Aug. 20, 1935. L. G. TUBBS **2,011,663**

REGULATING SYSTEM

Filed May 4, 1934

Fig. 1.

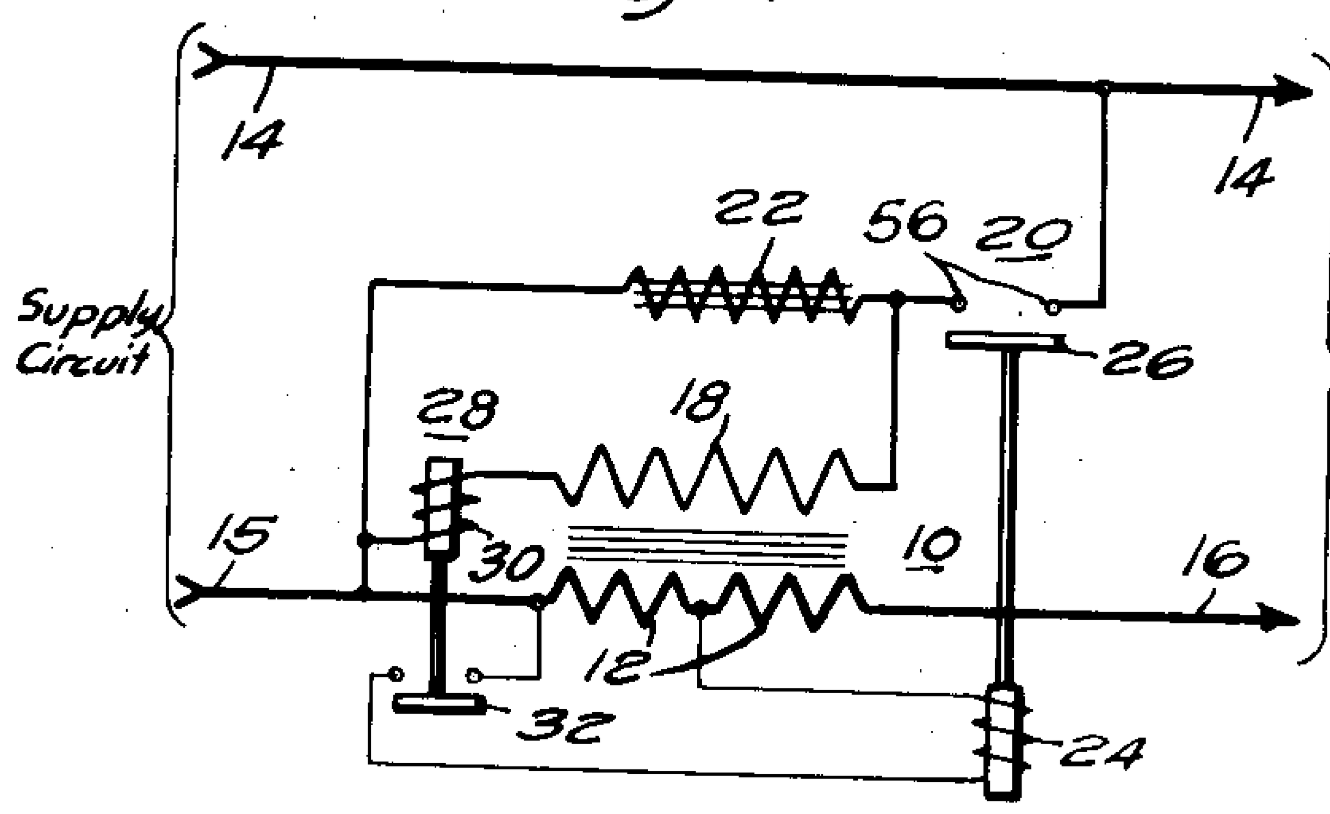


Fig. 5.

