

- [54] **SUPPLEMENTAL INSULATION WITH BYPASS IMPEDANCE FOR ELECTRICAL LINES**
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- [52] U.S. Cl..... **174/141 R**, 174/182, 174/209, 174/211, 338/7
- [51] Int. Cl..... **H01b 17/48**, H01b 17/50
- [58] Field of Search..... 174/139, 140 R, 140 C, 174/140 H, 140 S, 140 CR, 141 R, 141 C, 144-150, 182, 209, 211; 338/7, 9

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[57] **ABSTRACT**

This invention relates to insulator assemblies for electrical lines, which are provided with supplemental insulation covering the pins, caps, support or suspension fittings of these assemblies as well as parts of their support and suspension structures and of the conductors. In order to uniformize the voltage distribution over the insulators each cap is covered with an electrode connected through impedances to the electrodes on the neighboring insulator caps. The supplemental insulation may consist of silicone grease, insulating tape, or glass. The bypass impedance may consist of resistive, inductive or capacitive elements.

**4 Claims, 5 Drawing Figures**

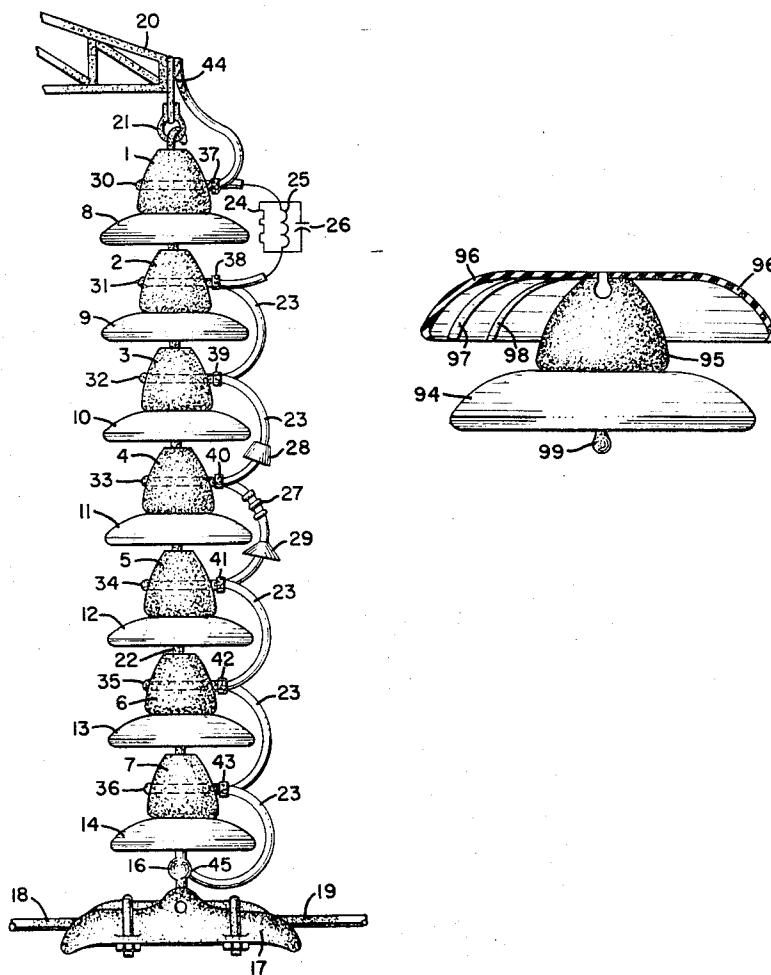


FIG. 1

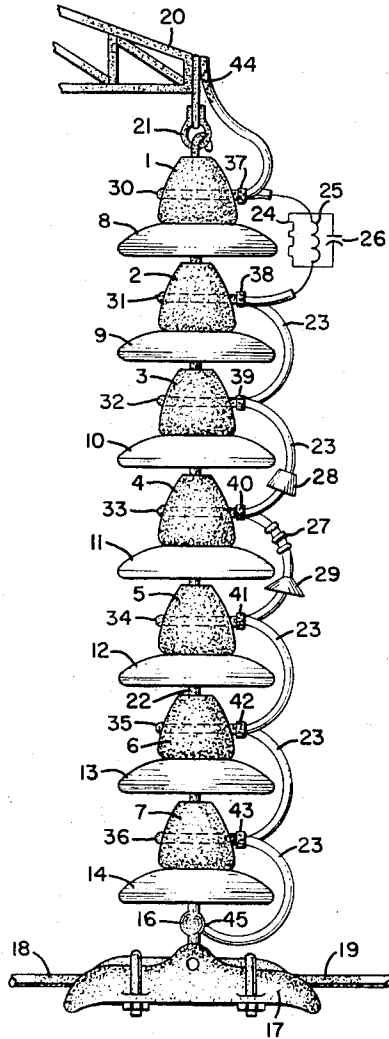


FIG. 2

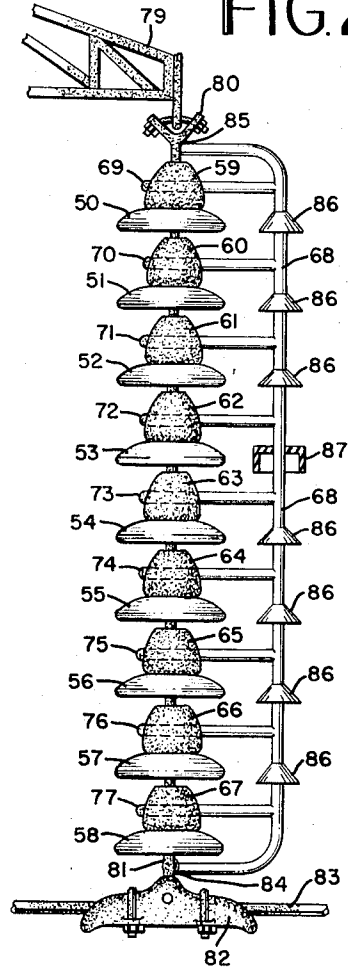


FIG. 3

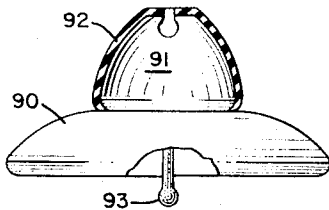


FIG. 4

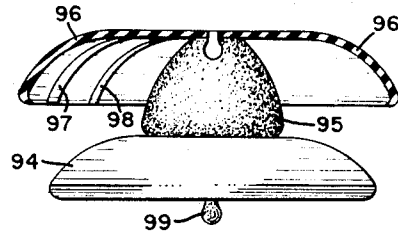
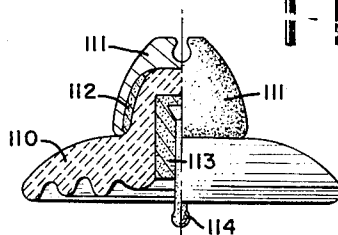


FIG. 5



## SUPPLEMENTAL INSULATION WITH BYPASS IMPEDANCE FOR ELECTRICAL LINES

The primary purpose of this invention is to increase the leakage impedance of insulator assemblies for electrical lines, and thereby increase the flash-over voltage of these assemblies.

The second purpose of this invention is to provide bypass impedances to insulation sections, such as insulator members, so that insulator fittings and other electrodes on the insulation are connected by means of these impedances to neighboring fittings and other electrodes at the insulation sections, in order to achieve a uniform voltage distribution over these sections.

