

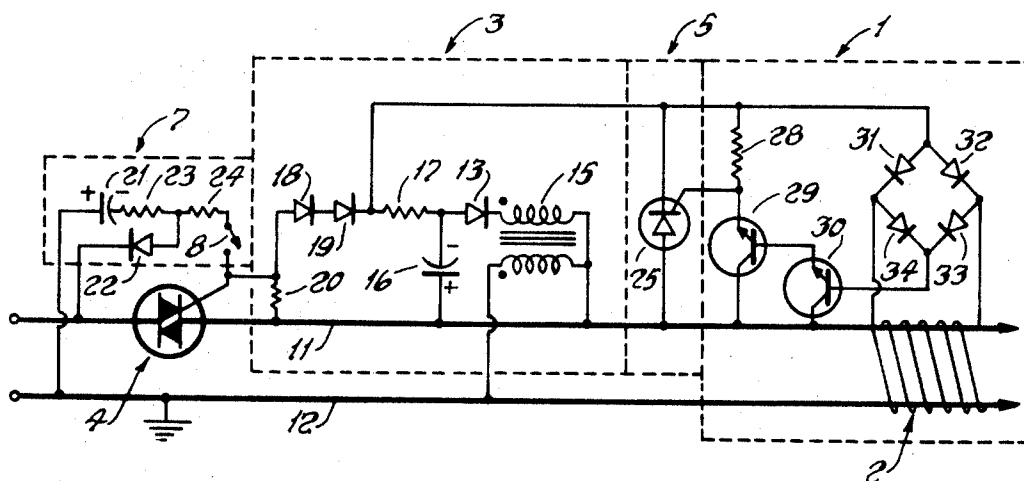
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 [21] Appl. No. **40,469**
 [22] Filed **May 21, 1970**
 [45] Patented **Nov. 2, 1971**

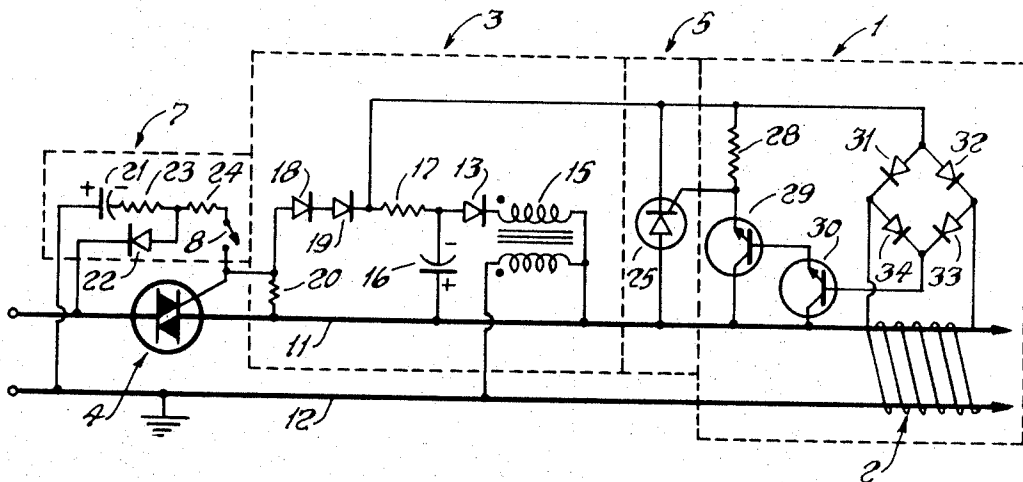
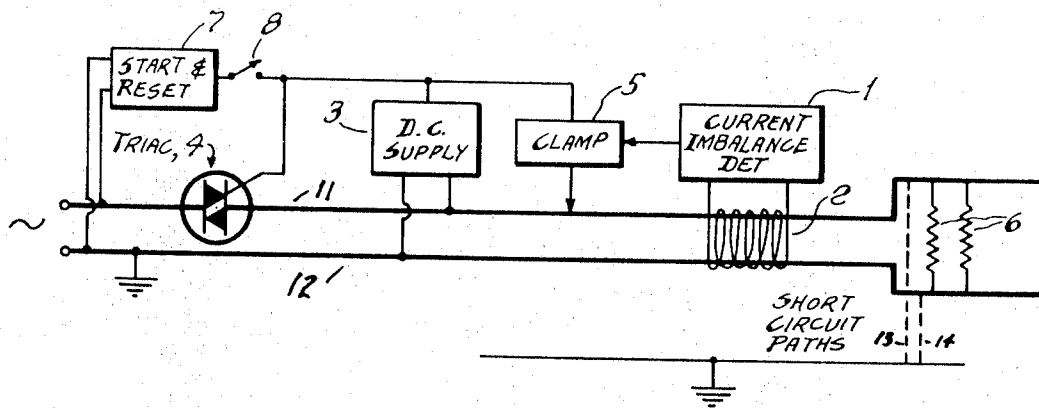
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[54] **ELECTROCUTION PREVENTION CIRCUIT**
10 Claims, 6 Drawing Figs.

[52] U.S. Cl. 317/18 D,
 317/27 R, 317/33 SC, 317/33 C
 [51] Int. Cl. H02h 3/16,
 H02h 3/28
 [50] Field of Search 317/33, 18,
 27; 307/94

ABSTRACT: A circuit which prevents accidental electrocution is described. It may be used as an integral part of the electrical service entrance panel or in individual branch circuits, and operates on the principle of interrupting the current in a period of time so short as to prevent ventricular fibrillation.