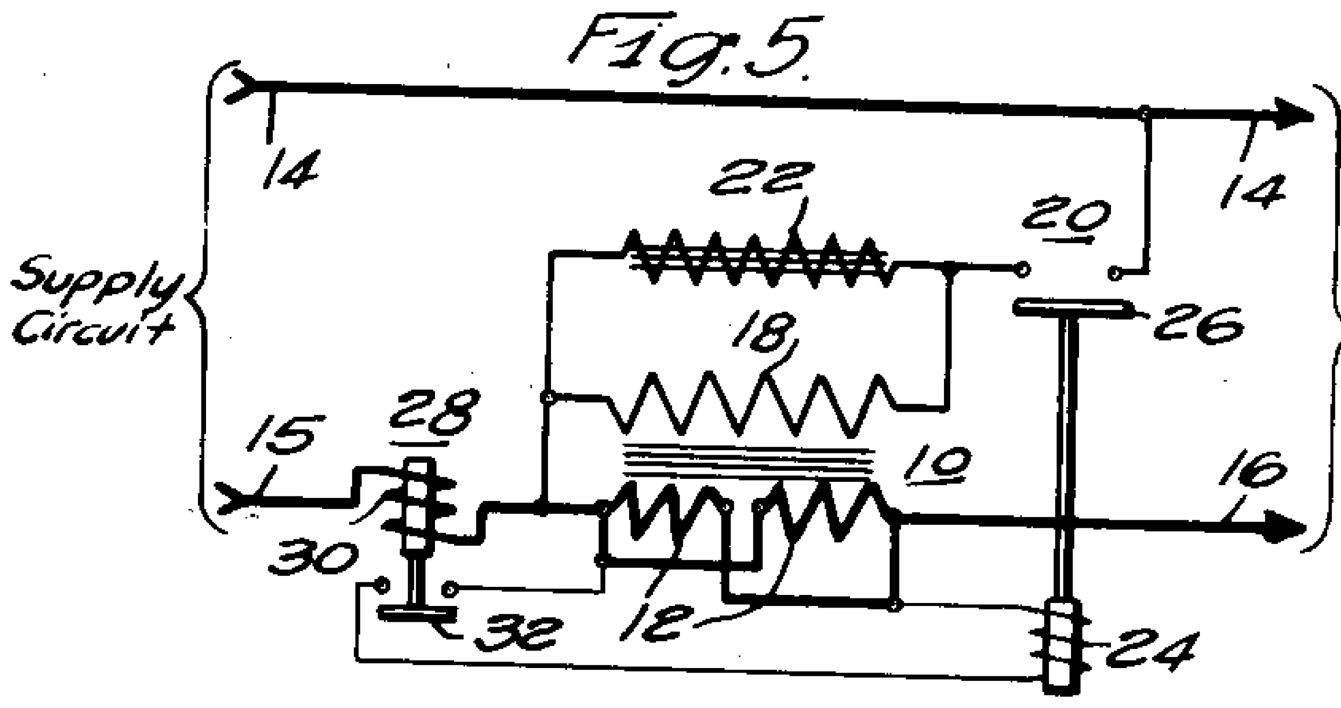


Fig. 2.

