In order to prevent arcing upon opening a mechanical switch it is proposed to place an electronic signal controlled switch in series with the mechanical switch and to provide a second mechanical switch for opening the signal path to the electronic signal controlled switch before the mechanical switch is opened.

7 Claims, 7 Drawing Figures
NON-ARCING SWITCH SYSTEM AND PROCESS

This invention is directed to a system and process for manually mechanically opening an electrical circuit in a repeatable manner so that electrical arcing across the mechanically separated switch contacts is avoided.

Most common electrical appliances are controlled by a simple mechanical switch which is relied upon to open and close the power supply circuit of the appliance. These simple mechanical switches are of low cost, high reliability, and high effectiveness in opening the electrical circuit. One disadvantage of the simple mechanical power switch, however, is attributable to the fact that electrical arcing occurs across the switch contacts when the switch is actuated from closed to open condition. The arcing causes undesirable radio interference and radiation to be broadcast outwardly from the switch. Since the switches are in most instances manually operable, the appliance user is sufficiently proximate the switch to physically receive a substantial proportion of the broadcast radiation.

It has been known for some time that electronically actuable switches may be substituted for most common mechanical power on-off switches. These switches can be controlled by varying mechanically, optically, or electronically the electronic signal used to control the switch. Most commonly these switches utilize a very low level electronic signal to permit them to be turned on and are turned off when the current flow through falls below a predetermined latching level. Where the electronic switch is controlling an alternating current power source, switching on and off will normally occur during each half cycle. These electronic switches offer advantages in that they can be readily constructed so that they do not generate either radiation or radio interference upon switching. Further, mechanically controlling the electronic signals supplied to these switches does not present any arcing or radiation disadvantages, since signal current typically flows only during a minute portion of each half cycle and is typically of a very low power level.

The widespread substitution of electronic switches for mechanical switches in electrical appliance power circuit controls has not occurred at least in part because electronic switches permit some level of power conduction even in their high impedance state. Further, they may over a period of time enter a failure mode in which progressively larger power levels are transmitted in their intended high impedance state. Hence something less than the positive on-off actuation of a mechanical switch may be actually achieved in use.

It is an object of our invention to combine the advantages of mechanical and electronic switches in a single switching system. It is a more specific advantage to provide an electrical switching system that is free of electrical arcing and resulting radiation and radio interference disadvantages while at the same time providing positive and reliable on-off switching characteristics normally associated with mechanical switches.

These and other objects of our invention are accomplished in one aspect by a process for mechanically switching an electrical circuit while alleviating electrical arcing comprising initially conducting electrical current through a first switch having manually actutable separable contacts and a second switch in series therewith which is initially biased from a high impedance state to a low impedance state by an electronic control signal. The control signal conduction path is manually interrupted to return the second switch to its high impedance state, and, thereafter, the actutable contacts of the first switch are manually separated so that electrical arcing therebetween is avoided.

In another aspect our invention is directed to a non-arcing switch system adapted to be located in an electrical circuit including an electrical power source and an electrical load. The system is comprised of a controlled electronic valve means including first and second major current carrying terminals and at least one control terminal. The first major current carrying terminal serves as one external connector of the switch system. An impedance is connected to the control terminal. The switch system is also comprised of a switch means including a first terminal conductively associated with the second valve terminal, a second switch terminal serving as a remaining external connector for the switch system, a third switch terminal conductively associated with the impedance and through the impedance with the control terminal, and manually operable means for sequentially electrically interconnecting the first, second, and third switch terminals in that order and for electrically disconnecting the first, second, and third switch terminals in the opposite sequence.

Our invention may be better understood by reference to the following detailed description considered in combination with the drawings, in which

FIG. 1 is a schematic circuit diagram of a switch system formed according to our invention;
FIG. 2 is an elevation of the switch system with housing being shown in section;
FIG. 3 is a plan detail of the moveable switching disc and the control yoke;
FIG. 4 is a plan detail of the fixedly mounted switching disc;
FIG. 5 is a plan detail of the thyristor shown in FIG.
FIG. 6 is a schematic circuit detail of an alternative electronic valve means substitutable for the thyristor shown in the schematic circuit diagram of FIG. 1; and
FIG. 7 is a schematic circuit detail of an alternative electronic valve means and impedance substitutable for the thyristor and impedance shown in the circuit diagram of FIG. 1.