The third purpose of this invention is to provide insulation for electrical lines, and particularly for EHV and UHV, which is de-sensitized against pollution.

Its fourth purpose is to reduce the ohmic losses due to the leakage current, and to reduce the corona losses, and thus to improve the efficiency of an electrical line to which this invention is applied.

The fifth purpose of this invention is to reduce the radio and television interferences caused by electrical lines.

The sixth purpose of this invention is to provide a convenient discharge path for conducting the overcharge due to lightning discharge or switching surge to ground.

Its seventh purpose is to increase the basic impulse levels of an electrical line against lightning and switching surge impulses.

A further purpose of this invention is to use the bypass impedance, in capacitive form, for compensation of some of the inductive impedance of an electrical line.

The ninth purpose of this invention is to provide a supplemental insulation that can be easily backfitted on existing electrical lines.

The tenth and final, but not the least, purpose of this invention is to make possible savings on the insulation of electrical lines by the use of the inexpensive supplemental insulation, which may increase the leakage path of the insulation to such extent that fog-type insulators may be replaced with ordinary insulators, and even these may be reduced in quantity.

The key idea of this invention is to cover the pins, caps, fittings, and part of the support, or of the suspension structure as well as part of the conductors with supplemental insulation in order to keep the leakage current at a magnitude below about 50 miliamperes, below which no insulator assembly flashover can occur, as experience has abundantly shown. The following groups of materials can be used for supplemental insulation.