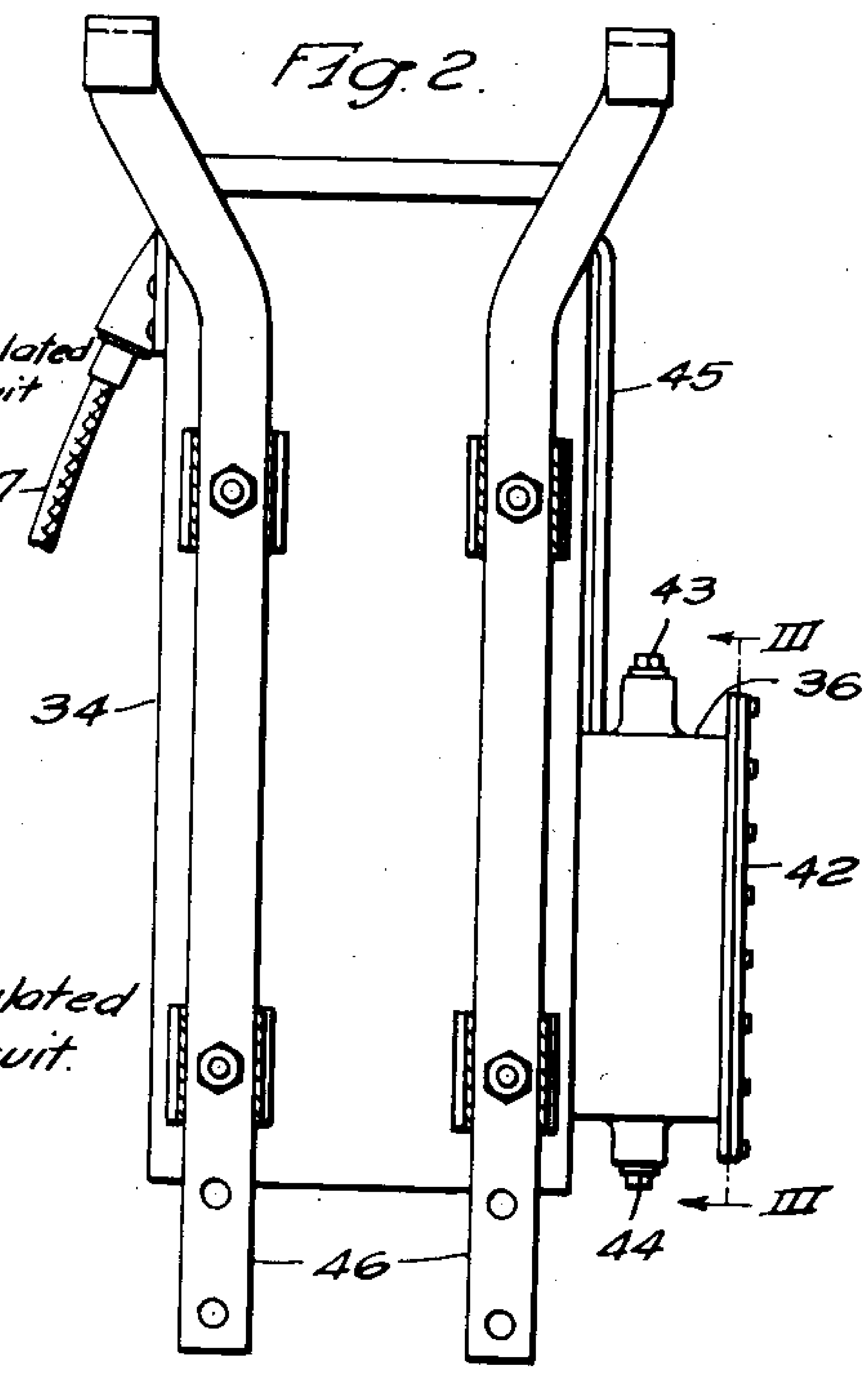


Fig. 3.

