July 29, 1941. T. A. RICH ET AL 2,251,004

THERMAL VOLTAGE RESPONSIVE RELAY

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Fig. 1.

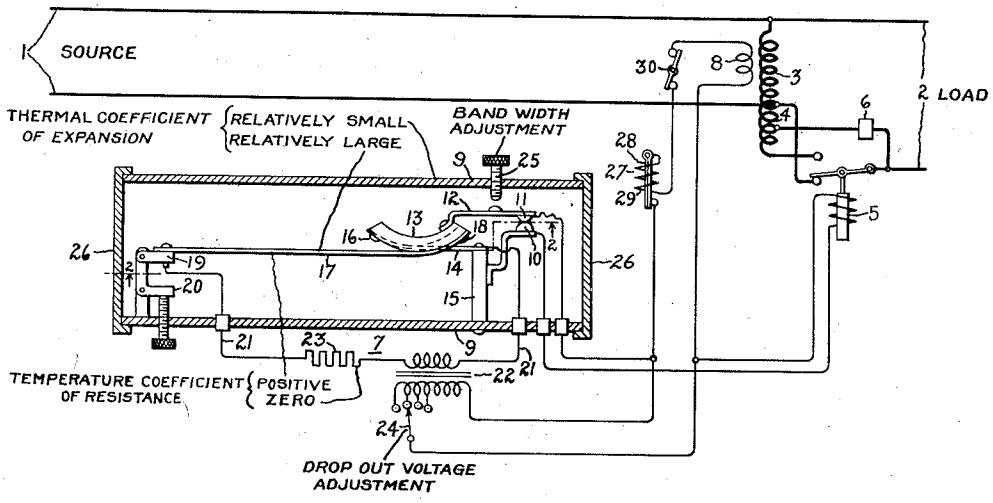


Fig. 2.

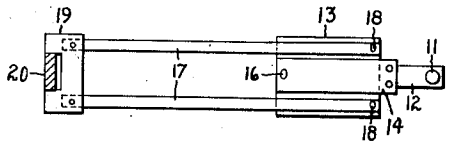
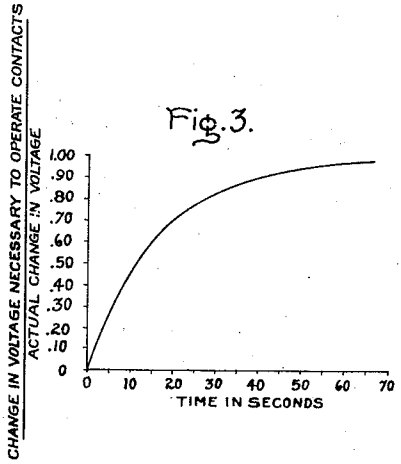


Fig. 3.



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2,251,004

THERMAL VOLTAGE RESPONSIVE RELAY

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Application November 29, 1938, Serial No. 243,033

4 Claims. (Cl. 175—320)

This invention relates to control systems and more particularly to improvements in control systems for automatic voltage regulators.

An object of the invention is to provide a novel and simple primary voltage sensitive control relay.

Another object of the invention is to provide a thermal voltage sensitive regulator control element having an inherent time delay in its operation.

A further object of the invention is to provide a thermal voltage sensitive relay having means for adjusting its drop-out voltage and its pick-up voltage.

An additional object of the invention is to provide a novel and simple thermal voltage sensitive relay which is compensated for variations in ambient temperature.

The invention will be better understood from the following description taken in connection with the accompanying drawing and its scope will be pointed out in the appended claims.

In the drawing Fig. 1 is a diagrammatic illustration of the invention applied to an automatic one-step voltage booster, Fig. 2 is a sectional view of the voltage relay taken on the line 2—2 of Fig. 1, and Fig. 3 is a curve illustrating the time delay characteristic of the thermal voltage responsive device.

