

Oct. 19, 1943.

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2,332,073

ELECTRIC CIRCUIT CONTROL

Filed July 11, 1940

2 Sheets-Sheet 1

FIG. 1

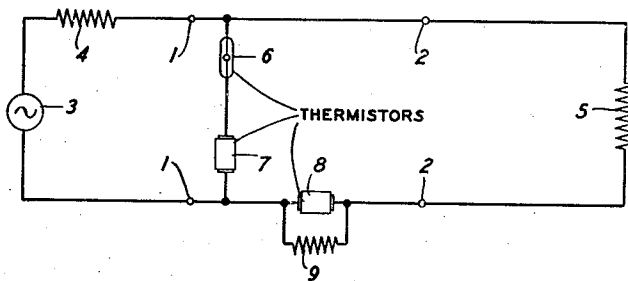
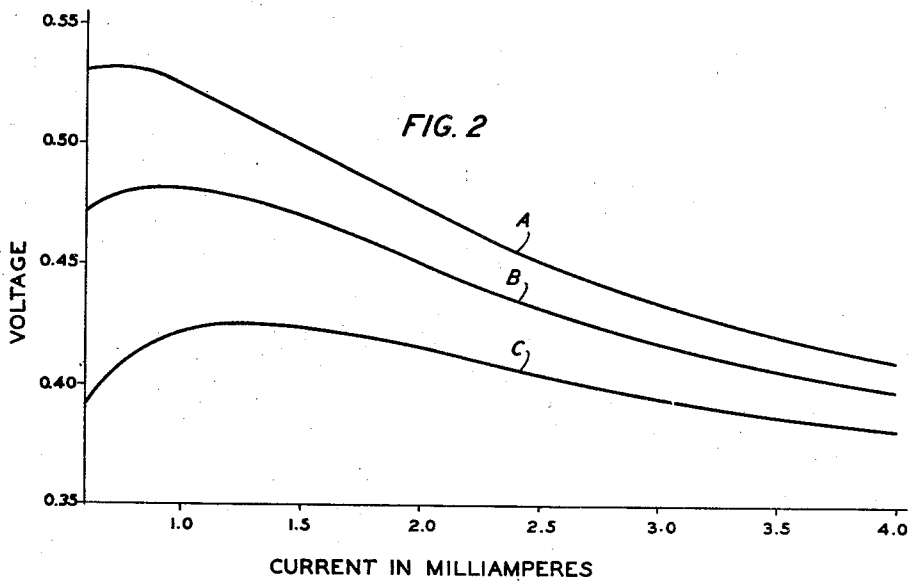


FIG. 2



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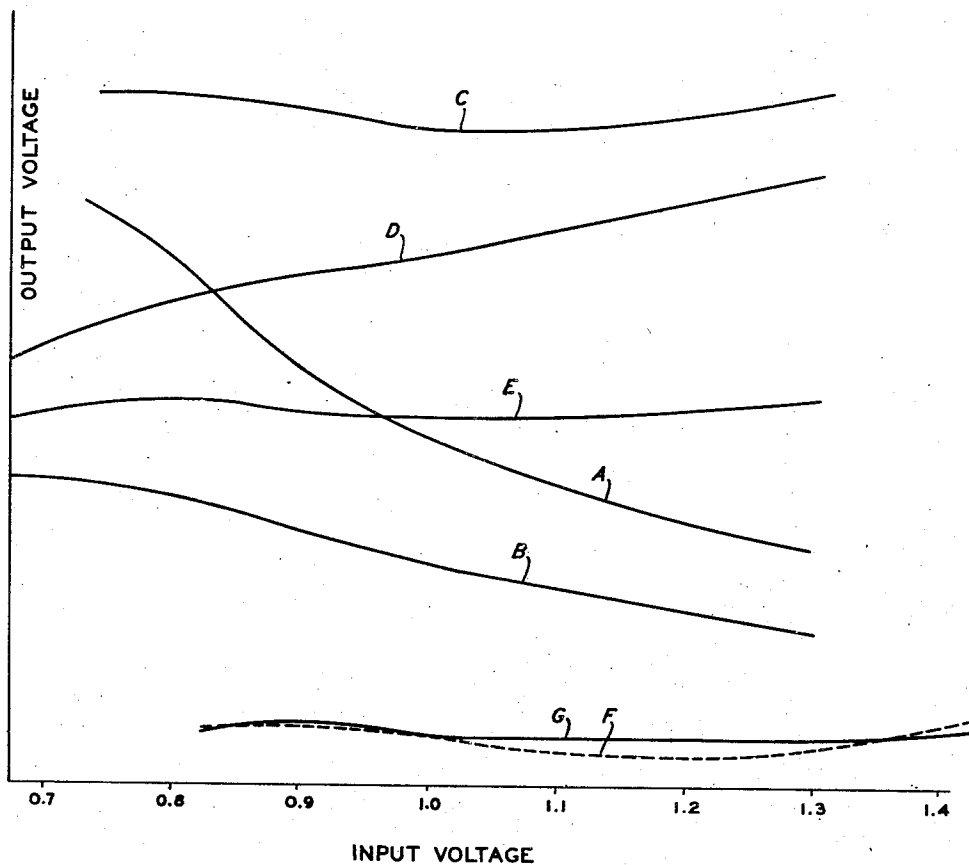
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FIG. 3



