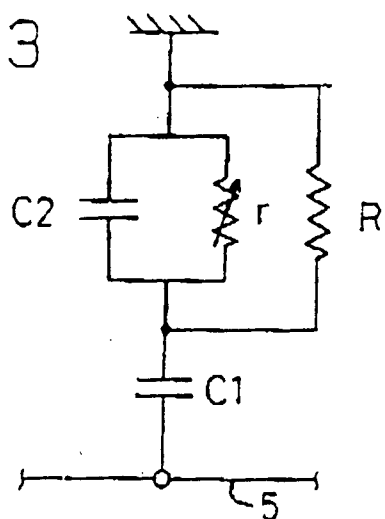


Fig.4

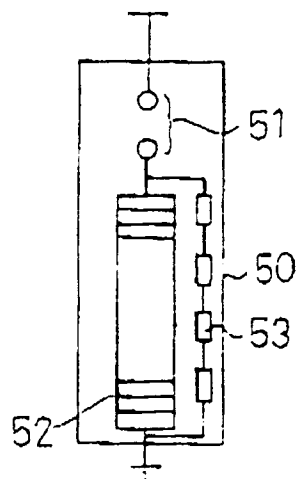


Fig.5

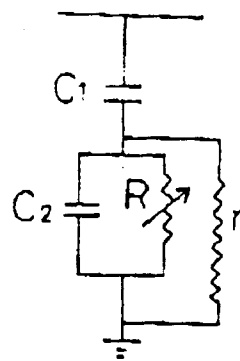


Fig.6

