Sept. 2, 1941. E. FRIEDLÄNDER 2,254,941

RELAY SYSTEM

Filed March 9, 1938

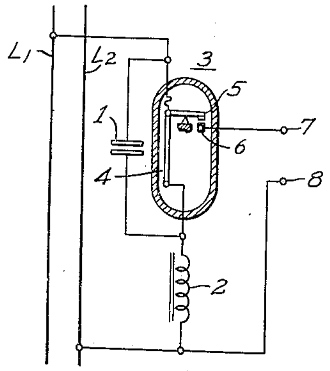

Fig. 1.

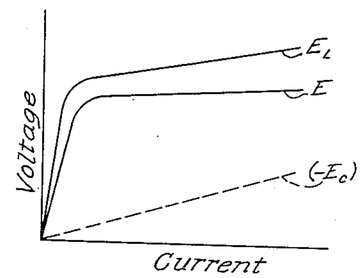

Fig. 2.

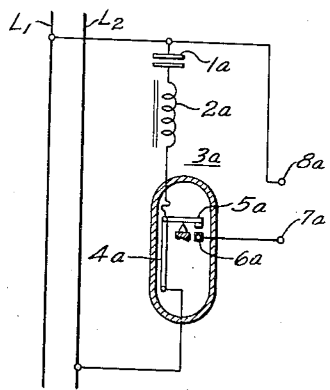

Fig. 3.

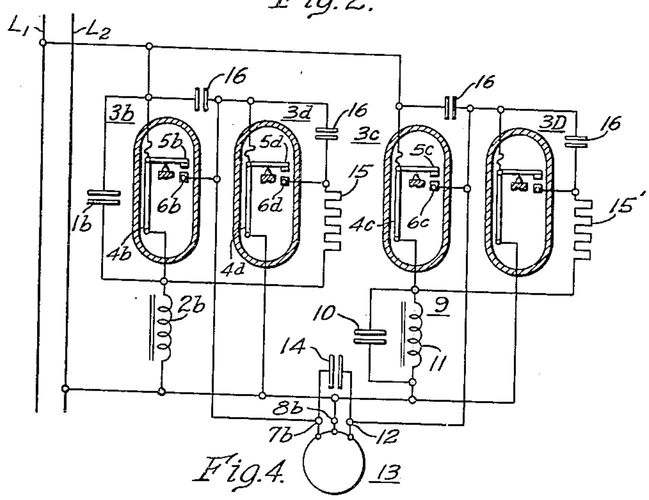

Fig. 4.

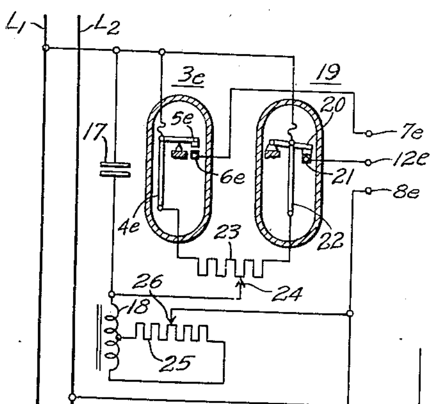

Fig. 5.

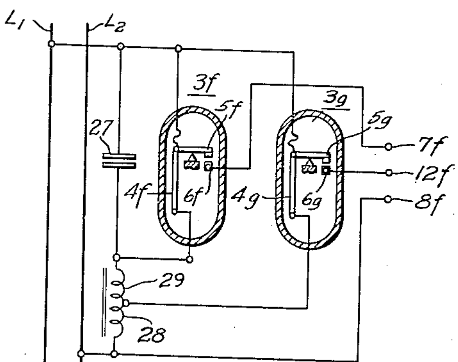

Fig. 6.

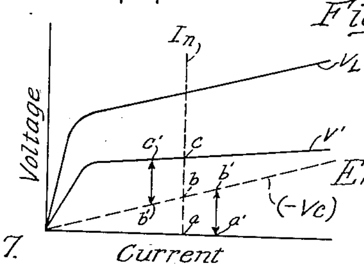

Fig. 7.

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RELAY SYSTEM

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9 Claims. (Cl. 175—320)

This invention relates to a control system and it has particular relation to a relay control system energized through a tuned circuit.

