

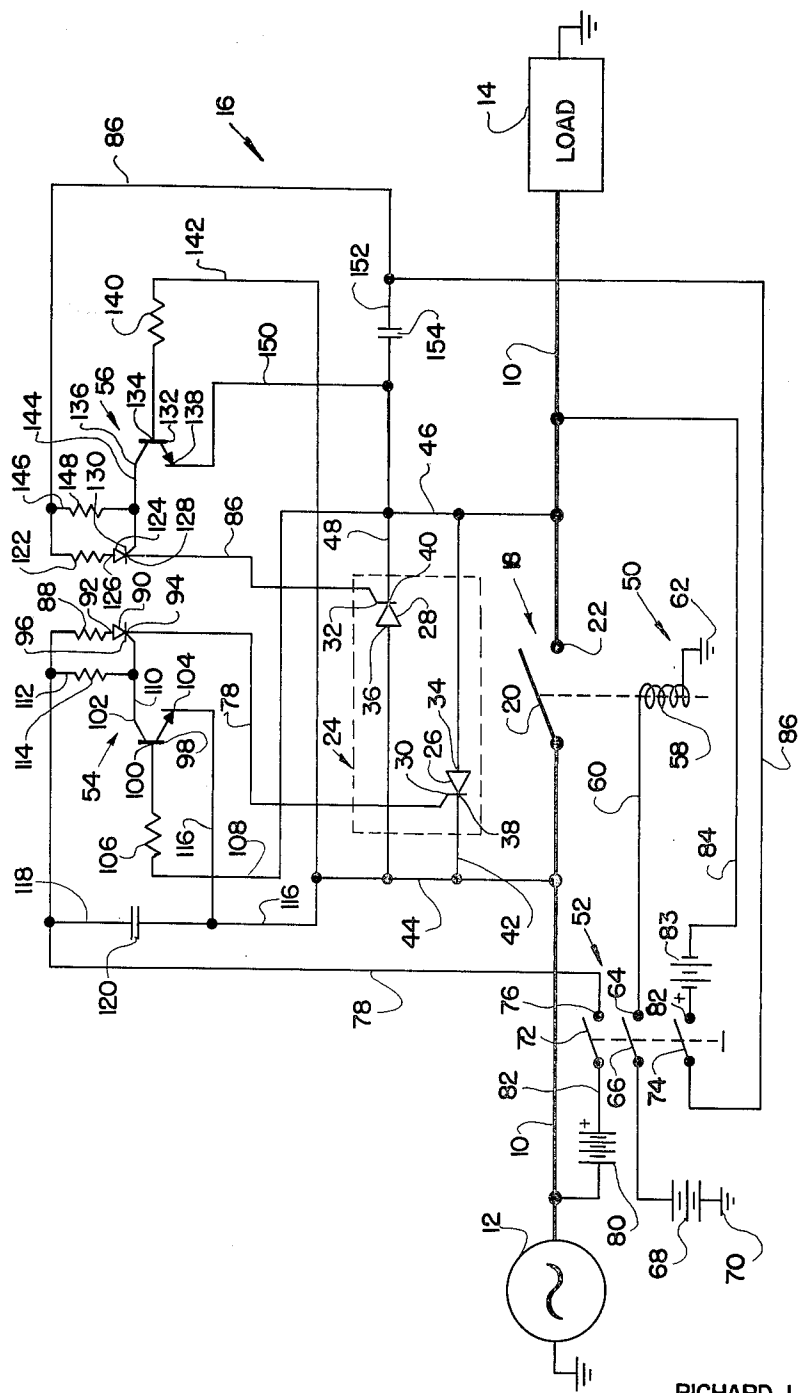
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RADIO NOISE-FREE SWITCH

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RADIO NOISE-FREE SWITCH

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This invention relates to electrical switches and has as its general object the provision of a switch usable in a power line between a source of energy of varying potential and a load and which may be closed and opened under comparatively heavy power loads and will yet generate substantially no radio noise.

A further object of the invention resides in the provision of a switch of the type referred to and which includes a main switching means and an auxiliary switching means, the latter being adapted to close and open respectively before and after closing and opening of the former and at comparatively low voltage conditions whereby to substantially eliminate radio noise.

A still further object of the invention resides in the provision of a switch of the type mentioned wherein the main switching means is of the mechanical type and wherein the life of the contacts thereof is substantially increased by the operation of the auxiliary switching means.

Still another object of the invention is to provide a switch of the type mentioned and which exhibits characteristics of comparatively low power loss.