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ELECTRIC CIRCUIT CONTROL

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12 Claims. (Cl. 171-229)

The present invention relates to electric current transmission systems and more particularly to the modification, control and stabilization of current and voltage in such systems.

One of the objects of this invention is to provide ambient temperature compensation for a thermally operated control device that is variably heated in accordance with changes in the circuit but that is incidentally influenced by changes in ambient temperature to which it is exposed.

Another object of this invention is to provide apparatus that on insertion between a current source of inconstant voltage and a load circuit will absorb or otherwise reduce the voltage fluctuations and deliver current to the load at substantially constant voltage.

A further object of the invention is to provide an improved voltage stabilizer or regulator utilizing a circuit element having a high temperature coefficient of resistance, the resistance of which is automatically varied in response to changes in the voltage of the current source.

A more particular object is to provide such a voltage stabilizer in which the voltage regulating function is accurately performed despite wide variations in the temperature of the ambient surrounding the responsive element.

In accordance with a preferred form of the present invention there is provided an electric regulator of the kind described comprising a plurality of circuit elements each of which has a high temperature coefficient of resistance. Elements of this character are hereinafter designated thermistors. One of the thermistors provided is of a type, sometimes known as self-heating, in which variations in the effective amplitude of the current traversing the element give rise to marked changes in its temperature and resistance. The other type of thermistor provided is substantially unaffected in temperature and resistance by the current traversing it, but it undergoes marked changes in resistance in response to changes in ambient temperature. The self-heating thermistor in accordance with the preferred embodiment of the invention constitutes the primary voltage regulating element, and one or more other thermistors of the other type specified function primarily to compensate for fluctuations in ambient temperature. The two types of thermistors may be so correlated as to characteristics and circuit relation, as in the embodiment hereinafter to be described, that a substantially constant output voltage is obtained despite fairly wide variation of both the applied voltage and the ambient temperature.

The nature of the invention and its various objects, features and advantages will appear more fully from a consideration of the preferred embodiment illustrated in the accompanying drawings in which:

Fig. 1 shows schematically the circuit of a voltage regulating system in accordance with the invention; and

Figs. 2 and 3 comprise curve diagrams to which reference will be made in the course of the description of the Fig. 1 circuit.

Referring now to Fig. 1, there is illustrated schematically a voltage stabilizer in accordance with the invention having a pair of input terminals 1 and a pair of output terminals 2 connected in tandem circuit relation between a current source 3 of fluctuating voltage and a load adapted to be operated at constant voltage and represented by the resistance 5. Connected in series with the source 3 is an impedance 4 which may be made up wholly or in part by the internal resistance of source 3. The source may be, for specific example, an oscillator or a pair of busbars supplying current of carrier frequency at approximately constant voltage for a repeater regulating channel in a multiplex carrier telephone system. It will be understood that the example suggested is purely illustrative.