In the design of a relay, one of the major problems is to provide a relay both with a sensitive response and a response that remains accurate and reliable. If an electromagnetic relay is employed, a condenser may be connected in series with the winding of the relay and tuned to respond to a predetermined condition of an alternating current circuit. Such a system, though sensitive, is not entirely satisfactory for the reason that the winding of the electromagnetic relay changes its impedance during actuation, thereby varying the tuning of the relay system.

Resonant circuits may be employed which do not change their characteristics during relay actuation provided separate iron core choke coils and series condensers are employed. If a choke coil in a resonant circuit for relay actuation is given a direct current premagnetization dependent on the potential of a tuning condenser from a rectifier connected in series with the resonant circuit, stable operation may be obtained. Such systems, however have the disadvantage of requiring a number of additional elements, such as choke coils and rectifiers.

According to my invention, a control system is provided wherein a tuned or resonant circuit is employed for actuating a switch or relay device having an actuating element which does not change the inductance or capacitance of the tuned circuit during the actuation of the device. For this purpose, a thermal switch or relay has been found suitable. The thermal switch may have an actuating element comprising a wire or a bimetallic unit which, when heated, changes in dimension to operate the switch contacts. Such a system does not change its inductance or capacitance during actuation, the actuating element being, in effect, a constant resistance.

Accordingly, it is an object of my invention to provide a sensitive control unit having an accurate and reliable actuating system.

It is also an object of my invention to provide a control relay system having a tuned energizing system associated with a relay actuating element which, during actuation, does not vary the tuning of the energizing system

A further object of my invention is to provide a control relay system employing a thermally actuated relay controlled by a tuned circuit.

Another object of my invention is to provide an accurate and sensitive control system responsive to two different values of a variable condition.

A still further object of my invention is to provide a tuned control system for maintaining a variable condition accurately between two predetermined limits.

Other objects of my invention will be apparent from the following description taken in conjunction with the accompanying drawing, in which:

Figure 1 is a diagrammatic view of a thermally actuated relay associated with a tuned control circuit;

Fig. 2 is a graphic representation of the voltage-current relationships in the control system of Fig. 1;

Fig. 3 is a diagrammatic view of a modification of the circuit of Fig. 1;

Figs. 4, 5 and 6 are diagrammatic views of various modifications of circuits responsive to two different conditions of an alternating current circuit; and,

Fig. 7 is a graphic representation of the voltage current relationships of the circuit illustrated in Fig. 6.

Referring to the drawing, Figure 1 depicts a tuned circuit comprising a capacitance **1** and a choke coil or inductance **2** having an iron core connected in series across the conductors L_1 and L_2 of an alternating current circuit. A relay **3** has an actuating element **4** connected in parallel with the capacitance.

As pointed out above, the relay actuating element **4** is so selected that its impedance remains constant during the actuation of the relay, and a thermal actuating element has been found desirable for this purpose. During actuation the thermal element **4** moves a pivoted contact member **5** into engagement with a fixed contact member **6**. A pair of output terminals **7**, **8** are provided for the control system, and are connected respectively to the fixed contact member **6** and the conductor L_2.

The iron core choke coil **2** and the capacitance **1** are so proportioned as to produce the voltage-current relationships shown in Fig. 2, wherein voltage is represented by ordinates and current by abscissae. The voltage across the choke coil **2** with respect to the current flowing therethrough is shown by a curve E_L, the voltage across the capacitance (shown above the current axis for convenience) by a curve ($-E_c$), and the resultant voltage across the tuned circuit by a curve E. It will be noted that the resultant voltage curve E has a voltage-current relationship such that the current increases slowly with respect to voltage to a certain point, and then increases rapidly with respect to a further change in voltage. If the operating point of the relay system is so adjusted that the system normally operates adjacent the nearly horizontal portion of the curve E, any increase in voltage across the conductors L_1, L_2 will be accompanied by a large increase of current through the tuned circuit and by an accompanying large increase of voltage across the capacitance 1. Since the relay 3 is responsive to the voltage across the capacitance 1, such an increase of voltage positively energizes the relay to close its contact members 5, 6. Any device to be controlled by the relay 3 may be connected to the output terminals 7, 8.

Although the relay 3 of Fig. 1 responds to a change in voltage, it may be connected to respond to other variable conditions. For example, if it is desired to have the relay respond to the temperature of a furnace, the temperature may be employed for controlling an alternating voltage which is supplied to a relay system similar to that shown in Fig. 1. If it is desired to have the relay respond to current changes, the current may be passed through a resistance, and the voltage drop across the resistance may be employed for energizing the above relay system.