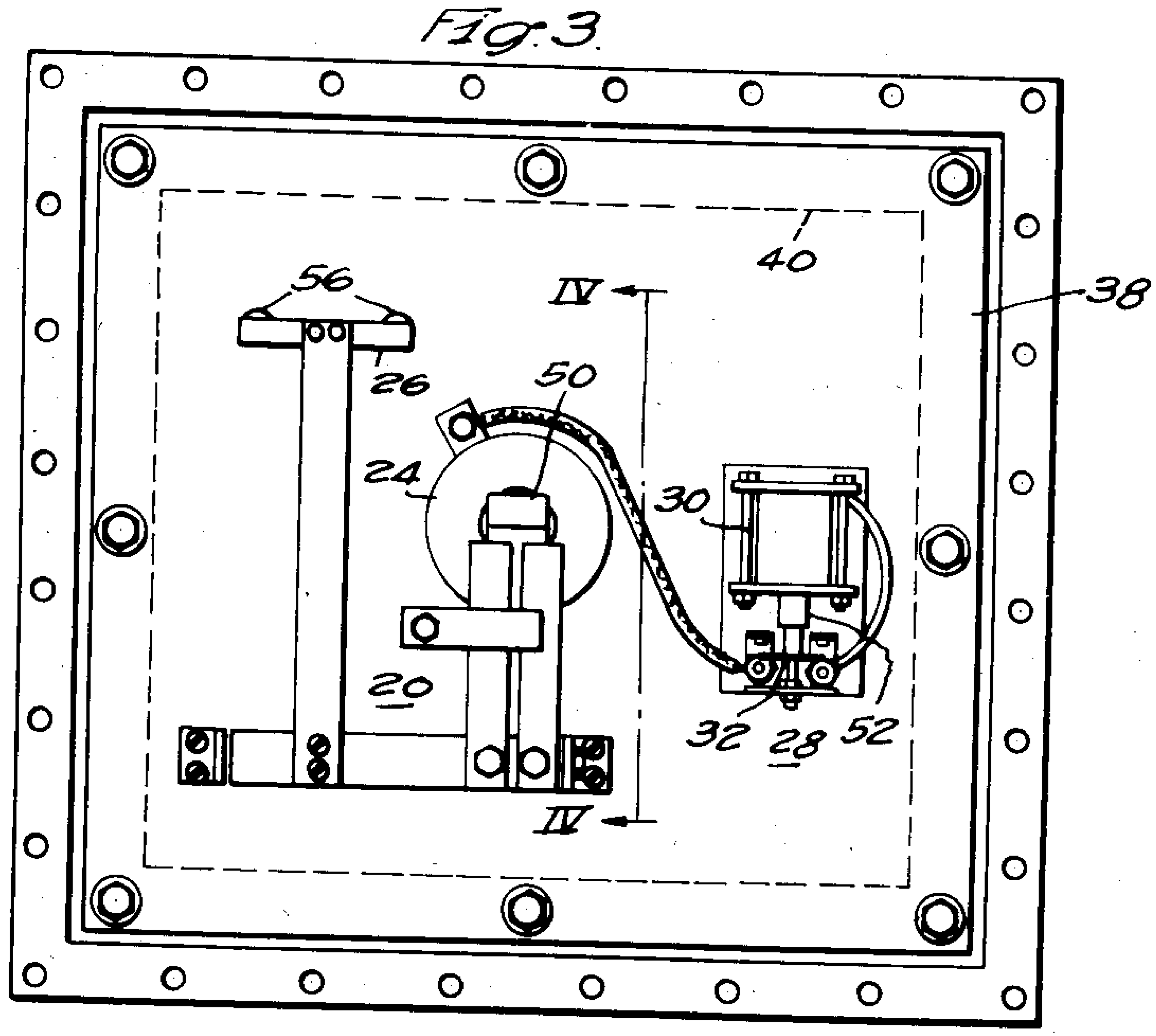
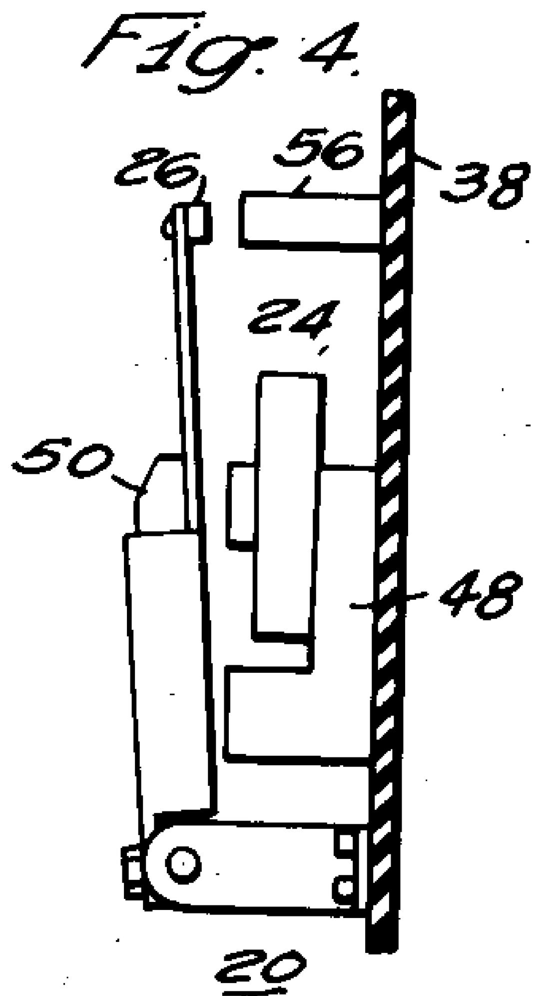


Fig. 4.



