United States Patent

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[54] **SURGE-MODIFYING LIGHTNING ARRESTER CONSTRUCTION**
14 Claims, 8 Drawing Figs.

[52] **U.S. Cl.** **317/61.5,** 317/69, 336/175
[51] **Int. Cl.** **H02h 1/04,** H02h 3/22
[50] **Field of Search** 317/61.5, 69, 61, 66; 336/175, 96, 212, 233; 252/62.56

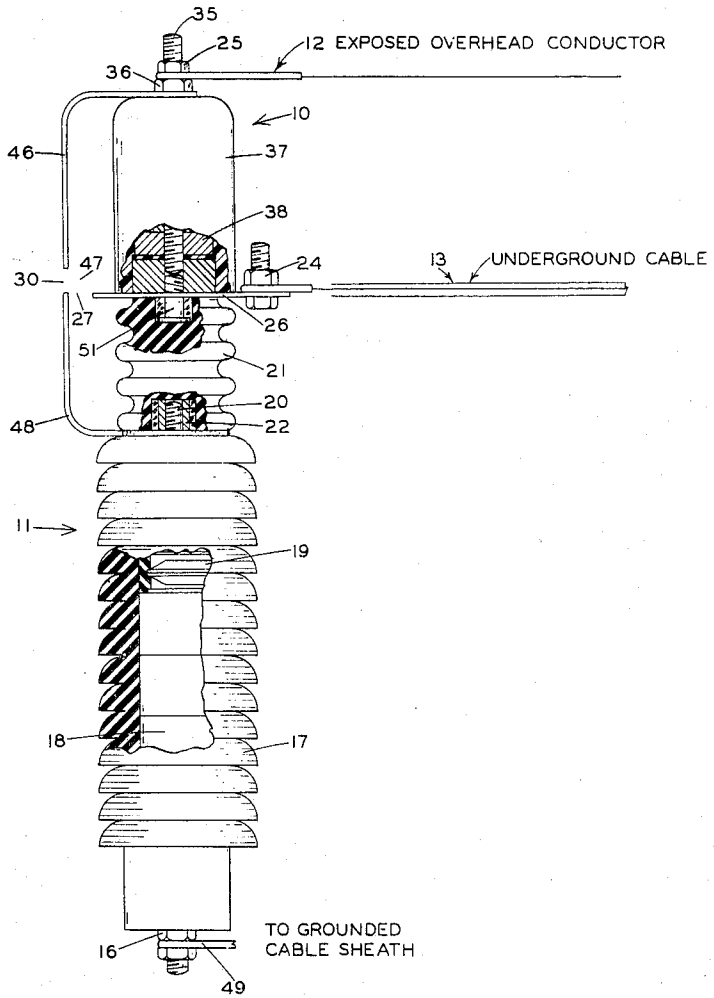
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ABSTRACT: A valve-type lightning arrester construction includes a fast-responsive, magnetically saturable inductive member effective to facilitate uniform distribution of surge current discharging through the bound silicon-carbide blocks of the current-limiting valve material forming a part of the arrester, the improved current distribution throughout the blocks increasing the magnitude of the current which can be discharged through the blocks and concurrently decreasing block damage attending "fulgurite channeling." An additional desideratum is a greater degree of protection from damage by superimposed surges, such as are initiated by lightning strokes to an exposed overhead electrical conductor, to connected cables or apparatus at points of electrical discontinuity, e.g., at the junction of an overhead line conductor with an underground cable.