Noting FIG. 1, it can be seen that a power source 1 is connected by a terminal 3 to an electrical load 5. In the circuit shown the power source is preferably an alternating current power source. Typically the power source is the common residential 110 volt, 60 hertz power source. The electrical load is connected to terminal 7, which is a first major current carrying terminal for the triac (or bilateral gate controlled thyristor) 9. The second major current carrying terminal 11 of the triac is connected to a first terminal 13 of a mechanical switch 15. The switch is connected to the power source through a second terminal 17.

The triac also includes a gate terminal 19 which is electrically connected to a third terminal 21 of the switch through an impedance 23. A snubber 25 is connected across the major current carrying terminals of the triac to protect the triac against damage and/or self triggering due to high rates of voltage increase across the terminals. Snubbers are well known in the art and need not be discussed in detail. A simple snubber is provided by a resistance and capacitance in series rela-
tion connected across the major current carrying terminals in parallel with the triac. The switch is provided with a first set of contacts 27 that selectively interconnect the first and second switch terminals 13 and 17. The switch is also provided with a second set of contacts 29 that selectively interconnect the second and third switch terminals 17 and 21. It can be seen that the switch is constructed so that the first contacts are closed before the second contacts can be closed and that the second contacts are opened before the first contacts can be opened.

In use, the load 5 may take the form of an appliance motor or the primary transformer winding of a television set, for example. It is recognized that the load could be any conventional load capable of utilizing an alternating current power source. In the initial circuit condition no power is supplied to the load, since the triac 9, lacking a gate signal, is in its high impedance state and the mechanical switch 15 is fully open, so that contacts 27 and 29 are open.

To energize the circuit and supply power to the load it is merely necessary to close the first set of contacts 27 and the second set of contacts 29 in that order. When the contacts 27 are closed, the first and second terminals 13 and 17 of the switch are electrically joined to connect the power source to the second terminal 11 of the triac 9. At this instant, however, the contacts 29 are still not closed. This leaves the triac in a condition in which the full potential of the power source is unimpeded across the major current carrying terminals 7 and 11, since the triac remains in a high impedance state, the gate terminal 19 being still isolated from the circuit by the open contacts 29.

Upon closing the contacts 29 a signal is supplied to the gate terminal 19 of the triac to switch it from its high impedance state to a low impedance state. The impedance 23 limits to a low level the current supplied to the gate to prevent the gate signal path from shunting more than a small proportion of current from the major conduction path through the circuit. The impedance placed in the gate signal path between the third switch terminal 21 and the gate terminal 19 of the triac may take one of a variety of conventional gate impedance forms. Typically the impedance may amount to nothing more than a single resistor. So long as the contacts of the switch 15 remain closed the triac is turned on at the beginning of each half cycle provided by the power source, by a new gate signal being transmitted to the gate terminal of the triac. The triac is turned off automatically each time the polarity of the potential across its major current carrying contacts is reversed. It is to be noted that the gate signal occurs for only a short period at the beginning of each half cycle, since gate current is extinguished once the triac is switched to its low impedance state. The snubber 25 is provided to protect the triac against a high rate of voltage increase. Where the power source does not impinge upon the voltage increase tolerance of the triac, the snubber may, of course, be omitted from the circuit entirely.

When it is desired to interrupt power delivery to the load, the contacts 29 of the switch 15 are first opened before the contacts 27 are opened. In this way the triac is automatically switched to a high impedance state at the conclusion of the next half cycle and is not provided with an additional gate signal that could trigger it to its low impedance state. Power to the load is thus interrupted at the end of the first half cycle following the opening of the contacts 29.

To provide a positive mechanical open within the power conduction path within the circuit the contacts 27 are then opened. No arcing occurs as the mechanical open is formed, since current flow has already been terminated within the circuit. No arcing occurs when the contacts 29 are opened because of the low current and voltage levels normally utilized in this portion of the circuit and because gate current only flows for a minute fraction of each half cycle.

In FIGS. 2 through 5 inclusive a switch system 106 is illustrated which combines the triac 9, switch 15, and impedance 23 together with the electrical interconnections shown in FIG. 1. While the snubber 25 is not shown as a part of the system, it could be included, if desired.