The drawing shows a preferred embodiment of the invention and such embodiment will be described, but it will be understood that various changes may be made from the construction disclosed, and that the drawing and description are not to be construed as defining or limiting the scope of the invention, the claims forming a part of this specification being relied upon for that purpose.

The single figure of the drawing is a schematic illustration of a switch embodying the present invention and which is incorporated in a power line between a generator and a load.

Referring now particularly to the drawing, it will be observed that a power line 10 extends between a source of electrical energy of varying voltage 12 and a load 14. The electrical energy source 12 is shown as comprising an alternating current generator but the switch of the present invention is equally adaptable for use with other sources of varying potential both D.C. and A.C. Similarly, the character of the load 14 may vary widely within the scope of the invention.

The switch of the present invention is identified generally by the reference numeral 16 and a first portion thereof comprises a main switching means 18. The main switching means 18 may vary in form but is shown as being of the mechanical type and comprising a switching member or arm 20 and an associated contact 22. The switching member or arm 20 is movable in one and an opposite direction for opening and closing operation and, more specifically, upward swinging movement thereof to the position shown effects opening operation and downward swinging movement to engagement with the contact 22 effects closing operation.

In accordance with the invention the switch 16 also includes an auxiliary switching means indicated generally at 24 and which is connected with the power line 10 in parallel with the first or main switching means 18. The auxiliary switching means 24 may vary in form but in accordance with the presently preferred practice and where an alternating current supply 12 is involved, the said means comprises first and second oppositely oriented unidirectional conducting elements 26 and 28. More particularly, the elements 26 and 28 take the form of silicone

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controller rectifiers having gate terminals 30, 32, anode terminals 34, 36 and cathode terminals 38 and 40. The controlled rectifier 26 has its anode and cathode terminals 34 and 38 connected in a line 42 extending between first and second branch lines 44, 46 connected with the power line 10 respectively on the generator and load side of the first or main switching means 18. The controlled rectifier 28 has its anode and cathode terminals 36, 40 connected in a line 48 which also extends between said branch lines 44 and 46. As will be seen the rectifier 26 is arranged in the line 42 to conduct when the voltage on the load side of the switching means 18 is positive with respect to the voltage on the generator side of said switching means. Conversely, the rectifier 28 is arranged to conduct when the voltage on the generator side of said power line is positive with respect to the voltage on the load side thereof.

Further in accord with the invention, the switch 16 includes a control and operating circuit means connected with the power line 10 and with the main and auxiliary switching means 18 and 24. Said operating and control circuit means may vary widely in form but as shown comprises a selectively operable means 50 for opening and closing the main switching means 18, a selectively operable actuating means 52 and first and second gate supply circuits 54 and 56. The selectively operable means 50 for operating the main switching means 18 is shown as comprising an electrical force generating means in the form of a relay coil 58 connected in a line 60 and provided with a local ground 62. The line 60 extends to a contact 64 associated with a switch member 66 which in turn, is connected with an electrical energy source 68 in the form of a battery grounded locally at 70. Thus, the switch member 66 can be moved to a closed position whereby to energize the relay coil 58 and to close the switching member or arm 20 in the usual manner. De-energization of the relay coil 58 on opening movement of the switch member 66 will result in opening movement of the switching member 20 to the position shown.

The selectively operable actuating means 52 may vary in form but is shown as comprising first and second switch members 72 and 74 connected for gang operation with the switch member 66. The switch member 72 has an associated contact 76 in a line 78 extending to a control circuit means including the gate supply circuit 54. Opposite the contact 76 the switch member 72 is connected with the power line 10 on the generator side of the main switching means 18 through an electrical energy source in the form of a battery 80 and by means of a line 82.

The switch member 74 has an associated contact 82 in a line 84 connected with the power line 10 on the load side of the main switching means 18. An energy source in the form of a battery 83 is disposed in the said line 84. The opposite side of the switch member 74 is connected with a line 86 extending to the control means including the gate supply circuit 56.

Referring now to the gate supply circuit 54, it will be observed that the line 78 extends to a resistor 88 and thence to a control switching means 90 and the aforementioned gate terminal 30 of the controlled rectifier 26. The control switching means 90 preferably comprises a controlled rectifier as shown with an anode terminal 92, a cathode terminal 94 and a gate terminal 96. The controlled rectifier 90 is oriented in the line 78 to conduct from the switch member 72 to the gate terminal 30 of the rectifier 26 when the potential at said switch member is positive with respect to the potential at said gate terminal.

The gate supply circuit 54 also includes a line voltage responsive means which is operable to effectively "open" and "close" the control switching means or rectifier 90.