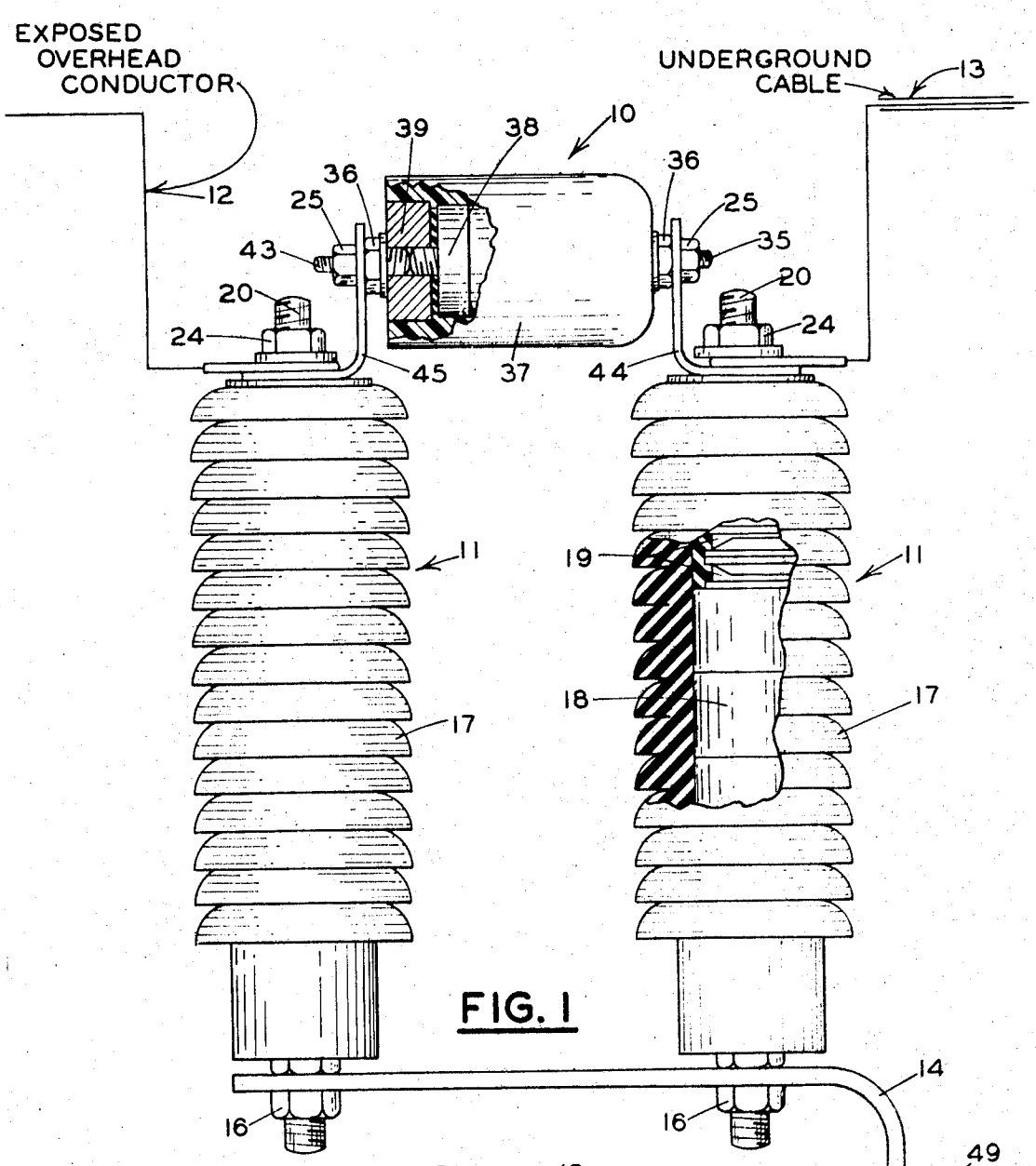


FIG. 1

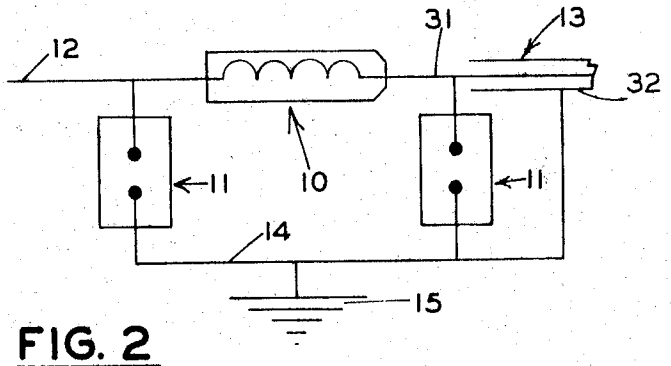


FIG. 2

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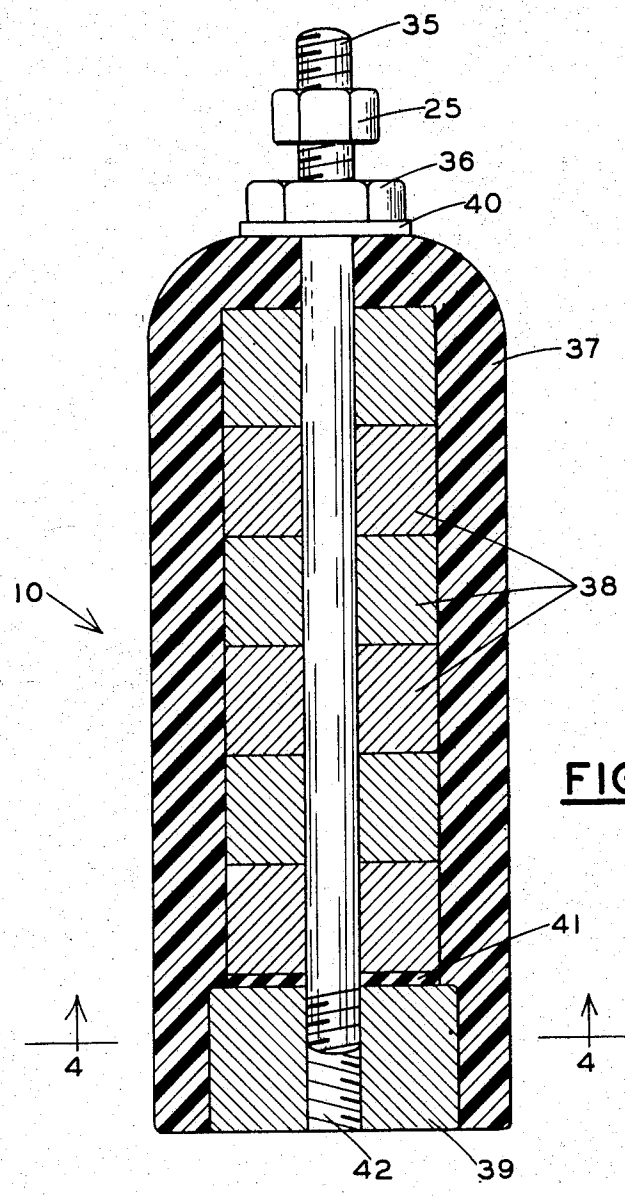