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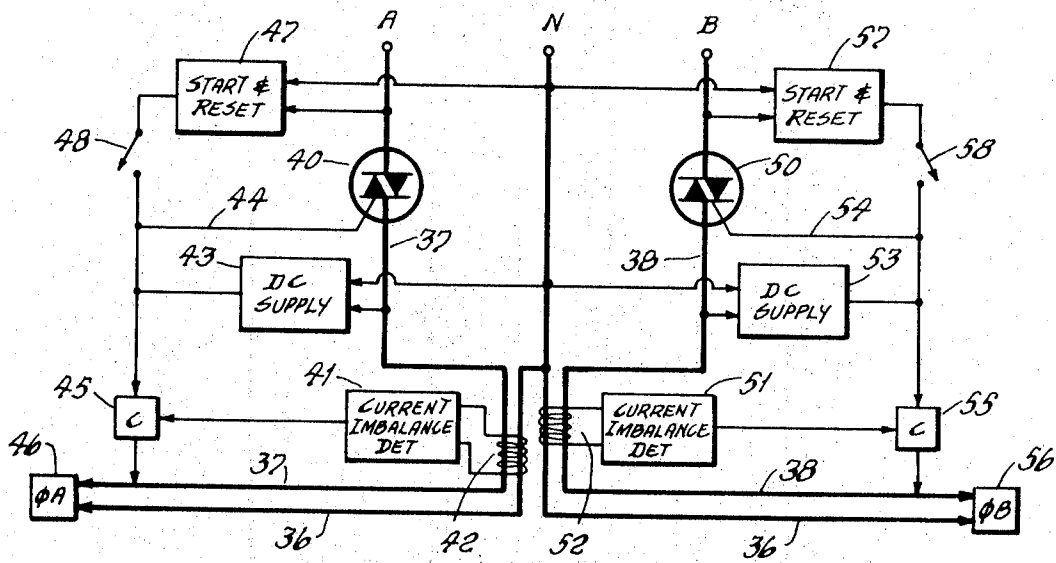