1. Plastics, PVC, polyethylene, nylon, Mylar in melted or in diluted state.
2. Cement, gypsum, mortar, Transite (that is, a mixture of cement with asbestos fibers, or a mixture of cement with other organic or inorganic fibers).
3. Sulphur and sulphur compounds.
4. Vegetable oil, in pure form, or as an ingredient of paint.
5. Petroleum or coal products, heavy mineral oil, bitumen asphalt, tar, pitch, paraffine.
6. Silicone grease, petroleum jelly (petrolatum, Vaseline).

7. Rubber, latex, vulcanized rubber, rubber cement.

8. Laquer, shellac, enamel, cambric.

9. Cotton, wool, jute, silk.

10. Combinations of the above materials.

11. Glass fiber fabric, with or without silicone grease, is the material of choice for very high voltage lines.

The same goes for glass applied in liquid state. While some materials must be applied in a manufacturing plant, other materials can be used directly in the field.

The purpose of the bypass impedance is to uniformize the voltage distribution on the members of the insulator assembly. If the assembly contains no metallic parts, no shunt impedance is necessary. In such case, a conductive layer put on top of the supplemental insulation would only increase the leakage current, thereby the leakage losses, and reduce the amount of pollution that the insulator assembly may withstand without flashing over. But if the insulator assembly contains metallic fittings such as caps and pins, the non-uniform voltage distribution reduces the efficiency of the insulation by overstressing the insulator discs near the conductor and near the suspension point at the tower. By connecting the consecutive metallic parts with shunt impedances, the insulator units can be graded so as to uniformize the electric stress upon them. This impedance may take the form of a resistance, inductance, capacitance or of a combination of them. A resistance has the disadvantage of increasing the leakage current and thereby causing additional ohmic losses. The role of the resistance may be left to the pollution layer that will settle upon the supplemental insulation anyway. But, since this layer is not uniform, it cannot uniformize the voltage distribution on the members of an insulator string or other insulator assemblies. Therefore, another shunt impedance may be necessary. In cases where voltage distribution is not a problem, supplemental insulation alone may be used. Where only voltage distribution on the insulator members of an insulator assembly is a problem, shunt impedance alone, without supplemental insulation may be applied.

If the insulator assembly is long, the gas itself is not linear, that is the flashover voltage of the assembly is not a linear function of its length. To linearize the gap, metallic or semiconductive electrodes may be introduced into it, provided that the voltage distribution between these electrodes can be made uniform. This can be achieved through a uniform shunt impedance between them. So, for long insulator strings, metallic fittings may serve to linearize the gap, so that its flashover voltage may be greater than that between two rod electrodes separated by the same gap length. The shunt impedance may consist again of a resistance, inductance, capacitance, or a combination of them. However, if capacitive impedances are selected, they may serve not only for grading of the insulator assembly, but also for compensation of the inductive impedance of the line, and for attenuation lightning and switching surges.

The resistive impedance may be either metallic or electrolytic. The first has a positive temperature coefficient, the second has a negative temperature coefficient. By proper mixture of the two ingredients it is easy to obtain a combination of zero temperature coefficient, the more so that the electrolyte, by addition of clay or other equivalent additive, can be brought to the consistency of a paste. The mixture of this paste with

metallic powder can be put into insulating tubes of glass or plastic. Through addition of metallic powder or semiconductive powder, the known greases, such as silicone grease, petroleum jelly (petrolatum), asphalt, tar, bitumen, pitch, as well as materials such as cement, gypsum, calcium, mortar, may be made semiconductive and used for the purpose of this invention. The main emphasis, however, is put on the just described mixture of electrolytic paste with a metallic powder, put into rigid or flexible tubes, forming "drip loops" around the insulator members. The color of these tubes can be selected so as to blend into the surrounding and be inconspicuous, for example light bluish or gray. Since the flexible tubes are movable, they have the additional advantage of being moved by the wind and thus shake off the pollution that has covered them.

It may seem that since resistance grading is absolutely effective for linearization of the voltage distribution on insulators of a string, there is no need for other grading methods. This, however, is not the case. Though resistance grading is not frequency dependent, still for steep waves the voltage distribution may be determined by the distribution of capacitances, not by that of resistances, which may be entirely different than the distribution of the capacitances. Besides, resistance grading has the disadvantage of increasing the leakage current, and thereby increasing the losses caused by it. Obviously, the shunt impedance can be inductive, thus avoiding the above disadvantage. Also the temperature of the insulators can be kept low. An inductive impedance can bring the voltage on the string and its leakage current into phase, which is an advantage, since when these phasors are out of phase, the flashover arc is easily sustained. At the same time, the arithmetic sum of all voltages on the insulator members does not exceed the magnitude of the total voltage on the string.