Said line voltage responsive means comprises a transistor 98 having a base terminal 100, a collector terminal 102 and an emitter terminal 104. The base terminal 100 is connected through a resistor 106 with the aforementioned branch line 46 by means of a line 108. The collector terminal 102 is connected with the gate 96 of the controlled rectifier 90 by a line 110 and with the aforementioned line 78 by means of a line 112 extending between the line 78 and the line 110. A resistor 114 is connected in the line 112. The emitter terminal 104 of the transistor 98 is connected with the aforementioned branch line 44 by means of a line 116 and a line 118 extends from the line 116 to the line 78. Disposed in line 118 is a capacitor 120.

Referring now to the gate supply circuit 56, it will be observed that the said circuit is substantially identical with the circuit 54 but in a reverse arrangement. The aforementioned line 86 from the switch member 74 extends to a resistor 122, a controlled rectifier 124 having anode and cathode terminals 126 and 128 and a gate terminal 130 and thence to the gate terminal 32 of the rectifier 28. The controlled rectifier 124 constitutes a control switching means as in the case of the rectifier 90. Associated with the said control switching means is a line voltage responsive means comprising a transistor 132. The transistor 132 has a base terminal 134, a collector terminal 136 and an emitter terminal 138. The base 134 of the transistor is connected through a resistor 140 with the aforementioned branch line 44 by means of a line 142. The collector 136 of the transistor is connected with the gate terminal 130 of the controlled rectifier 124 by means of a line 144. Extending from said line 144 to the line 86 is a line 146 which has disposed therein a resistor 148. The emitter terminal 138 of the transistor 132 is connected with the aforementioned branch line 46 by means of a line 150. Extending between the line 150 and the line 86 is a line 152 and disposed therein is a capacitor 154.

OPERATION

In operation of the switch 16 as shown, the switch members 72, 66 and 74 may be opened or closed simultaneously. Generally speaking, it will be observed that closing of the switch members 72, 66 and 74 will result in closing of the main switching means 18. Prior to closing of the said main switching means however, the controlled rectifiers 26 and 28 of the auxiliary switching means 24 will be "closed" or rendered conductive and, moreover, such closing of the auxiliary switching means will occur when the power line voltage is substantially below peak line voltage. More specifically, the auxiliary switching means is "closed," or it may be said that the controlled rectifiers commence conducting, when power line voltage is substantially below 50% of the peak line voltage and, in fact, very near zero potential. Thus, the rate of current change at the instant when the auxiliary switching means starts to conduct will be as low as possible, the resulting fields generated will be of low magnitude, and little or no radio noise will be encountered. On subsequent closing of the main switching member 20, current will already be flowing through the power line 10, the branch lines 44 and 46 and the lines 42 and 48 and an excessive rate of change of current flow will not be encountered at the main switching means 18. Thus, little or no radio noise will be encountered on closing of the main switching means. In accordance with the invention the electrical resistance characteristics of the main switching means 18 is substantially lower than the corresponding characteristic of the auxiliary switching means 24. Thus, substantially all of the current will flow through the main switching means after the same has been closed.

In generally describing the opening operation of the switch 16, it should be noted that the capacitors 120 and 154 provide a time delay function whereby the auxiliary switching means 24 opens after the opening of

the main switching means 18. On opening of the switch members 72, 66 and 74, the switching member 20 opens with the generation of little or no radio noise and without arcing due to the continued flow of current through the branch lines 44, 46, the lines 42 and 48 and the control rectifiers 26 and 22. Thereafter, and as will be seen, a gate opening signal is removed from the gate terminals 30 and 32 of the rectifiers 26 and 28, and the said rectifiers serve automatically to open or cease conducting at very low voltage levels substantially below peak power line voltage, and, in fact, substantially at zero potential. As is well known, controlled rectifiers such as silicone controlled rectifiers have an inherent characteristic of becoming nonconductive in the absence of a gate opening signal or voltage on interruption of their anode current. Thus, closing of the auxiliary switching means occurs substantially at zero potential and little or no radio noise is generated.