FIG. 3

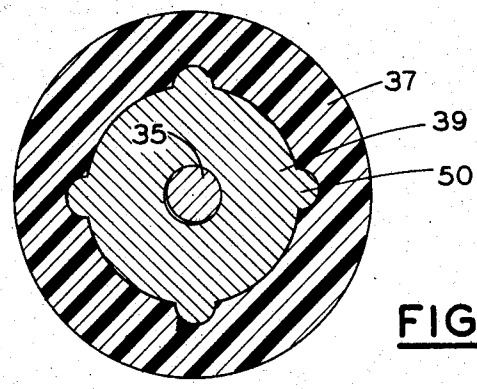


FIG. 4

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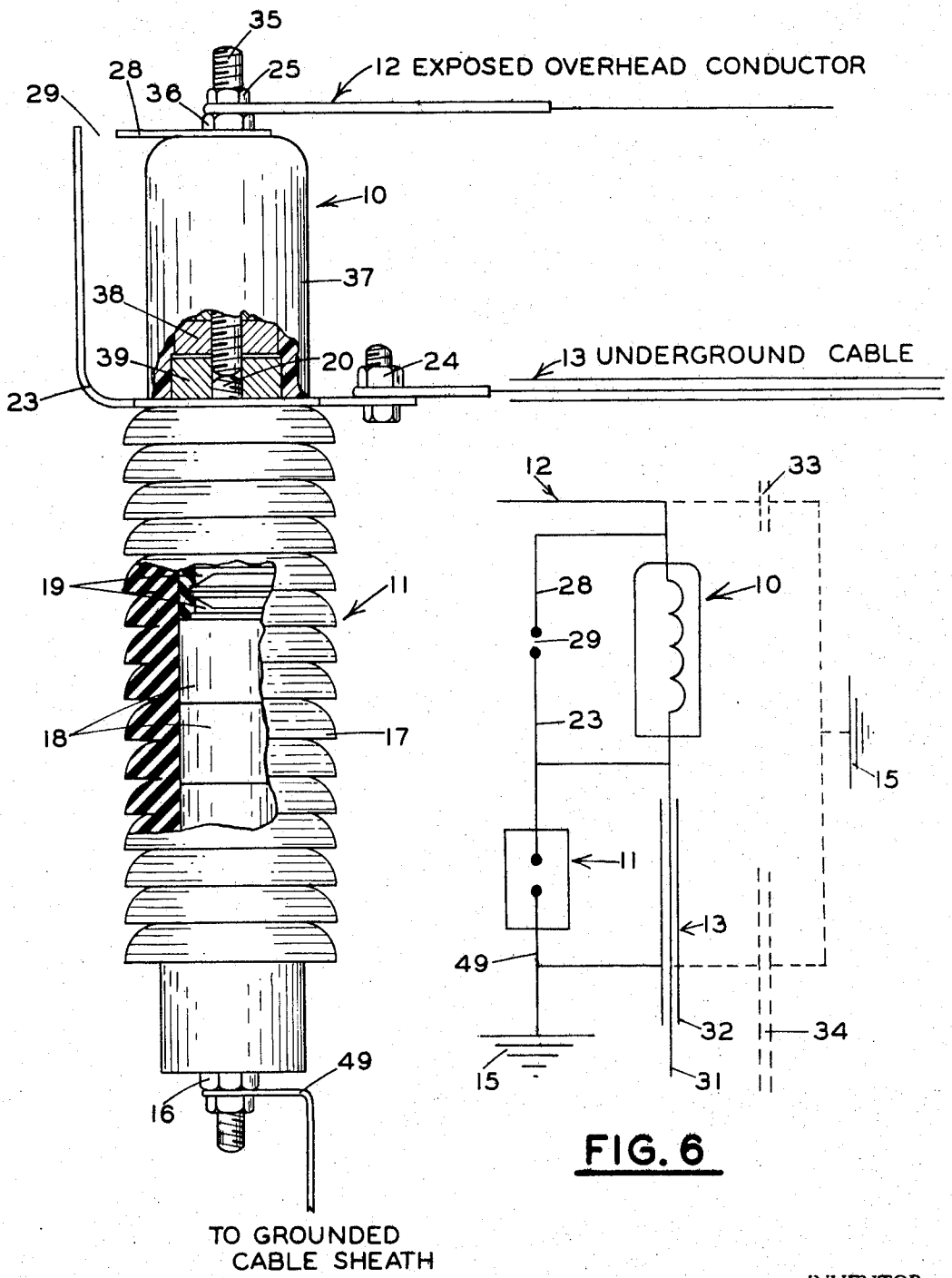


