SWITCHING DEVICE FOR POWER SUPPLY CIRCUIT

ABSTRACT: In a relay device provided with means for decreasing the exciting current to a value substantially less than the pickup current and adapted to connect a power supply to a load, a protective switching means responsive to faulty conditions of the power supply or load is provided to short circuit the exciting coil of the relay.
SWITCHING DEVICE FOR POWER SUPPLY CIRCUIT

This invention relates to a switching device of a power supply circuit and more particularly to a switching device of a DC source power supply circuit having a protection means for the power supply means and the load. A coil of the relay circuit is formed so as to be maintained energized through the continued closure of the control switch or through a self-holding contact connected in series with the exciting coil. Interruption of the load or opening of the contacts is effected by the opening of the control switch.

As well known in the art, the exciting current of a relay coil required to pickup its contacts is relatively larger than the minimum holding current necessary to hold the same in the energized state. In the above-mentioned commonly used mode of operation, the larger exciting current necessitated to pickup the contacts is generally supplied throughout the holding condition. The power loss of this relay circuit is therefore unavailing, and the stationary control switch is unable to be used or at least it is used only in a limited manner.

It is also well known in the art that permissible current breaking capacity of an electric contact is generally much smaller than the closing capacity of the same, and that is usually easier for electric components to lead electric current than to break it off. Therefore it has been impossible to miniaturize the control switch beyond a certain limit, because it is necessary to interrupt relatively large exciting current by the control switch.

Where it is desired to provide a protective device for the switching device and the load which resets the relay in response to the abnormal condition in the source and/or load, such protective device is also bulky because it is required to break expanding circuit which has been followed said relatively large exciting current.

It is therefore an object of this invention to provide a greatly simplified switching device of power supply circuit including a decreasing means to decrease exciting power loss of the relay, and an improved protective means which is small and compact, and can respond to abnormal conditions in the power supply and/or load circuit.

According to this invention, above-described object is accomplished by providing an automatic switching means for the energizing circuit of a relay of a switching device wherein a current limiting resistor is included in the relay energizing circuit to decrease the exciting current of the relay at a value smaller than its pickup current. Furthermore, interruption of the power circuit for protection is effected by shorting the exciting coil instead of opening thus simplifying the protective device.

The invention will be more fully understood from the following detailed description taken in conjunction with the accompanying drawings, in which:

FIG. 1 shows a circuit diagram to show the principle of the switching device embodying this invention;

FIG. 2 is a detailed circuit diagram of a preferred embodiment of this invention; and

FIG. 3 is a circuit diagram of a modified embodiment of this invention.

The principle of this invention will be considered with reference to FIG. 1 of the accompanying drawings. As shown in the FIG., in order to open and close a circuit which supplies power to a load 12 from a source of direct current 11, a main contact 14 of a relay 13 is interposed between one pole, for example, the positive pole, of the source 11 and the load 12. One terminal 15a of an exciting coil 15 of the relay 13 is connected to another pole of the DC source 11 via a control switch 16 while the other terminal 15b of coil 15 is connected to the positive pole of the source 11 via a transfer switch 17 and a protective resistor 18. Transfer switch 17 is used to change the excitation circuit of the coil 15 between its pickup up and holding and is interlocked with the control switch 16 in such a manner that the switch 17 is closed with the control switch 16 and is opened automatically after a predetermined interval or when the relay assumes the holding condition in order to establish a holding circuit for the relay 15 after completion of the pickup operation thereof, or after opening of the transfer switch 17, terminal 15b of the exciting coil 15 is connected to the juncture between main contact 14 of the relay 13 and the load 12 via a self-holding contact 19 of the relay 13 and a current limiting resistor 20. Between this current limiting resistor and the opposite terminal of the load 12 is interposed a protective switch 21 which is closed when a suitable fault responsive means (not shown) detects any faulty condition in the power supply 11 and/or load 12.

In operation of the switching device, to supply power to load 12 the control switch 16 is closed. Then the excitation coil 15 of the relay will be energized from the power supply 11 via transfer switch 17 interlocked with the control switch 16 and resistor 18 to close the main contact 14 in the load circuit. A predetermined interval after closure of the control switch 16, the transfer switch 17 is opened. By this time, however, as the main contact 14 and the holding contact 19 of the relay will have been closed, a small holding current will be supplied to the excitation coil 15 via current limiting resistor 10.

