

May 3, 1966

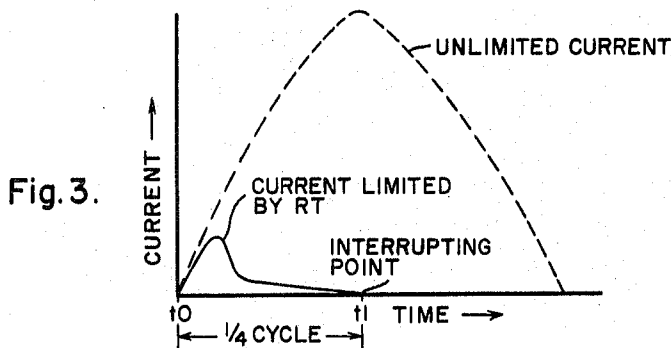
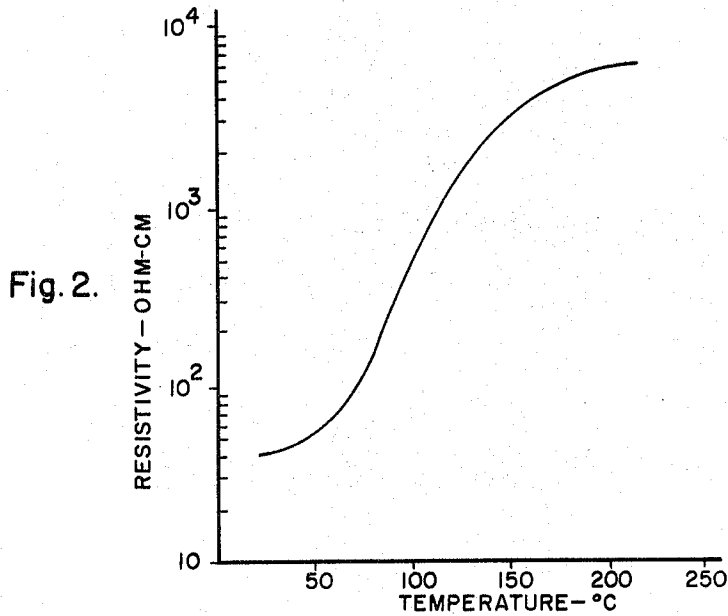
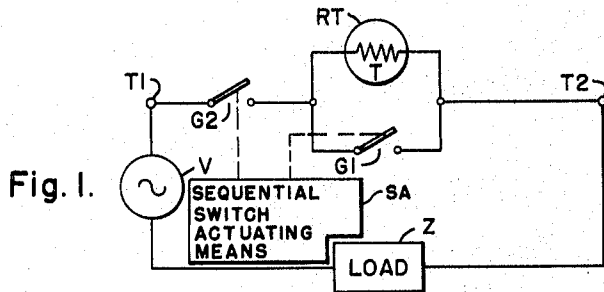
A. P. STROM ETAL

3,249,810

CIRCUIT INTERRUPTING APPARATUS

Filed Nov. 20, 1962

2 Sheets-Sheet 1



WITNESSES:

Bernard R. Gregory
James F. Young

INVENTORS
Albert P. Strom and
Thomas E. Browne, Jr.