Considering the operation of the switch 16 in greater detail and referring to a closing operation in particular, assume that the power line voltage 10 is substantially at a positive peak when the switch members 72, 66 and 74 are closed. As mentioned above, relay coil 58 will be energized to close the switching member 20 but closing of the auxiliary switching means 24 will occur prior to engagement of the said switching member with the contact 22. The closed switch member 72 provides a positive voltage signal through the line 78 to the control switching means or controlled rectifier 90. Additionally, a positive voltage signal is applied to the gate terminal 96 of the controlled rectifier 90 by means of the lines 112 and 110, the transistor 98 being nonconductive due to the presence of a potential at its emitter terminal 104 which is positive with respect to the potential at its base terminal 100. A positive voltage signal to the gate 96 serves to "open" the gate and thereby to "close" or render the controlled rectifier 90 conductive in the forward direction. Thus, the gate terminal 30 of the controlled rectifier 26 is provided with a positive voltage signal whereby to "open" said gate and to "close" or render conductive the rectifier 26. Said controlled rectifier 26, however, is not instantaneously effective to conduct current as it will be noted that the potential thereacross is in the rearward direction, i.e., branch line 44 is more positive than branch line 46.

Referring now to closing of the switch member 74, it will be observed that a positive potential is applied to the controlled rectifier 124 at its anode terminal 126 and to the gate 130 of said rectifier through the lines 146 and 144. With the line voltage at or substantially at positive peak, however, the voltage at the base terminal 134 of the transistor 132 will be positive with respect to the voltage at the emitter terminal 138 of said transistor. Thus, the transistor 132 will be rendered conductive and will maintain the gate 130 "closed" despite the positive signal in the line 86 from the battery 83. The gate terminal 32 of the rectifier 28 will not receive a positive signal necessary for "opening" of said gate and the said rectifier 28 will remain "closed" or nonconductive for the duration of the high power line voltage.

Still referring to the gate supply circuit 56 and the rectifier 28, it is to be noted that the transistor 132 will cease conducting as the power line voltage moves downwardly on its sine curve and is reduced from its peak value. More specifically, at a very low positive voltage, the transistor 132 will cease conducting and the necessary positive voltage signal will be applied to the gate 130 whereby to "open" the same and to render the rectifier 124 conductive. This results in the application of a positive voltage signal to the gate terminal 32 of the controlled rectifier 28 and the "opening" of said gate. Opening of the gate of the rectifier 28 results in "closing" or a conductive condition of the said rectifier. At this instant in time, the line voltage being at a very low positive value, the rectifier will begin to conduct a current

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flow from the branch line 44 through the line 48 to the branch line 46 and the auxiliary switching means 24 may be regarded as closed. When the line voltage follows its sine curve to the negative side, the rectifier 26 will commence conducting in a similar manner and current flow through the auxiliary switch means 24 will have commenced with little or no radio noise and will provide for closing of the switching member 20 with little or no radio noise.

Now from the foregoing it will be apparent that the operating and control circuit means of the present invention provides for "closing" of the rectifiers 26 and 28 when the potential thereacross is in a range extending between low forward potentials and through the rearward potentials. There can of course be no excessive rate of change of current flow when the rectifiers are subjected to rearward potentials and it is therefor possible only to "close" the auxiliary switching means 24 at very low voltages with the benefit of substantial elimination of radio noise. In the embodiment of the invention shown, the various elements are selected to provide for "closing" of the controller rectifiers 26 and 28 at approximately 1½ volts. This provision is made in a power line system wherein the peak power line voltages are on the order of 160 volts. Thus, "closing" of the auxiliary switching means 24 may be said to occur substantially at zero potential, the said potential being low enough to substantially eliminate radio noise.

Referring now to the opening operation of the switch 16 in greater detail, it will be observed that the capacitors 120 and 152 are arranged so as to be charged when the switch is in the closed condition. On opening of the switch members 72, 66 and 74, the relay coil 58 is de-energized and the switching member 20 opens. During this period of time, the capacitors 120 and 152 discharge to the lines 118 and 78 and the lines 152 and 86 respectively whereby to provide the necessary potential for maintaining the gate supply circuits 54 and 56 in operation and for maintaining the rectifiers 26 and 28 in "closed" condition. When the capacitors 120 and 152 are discharged so as to no longer provide gate signals for the rectifiers 26 and 28 the said rectifiers automatically "open" or become uncondutive at very low voltages and substantially at zero potential in accord with their inherent characteristics mentioned above. In the embodiment of the invention shown, said voltages may be on the order of 1½ volts and, little or no radio noise is generated in opening of the main switching means 18 and in opening of the auxiliary switching means 24.

The resistors 106 and 140 have not been defined as to function heretofore and it should be noted that the said elements serve to reduce voltage to an appropriate level respectively for the transistors 98 and 132. Resistors 114 and 88 serve as current limiters for the transistor 98 and the controlled rectifier 90. Resistors 122 and 148 similarly serve as current limiters for the controlled rectifier 124 and the transistor 132.