Referring now to Fig. 1, there is shown therein a main alternating current supply circuit 1 connected to an alternating current load circuit 2 through a step-up autotransformer having a common winding 3 and a series voltage boosting winding 4. A solenoid operated contactor 5 is arranged selectively to by-pass the winding 4 or connect it in series in the load circuit. In order to prevent interruption of the current in the load circuit during operation of the contactor 5, a by-pass 6 is provided for carrying the load current during a positional change of the contactor 5.

The operation of the contactor 5 in response to the voltage of the circuit 1 is controlled by a voltage sensitive device 7. Both the contactor 5 and the device 7 are energized in accordance with the voltage of the circuit 1 by means of a tertiary winding 8 on the voltage regulating transformer.

The voltage sensitive device 7 comprises a main supporting member 9 which is preferably constructed of metal and which is shown by way of example as being in the form of a tube or cylinder. Mounted at one end of the tube is a fixed contact 10 and a movable co-operating contact 11 carried by an arm 12 on a curved contact operating member 13. Member 13 is supported by means of a spring blade 14, one end of which is fastened to a suitable support 15 in the cylinder and the other end of which is fastened by any suitable means, such as by rivet 16, to the member 13. The spring blade 14 is straight in its natural or unflexed position. However, it is forced into a bent position conforming to the curvature of the middle portion of the member 13 by means of tension strips 17 which are fastened to the member 13 by any suitable means, such as rivets 18, and which pass through the cylinder and are fastened at the other end thereof to a yoke member 19. A suitable linkage 20 is provided for adjusting or setting the initial tension of the strips 17. These strips are made of metal having a relatively large thermal coefficient of expansion and they are connected by means of conductors 21 to the secondary winding of an adjustable ratio transformer 22 whose primary winding is connected to be energized by the tertiary winding 8. A substantially zero temperature coefficient of resistance resistor 23 is connected in series with the heating strips 17 for providing ambient temperature compensation in a manner which will be described more fully hereinafter. The contacts 10 and 11 serve to control the connection of the winding of the solenoid operating magnet of the contactor 5 to the tertiary winding 8.

The voltage ratio of the transformer 22 is made adjustable by means of a tap switch 24 in order to adjust the drop-out voltage of the relay 7. The band-width or pick-up voltage adjustment of the relay 7 is made by means of an adjustable stop member 25 for limiting the motion of the movable contact 11 away from the fixed contact 10.

In order to protect the device and prevent objectionable circulation of air through the tubular member 9, removable end caps 26 are provided therefor.

In order to prevent injury to the operating winding of the contactor 5 if the voltage of circuit 1 falls to such a low value as to be incapable of causing the contactor to pick up, a protective device 27 is connected in the energizing circuit of the contactor 5. This device is shown as consisting of a bimetallic switch arm 28 connected in series with a heater coil 29 and its arrangement is such that if a current above a predetermined value flows through the heater 29, the bimetallic switch 28 will open the energizing circuit of the contactor 5.

A manual control switch 30 is provided for selectively opening and closing the regulator control circuit so that the regulator may readily be taken out of service if desired.

The general operation of Fig. 1 is such that if the voltage of the supply circuit 1 falls below a predetermined value, the contacts 10 and 11 will engage each other, thereby energizing the contactor 5 and causing it to connect the boosting series winding 4 in the load circuit. Conversely, if the voltage of the circuit 1 rises above a predetermined value, contacts 10 and 11 will separate, thereby de-energizing the contactor 5 and causing it to open the circuit through the series winding 4 and complete a by-pass connection around this winding.

The mechanism comprising the curved member 13 together with the blade spring 14 and the tension members 17 is the sole invention of Theodore A. Rich and is described and claimed broadly in his application Serial No. 243,032, filed November 29, 1938, and assigned to the assignee of the present application. This mechanism causes the contacts to operate with a snap action. This snap action is the result of having the spring blade 14 and the tension members 17 conform to surfaces of the member 13 having different curvatures. These different curvatures are such that as the member 13 rotates in a clockwise direction, as viewed in the drawing, about a movable axis which corresponds approximately with the line where the spring 14 leaves engagement with the member 13, the vertical distance between the strips 17 and the spring 14 increases.