BY
Clement L. Mc Hale
ATTORNEY

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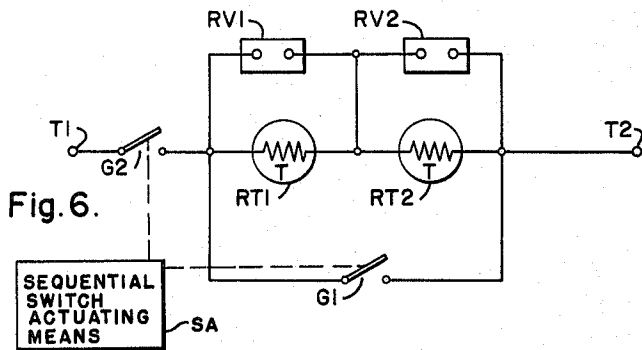
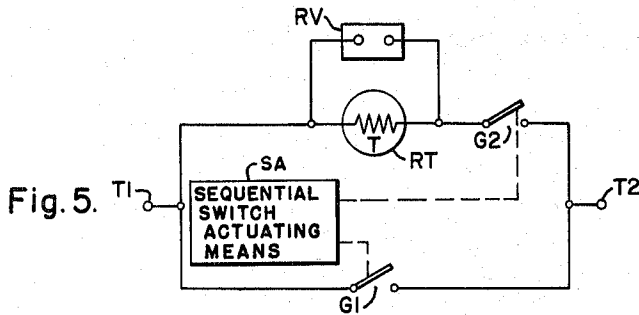
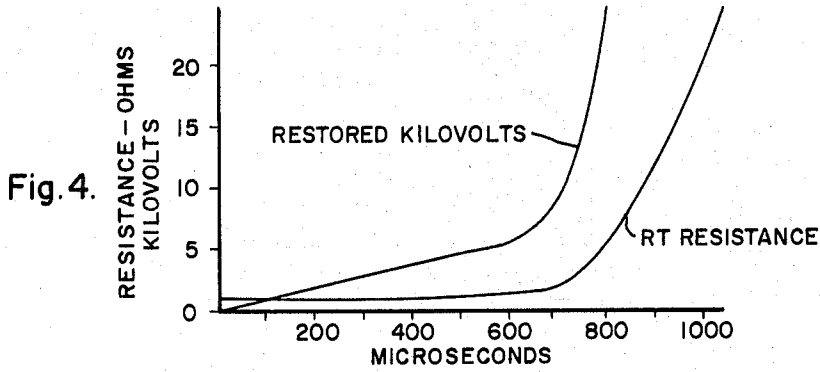
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CIRCUIT INTERRUPTING APPARATUS

Albert P. Strom and Thomas E. Browne, Jr., Forest Hills, Pa., assignors to Westinghouse Electric Corporation, Pittsburgh, Pa., a corporation of Pennsylvania
 Filed Nov. 20, 1962, Ser. No. 238,872
 4 Claims. (Cl. 317-11)

The present invention relates to circuit interrupting apparatus, and more particularly to circuit interrupting apparatus utilizing current limiting protecting devices.

In circuit interrupting apparatus it is desirable that the switch gap be opened with a low interrupting effort. That is, it is desirable that the circuit may be interrupted from conduction to open circuit conditions with a minimum of physical effort and while limiting the amount of arcing in the gap of the circuit breaker. Moreover, it is desirable that the medium in the arc space between the contacts quickly lose its ionization after current zero and recovers its dielectric strength. If such conditions are not present in circuit interrupters, excessive heat from the arcing will seriously damage the breaker structure and insulation, and greatly limit the life of the apparatus.

It is, therefore, an object of the present invention to provide improved circuit interrupting apparatus in which the switching gap is shunted with a device to limit the rate of application of energy to the gap by the connected circuit.

It is a further object of the present invention to provide circuit interrupter apparatus in which the energy appearing across the switching gap is dissipated through the use of positive temperature coefficient thermistor devices.

Broadly, the present invention provides circuit interrupting apparatus in which a thermistor having a large positive temperature coefficient (PTC), that is, its resistance increases by many times for a small increase in temperature, is placed across the gap of a switch with the energy across the switch being dissipated quickly so that the switch is not damaged and the circuit may be opened with a minimum of interrupting effort.

These and other objects will become more apparent when considered in view of the following specification and drawings, in which:

FIGURE 1 is a schematic diagram of one embodiment of the present invention;

FIG. 2 is a plot of the resistivity versus temperature characteristic of a thermistor having a positive temperature coefficient that may be utilized in the present invention;

FIG. 3 is a plot of current as a function of time which will be used to explain the operation of the present invention;

FIG. 4 is a plot of resistance and kilovolts as a function of microseconds which will be used to explain the operation of the present invention;

FIG. 5 is a schematic diagram of another embodiment of the present invention; and

FIG. 6 is a schematic diagram of another embodiment of the present invention for use in interrupting alternating and direct current.