Fig. 3

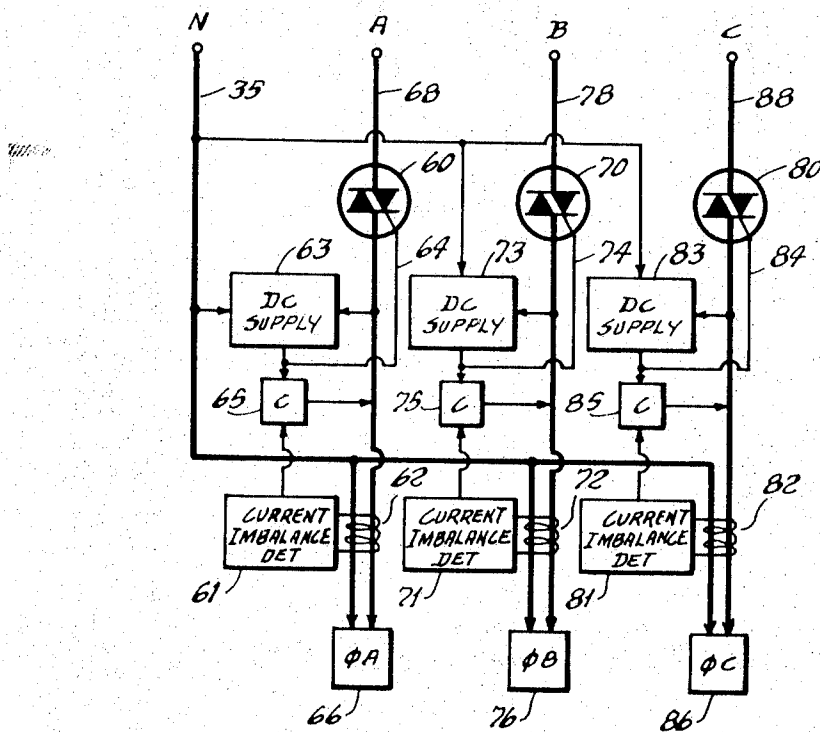


Fig. 4

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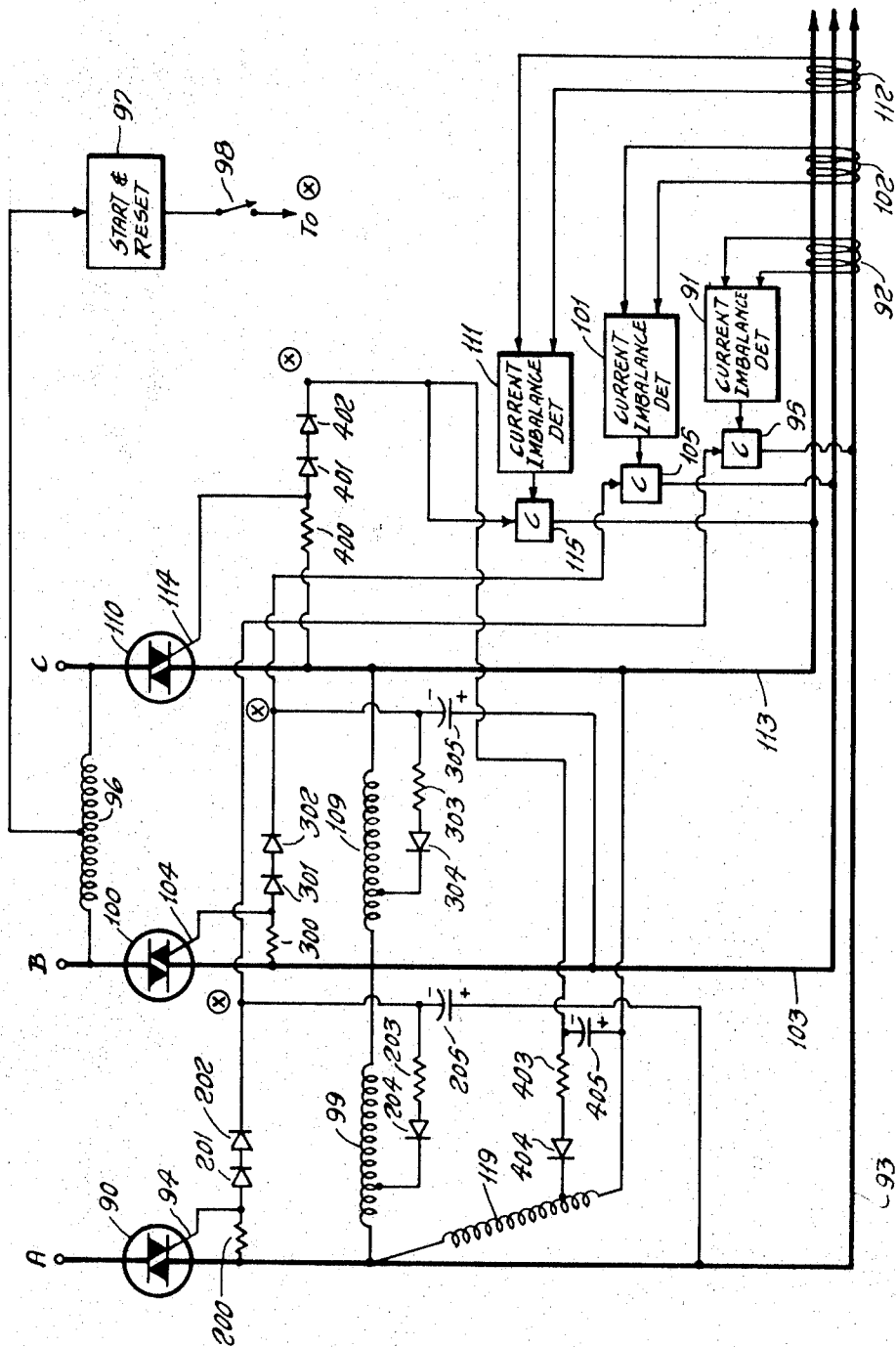


FIG. 5

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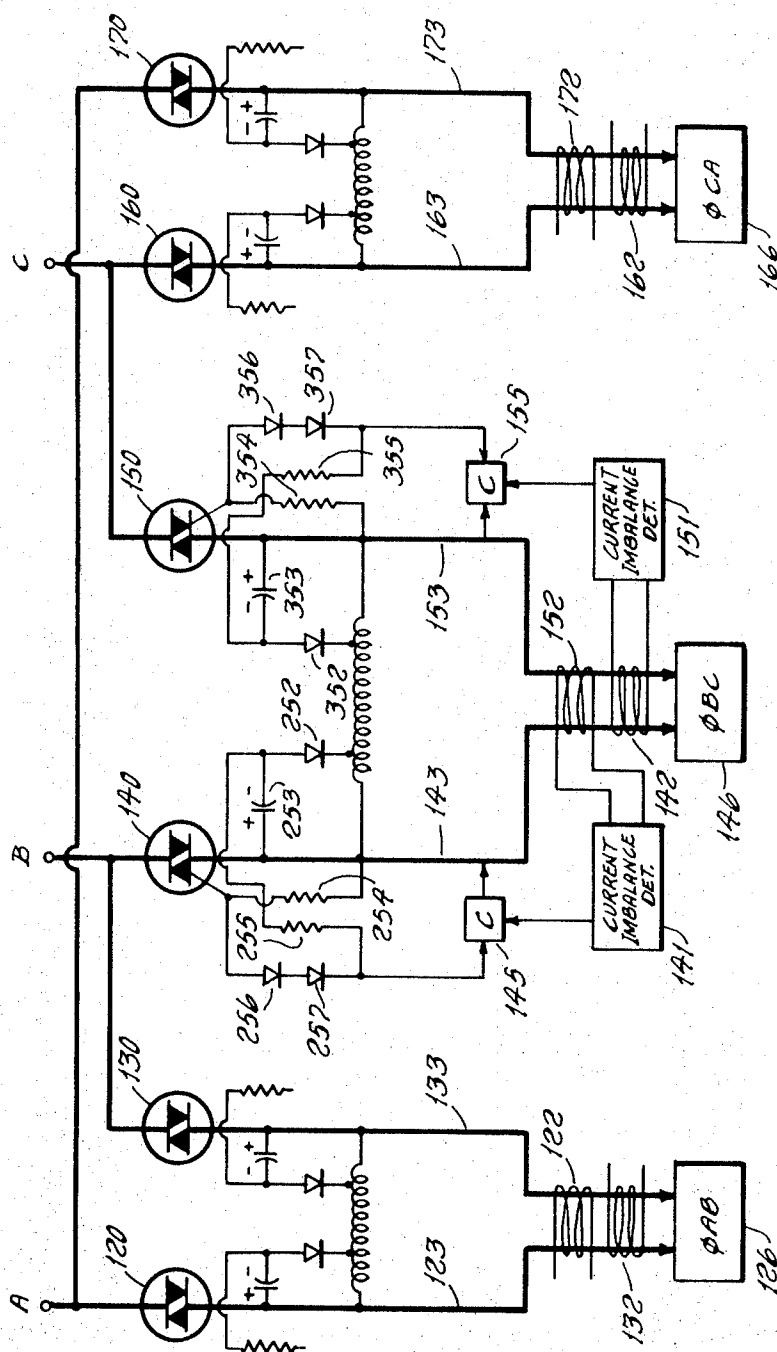