The voltage regulator shown in Fig. 1 comprises two thermistors, 6 and 7, connected in series with each other and arranged as a shunt connection across the input terminals 1. Thermistor 6 has a temperature coefficient of resistance that is negative in sign, and it is self-heating, that is, its temperature and resistance fluctuate widely with changes in the intensity of the current traversing the shunt connection. Although there are many thermistors having the characteristics specified for element 6, I find that a bead thermistor comprising the combined oxides of nickel, manganese and copper as more particularly described in the application of E. F. Dearborn et al., Serial No. 336,734, filed May 23, 1940 (U. S. Patent No. 2,282,944, granted May 12, 1942), is especially well adapted for the purpose at hand.

Thermistor 7 has a negative temperature coefficient of resistance and preferably is so constituted that the currents traversing it have negligible effect on its temperature and resistance. It may comprise, for specific example, a disc of the combined oxides of nickel, manganese and cobalt, as more fully described in the application of E. F. Dearborn, Serial No. 280,692, filed June 23, 1939

(U. S. Patent No. 2,274,592, granted February 24, 1942).

The regulator preferably includes also another thermistor 8, which may be of the same disc type as thermistor 7, and which preferably comprises the combined oxides of nickel and manganese as disclosed in the application of R. O. Grisdale, Serial No. 274,114, filed May 17, 1939 (U. S. Patent No. 2,258,646, granted October 14, 1941). It is shunted by a resistor 9 and interposed between the shunt connection and one of the output terminals 2.

An understanding of the construction and manner of operation of the regulator may be facilitated by a consideration of the curve diagrams comprising Fig. 2.

The relation between the current traversing a typical self-heating thermistor, such as specified for element 6, and the voltage appearing across its terminals may be as represented by curve A in Fig. 2, supposing that the ambient air temperature is constant at some normal or reference value T here taken as 60° F. Although the latter be constant, the temperature of the thermistor, which may be well above the ambient temperature, varies with changes in the applied voltage and with consequent changes in the electrical power absorbed and converted into heat within the thermistor. If a fixed resistor be connected in series with the self-heating thermistor, the voltage-current characteristic of the series combination at the reference temperature T will be modified and on proper choice of the resistor in the particular case the voltage across the terminals of the series combination may be made almost independent of the current flowing through it for a wide range of current values.

If the ambient temperature changes, as for example to a higher temperature, the voltage-current characteristic of the self-heating thermistor changes, and may take the forms shown by curves B and C of Fig. 2, which are specifically applicable to the curve A thermistor at ambient temperatures of 76° and 100° F., respectively. At each of these higher ambient temperatures a different value of series resistor is required to make the voltage across the combination substantially independent of the current.

On replacing the fixed resistor in whole or in part by an element such as thermistor 7, the effective resistance in series with thermistor 6 and therefore also the shape of the voltage-current characteristic, is made a function of the ambient temperature. By proper selection of the temperature-resistance characteristic of thermistor 7, the resultant characteristic may be maintained flat over a wide range of current for each of a range of ambient temperatures.

Fig. 3 comprises a family of curves relating the voltage of the source 3 and the voltage appearing across the circuit beyond resistor 4 for various circuit conditions and ambient temperatures. With only thermistor 6 connected across the circuit and with the load 5 disconnected, the two voltages may be related in the manner shown by curve A of Fig. 3, the ambient temperature being maintained at the reference temperature of 60° F. On increase of the ambient temperature to 100° F. the voltage relation may be as represented by curve B of Fig. 3. With a resistor of the proper value interposed in series with thermistor 6 the voltage characteristic at 60° may be as shown by curve C. Whereas the terminal voltage in this case is substantially independent of the applied voltage, it does not remain so at

higher temperatures, as will appear from curve D which is plotted for an ambient temperature of 100°.

If now the assumed fixed resistor in series with thermistor 6 be replaced by a thermistor 7 proportioned to have the same resistance at the reference temperature, the voltage characteristic of the combination at that temperature will be the same as before, that is, as shown by curve C. On increase of the ambient temperature, the resistance of thermistor 7 decreases, which is in the proper direction to match the series resistance required to maintain the voltage constant. By proper selection of the temperature-resistance characteristic of thermistor 7 the voltage across the combination may be held substantially constant at each ambient temperature within a substantial temperature range. At 100°, for example, the voltage relation may be as shown by curve E. To a first approximation then, the input voltage versus output voltage characteristic remains substantially horizontal over the respective ranges of the variables, but the change in ambient temperature is accompanied by a change in the voltage across the series combination. In other words the voltage is different at each ambient temperature but at each ambient temperature it is substantially independent of input voltage and current fluctuations.