Referring to FIG. 1, the circuit interrupter is shown for use between a source of alternating potential V and a load circuit including a load Z . The interrupter circuit includes the primary interrupting switch $G1$ which has connected thereacross a positive temperature coefficient thermistor device RT . Connected in series with the parallel combination of the switch $G1$ and the thermistor RT is the isolating switch $G2$, which is, in turn, connected to the terminal $T1$. When the switch $G2$ is opened the potential source is completely isolated from the load.

Thermistor devices having positive temperature coeffi-

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icients which may be utilized in the present invention have been disclosed in U.S. Patent No. 2,976,505, by Y. Ichikawa, issued March 21, 1961, and assigned to the same assignee as the present application. A typical characteristic of one of the aforementioned devices is shown in FIG. 2. It may be seen from this plot of resistivity as a function of temperature that for a small increase in temperature there is a substantial increase in the resistivity of the device. The increase in resistivity is such that the conductivity of the device decreases to the order of 1% of the normal conductivity as the temperature rises from room temperature to approximately 200° C.

Now referring to the plots of FIGURES 3 and 4 and the circuit of FIGURE 1, if a fault occurs at some point in the circuit past the terminal $T2$ or if other conditions necessitate the isolation of the source from the external circuit, the switches $G1$ and $G2$ must be opened. The switch $G1$ is opened at time $t0$. The current then passing from $T1$ to $T2$ ordinarily passing through the closed switch $G1$ will tend to be transferred to the PTC shunt RT . Until the first current zero is reached, the voltage tending to transfer current to the thermistor RT will only be the arc voltage; thus negligible heating of the shunt RT will occur until the end of the half cycle. Near a current zero, on current reversal, the arc across the gap of the switch $G1$ momentarily extinguishes. This occurs partly as a result of a low shunting resistance of the thermistor RT operating at a relatively low temperature. After reversal, all of the current must flow in the thermistor shunt RT . The voltage available to rekindle the arc across the gap of the switch $G1$ is then only the IR drop in the thermistor RT . Since the resistance is initially very low, the arc gap of the switch has a relatively long time after current zero to lose its ionization and recover its dielectric strength. On the other hand, as the voltage rises on the PTC shunt RT , the shunt heats up and its resistance increases very rapidly with the increase in temperature, as can be seen from FIGURES 2 and 4. This action tends to limit the current and change its phase, as can be seen by FIGURE 3. The value of the current is reduced to a small fraction of the value it would have been without the shunt, the unlimited current being shown by the dotted curve of FIG. 3. The limited current passes through a zero value at approximately $\frac{1}{4}$ cycle after $t0$, the zero at which the arc was interrupted, and thus, when the circuit voltage is also at a zero value. The small resistance limited 100% power factor current can then easily be interrupted by another series switch $G2$, which may be opened simultaneously with or in a predetermined time relation immediately after the opening of the switch $G1$ by any conventional sequential switch actuating means SA . The switch $G2$ then isolates the load completely from the power source, interrupting the residual current which would pass through the circuit at the time $t1$.

It can be shown for a PTC thermistor, as disclosed in the patent by Y. Ichikawa, supra, having a resistance of one ohm and a volume of 500 cubic centimeters that such a thermistor, having characteristics of those of FIGURE 2 will have a diameter of 13.5 centimeters and a thickness of 3.5 centimeters. The specific heat of such a material is approximately 0.1 with a density of about 5 grams per cubic centimeter. The maximum voltage gradient on the thermistor, assuming the arc voltage to be 600 volts, would then be 172 volts per centimeter. The temperature rise during the initial half-cycle of arcing across the switch $G1$ would then be approximately 3° C. If a 20,000 ampere arc current is assumed, the initial rate of rise of voltage on the switch $G1$ will be approximately 10.6 volts per microsecond. This being an extremely low rate of rise for an interrupter, very little interrupting effort will be necessary to interrupt the current in the switch $G1$ at

the first current zero and thus readily transfer the current to the shunt RT.