FIG. 5

FIG. 6

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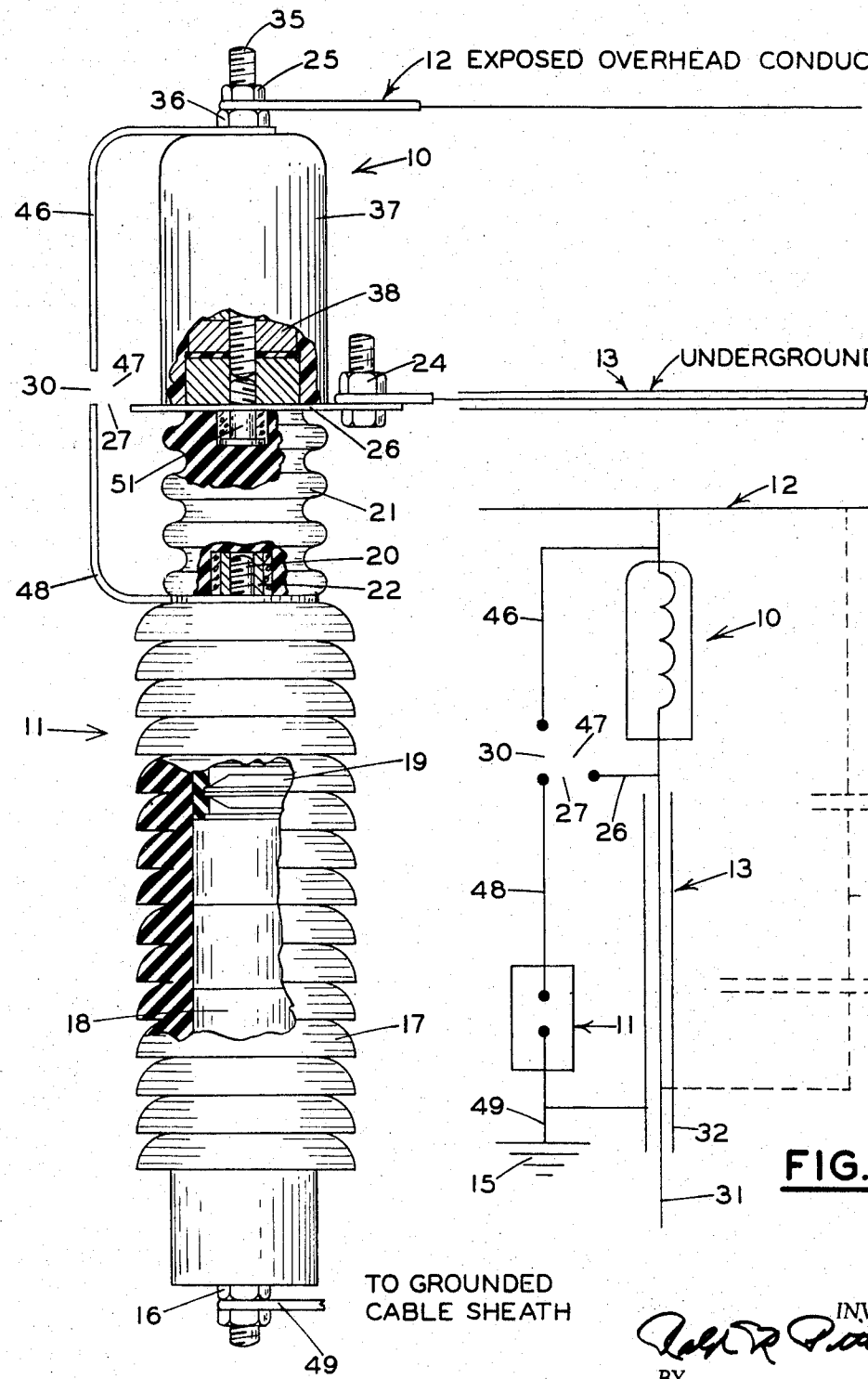


FIG. 7

FIG. 8

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SURGE-MODIFYING LIGHTNING ARRESTER CONSTRUCTION

BACKGROUND

This invention relates generally to lightning arresters, and specifically to the construction of a valve-type arrester having improved uniformity of surge current distribution in the valve material, along with protective characteristics which are not adversely affected by the electrical properties of the connected circuits when applied at the points of electrical discontinuity of a circuit.

A lightning arrester is employed in electrical power systems to provide a low-impedance path to ground and thereby preclude the occurrence of the application of excessive and damaging voltages to the insulation of connected apparatus, such as might be caused by lightning or switching surges, and, at the same time, to present an almost open circuit path to ground under normal conditions. The ideal lightning arrester would have the ability to instantaneously switch from an open circuit condition to a zero-resistance condition to dissipate abnormal surges, and instantly switch back to the open-circuit condition when normal operating conditions again prevail.

Currently available valve-type arresters are a compromise between sparkover voltage and ampacity with accompanying voltage drop, and the maximum voltage stress across the protected insulation is either the sparkover voltage or the voltage drop accompanying the surge current passage through the current-limiting resistors which make up the "valve" structure.

The nonlinear resistance or valve material is usually silicon carbide, made in the form of blocks with some binding material. The most important deficiency of the material is its inability to reduce in resistance with a precipitousness compatible with the rate of rise with time of the applied surge current, which, in the case of lightning surges, may rise at rates of the order of 5,000 amperes per microsecond, and may exceed 100,000 amperes in magnitude. Because of the small but important inherent nonuniformity of the silicon carbide valve material, a suddenly applied current may pass through only a particular region of the valve block, thermally fusing the material to a permanently low resistance path. Arresters are thus destroyed by such "hot channels" and the resulting fulgurites evidence such destruction.

Valve arresters are intended to function; i.e., discharge, at some predetermined voltage within some predetermined time of application of the voltage, this "voltage level" often being referred to as the "protective level," and the protected insulation, if it has an electrical strength exceeding the "protective level" will be protected.

This simple analysis neglects the connected-circuit electrical properties, which substantially affect the stress not only on the connected arrester but also on the protected insulation. As an example, an overhead line terminated at a transformer is practically a 100 percent positive surge reflection situation, the surge voltage transmitted by the line almost doubling in magnitude unless quickly limited by arrester discharge. As another example, an overhead line terminal at an underground cable is a negative reflection situation, the charging of the capacitance of the cable reducing the voltage at the junction while the charging takes place, thus tending to prevent arrester operation and permitting a voltage surge to enter the cable, wherein it may double at some open-circuit point and thereby overstress the cable insulation.