The operating characteristic last described may be quite satisfactory for some services where it is important that rapid voltage fluctuations be suppressed but immaterial whether the voltage changes slightly at the comparatively slow rate of ambient temperature changes. Such gradual voltage changes as do appear may, depending on the characteristic of the thermistor employed and the circuit parameters, be negligible. For more precise voltage regulation in any case, however, the thermistor 8 is included in series with one of the output leads of the regulator.

Inasmuch as thermistor 8 has a negative temperature coefficient of resistance, its resistance decreases with an increase in ambient temperature thereby decreasing the impedance in series with the load 5 and consequently increasing the voltage appearing across the load. It has been observed above that in the absence of thermistor 8, the voltage across the load tends to decrease with an increase in ambient temperature, hence thermistor 8 operates to counteract this tendency. By selecting for thermistor 8 an element having the proper resistance-temperature characteristic the one tendency can be made substantially to neutralize the other so that the load voltage remains constant at all temperatures within the operating ambient temperature range. Curves F and G of Fig. 3, applicable at 60° and 100°, respectively, show the accurate stabilization of voltage across the connected load for the specific example herein set forth. In order that the thermistor 8 may introduce the proper resistance-temperature characteristic, it may be found convenient to shunt it with a resistor 9 and to adjust the latter to such value as may be found optimum.

In one instance of practice in accordance with the invention, the self-heating thermistor 6 had the voltage-current characteristic shown in the curves of Fig. 2, thermistor 7 had resistance values of 40, 29 and 18 ohms at ambient temperatures of 60°, 76° and 100° F., respectively, thermistor 8 had resistance values of 690, 465 and 265 ohms at the respectively same temperatures, the load resistance 5 was 575 ohms, resistance 4

was 307 ohms, and shunting resistance θ was 1000 ohms. The electromotive force of the source was approximately one volt. The thermistors, suspended in a wax-filled metallic container, were exposed to and slowly affected by changes in ambient temperature, and operated to maintain substantially constant voltage at all ambient temperatures for which they were designed.

Although the present invention has been described and illustrated largely in terms of a single embodiment, it will be appreciated that the underlying principles are susceptible of practical application in a variety of other embodiments within the spirit and scope of the appended claims.

What is claimed is:

1. In combination with an electrical circuit connecting a current source and a load, a voltage stabilizer comprising a self-heating thermistor and a second thermistor connected in series with each other across said circuit in shunt relation to both said current source and said load, both of said thermistors being exposed to and substantially affected in resistance by changes in ambient temperature and both having negative temperature coefficients of resistance, said second thermistor being substantially unaffected in resistance by current traversing it but substantially only by said changes in ambient temperature, and a third thermistor, having a negative temperature coefficient of resistance and exposed to and substantially affected in resistance only by changes in the ambient temperature, connected in series in said circuit between said stabilizer and said load.

2. In an electrical circuit, an L-type network comprising as the shunt arm two thermistors in series with each other and as the series arm a third thermistor, all of said thermistors being subject alike to changes in ambient temperature substantially affecting their respective resistance values, one of said two thermistors being substantially affected in temperature and resistance by current traversing said shunt arm and the others of said thermistors being substantially unaffected by said current.

3. In combination with an electrical circuit connecting a current source and a load, a voltage stabilizer comprising a current-dependent thermistor the resistance of which varies with current substantially only in dependence on changes in the heating effect thereof, and a second thermistor connected across said circuit in series with said current-dependent thermistor, said current-dependent thermistor having the characteristic that over a substantial range of current values an increase in the effective amplitude of the current traversing it is accompanied by a decrease in the voltage drop across it, and the further characteristic that the rate of said decrease in voltage drop varies in magnitude with changes in the ambient temperature, said second thermistor being substantially unaffected in resistance by current traversing it but substantially only by said changes in ambient temperature.

4. In combination with a circuit carrying electrical oscillations, a shunt connected across said circuit and comprising two thermistors, one of said thermistors being a current heated thermistor the temperature and resistance of which are substantially dependent on the effective amplitude of the oscillations traversing said shunt and substantially independent of the instantaneous

amplitude of said oscillations, and the other of said thermistors being a thermistor affected in resistance substantially only by changes in ambient temperature, both of said thermistors having negative temperature coefficients of resistance.