Fig. 6

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ELECTROCUTION PREVENTION CIRCUIT

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates to electrocution prevention and, more particularly, to a system whose response time is fast enough to prevent fibrillation of the human heart due to electric shock induced by accidentally providing a ground path for electric current.

Electric shock from 120 v. 60 cycle household power kills many victims needlessly each year. With the omnipresent metal ground aboard ships and metal frame mobile homes, the danger is even greater. Devices have been developed which interrupt the line voltage when there is a ground path provided by accidental contact by some exposed part of the human body to a current carrying load or exposed wire. Until the development of a high-current-carrying switching device, called the "Triac," these devices utilized relays whose response times were too slow to prevent fibrillation, the major cause of death from household electrical systems. The development of the Triac, whose response time is on the order of 0.001 second, has provided a means for interrupting the flow of house current within a time short enough to prevent fibrillation. Its use in the subject ground fault interrupter system with its control circuitry prevents electrocution.

It has been found that the stimulating effect of current through the heart can derange its action, causing ventricular fibrillation without damage to the cardiac tissues. This derangement results in death within a few minutes unless the fibrillation is arrested. The heart is most sensitive to fibrillation for shocks occurring during the partial refractory phase of its cycle, which is about 20 percent of the whole cycle and which occurs simultaneously with the T wave of the electrocardiogram. With shocks of a duration of about 0.1 second or less, it is practically impossible to produce ventricular fibrillation unless such shocks coincide in part at least with this sensitive phase of the cardiac cycle. Because the middle of the partial refractory phase is more sensitive than its beginning or end, the threshold current above which fibrillation occurs varies inversely with shock duration but not uniformly, being most sensitive to change as the duration approaches the duration of one heart beat. Within the sensitive phase of the heart cycle, the threshold fibrillating current for shock durations of about 0.1 second or less is 10 or more times the threshold for durations of 1 second or more. Shocks one-third or more of the heart cycle in duration may cause ventricular fibrillation, even though they would not extend into the sensitive phase of the cycle if the heart continued its normal beat after the initiation of the shock. The reason for this is the initiation of a premature heart beat which brings about a premature sensitive phase prior to the end of the shock. The current required to initiate fibrillation increases markedly as the duration is decreased below 0.03 second.

Thus it is readily apparent that to avoid fibrillation and subsequent death, the electric circuit be broken before it coincides with the partial refractory phase of the heart beat cycle. If the shock victim is so unfortunate as to have initiated the shock current path during this critical phase, a current interruption in .03 second or less markedly reduces the chances of fibrillation and subsequent death.

Unfortunately, the time constants involved in the best of relay-type feedback circuits cannot open the current path quickly enough to prevent such fibrillation.

The present invention solves this response time problem by utilizing the rapid response time of a Triac along with special activation circuitry to interrupt the current path. The Triac is a solid-state semiconductor, five-layer NPNPN junction device having a gating electrode which is capable of switching high power flow through the device. Not only is this device capable of handling currents on the order of hundreds of amperes but its response time is on the order of 0.001 second, making it an ideal switch for shock prevention circuits.

The present invention makes use of these operating characteristics and provides a shock prevention system which is capable of preventing electrocution by accidental grounding. The subject circuit contains no RC circuits in the activation section, thus permitting maximum use of the Triac's fast response time while at the same time limiting the false alarm rate of the system.

It is therefore an object of this invention to provide a system which can protect individuals from electrocution when they come into contact with electric current.

It is a further object of this invention to provide a device which utilizes a gate-controlled bidirectional semiconducting switch in combination with activation circuitry to prevent electrocution of individuals accidentally providing a ground path for electric current through their bodies.

Other objects, advantages and novel features of the invention will become apparent from the following detailed description thereof when considered in conjunction with the accompanying drawings in which like numerals represent like parts throughout and wherein:

FIG. 1 is a block diagram of the Triac electrocution prevention system in a two-wire single-phase power transmission system;

FIG. 2 is a schematic diagram of circuits utilized by the system shown in FIG. 1;

FIG. 3 is a diagram showing a pair of Triacs in a split phase transmission system;

FIG. 4 is a diagram of three of these devices in a three-phase "Y" power transmission system;

FIG. 5 shows the use of Triac electrocution prevention systems in a three-phase Delta transmission system in which there is mutual coupling across the transmission lines at the load; and

FIG. 6 shows the use of six Triacs in a three-phase Delta system in which no mutual coupling occurs.