Since tuned circuits may be designed to provide an appreciable current change in response to a variation in frequency, a similar relay system may be designed for actuation in accordance with the frequency of an alternating current circuit. If the frequency and voltage of an alternating-current circuit both vary and it is desired to make the relay responsive to voltage only, a voltage proportional to the frequency change may be introduced in series with the tuned circuit.

Although the actuating element 4 of the relay 3 in Fig. 1 is in parallel with the capacitance 1, it may be connected in series with the tuned circuit as shown in Fig. 3 wherein the reference characters 1*a* to 8*a* correspond respectively to the reference characters 1 to 8 of Fig. 1. For some purposes the parallel connection of Fig. 1 is preferable for the reason that higher voltages may be applied to the actuating element 4*a*. It should be noted in Fig. 3 that the current flowing through the terminal 7*a* also flows through the actuating element 4*a* of the relay. Consequently, once the relay operates to close its contacts 5*a*, 6*a*, a holding circuit is established for the actuating element 4*a* through the load across the terminals 7*a*, 8*a*.

Instead of a single fixed contact member 6, a pair of fixed contact members may be employed with each of the relays 3, one being contacted by the movable member 5 when the actuating element 4 is deenergized, and the other being contacted by the movable element 5 when the actuating element 4 is energized. Each of the fixed contacts may be employed for control purposes.

It is also possible to connect a plurality of relays for response to different conditions of an alternating-current circuit. For example, Fig. 4 illustrates a system designed to maintain a certain variable, such as voltage, between two predetermined limits. In Fig. 4, a capacitance 1*b*, a choke coil 2*b* and a relay 3*b* are connected between the conductors L_1, L_2 of a single phase circuit and the output terminals 7*b*, 8*b* in the same manner set forth in Fig. 1 for response to an increase in voltage above a predetermined value.

For response to a drop in voltage, a second relay 3*c*, which is similar in construction to the relay 3, is connected with its actuating element 4*c* in series with a tuned parallel circuit 9, comprising a capacitance 10 and an iron core choke coil 11, across the conductors L_1, L_2. The fixed contact member 6*c* of this relay 3*c* is connected to a terminal 12.

The first relay 3*b* is adjusted to close its contact members when the voltage across the conductors L_1, L_2 rises above a predetermined value, whereas the tuned circuit 9 is proportioned to increase the current through, and actuate the relay 3*c* when the voltage across the conductors L_1, L_2 falls below a predetermined value. The output from these relays 3*b*, 3*c* may be employed for controlling a motor 13, which may be the operating motor for a voltage regulator such as a step transformer. The motor 13 may be a two-phase motor having a central lead connected to the terminal 8*b*, and two outer leads connected to the terminals 7*b*, 12. Across the two outer leads of the motor 13, a condenser 14 is connected for controlling the phase relationships in the two windings of the motor.

Under operating conditions, if the motor 13 is connected to the conductors L_1, L_2 through the terminals 7*b*, 8*b*, it will rotate in one direction, whereas if the motor is connected through the terminals 8*b*, 12, it will rotate in the opposite direction and may be used therefore for increasing or lowering the voltage across the conductors L_1, L_2 to compensate for any departure of this voltage from a predetermined value.

In some cases it has been found desirable to control the rate of reopening of the contact members of the relays 3*b*, 3*c*. For this purpose an auxiliary relay 3*d*, similar to the relay 3, may have its actuating element 4*d*, connected between the fixed contact member 6*b* of the relay 3*b* and the conductor L_2. Because of this connection, the contact members 5*d*, 6*d* of the relay 3*d* will be closed when the contact members 5*b*, 6*b* of the relay 3*b* are closed. The contact members 5*d*, 6*d* are connected between the fixed contact member 6*b* and the lower end of the actuating element 4*b* of the relay 3*b*. Consequently, whenever the contact members 5*d*, 6*d* close in response to a closure of the contact members of the relay 3*b*, the actuating element 4*b* of the relay 3*b* will be short circuited through the contact members 5*d*, 6*d*, and the current which heats the actuating member 4*b* consequently will be diminished.

