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VOLTAGE REGULATOR

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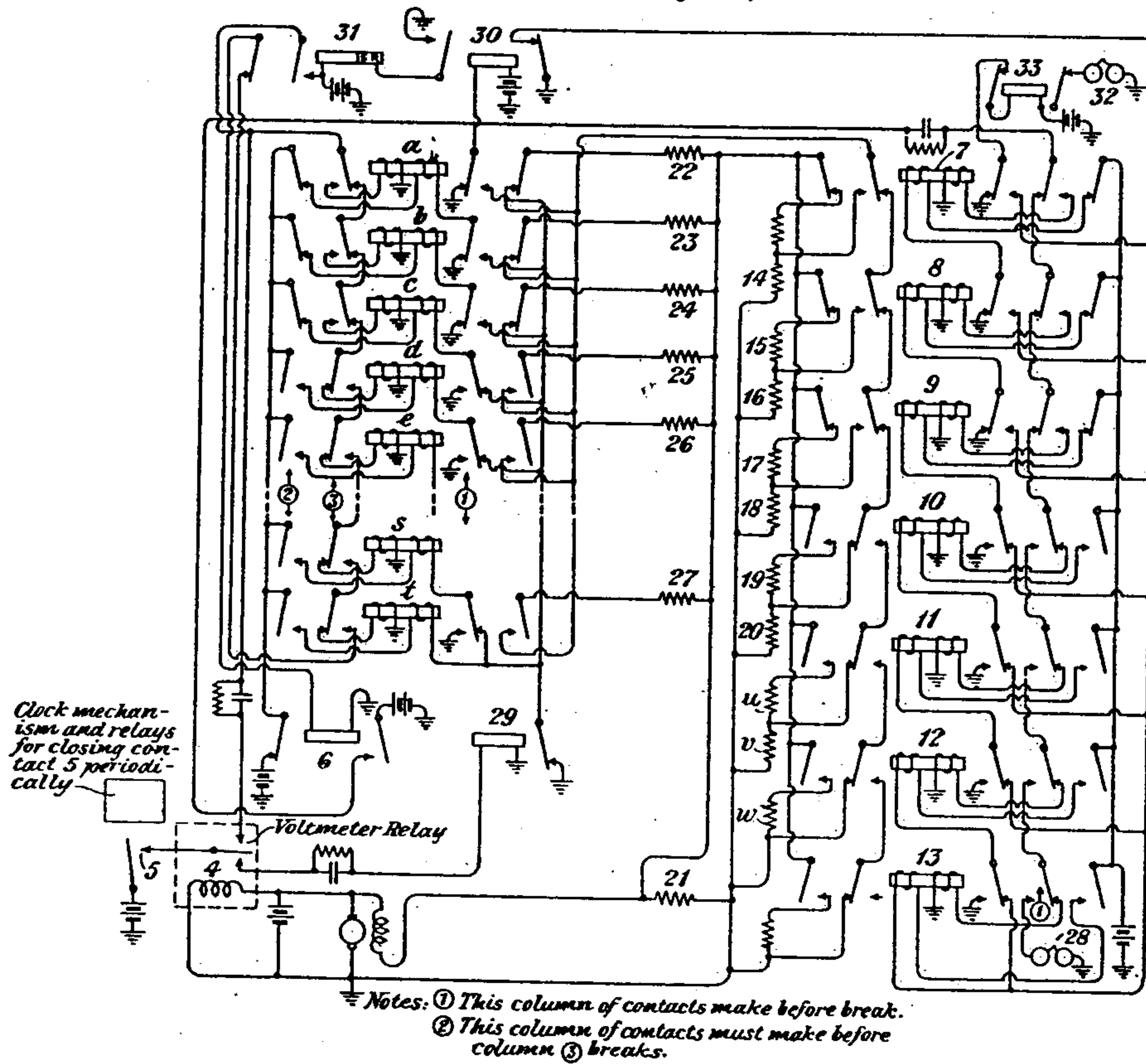