Further calculations show the voltage rate of rise on the thermistor, used on a 6900 volt, 20,000 ampere circuit, would actually fall in the first 600 microseconds from 10.6 to about five or six volts per microsecond giving the arc space a long period in which to recover dielectric strength. Because of the suddenly increasing resistance of the thermistor device RT, the voltage rate of rise would then increase rapidly, so that the full peak voltage would be restored in about 1000 microseconds, as is shown in FIG. 4. The voltage then will actually rise above the peak circuit voltage across the thermistor. This reverses the current rate of change and rapidly decreases the current since the resistance of the thermistor RT approaches about 100 ohms to limit the current to a final value of about 100 amperes. The resistance limited current may then be interrupted by the switching gap G2 at the next current zero, ¼ cycle after the current has been transferred to the shunt RT. Calculations indicate that a 20,000 ampere current, 28,000 amperes peak, can be limited to a maximum of 5000 peak amperes before the current is brought to zero. The thermistor will not overheat under these conditions since the energy input is reduced by the high resistance of the device with increasing temperature to a value that gives a temperature rise of about 4° C. per half cycle with full voltage impressed after the current has been limited. For a breaker for which repetitive interruptions are required over a short time period, two or more shunts may be provided. A new shunt may be inserted on reclosure, allowing the first thermistor shunt to cool. Moreover, thermistor shunts of this type could be utilized with higher voltages by placing them in series circuit relation.

Another embodiment is shown in FIGURE 5, in which a voltage sensitive resistor RV is connected across the thermistor device RT. In using a thermistor device having a rapidly increasing resistance, a voltage of many times peak line voltage may appear across the shunt if the current is limited too quickly. The shunt is useful in that it reduces the current rapidly, however, the voltage should not become so large that there is danger of flash-over across the shunt itself. To prevent such danger, a voltage sensitive resistor, such as a lightning arrester valve element or voltage limiting non-linear resistor, which are both well known in the art, may be used in parallel with the thermistor RT. Such a non-linear voltage sensitive resistor has a high resistance at low impressed voltages. However, when a predetermined voltage is reached, the resistance has decreased to a much lower value.

Thus, under normal operation of FIGURE 5 with the switches G1 and G2 closed, very little current flows through the arrester element RV connected in parallel with the low resistance thermistor element RT. However, when G1 is opened, the rapid increase in IR drop on the RT shunt may cause the voltage to exceed a given value of about 2 or 3 times normal peak voltage. The voltage sensitive element RV then carries most of the current as its resistance decreases due to the effect of such overload voltages. Therefore, any further voltage increases across the positive temperature coefficient thermistor device RT are prevented. It should also be noted in the circuit of FIG. 5 that the switch G2 is placed in series with the thermistor RT. This is an alternate connection for the switch G2 from the arrangement of FIG. 1. However, in both circuits the switch G2 is in a series circuit relationship with the thermistor RT to permit the desired operation for the circuit interrupter circuit. Shunting the thermistor block with the arrester elements may also be used when several thermistor units are used in series as in a high voltage installation. So, if the resistance of one unit rises faster than others of the series, tending to take much more than its share of voltage, the current will bypass that unit by way of the arrester element until the other units rise to about the same resist-

ance. Moreover, using such parallel combinations, the individual thermistor units need not be so carefully matched.

FIGURE 6 shows a circuit interrupter for interrupting alternating current or high magnitudes of direct current. The parallel combination including the thermistor RT1 having a positive temperature coefficient and the voltage sensitive arrester element RV1, is connected in series circuit relation with the parallel combination including the thermistor element RT2 and the arrester element RV2. The switch G1 is connected across the elements RT1-RV1 and RT2-RV2. Connected in series with the parallel circuit of switch G1 and these shunting elements is the switch G2 to completely isolate a voltage source from the rest of the circuit. By using the parallel combinations, the initial resistance across the gap G1 may be made extremely low. When the switch G1 is open, the arc voltage rapidly shunts current into the positive temperature coefficient thermistor elements RT1 and RT2. The arc at G1 becomes unstable and is extinguished. As the resistance increases, the current will be limited to a low value which then may be easily interrupted by the isolating switch G2. If, for example, a 50,000 ampere, 600 volt circuit is to be interrupted, an arc voltage of 500 volts will shunt the current into a 0.01 ohm thermistor element thereby increasing the resistance of the thermistor elements to about 1 ohm, leaving only 600 amperes to be interrupted by the switch G2. The arrester elements RV1 and RV2 serve to protect the thermistor devices against overvoltages, as explained in reference to FIG. 5.