Similar advantages can be achieved by means of a capacitive shunt impedance. It can be produced by encapsulation of condenser plates in glass, plastics and other insulating materials, and placing them in rigid or flexible tubes. Multiconductor cables, with their alternate conductors connected to one or the other terminal, can conveniently replace the capacitors consisting of insulated plates. Another way leading to the same goal is to increase the internal series capacitances of the insulators. This can be achieved by use of a conductive cement for fastening the pin and the cap to the insulator body, or by putting high dielectric constant materials, such as  $TiO_2$  (titanium dioxide) in powder form as an additive into the mentioned cement. Another way is to use conductive grease, for covering the underside surfaces of the insulators. External or internal capacitances around the insulators may be also used for partial compensation of the inductive impedance of the line. While the increase of the internal capacitances of the insulators is a measure that can be taken only in the manufacturing plant, external capacitance may be added during the initial installation, or as a backfit in field.

Of course, a combined bypass impedance consisting of resistive, inductive, and capacitive elements in parallel and series connection can be applied.

The way in which the preceding ideas can be applied in devices serving for improvement of the pollution performance of electrical lines, can be best seen in the drawing accompanying this specification.

In this drawing, FIG. 1 shows a schematic elevational view of a suspension insulator string provided with supplemental insulation, and flexible shunt impedances connecting the caps of the insulators. FIG. 2, shows a schematic elevational view of a suspension insulator string with a rigid shunt impedance. In the partly cross sectional view of an insulator shown in FIG. 3, a layer of supplemental insulation can be seen. FIG. 4 shows the cross sectional view of an umbrella like rain shield above an insulator. FIG. 5, shows a partly cross sectional elevational view of an insulator with increased internal series capacitance.

In detailed consideration of FIG. 1, it can be seen that the caps, 1, 2, 3, 4, 5, 6, and 7, of the insulators 8, 9, 10, 11, 12, 13, and 14 are covered with supplemental insulation (shown in the drawing by stippling) such as an insulating tape, made of glass fiber fabric used with silicone grease, plastic adhesive, or latex. Such tape also covers the support fitting 16 and the support clamp 17, as well as parts of the conductor 18, and 19, on both sides of clamp 17. Also a part of the tower angles 20, and the support fitting 21 at the tower are covered with the same tape, which is also put on the accessible parts of the pins. One of these pins is indicated with the numeral 22. Consecutive metallic parts, such as 20, 21, 1, 2, 3, 4, 5, 6, 7, 8, 16, 17, 18, and 19 are connected to shunt impedance tube 23. This tube (23) contains the shunt impedance which may be resistive 24, inductive 25, or capacitive 26, as is schematically indicated. Tube 23 may be smooth or corrugated as indicated with the numeral 27. Cylindrical rain shields 28, or conical rain shields 29, prevent the formation of a continuous stream of rain water along the tube 23. Metallic electrodes 30, 31, 32, 33, 34, 35, 36, are in direct contact with the insulator caps 1, 2, 3, 4, 5, 6, 7, respectively. These electrodes 30 to 36 are connected, by means of connectors 37, 38, 39, 40, 41, 42, 43, to respective points of the bypass impedance enclosed in tube 23. Electrodes 30, 31, 32, 33, 34, 35, 36, as well as connectors 37, 38, 39, 40, 41, 42, 43, are covered with tape, which also covers the connection point 44 of the bypass impedance to the tower, and the connection point 45 of the bypass impedance to fitting 16.

FIG. 2 shows a string of suspension insulators 50, 51, 52, 53, 54, 55, 56, 57, 58, whose caps 59, 60, 61, 62, 63, 64, 65, 66, 67, are metallicity connected to the shunt impedance placed in rigid tube 68, by means of the conductors 69, 70, 71, 72, 73, 74, 75, 76, 77. These conductors as well as the caps 59, 60, 61, 62, 63, 64, 65, 66, and 67 are covered with an insulating tape (as designated in the drawing by stippling) which may be replaced with a layer of silicone grease or plastic, as mentioned before. It can be seen that the supporting angles 79 of the tower, the suspension fitting 80, and 81, conductor clamp 82, as well as a part of the conductor 83 are all covered with the same tape, or with an equivalent insulating material, and so are the connection points 84 and 85 of the bypass impedance in tube 68, to the fittings 80 and 81. Rigid tube 68 is provided with conical rain shields 86 which serve to prevent the formation of a continuous stream of rainwater along tube 68. Cylindrical rain shields, such as 87, shown in cross section, may also be used for this purpose.