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2,011,663

REGULATING SYSTEM

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Application May 4, 1934, Serial No. 723,880

10 Claims. (Cl. 171—119)

My invention relates to apparatus for adjusting the voltage of an alternating-current electrical circuit, and it has particular relation to equipment capable of automatically raising the voltage in a single step when the circuit loading exceeds a given value.

In present day electrical distribution systems, it is customary to supply energy to distant points of consumption through relatively long feeder circuits. As the loading of such a circuit increases, the voltage drop through its impedance is similarly raised with the result that the receiving end voltage is much lower for heavy values of loading than when but relatively small values of current are transmitted. In many instances the nature of the load supplied is such that the resulting relatively wide variation in voltage is, while of course undesirable, not objectionable to the point that further expenditure for feeder circuit regulators of the multi-step and other relatively expensive types which heretofore only have been available is not justified. My invention is directed to an improved type of single-step automatic voltage adjuster which, because of its low cost and extreme simplicity can practically be applied in situations of the above outlined type.

One object of my invention is to reduce the cost of equipment adapted to automatically boost in a single step, upon the occasion of a predetermined loading, the voltage of an alternating-current circuit.

Another object of my invention is to provide an improved control system for such boosting equipments.

A further object of my invention is to increase the reliability of operation of equipments of the type under consideration.

An additional object of my invention is to improve the mechanical construction of regulating units of the class described.

In practicing my invention I associate with the circuit to be regulated a booster transformer having a secondary winding connected in series with one of the circuit conductors and a primary winding adapted to be energized by the circuit voltage upon the actuation of a control relay or contactor which is responsive to the circuit loading. To limit the voltage induced in the primary winding of this transformer when its energizing circuit is open, a shunting reactor is connected thereacross to provide a suitable burden. To assure that the main control relay will discontinue the transformer energization when the circuit loading has been reduced to a value predeterminedly lower than the relay actuating value, an auxiliary control device responsive to such a lower value of loading is utilized in conjunction with the first-named relay.

My invention, itself, together with additional objects and advantages thereof will best be understood through the following description of a specific embodiment when taken in conjunction with the accompanying drawing in which:

Figure 1 is a diagrammatic view of apparatus and circuits showing a preferred form of the regulating system of my invention applied to a single-phase feeder circuit;

Fig. 2 is a view in rear elevation of one form of casing structure adapted to house the several pieces of apparatus diagrammatically represented in Fig. 1;

Fig. 3 is a view taken on section line III—III of Fig. 2 showing the interior of the relay housing structure comprised by the equipment of the preceding figures;

Fig. 4 is a view taken on section line IV—IV of Fig. 3 showing the appearance of the main control relay when viewed from the side; and

Fig. 5 is a diagrammatic reproduction of the basic system of Fig. 1 showing certain modifications in the connections thereof.

Referring to the drawing and particularly to Fig. 1 thereof, the voltage adjusting means of my invention are there diagrammatically represented as comprising a booster transformer 10 having a secondary winding 12 connected in series with one of the conductors of the circuit to be regulated, and a primary winding 18 adapted to receive energization from the circuit voltage upon the actuation of a main control relay or contactor 20. The supply side of the mentioned circuit is designated by conductors 14 and 15 and the regulated side by conductors 14 and 16. To restrict or limit the value of voltage induced in primary winding 18 by the flow of circuit current through the secondary winding 12 when the primary winding energizing circuit is interrupted, a reactor 22 is connected in parallel with the primary winding to provide a suitable burden.

The actuating winding 24 of the contactor 20 is represented as deriving its energization from the voltage which appears across a portion of the secondary transformer winding 12, which voltage is substantially a direct function of the circuit loading. When the magnitude of this loading rises to a given value, of say one-half the full current rating of the regulated circuit, the contactor 20 actuates its contact member 26 upwardly thereby completing an energizing circuit for primary winding 18, which circuit may be traced from the circuit conductor 14 through the contact member 26 and the winding 18 to the circuit conductor 15. Thus energized, transformer 10 causes its secondary winding 12 to introduce into the circuit an additive or boosting component of voltage the magnitude of which may be of the order of from 5 to 10 per cent of the normal circuit voltage rating, or of other suitable value.