5. In an electrical circuit, a source of oscillations of fluctuating mean intensity, a load connected to said source, and a transmission modifier connected in tandem circuit relation between said source and said load, said transmission modifier comprising input and output terminals and a pair of leads connecting said input and output terminals, two thermistors connected in series with each other as a shunt branch across said pair of leads, both of said thermistors being exposed to and substantially affected in resistance by variations in ambient temperature, one only of said thermistors being substantially affected in temperature and resistance in response to fluctuations in the intensity of oscillations traversing said shunt branch, said one thermistor having the characteristic that over a substantial range of current values an increase in the effective amplitude of the current traversing it is accompanied by a decrease in the voltage drop across it, and the further characteristic that the rate of said decrease in voltage drop is a function of said ambient temperature, the other of said thermistors having a resistance that varies in dependence on the said ambient temperature in such manner that the voltage drop across said two thermistors in series is substantially constant, at each ambient temperature in a range of ambient temperatures, irrespective of changes in the current through said thermistors.

6. A combination in accordance with claim 5 comprising a third thermistor interposed in series relation in one of said leads, said third thermistor being exposed to and substantially affected in temperature and resistance by said variations in ambient temperature and substantially unaffected by oscillations traversing it, said third thermistor having a temperature coefficient of resistance of such sign that its resistance changes in response to variations in ambient temperature in the same sense as concomitant voltage changes across said shunt branch.

7. In a circuit carrying fluctuating current, a transmission modifier interposed in said circuit comprising a circuit combination that includes a first impedance element traversed by said current and having the characteristic that throughout a substantial range of current values a given increase in the current through it is accompanied by a decrease in the voltage across it the rate of which decrease in voltage is substantially different for different ambient temperatures within a range of operating ambient temperatures, whereby the effect of a given change in current on the voltage across said circuit combination tends to vary with changes in ambient temperature, and a compensating impedance element in said circuit combination, said compensating element having the characteristic that a given increase in the current through it is accompanied by an increase in the voltage across it, the rate of which increase in voltage also is different for different ambient temperatures within said range, said compensating impedance element having its rate of increase in voltage with given increase in current at any given ambient temperature within said range complementarily related to the said rate of decrease in voltage across said first impedance element with given increase

in current at the given ambient temperature to maintain the said effect of a given change in the current traversing said elements on the voltage across said combination substantially the same at all ambient temperatures within the said operating range of ambient temperatures.

8. A combination in accordance with claim 7 in which said first impedance element and said compensating impedance element are thermistors.

9. In a circuit carrying electrical current of variable intensity, two impedance elements in series circuit relation whereby both are traversed by the same said current, one of said impedance elements having the characteristic that a given increase in the current through it is accompanied by a decrease in the voltage drop across it, the extent of which decrease in voltage drop is substantially dependent on the ambient temperature, the other of said impedance elements having the characteristic that a given increase in the current through it is accompanied by an increase in the voltage drop across it, the extent of which increase in voltage drop is substantially dependent on the said ambient temperature and varies with ambient temperature in the same sense as concomitant variations in the said extent of change in voltage drop across said one impedance element.

10. A combination in accordance with claim 9 30 in which each of said two impedance elements is a thermistor.

11. A combination in accordance with claim 9 in which more particularly the said rate of decrease in voltage drop across said one impedance element is substantially equal to the said rate of increase of voltage drop across said other impedance element.

12. In combination with an electrical circuit connecting a current source and a load, a voltage stabilizer comprising a current-dependent 5 thermistor the resistance of which varies with current substantially only in accordance with the heating effect thereof, and a second thermistor connected in circuit in series with the first thermistor, both of said thermistors being exposed to 10 and substantially affected in resistance by changes in ambient temperature, said first thermistor having the characteristic that over a substantial range of current values an increase in the current through it is accompanied by a dropping off in the voltage across it, the rate at which 20 said voltage drops off being a function of ambient temperature and said second thermistor having the characteristic that an increase in the current through it is accompanied by a rise in the voltage across it, the rate at which said voltage rises being substantially equal, over a range of ambient temperatures, to the said rate at which the voltage across said first thermistor drops off.

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