The most potentially damaging condition occurs when the magnitude of the cable capacitance is sufficient to hold the surge voltage at a level just low enough to prevent arrester sparkover, so that no surge-to-ground dissipation occurs, the maximum surge energy entering the cable to be doubled at some reflection point therealong.

An additionally hazardous situation develops when a transient surge, such as may be caused by a switching operation, travels along an underground cable until it meets the relatively massive surge impedance barrier of an overhead line at its point of connection therewith. Here again the reflected surge potential adds directly to the original surge voltage, and this voltage amplification may overstress the insulation at or near the cable terminal.

SUMMARY OF THE INVENTION

The arrester construction has as a component an inductor, which also functions as an inductive surge-wave modifier, and which is interposed in series circuit relationship with a protected conductor; i.e., a conductor which requires some predetermined excess-voltage limitation to preclude voltage-stress damage to the insulation of connected lines or apparatus. An important consideration in such a concept is the requirement that the inductor possess the ability to instantly respond to superimposed fast-rise surge currents caused by atmospheric discharges, or otherwise, while being insignificantly affected by the normal slow-rise current, such as that of 60 Hz. frequency.

The extent to which the electrical composite of a superimposed fast-rise surge and the accompanying slow-rise dynamic current is affected voltagewise upon meeting a lumped inductance is measured by the respective rates of change of current; i.e., L di/dt, L representing the inductance and di/dt the rate of change of current. Lightning currents and transient surge currents cause very substantial induced voltages in a very small inductance, because they are characterized by exceedingly rapid change in amplitude, with rates of rise of the order of thousands of amperes per microsecond, while the normal dynamic current, with its relatively insignificant rate of change, has a corresponding relatively negligible effect.

As is commonly known, a surge current influenced by an inductive member is retarded in time to lag behind the impelling voltage, and the rate of rise delayed while the magnetic core is being saturated, to thereby require a slightly longer time to current crest. If a surge current is so altered in character before being applied to an associated valve-type discharge structure, the impact of the surge on the nonlinear current-limiting resistance blocks will be concurrently reduced by the short but important increase in time to permit the arrester blocks to become more fully conductive.

Absolute uniformity of resistance throughout the volume of a stacked group of silicon carbide blocks, while the desired property, is not attainable under practical manufacturing procedures. In addition, nonuniformity of electrical contact resistance between the blocks, as well as with the terminal conductors, is the prevailing condition.

Whether in granular form or molded blocks, silicon carbide has a resistance characteristic of decreasing its resistance nonlinearly with impressed voltage, the rate of increase in conductivity being greatest during the first microsecond of voltage application. It is during this interval that the nonuniformity of precipitously steep current rise may initiate thermal channeling through the blocks by melting and thereby destroying the material as a nonlinear current-limiting resistor. An extremely short-time delay in current rate-of-rise not only alleviates "channeling" but also concurrently reduces the voltage drop across the resistors, and this is the voltage normally applied to the insulation to be protected.

The arrester construction of the invention, when applied with the inductive surge-wave modifier interposed as the connecting member between a terminal of an exposed overhead conductor and a terminal of an associated underground cable, provides enhanced protection for the insulation of the cable. Absent the inductive surge-wave modifier, the voltage impelling a surge current moving from the high surge impedance overhead conductor to the relatively low surge impedance of the cable cannot rise to sparkover the gaps of the arrester and dissipate the surge energy to ground until the capacitance of the cable is charged. The interposition of the inductance of the surge-wave modifier provides a reflecting barrier to the entrance of surge energy into the cable for the few

microseconds prior to magnetic saturation of the core, this short-time nullification of the capacitance effect of the cable enabling a more prompt sparkover of the line-to-ground discharge path. Similarly, a surge traveling from the cable to the connected overhead terminal will meet the lumped inductance of the surge-wave modifier, to facilitate line-to-ground sparkover.

For optimum operation, the arrester construction herein requires an inductive device capable of magnetically responding practically instantly to current variations therethrough, and particularly when such variations are notable for rates of current rise up to 5,000 amperes per microsecond, such rates being characteristic of transient surge currents. To meet this requirement, the magnetic core elements are preferably ferrites having a high quality or Q-factor at frequencies in the 200–300 megacycle range. One such material is a sintered nickel-zinc ferrite containing relatively small amounts of the oxides of cobalt and manganese, which is described in further detail in U.S. Pat. No. 3,036,009.

THE DRAWINGS

FIG. 1 is an elevational view of a preferred embodiment of the invention, shown partly in section;

FIG. 2 is a diagram of the circuitry appropriate to the embodiment of FIG. 1;

FIG. 3 is an elevational view of the inductive surge-wave modifier of the invention, shown principally in section;

FIG. 4 is a section taken along the line 4—4 of FIG. 3;

FIG. 5 is a second embodiment of the invention, shown partly in section;

FIG. 6 is a circuit diagram appropriate to the embodiment of FIG. 5;

FIG. 7 is a third embodiment of the invention, also shown partly in section; and

FIG. 8 is a circuit diagram illustrating the application of the embodiment of FIG. 7 to associated circuitry.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The arrester construction illustrated at FIG. 1 includes generally a pair of similar voltage-limiting, arc-quenching discharge members 11, and an inductive surge-wave modifier 10. In more detail, the arrester of FIG. 1 comprises a pair of elongate, transversely spaced housings 17 of weather-resistant insulating material, such as porcelain. Within each housing is disposed the group of elements which constitute a well-known voltage-responsive, arc-extinguishing structure, including the quench gaps 19 and the serially related current-limiting silicon carbide resistor blocks 18. The ground terminal members 16 extend outwardly from their connection with the end resistor block, and in connection with the grounded mounting bracket 14, and provide a ground connection for the discharge path as indicated symbolically by the conductor 49 and the ground 15.