Upon occurrence of an abnormal condition in the source 11 or load 12, above-described detector will detect such abnormal condition to close the protective switch 21 which may comprise a relay or a semiconductor switching element, short circuiting the exciting coil 15 of the relay 13 to disconnect the load 12 from the source 11. The protective switch 21 is then opened automatically.

To reclose the load circuit, once the control switch 16 is opened and is then closed again. When the abnormal condition is still persisting and the protective switch 21 is again closed, the relay 13 will be again opened immediately. On the other hand, when the abnormal condition has cleared by the time of the reclosure of the relay and the protective switch 21 is held open, the normal supply of the power to the load will be resumed. To open the load circuit under normal condition it is merely necessary to open the control switch 16.

As above described, the holding current of a relay is generally considerably smaller than the pickup current. In other words, once the relay has been operated, its exciting current may be decreased substantially without causing the relay to open. Thus, for example, by an experiment in a relay requiring a pickup current of 1.90 mA, the exciting current through the relay coil may be reduced as small as to 10 mA.

Where the relay is energized with this minimum holding current (i.e. 10 mA) the relay has a tendency to be opened by small vibration or shock, but it is not required to supply large pickup current (i.e. 190 mA) throughout the operation of the relay. Thus, for example, the holding current may be reduced to about 1/6 of the pickup current or to about 60 mA.

For this reason, in the circuit shown in FIG. 1, the value of protective resistor 18 is selected to assure sufficient pickup current to the relay coil 13, whereas the value of current limiting resistor 20 is selected to supply essentially smaller but adequate current for holding.

Furthermore, the permissible current capacity of an electric contact is greatly different between closing and interruption. For example, it is known that a contact capable of closing DC current of 1.5 amperes has an interrupting capacity of only about 0.2 A where it is used to interrupt a DC inductive circuit of 48 volts and at a power factor of 0.4.

As is mentioned in the arrangement shown in FIG. 1, the control switch 16 is required to close a relatively large current required to pickup relay 13 but to interrupt the relatively small holding current which is limited by the current limiting resistor 20. Consequently, the rating of the control switch 16 may be reduced considerably than the case where resistor 20 is not used. Moreover, in the circuit shown in FIG. 1, since in...
order to deenergize relay coil 15 in response to the occurrence of an abnormal condition, the relay coil is short circuited by means of protective switch 21 instead of opening the self-holding circuit, it is possible to simplify the deenergizing means, i.e. the protective switch 21, in this case. As the current flowing through the protective switch 21 flows into it, the deenergizer 15 in response to the abnormal condition of the source and/or load is limited to a relatively small value by the current limiting resistor 20, the switch 21 as well as the fault detector can be miniaturized.

FIG. 2 shows a circuit diagram of one embodiment of this invention in which corresponding elements are designated by the same reference numerals as in FIG. 1. One terminal 15a of relay coil 15 is connected to the negative pole of DC source 11 through control switch 16 while the other terminal 15b is connected to the positive pole of the power supply 11 through a protective resistor 18 and a diode 22 connected in the forward direction with respect to the source. Connected across the source 11 is a series circuit comprising said protective resistor 18, and a parallel combination of diode 23 polarized in the backward direction with respect to the source 11, a capacitor 24 and third contact 25 of the relay 13. Capacitor 24 cooperates with impedance of the exciting coil 15 to form a time constant circuit which is equivalent to the excitation transfer switch 17 of FIG. 1 and is of relatively large value of capacitance. The value of the protective resistor 18 is so selected that the current flowing through it upon closure of the control switch 16 is smaller than the reference value of the circuit current of the relay 13. The main contact 14 and the self-holding contact of the relay 13 and the current limiting resistor 20 are connected in the same manner as in FIG. 1.