Ordinarily a direct short circuit would decrease the current through the actuating element 4*b* too greatly, and for this reason a resistance member 15 is connected in series with the contact members 5*d*, 6*d*. Because of the decrease in current flowing through the actuating element 4*b*, the relay contact members 5*b*, 6*b* will tend to reopen somewhat more rapidly. If the increase in potential across the conductors L_1, L_2 is very large, the current through the actuating element 4*b* of the relay 3*b* is strong enough to keep the contact members 5*b*, 6*b* closed despite the action of the relay 3*d*, and the motor 13 consequently will run continuously. But if the potential variation is relatively small, the action of the relay 3*d* will cause the contact members 5*b*, 6*b* to reopen after a brief interval and result in intermittent operation of the motor 13. A similar relay 3D and resistance element 15′ are shown for the thermal actuating element 4*c* of the relay 3*c*.

In order to protect the contacts of the relays against the effects of high voltage, a condenser 16 may be connected across each pair of contacts.

This is particularly desirable if the contacts are enclosed in a vacuum.

Because of the tuned circuits made up of the iron core choke coils and capacitances, the control of the thermal relays is very sensitive and accurate. Therefore, the low voltage and high voltage relays of Fig. 4 may be adjusted so that the difference between their operating limits is very small.

It is also possible to operate two different relays at different values of a variable condition by means of one tuned circuit. For example, in Fig. 5 a capacitance **17** and a chock coil **18** are connected in series across the conductors L_1, L_2. Two relays **3***e* and **19** are provided for actuation by the voltage across the condenser **17**. The first relay **3***e* is similar to those previously described, and is connected to be actuated when a variable condition, such as voltage, of the conductors L_1, L_2 rises above a predetermined value.

The second relay **19** has a pair of normally closed contact members **20**, **21**. Energization of the actuating element **22** of this relay opens the contact members **20**, **21** and the circuit associated with them. The actuating element **22** is connected for actuation at a value of voltage lower than that employed for actuating the relay **3***e*.

For adjustment purposes the lower ends of the actuating elements **4***e*, **22** of the relays **3***e*, **19** are bridged by a potential divider or resistance **23** having a movable tap **24** connected to the tuned circuit between the condenser **17** and the choke coil **18**. The upper ends of the actuating elements **4***e*, **22** are connected to the conductor L_1. By varying the tap **24** the operating points of the relays **3***e*, **19** may be controlled as desired. Since a displacement of the tap **24** introduces resistance in series with one of the actuating elements while reducing the resistance in series with the other actuating element, the total resistance across the capacitance **17** tends to remain constant.

A second adjustment is provided by connecting a second divider **25** across a portion of the choke coil **18**, the divider having a movable tap **26** connected to the conductor L_2. The fixed contact members **6***e*, **21** of the relays **3***e*, **19** are connected respectively to terminals **7***e* and **12***e* and a third terminal **8***e* is connected to the line L_2. These three terminals **7***e*, **8***e* and **12***e* correspond to the terminals **7***b*, **8***b* and **12** shown in Fig. 4.

Another relay system that is energized from a single tuned circuit is shown in Fig. 6. In this arrangement a capacitance **27** and a choke coil **28** are connected in a series tuned circuit across the conductors L_1, L_2. A pair of relays **3***f*, **3***g*, which are similar to those shown in Figs. 1 to 4, are connected for energization from this tuned circuit. The first relay **3***f* has its actuating element **4***f* connected directly across the capacitance **27**. The second relay **3***g* has its actuating element **4***g* connected across the capacitance **27** and a portion **29** of the choke coil **28**.

The voltage-current relationships of the circuit shown in Fig. 6 are apparent from a study of Fig. 7 wherein ordinates represent voltage, and abscissae represent current flowing through the series circuit comprising the capacitance **27** and choke coil **28**. In this figure three voltage curves are shown; one V_L for the voltage across the choke coil **28**, a second ($-V_c$) for the voltage across the capacitance **27** (shown above the current axis for convenience), and a third V′ which represents the voltage across the portion of the choke coil **29** employed for actuating the relay **3***g*. If the relays are exactly alike, the circuit containing the capacitance **27** and choke coil **28** is so proportioned that for a normal current I_n the voltage across the capacitance **27**, represented by the ordinate *ab*, is equal to the voltage *bc* across the capacitance plus that portion **29** of the choke coil employed for actuating the relay **3***g*.

If the voltage across the conductors L_1, L_2 decreases, the current through the tuned circuit also decreases, but the voltage *bc* employed for energizing the relay **3***g* increases to a value *b′c′*, as shown in Fig. 7, sufficient for actuating the relay **3***g*.