To insure that the contactor 20 will discontinue the transformer energization when the regulated circuit loading has dropped to a value somewhat below the one previously named, or, for example, to approximately one-third of the full-current rating of the circuit, an auxiliary relay 28 is utilized to render ineffective the first named relay or contactor when the circuit loading has been so reduced. As shown, this auxiliary device comprises an actuating winding 30 through which the current set up in the primary winding 18 of the transformer flows and a contact member 32 which serves to complete the energizing circuit of the main control contactor.

It will thus be seen that the apparatus of my invention functions to boost the voltage of the regulated circuit when the loading exceeds a predetermined value and to discontinue boosting when the load falls below a predetermined value. The value of load at which boosting begins must necessarily be higher than that at which boosting discontinues by a sufficient margin to allow stable operation of the relays and to prevent too frequent operation. The values previously mentioned as being of the order of one-half rated load for cutting in and one-third rated load for cutting out of the boosting equipment are in practice found to satisfactorily comply with this requirement.

The complete equipment is preferably so constructed that the boosting transformer 10 and the bridging reactor 22 may be placed in a main tank, represented at 34 in Fig. 2, which is adapted to receive insulating oil in much the same manner as does the tank of the usual type of distribution transformer. Inasmuch as devices 10 and 22 may be of standard constructions well known in the art, no attempt to represent their details is herein deemed justified.

The main control contactor 20 and the auxiliary relay 28 are preferably positioned in a separate oil tight compartment 36 which may be attached to one side of the main tank 34 in the manner also shown in Fig. 2. Preferably this compartment is also filled with insulating oil, the presence of which is found to improve the operating characteristics of the relay devices. In the represented construction, these two devices are mounted upon a panel of insulating material, shown at 38 in Figs. 3 and 4, which panel is positioned over an opening 40 in the side of the tank structure 34 in a manner to form an oil-tight partition between the relay compartment and the transformer tank. The relay compartment is provided with a removable cover 42, oil filling and drain plugs 43 and 44, and a vent connection 45 which interconnects the space above the oil level in the compartment with that of the oil level in the main tank 34.

The structure represented in Fig. 2 is further equipped with supporting brackets 46 which facilitate attachment to the conventional type of overhead distribution line pole. Connections of the equipment with the conductors of the circuit to be regulated are made through the medium of leads 47 shown as being brought out near the top of the main tank structure in conventional manner.

In order to keep the bulk of the relay apparatus at a minimum, it is desirable to build the main control contactor 20, which must be of a relatively large current-controlling capacity, in the form of an iron core structure having an air gap in the magnetic circuit. Such a device, the mechanical details of one preferred form of which are illustrated at 20 in Figs. 3 and 4, has a relatively wide differential between its pick-up and drop-out voltages, this resulting from the fact that the air gap in the magnetic circuit, shown as comprising stationary and movable core members 48 and 50, is relatively wide when the device occupies the open contact position illustrated in Fig. 4, and is substantially eliminated when the armature 50 is attracted to the closed contact position. This air-gap reduction greatly reduces the reluctance of the magnetic circuit so that to permit the armature to drop out the voltage applied to winding 24 must be reduced far below the value appropriate for drop-out in the contemplated application.

To overcome this disadvantage the before described combination of the auxiliary relay 28 is made, which relay may be of much smaller construction than the main device 20 and which preferably is of the solenoid type illustrated in Fig. 3. Since the magnetic reluctance of such a solenoid device does not appreciably change upon the actuation of the movable armature member, indicated in Fig. 3 at 52, the pick-up and drop-out voltages may be made substantially coincident. However, to design such a relay for the relatively large capacity required in the main control device 20 would result in such an exceedingly bulky and expensive structure as to be impractical. Accordingly, I have evolved the present novel combination which utilizes an air gap magnetic structure type of relay or contactor to control the energizing current of the booster transformer and an auxiliary solenoid type of relay to assist in the control of the first named device.