FIG. 3 illustrates a suspension insulator 90, whose cap 91, is provided with a layer 92 of supplemental in-

sulation. A similar layer may cover the pin 93, shown with part of the insulator 90 broken away.

FIG. 4, presents a suspension insulator 94, whose cap 95 supports a rain shield 96, made of flexible plastic. This rainshield is flexed and moved during the wind, which shakes off the pollution accumulated on top of the rain shield. The left side of the cross section shows that the plastic material 96 may be provided with plastic ribs 97 and 98 which, in an umbrella like fashion, maintain the shape of rain shield 96. The pin (99) of insulator 94, may be covered with supplemental insulating material.

FIG. 5 shows a suspension insulator 110 and its cap 111 drawn partly in elevational and partly in cross sectional view. The cement 112 holding the cap 111 to the insulator body 110, and cement 113 fastening the pin 114 to the insulator body are either made conductive by addition of conductive materials such as metal powder, or carbon black, or made of high dielectric constant by adding titanium dioxide (TiO<sub>2</sub>) to the cement. Either way leads to an increase of the internal capacitance of the insulator.

The operation of this invention consists in adding supplemental insulation to an insulator assembly by covering its exposed metallic fittings with an insulating material as described in this specification. The same material is also used to cover a part of the supporting tower as well as some part of the conductor, in dependence on the desired degree of reduction of the leakage current of this insulator assembly. Supplemental insulation alone increases the leakage resistance and thereby reduces the leakage current.

However, it has little effect, if any, on the voltage distribution on the insulator members of the assembly. Optimal insulation cannot be achieved if the insulator members on the ends of the insulator assembly are overstressed, while other insulators are understressed. To uniformize the voltage distribution on the insulators, each of their metallic fittings is connected to those of the neighboring insulators by means of shunt impedances, which may be resistive, inductive, capacitive, or a combination of any two or of all three. Each kind has its specific advantages and disadvantages, and also has its own area of applicability. The grading of the insulators must not necessarily be uniform, but the insulators at the ends of the insulator assembly may be deliberately somewhat understressed, since any flashover is usually initiated on these insulators.

The shown embodiments and design solutions are illustrative only. It is obvious that many modifications, variations and changes of this invention can be made by addition, subtraction, or substitution of some elements by equivalents. It is also obvious that this invention, though illustrated on suspension insulator strings only, pertains just as well to support insulators, such as line

post insulators in substations, to strain (guy) insulators, and to bushing insulators. The measures presented in this specification do not necessarily have to be applied to entire insulator assemblies, but may be applied only to the insulators near the ends of the assembly. On the other end of the application spectrum, the supplemental insulation of this invention may be applied to all the towers and all the conductors of an electrical transmission line, so that no metallic part of it is exposed to pollution. It is to be understood that all the variations of this invention including its various scopes of application fall within the domain, and are in the sense of this invention as defined by the following claims.

I claim:

1. In combination, a metallic supporting structure, an insulator assembly consisting of metallic and insulating parts supported by said metallic supporting structure, and a conductor attached to said insulator assembly; a bypass impedance consecutively electrically connected to said metallic supporting structure, to all metallic parts of said insulator assembly, and to said conductor; and a portion of said metallic supporting structure as well as all of said metallic parts of said insulator assembly and a length of said conductor being covered with supplemental insulation, so that no electrical connection between any of said metallic supporting structure, said metallic parts of said insulator assembly, and said conductor exists, except through said bypass impedance.

2. In a combination, as in claim 1, said bypass impedance comprising insulating tubes filled with a mixture consisting of metallic powder having a positive temperature coefficient of resistance, an electrolyte having a negative temperature coefficient of resistance, and a clay; said metallic powder and electrolyte being present in such proportions as to form a temperature independent resistor, since the positive temperature coefficient of resistance of the metallic powder cancels the negative temperature coefficient of resistance of the electrolyte, and said clay being present in an amount sufficient to give the mixture the consistency of a paste.

3. In a combination, as in claim 1, said insulating parts including cement fastening the same to said metallic parts, said insulating parts having an increased internal series capacitance which is achieved through addition of titanium oxide powder of high dielectric constant to said cement.

4. In a combination, as in claim 1, wherein said supplemental insulation on at least one of said metallic parts extends outwardly therefrom to form a rain shield, said rain shield being made of flexible insulating material and being of such thickness as to be capable of being flexed by the wind to shed contaminants and also being capable of being flexed and washed by rain.

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