In the switch system a thermally conductive housing 102 is provided. A mechanical switch is included within the housing made up of a fixed insulative disc 104 provided to separate fixed switching disc 106 from the housing. The disc is formed of an insulative material and is provided with a terminal 108 (corresponding to terminal 17) which extends between the upper and lower surfaces of the disc and is attached adjacent the lower surface to an electrical lead 110 provided with an insulative coating and extending through an aperture in the housing. Externally of the housing the lead 110 is connected to a first external connector 112, which may take any conventional form. Angularly spaced from the terminal 108 along the periphery of the disc is a terminal 114 (corresponding to terminal 13) which is constructed similarly as terminal 108. A third terminal 116 is similar to terminals 108 and 114 and is angularly positioned so that it is separated from the terminal 108 by the terminal 114 in a clockwise direction when viewed as in FIG. 4.

A moveable switching disc 118 is formed of an insulative material and carries a conductive area 120 on its lower major face adjacent its periphery. The conductive area does not extend entirely around the periphery of the disc. The moveable switching disc is rotatably mounted over the fixed switching disc by a central pin 122. The pin may be spread at opposite ends to hold the discs in the desired staked relation.

Extending upwardly from the upper major surface of the movable disc is an actuator pin 124. The pin may be formed integrally with the moveable disc or may be attached thereto in any convenient conventional manner. The pin is slidably fitted within a slot 126 in a yoke 128 extending laterally outwardly from the end of the actuator arm 130.

The actuator arm extends through an aperture 132 in the housing. An insulative bushing 134 is shown fitted within the aperture. The actuator arm is provided with a first shoulder 136 which limits the extent to which the actuator arm may be slid into the housing and a second shoulder 138 which limits the extent to which the actuator arm may be retracted from the housing. The shoulders abut the busing located within the aperture 132. A knob 140 is threadedly or otherwise removably attached to the outer end of the actuator arm. An externally threaded mounting bushing 164 is attached to the exterior surface of the housing and mounts a portion of the insulative bushing. The housing may be mounted to an electrical appliance or at any other convenient loca-
tion using the threaded bushing or any other conventional mounting connector.

The triac 142 is shown provided with a heat dissipating mounting 144 which is attached to the housing by a bolt 146. A first terminal 148 of the triac is soldered to an insulated lead 150 that extends through an aperture in the housing and is attached at its opposite end to a connector 152 which may be identical to connector 112. The connector 152 serves as a second external connector for the switch system. The terminal 154 of the triac is connected to switch terminal 114 by lead 156. The gate terminal 160 of the triac is connected through impedance 158 to the gate switch terminal 116 by electrical lead 162.

In the position shown the mechanical switch is in a full open condition. The switching system 100 may be connected in an electrical circuit including a load and a power source utilizing electrical connectors 112 and 152. To apply electrical power to the load it is merely necessary to pull the knob 140 outwardly from the housing 102 so that shoulder 138 abuts the bushing 134. This causes the yoke 128 to pull the pin 124 to the left and to rotate the moveable switch disc 118 clockwise in FIG. 3. The conductive area 120 associated with the bottom major surface of the moveable disc is then moved from a position in which it contacts only terminal 108 of the fixed switch disc to a position in which it overlies and interconnects terminals 114 and 108. This places the potential supplied by the power source across the terminals 148 and 154 of the triac. The triac is not gated from its initial high impedance state to a low impedance state, however, until the conductive area 120 is rotated still further to overlie the gate terminal 116. The triac then switches to its low impedance state.

To utilize the switch system to de-energize the load it is merely necessary to push the knob 140 inwardly until the shoulder 136 abuts the bushing. The conductive area and moveable disc are then rotated counterclockwise in FIG. 3. This results in the gate terminal 116 being first disconnected from the conductive area with the result that the triac reverts to its high impedance state with the next following half cycle supplied by the power source. At this point in time then the triac 142 is effectively preventing current flow through the switch system. Continued counterclockwise rotation disengages the conductive area from the switch terminal 114 and provides the positive mechanical open desired in the circuit for maximum reliability and elimination of leakage currents. There is no arcing as the conductive area disengages from the terminal 114, since the triac has already reverted to its high impedance state.