The Triac has only recently become available to switch large amounts of power. The development of the Triac had its beginnings in the silicon-controlled rectifier technology. The silicon-controlled rectifier (SCR) made practical for the first time in the electrical power industry the widespread use of static electric power switches. The SCR is a solid-state semiconductor, four-layer PNPN junction device having a gating electrode which is capable of turning on power flow through the device with only a relatively small gating signal. The conventional SCR is a nongate turnoff device, however, in that once conduction through the device is initiated, the gate thereafter loses control over conduction through the device, and it has to be turned off by external commutation circuit means which usually operate to reverse the potential across the SCR.

In addition to the SCR, recent advances in the semiconductor art have made available to industry new solid-state semiconductor power switching devices which are controlled turn-on, bidirectional conducting devices. The term, "bidirectional conducting device," is taken to mean that the device capable of conducting electric current in either direction through the device depending upon the polarity of the potentials across the device. One of these last-mentioned devices, referred to as a Triac, is a gate controlled turn-on NPNPN junction device which, similar to the SCR, is a nongate turnoff device in that it must be turned off by external commutation circuit means. While the preferred form of the Triac is a five-layer gate-controlled device, it should be noted that four-layer PNPN and NPNPN junction gate-controlled Triac devices are practical as well as other variations. In any of these variations the Triac characteristics mentioned above are present.

According to the teachings of this invention, this bidirectional semiconductor switching device is utilized in a ground fault interruption circuit as illustrated in FIG. 1. In this figure, a source of power as found in a typical residential installation is shown consisting of one "hot" line 11 and one neutral line 12, the latter being grounded prior to any branch circuit power taps.

Under normal operating conditions, the entire load current is conducted by the "hot" and the neutral lines between the source and loads 6. Under such conditions, the "hot" and neutral lines carry equal currents but of opposite polarity. Thus, a current transformer, such as that shown by inductor 2, which encircles these lines would have no output as there would be no net magnetic flux with which to excite it.

Should a path develop between either of these load carrying lines, as shown diagrammatically by dotted line 13 and by dotted line 14, and ground, a portion of the current would be carried by the ground path. This would result in unequal currents being carried by lines 11 and 12 which would result in an output from transformer 2.

Such an output is used in a feedback circuit consisting of current imbalance detector 1, clamp 5 and DC supply 3 to switch-off Triac 4, thus preventing current from continuing through the ground path. If this ground path is provided by a living creature, its death is prevented by sufficiently rapid interruption of the current.

Feedback arrangements utilizing relays have not been adequate in the past because of the unacceptably long time constants in their feedback loops.

The aforementioned device, known as a Triac, is utilized by this invention to provide a current interrupting switch with such a short response time that line current can be interrupted before the next half cycle of current can flow in the ground path or in any point beyond the interrupting device. Thus, the maximum time in which 60-cycle current could flow through a victim would be 0.0084 second.

Triac 4 is switched without the use of RC elements in the control circuit by shunting its control circuit supply, DC supply 3, through clamp 5 to line 11 which removes the gate voltage on the Triac. Triac 4 is initially activated by supplying its control electrode with -3 volts. This voltage is developed by start supply 7 and is momentarily placed across Triac 4 by momentary contact switch 8. As soon as Triac 4 is fired, DC supply 3 maintains -3 volts across the Triac until this voltage is clamped to line 11 on the load side of Triac 4 when a current imbalance is detected. Clamping the gate to the load side of the line in which the Triac is inserted reduces the gate voltage to zero on the next zero crossing of the current in that line. At this time Triac 4 is shut off and remains off because DC supply 3 derives its power from line 11 on the load side of Triac 4. Thus, no power will be delivered through Triac 4 to supply 3 once the Triac has been shut off and, thus, no gate voltage can be supplied by supply 3 after this time. This insures that no more current will flow through the individual who touches a "hot" line after the current in that line has been interrupted by the Triac.

FIG. 2 is a detailed schematic diagram of a feedback circuit which may be utilized in inactivating Triac 4. In FIG. 2, Triac 4 is shown located in line 11, the starter supply is shown in dotted box 7 and is connected across lines 11 and 12. Diode 22, capacitor 21 and resistors 23 and 24 form this supply which provides the negative potential and gate current required to initiate conduction of Triac 4. DC supply 3 is outlined in dotted form and is composed of transformer 15 connected also across lines 11 and 12. Transformer 15 is a 10:1 autotransformer which is used to provide an AC power source during normal operation. Its output feeds the DC power supply composed of diode 13 and electrolytic capacitor 16 which is used to provide a potential which is negative with respect to the control terminal of Triac 4. This negative potential is supplied through resistor 17 and supplies the gate current to maintain continuous conduction of Triac 4 after it has once been triggered on. Resistor 20, which in the preferred embodiment, is 1,000 Ω , serves to inhibit Triac conduction until potential is supplied the gate by momentarily closing switch 8.

The aforementioned current imbalance detector 1 is shown in dotted outline. Current imbalance is sensed by transformer 2 which may be any type of inductor whose coils surround lines 11 and 12 and whose turns ratio meets the requirements mentioned hereinafter. The output of this transformer is cou-

pled to a full wave bridge composed of diodes 31-34, which convert the output of the transformer to a DC output. A Darlington amplifier composed of transistors 29 and 30 and resistor 28 (470 Ω) amplifies the output of the bridge by a factor of 10^4 . The output of the Darlington amplifier triggers silicon-controlled rectifier 25 which clamps the gate of Triac 4. This clamping action continues until electrolytic capacitor 16 is discharged to a value below which SCR 25 no longer conducts. Resistor 28 serves to inhibit spontaneous triggering of SCR 25. Diodes 18 and 19 provide a voltage drop greater than that across SCR 25 when it is conducting so as to insure Triac turn off.