As the protective switch 21 is used a semiconductor switching element, for example, a silicon controlled rectifier element (SCR) poled in the forward direction with respect to DC source 11. The gate electrode of the silicon controlled rectifier element 21 is connected to the output of fault detectors. More particularly, an OR circuit 26 comprised by three diodes 27a, 27b and 27c is connected to the gate electrode so as to supply it a signal upon each detection of faults or abnormal conditions of the source 11 and/or load 12. For example, one terminal of the diode 27a is connected to the junction between the source 11 and load 12 through a protective resistor 29 and a nonlinear element 28, for example, a Zener diode, which rapidly decreases its internal resistance when the voltage across it exceeds a predetermined value. Thus, upon occurrence of an abnormal high voltage of the source 11, the nonlinear element 28 becomes conductive immediately to apply a signal to the gate electrode of the silicon controlled rectifier element 21 through diode 27a to render the rectifier element conductive.

The switching device shown in FIG. 2 operates as follows: During the period wherein the power is not supplied to the load or under the condition shown in FIG. 2, capacitor 24 is charged from DC source 11 through resistor 18 so that the terminal voltage of the capacitor 24 is substantially equal to the terminal voltage of the source 11. Under this condition, closure of control switch 16 discharges the charge of the capacitor 24 through diode 22 and relay coil 15 to cause the relay 13 to close its contacts 14, 19 and 25. Thus, the power is supplied to the load 12 and the self-holding circuit for the relay is established in the same manner as in FIG. 1. Contact 25 serves to discharge the charge remaining in capacitor 24. Short circuit around the relay coil 15 by contact 24 is prevented by the inclusion of diode 22.

Should the source 11 be inadvertently connected with reverse polarity, capacitor 24 would be protected by diode 23 connected in parallel therewith. Further, closure of control switch 16 does not result in the operation of relay 13 because of the presence of diode 22, thus positively preventing supply of power of opposite polarity to load 12. Furthermore, when the voltage of the source 11 exceeds a predetermined value by some reason, the nonlinear element 28 becomes conductive to apply a signal to the gate electrode of the silicon controlled rectifier element 21 through diode 27a to render it conductive to substantially short circuit the relay coil 15. Thus, the relay is deenergized to interrupt the power to the load 12.

To resume power supply to the load 12 from source 11 under this condition, once the control switch 16 is opened and is then reclosed as has been described in connection with FIG. 1. In this case, from the opening to the reclosing of the control switch 16 there must be quiescent period which is substantially larger than the time constant of the time constant circuit comprised by capacitor 24 and resistor 18. Thus, after the relay 13 has been deenergized by some abnormal condition of the source, the relay can not be reenergized unless the control switch 16 is once opened. Moreover, said quiescent period positively prevents supply of power to the load too frequently in the presence of the abnormal condition. Thus, with the embodiment shown in FIG. 2, in addition to various advantages described above, all advantages described in connection with FIG. 1 can be realized.

Although in the embodiment shown in FIG. 2, a means responsive only to the abnormal voltage of the source 11 has been illustrated as comprising fault detecting means, it is to be understood that such detector may be so constructed that it can detect a number of abnormal conditions at a number of points in the power circuit system. The OR circuit functions to supply all outputs of a plurality of fault detectors to a single protective switch 21.

FIG. 3 illustrates a modified embodiment of this invention wherein power is supplied to the load 12 through a conventional inverter circuit and wherein corresponding elements are designated by the same reference numerals as in FIG. 2.

In the embodiment shown in FIG. 3, the current limiting resistor 20 which is included in the holding circuit of relay 13 also functions as the protective resistor for the silicon controlled rectifier element 21 connected through a diode bridge rectifier circuit to an output coil 33 of an inverter 31 of which input coil 32 is connected via the relay 13 to the source 11. Accordingly, when the inverter 31 becomes inoperative for some reason the holding circuit of relay 13 will be deenergized. Dependent upon the type, the inverter 31 usually requires certain time lag until its output voltage builds up to normal voltage. For this reason, it is advantageous to connect a resistor 34 in series with relay contact 25 to prolong the discharge time of the capacitor 24 thus enabling to maintain the relay 13 in its operative condition by the discharge current of capacitor 24 until the output of the inverter 31 builds up to normal to establish the holding circuit for the relay. Similar to the embodiment shown in FIG. 2, current limiting resistor 250 may be connected to the source 11 only through the main relay circuit 14.