It is recognized that a variety of electronically controllable electronic valve means may be substituted for the triac which has been discussed in connection with the embodiments of FIGS. 1 through 5 inclusive. In FIG. 6 a transistor 30 and diode 32 are shown attached to terminals 7, 11, and 19 of the circuit of FIG. 1 in place of the triac 9. It is to be noted that the anode of the diode is connected to terminal 7 while its cathode is connected to the transistor emitter, since in this instance the transistor is a PNP transistor. Where an NPN transistor is substituted the sense of the diode is reversed so that its anode is connected to the transistor emitter. The base and collector of the transistor are in each instance connected to the terminals 19 and 11, respectively.

In FIG. 7 another alternative embodiment is disclosed in which the silicon controlled rectifier 40 is substituted for the triac 9. The cathode of the SCR is connected to the terminal 7 while its anode is connected to terminal 11. In order to avoid shunting of the SCR when it is reverse biased a diode 42 is connected in series with the impedance 23 so that its anode is attached to terminal 21 of the switch. The SCR performs similarly as the triac, but permits only unidirectional current flow to the load. In this instance the power source could as well be a pulsating direct current source as an alternating current source. In the former instance no diode 42 would be required. It is also anticipated that the triac 9 could also be used with a pulsating direct current source instead of an alternating current source.

It is anticipated that a number of variations could be introduced into the embodiments shown without departing from our teachings. For example, the relative locations of the power source and load in the circuit are immaterial, so long as they are serially related. It is also anticipated that still other elements may be added to the circuit disclosed without effectively changing its character. It is anticipated that the impedance 23 may take a form permitting control of the phase angle of firing of the thyristors. In the switch system 100 it is anticipated that the housing might serve as one connector to the power source. In this instance the electrical connection of the triac to the housing could be through the heat dissipation tab 144. While a specific mechanical switch has been illustrated, it is recognized that other equivalent mechanical switches are known to the art and could be substituted. Accordingly, it is intended that the scope of our invention be determined by reference to the following claims.

What we claim and desire to secure by Letters Patent of the United States is:

1. A non-arcing switch system adapted to be located in an electrical circuit including an electrical power source and an electrical load comprising controlled electronic valve means including first and second major current carrying terminals and at least one control terminal, said first major current carrying terminal serving as one external connector for said switch system, an impedance having one end connected to said control terminal, and mechanical switch means including a first terminal conductively associated with said second major current carrying terminal of said valve means a second switch terminal serving as a remaining external connector for said switch system, a third switch terminal connected to the other end of said impedance and through said impedance to said control terminal, and mechanically operable means for connecting the terminals of said switch means to apply power to an electrical load and for disconnecting the terminals of said switch means for removing power from an electrical load, said manually operable means effecting connection of said first and second terminals of the switch means before connection of the second and third terminals of the switch means before discon-
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7. Connection of the first and second terminals of the switch means during removal of power.

2. A non-arcing switch system according to claim 1 in which said electronic valve means is an electronic switch.

3. A non-arcing switch system according to claim 1 in which said electronic valve means is a gate controlled bilateral thyristor.

4. A non-arcing switch system according to claim 1 in which said electronic valve means is a silicon controlled rectifier having a cathode, an anode, and a gate, said anode and cathode constituting said first and second terminals of said electronic valve means, respectively, said gate constitutes said control terminal, and said impedance includes a diode oriented to permit current flow from said third switch terminal to said gate and to substantially impede current flow in the opposite direction.

5. A non-arcing switch system according to claim 1 in which said electronic valve means is a transistor having an emitter, base, collector, emitter junction, and collector junction and a diode having a rectifying junction therein, said diode being interposed between said first terminal and said emitter of said transistor and oriented so that said rectifying and emitter junctions are both forwardly biased in the same direction of current flow, said collector serving as said second terminal of said electronic valve means and said base serve as said control terminal of said electronic valve means.

6. A non-arcing switch system according to claim 1 in which said switch means includes a thermally conductive housing and said electronic valve means is mounted in low thermal impedance relation thereto.

7. A non-arcing switch system according to claim 1 additionally including means for reducing the rate of rise of voltage within said electronic valve means when closing said switch means to apply an electrical potential across said first and second major current carrying terminals.

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