A contraction of the heating strips 17 due to cooling will exert a torque on the member 13. The lever arm of this torque is approximately the vertical distance between the heating strips 17 and the spring 14. This torque is opposed by the bending torque of the spring 14. When the heating strips have contracted to the point where the force exerted by them times the lever arm of this force is greater than the moment of the spring, the member 13 is rotated clockwise. By reason of the curvatures of the surfaces of the member 13 the lever arm increases rapidly enough to maintain the torque of the heating strips 17 greater than the increasing torque of the opposing spring strip 14, although the force exerted by the heating strips 17 decreases. Thus the contacts 10 and 11 are snapped together. Upon heating of the strips 17 they expand and as the lever arm decreases rapidly when the member 13 turns counterclockwise, the contacts 10 and 11 will be snapped open.

The heating of the strips 17 is controlled by the heating effect of the current passed through them. By means of the adjusting mechanism 20 the initial tension of the members 17 is adjusted to the proper value. Thereafter, the voltage at which the contacts separate is controlled by adjusting the ratio of the transformer 22 by means of the adjusting member 24.

The proper adjustment or setting of the device 7 is obtained by first setting the adjusting means 24 on the tap which will cause the contacts 10 and 11 to separate when the voltage of circuit 1 reaches a predetermined value. The next step is to adjust the member 25 to the point at which contacts 10 and 11 close when the voltage falls a predetermined amount. The first adjustment is usually referred to as a drop-out voltage adjustment and the last adjustment is usually referred to as a bandwidth adjustment. "Band-width" may be defined as the difference between the voltage at which the contacts close and the voltage at which the contacts open expressed as a per cent of the voltage at which the contacts open.

As the strips 17 do not heat and cool or expand and contract instantaneously with changes in main circuit voltage, the device 7 has a time delay characteristic. An example is shown in Fig. 3. This time delay characteristic is inverse in that the larger the actual change in voltage with respect to the change in voltage necessary to cause operation of the contacts the shorter will be the time delay. Such an inverse characteristic is often desirable in automatic regulators as it prevents immediate response of the regulator to relatively small changes in voltage which often will correct themselves in a short time while it permits substantially immediate response to relatively large changes in voltage which ordinarily should be corrected immediately.

The curve of Fig. 3 can be used to determine the length of time necessary for the contacts to operate for a given voltage change. The voltage before the change occurs should remain nearly constant for about two minutes if the curve is to be strictly correct. Use of the curve can most easily be explained by an example. Assume that the drop-out voltage is adjusted for 110 volts and that the voltage applied to the control device has been 108 volts for two minutes. Assume now that the voltage is suddenly increased to 112 volts. Since the contacts are adjusted to operate at 110 volts the voltage change (from 108 to 110) necessary eventually to operate the contacts is fifty per cent of the actual change (from 108 to 112). From the curve it will be seen that a fifty per cent voltage change corresponds to a time delay of eleven and one-half seconds.

In order that the setting of the device 7 will remain undisturbed with changes in ambient temperature the tubular member 9 is made of a material having a thermal coefficient of expansion which is somewhat less than that of the heating strips 17 and in addition the substantially zero temperature coefficient of resistance resistor 23 is connected in series with the heating strips 17. The purpose of the resistor 23 is to reduce the overall temperature coefficient of the circuit containing the heating strips 17 to a relatively low value. Theoretically, if the circuit containing the heating strips 17 did not change its resistance with changes in temperature, complete ambient temperature compensation would be secured if the thermal coefficient of expansion of the supporting member 9 were the same as that of the strips 17 because then both of these elements would expand and contract by equal amounts for the same change in ambient temperature and hence there would be no ambient temperature produced differential expansion tending to cause operation of the contacts. However, changes in ambient temperature actually cause changes in the resistance of the heating strips 17, thereby causing changes in heating current to flow therein. For example, if the ambient temperature falls, the heating strips 17 tend to contract and also their electrical resistance decreases. This means that for a given voltage applied to the transformer 22 the current in the heating strips will increase and therefore the heating effect of the current in these strips will increase. Consequently, the temperature rise above ambient of the heating strips is not constant with variations in ambient temperature. By making the coefficient of expansion of the supporting means less than the coefficient of expansion of the strips 17

the heating strips will tend to contract enough more than the support for lower ambient temperatures to compensate for the fact that their temperature rise for the same voltage is greater. The net result is that the tension in the heating strips is the same.