In the following explanation, further describing the operation of the circuit shown in FIG. 2, the absolute values of all voltages are used. To insure triggering of the Triac on each half cycle, 500 milliamperes and 3 volts must be provided to the Triac gate although typical triggering conditions require but 200 ma. and 1.5 volts. The minimum required gate voltage below which no Triac will trigger is 0.1 volt and the maximum safe trigger current is 3 amperes. To insure enough energy storage in capacitor 16 over a period of one-sixtieth second to insure proper triggering, $R_{17} = (-1)/C_{16} \ln I_{g\text{trigger}}/I_{g\text{max}}$. In the preferred embodiment, $C_{16} = 100 \text{ mfd.}$, $t = 1/60$, $I_{g\text{max}} = 2.0$ solving: $R_{17} = 0.84 \Omega$ minimum. In the preferred embodiment R_{17} is chosen to be 12 Ω .

Inasmuch as the peak capacitor voltage is 17 volts, it is seen that $17 \text{ v.}/12 \Omega = 1.42 \text{ amperes}$ is the highest that the gate current can become. Thus, the 2 amperes initial current is never reached, thus providing adequate safety for the Triac, and the energy supply is more than adequate to insure triggering on either half of the cycle. Allowing for 1.0 volt drop across each of diodes 18 and 17 plus 3 volts necessary to trigger Triac 4 plus $I R_{17} = 0.2 \times 12 = 2.4$ volts across R_{17} yields a minimum supply voltage requirement of 7.4 volts which is easily met.

To insure the inhibition of Triac 4, triggering on the half cycle following the initiation of ground path current, the gate voltage of Triac 4 must be reduced to less than 0.1 volt. This is accomplished by triggering SCR 25 which serves to clamp C_{16} . The holding current of SCR 25 is 0.002 amperes. At this current level, the voltage drop across R_{17} is $0.002 \times 12 = 0.024$ volts. The voltage available to trigger the gate of Triac 4 is then 0.024 volts across the resistor +1.5 volts drop across SCR 25 = 1.524 volts. Thus, SCR 25 by itself cannot insure interruption of Triac 4. 2 additional 2 volts drop across diodes 18 and 19, however, prevents Triac 4 from triggering.

The gate of SCR 25 has an input impedance of 1,000 Ω and requires a gate current of 0.002 amperes and a gate voltage of 0.8 volts to insure triggering although typical operation requires much less gate power. The output impedance seen by the Darlington pair 29 and 30 is then $(1,000 + 470)/470,000 = 312 \Omega$. Inasmuch as the minimum current gain of the Darlington pair is 1,600, the input impedance of the Darlington pair is $312 \times 1,600 = 499,200 \Omega$. Current input requirement to the Darlington pair to insure triggering of SCR 25 is $0.002/1,600 = 0.125 \times 10^{-6}$ amperes and voltage input is 0.8 volts + 2 times the emitter base junction drop of transistor 30. Thus, the minimum input voltage requirement is $0.8 + 2(.5) = 1.8$ volts. Since the minimum input current times the minimum input impedance would generate less than 0.060 volts, it is readily apparent that input voltage is the critical parameter and minimum input current must be $1.8/498,000 = 3.6$ microamperes.

The maximum forward voltage drop across diodes 31-34 is 1 volt. Thus, the voltage output from the current transformer must be at least $1.8 + 2(1) = 3.8$ volts. Current transformer output must be at least 3.6 microamperes plus the reverse bias current leakage of diodes 31-34 which is 0.4 microamperes. This is 4 microamperes.

To design the current transformer, a determination of required system detection sensitivity must first be made. The minimum electric shock current from which 100 percent of victims may voluntarily release themselves is 0.009 amperes as stated in an article entitled "Effects of Electric Current on

Man," found in Electrical Engineering, Vol. 60, pages 63-66, 1941. An effective system to prevent electrocution is then designed to interrupt the main current when the ground path current is no greater than 0.009 amperes. Maximum current above which ventricular fibrillation may occur is 0.1 ampere. To provide an adequate margin of safety, but yet maintain sensitivity at a level where false triggering will not occur, the design current trigger level is set at 0.001 ampere. The turns ratio of the current transformer must not be greater than 1 to N2 max where $N2\ max = (0.001)/(4 \times 10^{-10}) = 250$. A turns ratio of 100 is chosen to insure proper triggering and to prohibit the generation of excessive secondary voltages. A zener diode clamp (not shown) may be placed across the rectifier bridge to protect voltage sensitive components.

The Triac may be used not only with the two-wire, single phase system shown in FIG. 1, but may also be used in the split phase, Y-type, and Delta electrical power delivery systems shown in FIGS. 3, 4, 5 and 6.