Further advantages in using the thermistor devices having rapidly rising positive temperature coefficients can be seen in that: Unusually low parallel resistances can be used in the initial gap resulting in very low interrupting efforts. Since the resistance increases to a high order of magnitude, current can be finally interrupted at a low value. The large rise in resistance makes the shunt self-protecting after current limiting. Voltage limited non-linear resistors can be used in parallel with the PTC elements to prevent overvoltage and to aid in distributing voltage on series connected thermistor elements.

Although the present invention has been described with a certain degree of particularity, it should be understood that the present disclosure has been made only by way of example and numerous changes in the details of circuitry and apparatus and the combination and arrangement of parts and elements may be resorted to without departing from the scope and the spirit of the present invention.

We claim as our invention:

1. A circuit interrupter comprising, first switching means, thermistor means comprising material having a positive temperature coefficient whose resistivity increases rapidly with temperature connected across said first switch means, voltage sensitive means having a resistance which decreases with voltage connected across said thermistor means, second switching means operatively connected in series with said thermistor means and switch actuating means for sequentially actuating the opening of the first switching means first and then actuating the opening of the second switching means in a predetermined time relation after the opening of the first switching means.

2. Circuit breaking apparatus for interrupting a circuit between a source of potential and a load circuit the combination of, interrupting switch means operative to disconnect a conducting path therethrough, a thermistor device comprising material having a positive temperature coefficient wherein its resistance increases rapidly with the temperature, said thermistor device being connected across said interrupting switch to provide a conducting path when said interrupting switch means is opened, voltage sensitive means having a resistance which decreases with increasing voltage connected across said thermistor device, isolating switch means operatively

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connected in series with said thermistor device, said isolating switch being opened a predetermined time after said interrupting switch to isolate said source of potential from said load circuit and switch actuating means for sequentially actuating the opening of the interrupting switch first and then actuating the opening of the isolating switch means a predetermined time after the opening of the interrupting switch means.

3. Circuit breaking apparatus for interrupting a circuit between a source of alternating potential and a load circuit the combination of, interrupting switch means operative to disconnect a conducting path therethrough, a thermistor device comprising material having a positive temperature coefficient so that its resistance increases rapidly with the temperature, said thermistor device being connected across said interrupting switch means to provide a conducting path when said interrupting switch means is opened, voltage sensitive means having a resistance which decreases with increasing voltage connected across said thermistor device, isolating switching means operatively connected in series with said thermistor device, said isolating switch means being opened a predetermined time after said interrupting switch means is opened and operative to isolate said source of potential from said load circuit and switch actuating means for sequentially actuating the opening of the interrupting switch means first and then actuating the opening of the isolating switch means a predetermined time after the interrupting switch means is opened.

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4. Circuit breaking apparatus for interrupting a circuit between a source of potential and a load circuit the combination of, interrupting switch means operative to disconnect a conducting path therethrough, a plurality of thermistor devices each comprising material having a positive temperature coefficient so that its resistance increases rapidly with the temperature, said thermistor devices being connected across said interrupting switch means to provide a conducting path when said interrupting switch means is open, a plurality of voltage sensitive devices each having a resistance which decreases with increasing voltage, one of said voltage sensitive devices being connected across each of said thermistor devices, isolating switch means operatively connected in series with said thermistor devices, said isolating switch means being opened in a predetermined time relation with respect to said interrupting switch means to isolate said source of potential from said load circuit and switch actuating means for sequentially actuating the opening of the interrupting switch means first and then actuating the opening of the isolating switch means a predetermined time after the interrupting switch means is opened.

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30 SAMUEL BERNSTEIN, *Primary Examiner.*