The line terminals 20 of the discharge structure project outwardly from the housings 17 at the respective line ends thereof, an exposed overhead line conductor 12 being connected to one terminal 20 by means of a cooperating terminal nut 24, and an underground cable 13 is similarly connected to the other terminal 20.

A first L-shaped inductor mounting bracket 45 is rigidly clamped between the top of one insulator by the terminal nut 24, extending first transversely toward the other insulator and thence upwardly above the associated insulator. Similarly, a second L-shaped inductor mounting bracket 44 is rigidly attached to the other insulator, extending transversely toward said one insulator and thence upwardly above the insulator to which it is fastened. The upstanding portions of the brackets 44 and 45 are disposed in opposed spaced relationship to one another, and the inductor 10 bridges the space therebetween, being rigidly secured at the underground cable terminal end by the projection of the through-conductor 35 through the bracket 44, the latter being engaged on its respective sides by the sealing nut 36 of the inductor housing and the terminal nut 25 of the inductor. In similar fashion, the other end of the inductor 10 is rigidly secured at the overhead conductor terminal end by the extension of the threaded stud terminal 43 through the bracket 45 and coaxially into the threaded housed inductor terminal 39, the bracket 45 being engaged at its respective sides by the other sealing nut 36 and the terminal nut 25. A more detailed description of the inductor 10 will follow in the reference to FIG. 3.

As may be seen by the circuit diagram of FIG. 2, a surge moving from the overhead conductor 12 to the conductor 31 of the underground cable 13, or a surge moving from the cable 13 to the overhead conductor 12, is intercepted by the serially connected inductor 10. Steep-front surge currents, upon arrival at a terminal of the inductor 10, will build up an L di/dt voltage to cause some dissipation of the surge to ground through the associated discharge member. While this is occurring, the remaining portion of the surge passing through the inductor is modified thereby by a retardation of the rate of rise of current, causing a relatively lower voltage sparkover of the gaps of the other discharge member. In this way the discharge duty of both discharge members is diminished as the current density in the current-limiting valve material of both discharge members attains a corresponding current-shared value. As indicated, the ground terminals of both discharge members are preferably connected to a grounded conducting shield 32 of the cable 13.

With the circuitry of FIG. 2, absent the inductive surge-wave modifier 10, one or the other, but not both of the surge discharge members would sparkover on the front of a transient surge, the remaining discharge member operating only if and when the voltage drop through the discharging unit exceeded the sparkover voltage level of the nonfunctioning unit. In addition, neither of the two discharge units could operate at all during the period that the cable capacitance was being charged, with the resulting admission into the cable of a substantial amount of perhaps damaging surge energy.

The inductive surge-wave modifier 10 of the invention is shown more in detail by the section elevation of FIG. 3. An elongate cup-shaped housing of insulating material 37 is preferably formed of some elastomeric plastic, so that it may be stretched over contained elements to provide a weather-tight assembly. A through conductor 35, which is preferably copper, extends coaxially within the housing 37, having a coextensive threaded terminal portion projecting therefrom, on which are fitted the metal sealing washer 40, the sealing nut 36 and the terminal nut 25.

Within the housing 37, the through conductor 35 extends through a core consisting of a stacked group of rings of magnetic material 38, terminating in threaded engagement with the housed conducting terminal 39. A washer 41, of elastomeric material, resiliently engages the outer face of the stacked group, as an additional hermetic seal. The housed terminal 39 is provided with a coaxially extending, internally threaded recess 42, and as shown in FIG. 4, is also provided with a plurality of peripherally spaced, outwardly extending protuberances 50, for engaging an end portion of the wall of the housing 37, so that the wall and terminal may be rotated as a unit.

The embodiment shown at FIG. 5 of the drawings includes the same surge-discharge structure 11 and the same surge-wave modifier described in connection with FIG. 1, in a modified configuration. The surge-wave modifier is here rigidly fixed in coextensive relationship at the line end of the elongate insulating housing 17, being joined thereto by the threaded engagement of the housed inductor terminal 39 with the projecting terminal 20 of the surge discharge member.

One leg of an L-shaped conducting electrode 23 is mechanically held between the line end of the housing 17 and the housed inductor terminal 39, being electrically connected thereto and having an end portion extending outwardly to provide for the attachment of a first line terminal 24.

The other leg of the L-shaped electrode extends in parallel-spaced relation with the inductor **10** to a point near the outer end thereof. A conducting line terminal electrode **28** extends transversely toward and in spaced relation with the outer end of the electrode **23** to form the inductor-shunting spark gap **29**, being rigidly attached to the outer end of the inductor housing **37** by the threaded engagement of the sealing nut **36** with the projecting end of the through-conductor rod **35**.

The inductive surge-wave modifier **10** is disposed in series with the line conductors **12** and **13** by their connection to the line terminals **24** and **25**, respectively.