In normal household application, a split phase system is used in which 240 volts is delivered and split into two single phase 120 v. lines, A and B, shown at 12 and 49. Neutral line 36 is the same as line 11 in FIG. 1. The protection circuit to the left of line 36 is exactly the same as that shown in FIGS. 1 and 2. It is this system which is duplicated for the second phase of the system shown to the right of line 36 in FIG. 3. Thus, elements 40 through 48 and 50 through 58 correspond to elements 1 through 8 of FIG. 1. Transmission lines 36 and 37 are surrounded by coil 42, and transmission lines 36 and 38 are surrounded by coil 52 to protect the respective phases of the split phase system. It should be noted that all 240 v. loads must be drawn from a point above sensor coils 42 and 43 and that there must be no mutual coupling between the single phase loads. This is indicated by loads labeled A and B at 46 and 56. Should the 240 v. loads require protection, both sensing coils 42 and 52 must encompass both transmission lines 37 and 38 and neutral line 36.

FIG. 4 shows how the Triac may be used to protect single phase loads derived from a three-phase Y-connected circuit such as found in laboratories, industrial and apartment house branch circuits. The original protection circuit is duplicated three times to protect each of the three branches of the "Y." As in the split phase application, there must be no mutual coupling between the loads in each branch. Should protection of three-phase loads be desired, all sensing coils 62, 72 and 82 must surround all three live transmission lines A, B and C, shown at 68, 78 and 88, respectively, and neutral wire N, shown at 35. Starting and reset circuitry is not shown but it is the same as that shown in FIG. 3. In FIG. 4, elements 61 through 65, 71 through 76 and 81 through 86 are the same as those corresponding elements in FIG. 3. Each of the three phases in the "Y" system are formed between neutral line 35 and lines 68, 78 and 88, respectively. The loads serviced by these lines are labeled A, B and C at 66, 76 and 86.

It will be appreciated that in large systems where capacitance to ground is appreciable, additional capacitors to ground must be installed in each of the three legs of the "Y" such that the overall capacitance to ground in each leg is equal to that in any other leg when measured on the load side of the sensor coils.

The Triac may also be inserted into the various phases of a three-phase Delta power distribution circuit either to interrupt all the lines to loads in which there is mutual coupling or to interrupt the lines to loads across individual single-phase branches in which there is no mutual coupling. The Delta system is used almost exclusively aboard Naval vessels because it can deliver three-phase power even when one of the transformers in one of the phases is knocked out or rendered inoperative as might occur during a Naval engagement.

Where, as in FIG. 5, the Delta circuit is used to deliver power to a load in which there is mutual coupling, only three Triacs, 90, 100 and 110, are necessary to interrupt the power carried by the three Delta lines 93, 103 and 113 to the load. Modification of the start and reset circuitry shown in FIG. 2 is

necessary when the three-phase Delta delivery system is used. In the three-phase Delta, the start and reset circuitry taps its power from an autotransformer 96 connected across the B and C phases which feed lines 103 and 113. The switch shown at 98 from supply 97 connects the appropriate bias to the gate electrodes 94, 104 and 114 through diodes 201, 202, 301, 302 and 401, 402, respectively. This starting bias is thus delivered to points labeled "X" when switch 98 is closed. The interrupt circuitry for the Delta system shown in FIG. 5 operates in the same manner as the circuitry described in FIG. 2 except that power for the DC supply is tapped from autotransformers 99, 109 and 119 at a 1/10 ratio with these transformers being coupled across the three transmission lines 93, 103 and 113 on the load side of Triacs 90, 100 and 110, respectively. In each case, the power is tapped closer to the line which is to be interrupted by that particular supply. Elements 203, 204 and 205; 303, 304 and 305; 403, 404 and 405 function in the same manner as elements 17, 13 and 16 in FIG. 2. Any net current imbalance between the three Delta transmission lines is sensed by coils 92, 102 and 112 which completely encircle these lines and which are coupled to current imbalance detectors 91, 101 and 111, respectively. These detectors generate signals which activate clamps 95, 105 and 115 to clamp points "X" to the load side of their respective lines. This interrupts the power to all of the transmission lines when a ground occurs in any phase. Again, in large systems where capacitance to ground is appreciable, additional capacitors to ground must be installed in each of the three phases such that the overall capacitance to ground in each phase is equal to that in any other phase. All values of capacitance are measured on the load side of the sensor coils.

Where there is no mutual coupling, there are usually three single-phase loads that branch off from the three-wire Delta delivery circuit as shown in FIG. 6 by labels AB, BC and CA at 126, 146 and 166. Each of these loads utilizes a pair of current carrying lines, shown at 123, 133; 143, 153; 163 and 173. Each line in the pair must be interrupted should accidental grounding occur in that phase. Thus, six Triacs, shown at 120, 130, 140, 150, 160, and 170, are required with attendant activation circuitry shown in the 200-300 series of numbers to cover these three single-phase loads and secure only the circuit which was grounded without interrupting the other circuits. The operation of the circuits in the 200 and 300 series are the same as those similar components in FIG. 5. In this figure the start and reset circuits are not shown but are similar to that of FIG. 5, there being a start and reset circuit for each single-phase pair of transmission lines. Power for these circuits is derived from autotransformers (not shown) between each of the phases, A, B and C. In each phase, as represented by lines 143 and 153 and load BC, the power for the DC power supplies to Triacs 140 and 150 is double tapped off autotransformer 251. Elements 252-257 deliver the gate voltage to Triac 140; and elements 352-357 deliver the gate voltage to Triac 150. These voltages are clamped at 145 and 155 to their respective lines in response to current imbalances sensed by detectors 141 and 151 occurring across coils 142 and 152, respectively. Phases AB and CA operate with similar circuitry (not shown).