At the present time it is believed that a stainless steel known as Carpenter No. 2 cutlery steel is best for the heating strips. This steel contains chromium, nickel and carbon. It can be hardened. In the hardened state and at about 70° C. it has a coefficient of expansion of 11×10^{-6} inches per inch per degree centigrade. The most suitable material known at the present time for the support 9 is a stainless steel containing 12 to 15 per cent chromium and 0.12 per cent carbon. This material has a coefficient of expansion of 10.53×10^{-6} inches per inch per degree centigrade.

Should the voltage of the line 1 drop approximately 75 per cent below normal the contacts 10 and 11 would of course close, thus energizing the solenoid 5 but this device would not pick up its armature. With the armature in the dropped-out position the solenoid has a relatively low reactance and thus a relatively high current would flow through the solenoid winding. It has been found that if this condition persists for a long enough time the contactor 5 will be injured.

In order to protect the winding 5 against this injury the protective device 27 is arranged to open its contacts and thus reduce the current in the winding 5. As soon as the protective device 27 cools, its contacts will again close thereby causing relatively high current to flow in the winding 5 but this will again cause the device 27 to be heated so that this device will alternately open and close its contacts, thus maintaining the entire system in a condition where it will automatically operate properly as soon as the voltage of circuit 1 returns to normal, while at the same time it prevents serious over-heating of the contactor 5.

While there has been shown and described a particular embodiment of this invention, it will be obvious to those skilled in the art that various changes and modifications can be made therein without departing from the invention and, therefore, it is aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

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

1. In a thermal relay, a supporting member, a switch, said switch having a tensioned operating member which snaps the switch contacts open and closed when the tension thereon changes a predetermined amount, a thermally expandible electrical conducting member having one end thereof fastened to said supporting member and having the other end thereof fastened to said operating member, said operating member being wholly supported by its tensioning means including said expandible member, and an electric circuit for passing a heating current through said expandible member.

2. In a thermal voltage regulating relay, a supporting member, a switch, said switch having a tensioned operating member which snaps the switch contacts open and closed when the tension thereon changes a predetermined amount, a thermally expandible electrical conducting member having one end thereof fastened to said supporting member and having the other end thereof fastened to said operating member, an electric circuit for passing a heating current through said expandible member, means for adjusting the drop-out voltage of said relay comprising a variable ratio transformer for supplying current to the heating circuit for said expandible member, and means for adjusting the band-width of said relay comprising an adjustable stop for limiting the separation of said contacts.

3. In an ambient temperature compensated thermal relay, a pair of contacts, a pair of thermally expandible members arranged so that a difference in thermal expansion and contraction thereof will operate said contacts, and a circuit having a positive temperature coefficient of resistance for heating one of said members in accordance with the voltage of an electric circuit, the other of said members having a lower coefficient of thermal expansion than said heated member so as to compensate for the temperature coefficient of resistance of said heating circuit.

4. In an ambient temperature compensated thermal relay, a pair of contacts, a pair of thermally expandible members arranged so that a difference in thermal expansion thereof will operate said contacts, a circuit having a positive temperature coefficient of resistance for heating one of said members in accordance with the voltage of an electrc circuit, the other of said members having a lower coefficient of thermal expansion than said heated member so as to compensate for the temperature coefficient of resistance of said heating circuit, and a substantially zero temperature coefficient resistor connected in said heating circuit for reducing the overall temperature coefficient of resistance of said circuit.

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