The components of the arrester of FIG. **5** are diagramed in FIG. **6**, along with a symbolic indication of the voltage-influencing capacitances of an overhead line conductor and an underground line conductor. A superimposed surge attempting to move from the exposed conductor **12** into the cable **13** first meets and begins its travel through and the magnetic saturation of the inductive surge-wave modifier **10**. Depending upon the *di/dt* of the surge, some or all of it passes through the inductor, and whatever does so is rendered less hazardous by the concurrent showing of the rate of rise. Assuming all of the surge passes through the inductor **10**; i.e., that the induced voltage thereacross is inadequate to sparkover the gap **29**, the retarded-rise wave will react with the cable capacitance, shown symbolically at the numeral **34**, which per unit of length is many times greater than that of the overhead line indicated at **33**. At the same time, the retarded-rise wave is impressed on the discharge structure **11**, causing it to sparkover at a voltage compatible with its slowed rate of rise. In the alternate situation in which the L *di/dt* voltage is such that sparkover of the gap **29** occurs, the divided surge is vectorially reunited at the cable end of the inductor, and the composite wave similarly treated.

The insulation to be protected may be readily coordinated with the voltage-limiting qualities of the arrester construction. As an example, an 8 kv., 60 Hz. line to ground cable may have a basic insulation level of 95 kv. with a surge rising to crest in 1½ microseconds and falling to one-half crest value in 40 ms. For protecting such a cable, the surge-discharge structure may have a sparkover voltage of about 47 kv., the inductive surge-wave modifier may have a magnetic core of six 1½-inch diameter, ¾-inch thickness ferrite rings, and the inductor shunting gap may have a ¾-inch electrode spacing. The dynamic voltage drop through the inductor at 1,000 amperes, 60 Hz. would be about 30 volts; the surge-voltage sparkover of the shunting gap about 30 kv.; and the L *di/dt* across the surge-wave modifier about 39 kv. at a *di/dt* of 500 amperes per microsecond.

The embodiment illustrated at FIG. **7** also includes the same surge-discharge member **11** and surge-wave modifier as hereinbefore described, with some additional members added to provide a modified circuitry. In this embodiment, the surge-discharge structure **11** has coaxially mounted thereon, at the line end, the insulator **21**, and the surge-wave modifier **10** extends outwardly from the outer end of the insulator. Attachment of the insulator **21** is effected by the threaded engagement of the projecting terminal **20** of the discharge structure with an internally threaded, coaxially extending socket insert **22**, which is rigidly secured to the insulator, as by cementing. At the other and outer end of the insulator **21**, the inwardly secured stud bolt **51** projects coaxially therefrom, the projection threadedly engaging the housed terminal of the inductor **10**.

An exposed overhead conductor **12** is indicated, connected to the projecting end portion of the inductor through conductor **35**, and an underground cable **13** is shown connected to the other terminal of the inductor through the terminal **25**. The latter terminal is engaged with a transverse extension of the conducting terminal plate **26**, which is rigidly clamped between the respective adjoining ends of the insulator **21** and the inductor **10**.

An intermediate L-shaped conducting terminal electrode has one leg thereof fixed between the adjacent ends of the insulator **21** and the housing **17**, extending first transversely therefrom and thence in spaced relation along the insulator to a point near its outer end. A portion of the terminal plate **26** is extended toward and in spaced relationship with the outer end of the electrode **48**, to provide a spark gap **27**, disposed electrically between the discharge member **11**, and that terminal of the inductor which is connected to the underground cable.

A line-terminal L-shaped conducting electrode **46**, one leg of which is supported by clamping between the outer end of the inductor housing **37** and the sealing nut **36**, extends first transversely therefrom and thence in spaced relation with the housing **37** to a point near and spaced from the outer end of the intermediate electrode **48**, thereby providing the spark gap **30** between the surge discharge member **11**, and that terminal of the inductor which is connected to the overhead conductor.

The outer end of the intermediate electrode **48** is preferably positioned coplanar with the terminal plate electrode **26**, so that the preferential spark paths will be either across the gap **27** or the gap **30**, which are preferably of equal length, the longer gap **47** being of such a length as to constitute an unpreferential spark relative to the others.

FIG. **8** is a circuit diagram of the arrester of FIG. **7**, along with some circuit connections. This diagram shows that a surge wave arriving at either end of the surge-wave modifier; i.e., either from the overhead line or the cable, will be accorded identical treatment with respect to its dissipation to ground through either, or both, of the spark gaps **27** and **30**, and the discharge member **11**. While the overhead line is shown connected to the outer line terminal and the cable to the other line terminal, it may be seen that they may be interchanged without affecting the operation of the arrester of this embodiment.

Common to the embodiments of the lightning arrester construction herein disclosed is a three-terminal surge-voltage protective device including two line terminals and a ground terminal, and a valve-type, voltage-limiting arc-extinguishing discharge member providing a preferred sparkover path to the ground terminal from either or both of the line terminals, there being a magnetically saturable, fast-response reactor interposed between the line terminals and in series circuit relation with the conductors, the surge voltage of which is to be limited. Also common to the arrester constructions herein presented is a structure embodying means for magnetically modifying transient electrical surge waves to inhibit their capability to destroy the silicon carbide components of a valve-type lightning arrester, this procedure functioning concurrently to enhance its protective qualities.