Finally, it is to be observed that the switch 16 has additional advantages over elimination of radio noise. As mentioned, the resistance relationship of the main and auxiliary switching means is such that the main switching means has substantially lower resistance than the auxiliary switching means. This provides for a condition wherein substantially all current flow occurs through the main switching means once the switch is closed. Thus, the silicone controlled rectifiers 26 and 28, comparatively expensive elements, may be utilized in very small size as compared with switches wherein such elements comprise the main switching and current carrying means. Substantially lower costs are encountered in the provision of such small rectifiers.

Power losses in the switch are desirably low as compared with a switch wherein silicone controlled rectifiers are employed as the principal switching and current carrying members. The main switching means 18 may be of

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a conventional mechanical type affording characteristics of extremely low power loss.

Still further, engagement of the switching member 20 with the contact 22 in the main switching means 18 should be noted as occurring only when the auxiliary switching means is first closed as stated. It is found that a substantial reduction in contact wear is thus achieved and an extremely long life of the contacts in the main switching means is to be expected.

The invention claimed is:

1. For use in a power line between a source of electrical energy of varying potential and a load, a switch comprising a main switching means in the power line, selectively operable means for opening and closing said main switching means, an auxiliary switching means connected with said power line in parallel with said main switching means, control circuit means connected with said power line and said auxiliary switching means an operable to close the latter only when the power line voltage is substantially at zero potential, and selectively operable actuating means connected with and adapted to arm said control circuit means for closing of said auxiliary switching means.

2. A switch as set forth in claim 1 wherein said main switching means has a substantially lower electrical resistance characteristic than said auxiliary switching means.

3. A switch as set forth in claim 1 wherein said auxiliary switching means is operable to open only when said control circuit means is inoperative to close the same and when the potential thereacross drops substantially to zero potential.

4. A switch as set forth in claim 1 which is particularly adapted for A.C. power and wherein said auxiliary switching means comprises first and second oppositely oriented unidirectional conducting elements each connected with said control circuit means and operated thereby to initially conduct only when power line voltage is substantially at zero potential.

5. A switch as set forth in claim 4 wherein said unidirectional conducting elements take the form of controlled rectifiers having gate terminals connected with said control circuit means and anode and cathode terminals connected with said power line in parallel with said main switching means as aforesaid.

6. For use in a power line between a source of electrical energy of varying potential and a load, a switch comprising a main switching means in said power line, an auxiliary switching means connected with said power line in parallel with said main switching means, and control and operating circuit means connected with said power line and with said main and auxiliary switching means and operable first to close said auxiliary switching means when the power line voltage is substantially at zero potential and thereafter to close said main switching means.

7. A switch as set forth in claim 6 wherein said main switching means has a substantially lower electrical resistance characteristic than said auxiliary switching means.

8. A switch as set forth in claim 7 wherein said control and operating circuit means is operable also to open said main and auxiliary switching means, and wherein said circuit means includes a delay device whereby said auxiliary switching means is opened after said main switching means.

9. A switch as set forth in claim 8 wherein said auxiliary switching means is operable to open only when said control means is operable to open the same and when the potential thereacross drops substantially to zero potential.

10. A switch as set forth in claim 9 which is particularly adapted for an A.C. power line and wherein said auxiliary switching means comprises first and second oppositely oriented unidirectional conducting elements each connected with said control and operating circuit

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means and operated thereby to conduct initially only when power line voltage is substantially at zero potential.

11. A switch as set forth in claim 10 wherein said unidirectional conducting elements take the form of first and second controlled rectifiers having gate terminals connected with said operating and control circuit means and anode and cathode terminals connected with said power line in parallel with said main switching means.

12. A switch as set forth in claim 11 wherein said operating and control circuit means includes first and second gate supply circuits connected respectively with the gates of said controlled rectifiers, each said gate supply circuit being operable to open its corresponding gate whereby to close its corresponding rectifier only when the rectifier is subjected to rearward potentials and low forward potentials in the range of 0 to 10 volts.

13. A switch as set forth in claim 12 wherein said main switching means takes the form of a mechanical switching member, movable in one and an opposite direction for opening and closing and wherein said control and operating means includes electrical force generating means for moving said member in at least one direction.

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14. A switch as set forth in claim 13 wherein each gate supply circuit includes a control switching means and a line voltage responsive operating means therefor, said control switching means being connected with the gate of the corresponding rectifier and said responsive operating means being connected with said power line, and said line voltage responsive means being operable to close said control switching means and to thereby open the gate and close the corresponding rectifier when line voltage is such that the rectifier is subjected to rearward potentials and low forward potentials in the range of 0 to 10 volts.

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