As shown, a current transformer 35 is connected in series with a power line between main relay contact 14 and the input of the inverter 31. Across the output terminals of the current transformer are connected input terminals of a diode bridge rectifier circuit 36, the output terminals thereof being connected across the gate and cathode electrodes of the silicon controlled rectifier element 21 via diode 27b comprising an OR circuit. The turn ratio of the current transformer 35 is selected such that when the inverter is operating normally from the power supply source 11 the current transformer 35 will provide an output signal which is insufficient to render conductive the silicon controlled rectifier 21, whereas when an abrupt and faulty current larger than the normal value flows through the inverter the current transformer will provide an output signal sufficient to render conductive the silicon controlled rectifier element 21. Thus upon occurrence of a faulty condition in the load current caused by, for instance, miscommutation or short circuiting of a load 12, the silicon controlled element 21 will become conductive to short circuit the relay coil 15 deenergizing the relay 13.

Another detecting means is connected to a diode 27c of the OR circuit which detects an abnormal high voltage impressed upon the load 12 due to the failure of the inverter 31. More particularly, across the output winding 37 of the inverter 31
are connected input terminals of a diode bridge rectifier circuit 38 in parallel with the load 12, output terminals of the rectifier circuit being connected across the gate and cathode electrodes of the silicon controlled rectifier element 21 via a protective resistor 39, a nonlinear element or Zener diode 40 and said diode 27c. Thus, the output AC voltage of the inverter 31 is rectified by the rectifier circuit 38 and then applied to the nonlinear element 40. Accordingly, when the output voltage of the inverter becomes excessively high, the nonlinear element 40 will conduct to render conductive the silicon controlled rectifier element 21, thus deenergizing relay 13. Although in FIG. 3, control switch 16 is shown located remotely, its operation is identical to those of FIGS. 1 and 2.

In this manner, the holding current of a relay adapted to supply power to a load is reduced so as to minimize a control switch for the relay. In addition, a simplified protective device is provided to positively protect the source and load upon occurrence of an abnormal condition.

We claim:

1. A switching device comprising a relay including an exciting coil and a main contact adapted to supply power from a source to a load; a pickup circuit for said relay including said exciting coil, a protective resistor and a control switch which are connected in series across said source; a holding circuit for said relay including said control switch, said exciting coil and a current limiting resistor which are connected in series across said source via said main contact of said relay, said current limiting resistor limiting the exciting current to a value less than the pickup current of said relay; an excitation circuit switching means to deenergize said pickup circuit after the relay has picked up; and a protective switching means connected in series with said current limiting resistor across said source, said protective switch being closed to short circuit said exciting coil of said relay when outputs from fault detectors are supplied whereby upon occurrence of abnormal conditions in the source and/or in the load, the relay is deenergized to disconnect said load from said source.

2. The switching device according to claim 1 wherein said excitation circuit switching means comprises a switch connected in series with said pickup circuit and interlocked with said control switch, said first-mentioned switch opening automatically after a definite time after closing thereof.

3. The switching device according to claim 1 wherein said excitation circuit switching means comprises a capacitor which is connected in parallel with said exciting coil and said control switch, said capacitor being connected in series with said protective resistor across said source so as to be charged thereby, the closure of said control switch causing said capacitor to discharge through said exciting coil thus causing said relay to pick up.

4. The switching device according to claim 1 wherein said protective switching means comprises a semiconductor switching element connected in the forward direction with respect to said source, said semiconductor switching element being connected to be rendered conductive in response to outputs from fault detectors to short circuit said exciting coil of said relay.

5. The switching device according to claim 1 wherein said current limiting resistor is connected through a rectifier circuit to the output of an inverter connected between said source and said load, and said holding circuit is energized by the output of said inverter.

6. The switching device according to claim 3 wherein a diode reversely poled with respect to the polarity of said source is connected in parallel with said capacitor so as to short circuit said capacitor to disable pickup of said relay when the polarity of source is reversed.

7. The switching device according to claim 3 wherein a contact of said relay is connected in parallel with said capacitor and diode poled forwardly with respect to the discharge current of said capacitor is connected between said exciting coil and said capacitor so as to cause said capacitor to discharge through said contact after said relay has picked up.

8. The switching device according to claim 4 wherein an OR circuit is connected to the input of said semiconductor switching element; said OR circuit including a plurality of inputs respectively receiving output signals from a plurality of fault detectors responsive to different types of faults of the power circuit.

9. The switching device according to claim 4 wherein said semiconductor switching element consists of a silicon controlled rectifier element.