In general, electrocution can be prevented by proliferation of the Triac in the "hot" lines of any system because of the uniquely fast response time and the current carrying ability of the Triac. Current imbalances can be sensed either about the two lines to a single-phase load or the three lines to loads in which there is mutual coupling, such as in polyphase motors. In each case, after a current imbalance has been detected, the gating element of the Triac is clamped to the load side of the line in which it is inserted. Because power to render the Triac operative is tapped from the load side of the Triac, once the Triac is turned off there is no way this device can be turned on again other than by manual resetting. Thus, complete protection against electrocution is provided by the Triac and the circuitry described herein.

What is claimed is:

1. A ground fault interrupter system for preventing electrocution of an individual coming into contact with an exposed high-voltage conductor of an AC electrical distribution system, comprising:

a bidirectional semiconductor switch placed in one of the transmission lines of said distribution system;

means for initially rendering said semiconductor switch conducting thereby to connect the power supply of said distribution system to a remote load thereof;

means for maintaining said semiconductor switch in said conducting state once current starts to be drawn by said load, and for subsequently rendering said semiconductor switch nonconducting within 0.03 seconds of the time a current imbalance of a predetermined magnitude occurs in the transmission lines of said distribution system caused by said individual when he creates a direct path between said exposed conductor and ground on the load side of said switch, whereby the current flowing in said distribution system is interrupted before the initiation of a premature heart beat in said individual thereby preventing ventricular fibrillation and subsequent electrocution of said individual;

said semiconductor switch including a gating electrode; and said means for maintaining said semiconductor switch conducting and nonconducting including means for supplying a predetermined voltage to said gating electrode whenever said semiconductor switch is conducting and for removing said predetermined voltage whenever said semiconductor switch is not conducting,

the voltage for said supply means being tapped from the load side of said switch such that said supply means is incapable of delivering said predetermined voltage to said gating electrode when said semiconductor switch is not conducting, whereby said switch remains nonconducting after said individual comes in contact with said high-voltage conductor.

2. The system as recited in claim 1 wherein said means for removing said predetermined voltage includes means for clamping said predetermined voltage to the load side of the transmission line in which said semiconductor is placed whenever said current imbalance occurs.

3. The system as recited in claim 2 and further including means for sensing said current imbalance and for generating a signal having an amplitude proportional to said imbalance, said signal activating said clamping means whenever the amplitude of said signal exceeds a predetermined value.

4. The system as recited in claim 3 wherein said sensing means includes an inductor surrounding the pair of the transmission lines in said electrical distribution system which includes the line in which said semiconductor is placed.

5. The system as recited in claim 4 wherein the state of said switch is changed from conducting to nonconducting within .001 seconds of the removal of said predetermined voltage.

6. The system as recited in claim 5 wherein said bidirectional semiconductor switch is a Triac.

7. In a system for preventing electrocution of an individual whose body establishes a direct path between a ground and a high voltage conductor in an AC electrical distribution system which includes a voltage source, a load remote from said source, and an electrical distribution network for connecting said source to said load, said distribution network including as part thereof at least one pair of transmission lines across which said load is connected, the combination of

a bidirectional gate-controlled semiconductor switching device capable of carrying high currents and having a response time of 0.001 seconds or less inserted into one line of said pair of transmission lines between said source and said load on the source side of any exposed portion of said line,

said device being placed in a conducting state by the application of a predetermined voltage at its gate and being returned to a nonconducting state by the removal of said predetermined voltage;

means for initially placing said device in a conducting state by momentarily applying said predetermined voltage to said gate;

means coupled to the load side of the line in which said device is inserted for maintaining said predetermined voltage on said gate as long as said device remains conducting and for removing said predetermined voltage from said gate whenever an imbalance exists between currents flowing in said pair of transmission lines, whereby the current flow in said pair of lines is interrupted before ventricular fibrillation can occur in an individual who establishes a path between said exposed portion and ground; and

said means for removing said predetermined voltage including means for clamping said predetermined voltage to the load side of the line in which said semiconductor is adapted to be inserted whenever said imbalance occurs.

8. The system as recited in claim 7 and further including an inductor adapted to surround both of said lines for sensing said current imbalance and means coupled to said inductor for generating a signal having an amplitude proportional to said imbalance, said signal activating said clamping means whenever the amplitude of said signal exceeds a predetermined level.

9. The system as recited in claim 8 and further including apparatus similar to that inserted and coupled to said one line for insertion and coupling in a like manner to the other of the pair of transmission lines, whereby both of said lines are disconnected from said source whenever a current imbalance occurs.

10. In an AC electrical transmission system in which transmission lines carry electrical power from a source to a load in which there is mutual coupling, apparatus for interrupting the flow of electricity in each line whenever a direct path is provided between any line and ground by the body of an individual, comprising:

a Triac inserted into each line between said source and said load and on the source side of any exposed section of said electrical transmission system;

means for rendering each of said Triacs initially conducting by providing a predetermined voltage at the control gates thereof;

means coupled to the line in which each Triac is inserted and on the load side thereof for maintaining the voltage on the gate of the Triac to which it is coupled as long as the Triac to which it is coupled is conducting; and

means responsive to a current imbalance between any of the lines caused by said individual providing said path for clamping the voltage delivered to the gates of all the Triacs are inserted on the load side of each Triac, whereby current flowing in each of the lines is interrupted whenever a direct path is provided between any line and by said individual.

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