To further analyze the operation of the described regulating equipment, as the loading of the regulated circuit 14—16 increases to one-half or other comparable proportion of the full rated value, the voltage appearing across the portion of series connected transformer winding 12 across which the actuating winding 24 of the main control contactor 20 is connected reaches the pick-up value of the contactor which under the influence of this voltage then actuates the contact segment 26 into engagement with the stationary contact members 56 with which it cooperates. The auxiliary relay 28 being set for response to a lower value of circuit loading has already closed its contacts to establish the main relay energizing circuit. The described action serves to apply line voltage to the primary winding 18 of transformer 10, which application raises the potential appearing across the secondary winding 12 of the transformer and thereby causes the contactor 20 to positively seal in. Thus energized, the transformer 10 introduces into the regulated circuit a boosting component of voltage.

This condition of operation continues until the loading of the circuit is reduced to the value at which the auxiliary relay 28 is set to drop out, which value, as before pointed out, may be of the order of one-third full circuit rating. It will be apparent that until such reduction is reached the operating winding 24 of the main contactor is subjected to a voltage substantially higher than the pick-up value, which condition prevents any low pressure or partial closing of the main contacts during times of reduced loading. When the load has reduced, however, to the point where the auxiliary relay 28 will no longer hold in, its contacts 32 will open, thus interrupting the energizing circuit of the main contactor 20 and causing it to drop out promptly, thereby interrupting the energizing circuit for the booster transformer and returning the equipment to the inactive or non-boost condition. Such a condition will persist until the circuit loading has again risen to the one-half or other predetermined proportion of the full rated value at which the main contactor 20 is set to actuate.

In the event that it is desired to adjust the magnitude of voltage boost which the equipment is capable of providing, this may be done by forming the secondary winding of the booster transformer 10 in a plurality of sections, two of which are represented at 12 in Figs. 1 and 5. When connected in series with each other as shown in Fig. 1, their effect is additive and the voltage introduced thereby into the regulated circuit is the sum of their individual voltages. This connection, therefore, provides a maximum voltage boost.

When connected in parallel as shown in Fig. 5, the total corrective voltage introduced into the circuit is equal to that produced in one of the sections only so that this connection provides a minimum value of boosting voltage. By virtue of the fact that the load current of the regulated circuit divides itself between the two windings, the regulating equipment is capable of connection in a circuit having twice the current rating that a series connection of the winding sections would make permissible. By bringing all four leads of the two secondary winding sections to the outside of the structure shown in Fig. 2, either of the two regulating ranges may be selected without opening up the regulator or in any manner changing the apparatus housed within the tank structure.

Instead of energizing the auxiliary relay 28 by the current which acts in the circuit through which reactor 22 is connected in shunt relation with the transformer primary winding 18, the relay may, as shown in Fig. 5, be directly connected in series with one of the main conductors of the regulated circuit, or energized by the current acting therein through the arc of a current transformer (not shown). Such a modification complies with the requirement that the relay 28 be responsive to the regulated circuit loading.

Although I have shown and described a certain specific embodiment of my invention, I am fully aware that many modifications thereof are possible. My invention, therefore, is not to be restricted except insofar as is necessitated by the prior art and by the scope of the appended claims.

I claim as my invention:

1. A regulating system for controlling the voltage of a supply circuit comprising a transformer having primary and secondary windings, the secondary winding being connected in series circuit relation with the supply circuit, means responsive to a predetermined value of current flowing in the supply circuit for connecting the primary winding across the circuit to cause the circuit voltage to effect an energization thereof and means responsive to a decrease in said current to a value substantially lower than said predetermined one for effecting a discontinuance of said connection.

2. A voltage-boosting regulator for an electrical supply circuit comprising a transformer having primary and secondary windings, the secondary winding being adapted for connection in series circuit relation with the supply circuit, a reactor connected in parallel-circuit relation with the primary winding to limit the voltage induced therein by a flow of current through the secondary winding, and means adapted to connect the primary winding across the supply circuit to effect winding energization by the circuit voltage when the current flowing in the circuit rises to a predetermined value.