If the voltage across the conductors L_1, L_2 increases, the current flowing through the capacitance **27** and choke coil **28** also increases, and the voltage *ab* across the capacitance increases to a value *a′ b′* sufficient for actuating the relay **3***f*. Therefore, the arrangement of Fig. 6 may be employed similarly to the arrangement shown in Figs. 4 and 5, the output terminals **7***f*, **8***f* and **12***f* of Fig. 6 corresponding to the terminals **7***b*, **8***b* and **12** of Fig. 4.

If the relay **3***c* of Fig. 4 were replaced by a normally closed relay similar to the relay **19**, shown in Fig. 5, the energizing circuit for the relay **3***c* could be similar to that employed for the relay **3***b*. In such a modification, a decrease in the voltage across the conductors L_1, L_2 would deenergize the modified relay **3***c*, thereby closing the contact members of the modified relay. The action of the auxiliary relay **3***d* in such a case should be modified to increase the current flowing in the actuating element of the modified relay **3***c*.

An auxiliary relay may be employed for increasing or decreasing the current flowing in the actuating element of any of the relays shown in Figs. 5 and 6 in a manner analogous to the employment of the relay **3***d* of Fig. 4. Protective condensers similar to the condenser **18** of Fig. 4 also may be employed for these other relays.

Although I have described my invention with reference to certain specific embodiments thereof, it is to be understood that my invention is not limited to the specific circuits, elements and arrangements disclosed, but is to be limited only by the appended claims as interpreted in view of the prior art.

I claim as my invention:

1. In a control system; a source of alternating energy; a plurality of electroresponsive control devices, each of said control devices having a thermal actuating element; and energizing means, including at least one tuned circuit for energizing said actuating elements from said source, said energizing means including impedance means adjustable for decreasing the flow of energy to one of said actuating elements and simultaneously increasing the flow of energy to another of said actuating elements.

2. In a relay system, a source of alternating energy, a tuned circuit connected for energization from said source, said tuned circuit including a capacitance member and an inductance member, a first electroresponsive device having a thermal actuating element connected for energization in accordance with the voltage across said capacitance member, and a second electroresponsive device having a thermal actuating element connected for energization in accordance with the resultant voltage across said capacitance member and a portion of said inductance member.

3. In a control system, a source of alternating

energy, a first electroresponsive control device having a thermal actuating element, a series tuned circuit for energizing said actuating element from said source, a tuned parallel circuit, and a second electroresponsive control device having a thermal actuating element connected for energization from said source through said tuned parallel circuit.

4. In a relay system; a source of alternating energy, a first relay device having a pair of normally open contacts and a thermally actuated closing element; a second relay device having a pair of normally closed contacts and a thermally actuated opening element; and energizing means, including at least one tuned circuit, for energizing said thermal elements from said source.

5. In a control system, a source of alternating current subject to variation from a predetermined condition, an electroresponsive control device having fixed-impedance actuating means, and tuned circuit energizing means for supplying energy from said source to said actuating means, said electroresponsive control device including control means effective when the variation of said source is in one direction and additional control means effective when the variation of said source is in the opposite direction from said predetermined condition.

6. In a control system, a source of alternating current subject to variation from a predetermined voltage, an electroresponsive control device having fixed-impedance actuating means, and tuned circuit energizing means for supplying energy from said source to said actuating means, said electroresponsive control device including control means operative when the voltage of said source increases beyond a predetermined point, and additional control means operative when the voltage of said source decreases beyond a predetermined point, said energizing means being more effective for variations beyond one of said predetermined points than for variations adjacent said predetermined voltage.

7. In a control system, a source of alternating current, a tuned circuit energized from said source, said tuned circuit including an inductive reactance and a capacitive reactance in series, and an electroresponsive device having a fixed-impedance actuating element connected across only one of said reactances.

8. In a control system, a source of alternating current, a tuned circuit energized from said source, said tuned circuit including an inductive reactance and a capacitive reactance, and an electroresponsive device having a plurality of thermal actuating elements connected for energization in accordance with the condition of one of said reactances, said actuating elements being energized to different degrees.

9. In a control device for an alternating current system; a circuit having a non-linear volt-ampere characteristic; control means; fixed-impedance, heat-responsive actuating means for said control means including an electrical resistance heater element; means for passing electrical current flowing through at least part of said circuit directly through said electrical resistance heater element for supplying heat to said actuating means, said actuating means being responsive to heat developed by said electrical current flowing in said electrical resistance heater element for operating said control means; and means responsive to an operation of said control means for varying the impedance offered to said electrical current.

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