What is claimed is:

1. A valve-type lightning arrester construction comprising an elongate housing of insulating material containing a surge-discharge structure which includes a quench-spark-gap portion and at least one block of nonlinear resistance material disposed in series circuit relation between a line terminal at one end of said housing and a ground terminal at the other end of said housing, and surge-modifying means mounted externally on the line terminal end of said housing and coextensive therewith, said surge-modifying means including a casing of insulating material having an elongate cavity therein, a rectilinear through-conductor extending longitudinally through said casing, terminal means at the respective ends of said casing, a nickel-zinc ferrite core disposed within the cavity and surrounding the through-conductor, and means connecting said surge-modifying means in series circuit relation with said surge-discharge structure, said surge-modifying means being effective to inductively alter the current-time relationship of electrical surges discharging from the line terminal to the ground terminal before contacting any part of said discharge structure.

2. A method for reducing fulgurite channeling through the nonlinear resistance blocks in the discharge path of a valve-type lightning arrester while the arrester is connected to an electrical conductor which transmits to the arrester an electri-

cal composite of normal dynamic energy and a surge wave of abnormal superimposed energy, comprising the step of retardingly modifying the current-rate-of-rise of the surge wave at its point of entrance to the discharge path by passing the surge wave through a single-turn, magnetically saturable ferrite-cored surge-wave modifier.

3. A valve-type lightning arrester construction comprising a pair of elongate, transversely spaced housings of insulating material containing elements constituting a voltage-responsive arc-extinguishing discharge structure including current-limiting silicon-carbide resistors each of which is susceptible to thermal damage by the sudden passage of a current surge therethrough within a predetermined time interval such that time for current deconcentration and heat dispersion from the initial current-carrying channel is unavailable, a first line terminal at one end of one of said housings connected to the discharge structure therein, a second line terminal at the adjacent one end of the other of said housings connected to the discharge structure therein, common ground-terminal means at the respective other ends of said housings connected to the respective discharge structures therein, and an inductive surge-wave modifier mechanically joining and electrically connecting said first line terminal to said second line terminal.

4. The arrester construction defined in claim 3, in which the inductive surge-wave modifier includes a magnetic core comprising a stacked group of discrete rings of magnetic material.

5. The arrester construction as in claim 3, wherein the inductive surge-wave modifier includes a magnetic core comprising a stacked group of discrete rings of ceramic ferrite material.

6. The arrester construction as in claim 3, in which the inductive surge-wave modifier includes a core comprising a stacked group of discrete rings of sintered nickel-zinc ferrite containing a relatively small proportion of the oxides of cobalt and manganese.

7. A valve-type surge arrester comprising a pair of adjacent elongate insulator housings each containing a similar series circuit assembly of current-limiting resistors and spark gaps, spaced line terminals at one pair of adjacent ends of said housings and spaced ground terminals at the other pair of adjacent ends of said housings, conducting means electrically connecting said spaced ground terminals, and conducting means electrically connecting said spaced line terminals, said last-named conducting means including a saturable inductive surge-wave modifier effective to implement surge sparkover of one of said series circuit assemblies and concurrently facilitate initiation of sparkover of the other of said series circuit assemblies.

8. A valve-type lightning arrester construction comprising an elongate housing of insulating material, a first conducting line terminal disposed at one end of said housing and a conducting ground terminal disposed at the other end of said housing, and elements constituting a preferential electrical discharge path interposed between said line and said ground terminals, said elements including a plurality of bound silicon carbide blocks subject to thermal damage upon the passage therethrough of a current having a predetermined rate-of-rise, characterized by means effective to reduce the rate-of-rise of current in said silicon carbide blocks, said means including an elongate inductive surge-wave modifier electrically connected and rigidly secured at its inner end to said first conducting line terminal and extending outwardly from said one end of said housing, and a second line terminal electrically connected to the outer end of said inductive surge-wave modifier, said surge-wave modifier including a magnetic core comprising a stacked group of discrete rings of magnetic material.

9. The arrester construction as in claim 8, wherein said stacked group includes rings of ceramic ferrite material.

10. The arrester construction as in claim 8, in which said stacked group includes rings of sintered nickel-zinc ferrite containing a minor proportion of the oxides of cobalt and manganese.

11. A valve-type lightning arrester construction comprising a first elongate housing of insulating material having an intermediate terminal member at one end thereof and a ground terminal member at the other end thereof, an insulator coextensive with said housing attached to said first intermediate terminal member and a first line terminal member secured at the outer end of the insulator, a second elongate housing of insulating material secured to said first line terminal member and extending coaxially outward therefrom, and a second line terminal member secured to the outer end of said second elongate housing of insulating material, a voltage-responsive, surge-discharge assembly disposed within said first elongate housing constituting a preferential electrical discharge path between said intermediate terminal member and said ground terminal member, said assembly including at least one block of bound silicon carbide, inductive surge-wave modifying means disposed within said second elongate housing and electrically connecting said line terminal members, and spark-gap means effective to sparkover upon the appearance of a predetermined voltage between (1) either or both of said line terminal members and (2) said intermediate terminal member.

12. The arrester construction as in claim 11, wherein the surge-wave modifying means includes a magnetic core consisting of a stacked group of discrete rings of magnetic material.

13. The arrester construction as in claim 11, in which the inductive surge-wave modifying means includes a magnetic core comprising a stacked group of discrete rings of ceramic ferrite material.

14. The arrester construction as in claim 11, wherein the inductive surge-wave modifying means includes a core of nickel-zinc ferrite containing a minor proportion of oxides of cobalt and manganese, the cobalt oxide not exceeding 3 percent weight and the manganese oxide not exceeding 5 percent weight, based on total percent weight.

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