3. A voltage-boosting regulator for an electrical circuit comprising a transformer having primary and secondary windings, the secondary winding being connected in series circuit relation with the circuit, and relay means adapted to energizably connect the primary winding across the circuit when the current acting therein rises to a given value and to discontinue said connection when said current is reduced to a value somewhat below the one first named.

4. Voltage-adjusting means for an electrical circuit comprising, in combination, a transformer having primary and secondary windings, said secondary winding being connected in series circuit relation with the circuit, relay means adapted to energizably connect the primary winding across said circuit when the current flowing therein rises to a given value and to discontinue said connection when said current is reduced to a value somewhat below the one first-named, and an impedor connected in parallel circuit relation with the primary winding to limit the voltage induced therein by a flow of current through the secondary winding when the primary winding is disconnected from the circuit.

5. In combination with an electrical supply circuit having a transformer connected therein in such manner that energization of the transformer effects an increase in the circuit voltage, a relay adapted to complete an energizing connection between the transformer and the circuit when the current flowing in the circuit rises to a given value, and a second relay adapted to make ineffective said first-named relay when said circuit current is reduced to a given value.

6. A voltage-controlling regulator for an electrical circuit comprising a transformer adapted to introduce a component of boosting voltage into the circuit, a relay adapted to energizably connect the transformer across the circuit when the current flowing in the circuit rises to a given value, and a second relay adapted to make ineffective said first-named relay when the circuit current is reduced to a value somewhat below the one first named.

7. In a system comprising an electrical supply circuit and a transformer having primary and secondary windings, said secondary winding being connected in series circuit relation with the supply circuit and said primary winding being adapted for connection across the supply circuit to receive energization by the voltage acting therein, the combination of a relay energized by a measure of the voltage appearing across said secondary winding and adapted to complete said primary winding energizing connection when the current flowing in the supply circuit rises to a given value, and a second relay adapted to deenergize said first-named relay when the supply

circuit current is reduced to a value predeterminedly lower than the one first-named.

8. A voltage-controlling regulator for an electrical supply circuit comprising, in combination, a transformer having primary and secondary windings, said secondary winding being adapted for connection in series circuit relation with the supply circuit and said primary winding being adapted for connection across the supply circuit to receive energization by the voltage acting therein, a reactor connected in parallel circuit relation with the primary winding of the transformer to limit the voltage induced therein by a flow of current through the secondary winding, a relay adapted to complete said primary winding energizing connection when the current flowing in the supply circuit rises to a given value, and a second relay energized by the current which flows through said transformer primary winding adapted to make ineffective said first named relay when the said supply circuit current is reduced to a given value.

9. In a system comprising an electrical supply circuit, a transformer having primary and secondary windings, said secondary winding being connected in series circuit relation with the supply circuit and said primary winding adapted for connection across the supply circuit to receive energization by the voltage acting therein, and a reactor connected in parallel circuit relation with the primary winding of the transformer to limit the voltage induced therein by a flow of current through the secondary winding, the combination of a contactor actuably energized by a measure of the voltage appearing across said secondary winding and adapted to complete said primary winding energizing connection when the current flowing in the supply circuit rises to a given value, and a relay actuably energized by the current which flows through said primary winding adapted to deenergize said contact when the said supply circuit current is reduced to a value predeterminedly lower than the one first named.

10. The combination with an electrical supply circuit of a booster transformer having primary and secondary windings, said secondary winding being connected in series circuit relation with the supply circuit and said primary winding being adapted for connection across the supply circuit to receive energization by the voltage acting therein, a reactor connected in parallel circuit relation with the primary winding of the transformer to limit the voltage induced therein by a flow of current through the secondary winding, a contactor adapted to complete said primary winding energizing connection when the current flowing in the supply circuit rises to a given value, and a relay adapted to make ineffective said contactor when said supply circuit current is reduced to a value predeterminedly lower than the one first named, said contactor being actuably energized by a measure of the voltage appearing across the secondary winding of said transformer, and said relay being actuably energized by a measure of the current which flows through said supply circuit.

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