Fig. 1

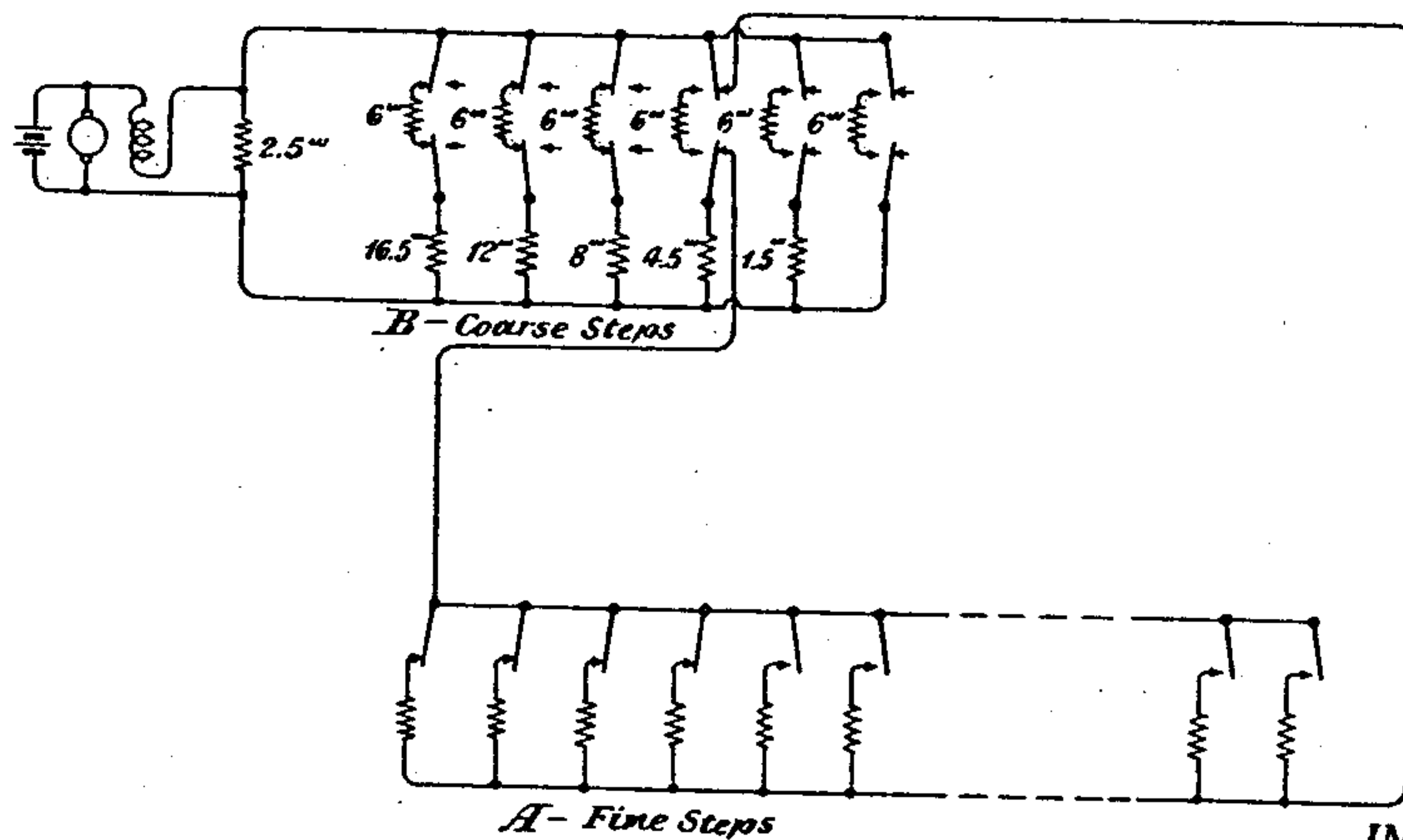


Fig. 2

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VOLTAGE REGULATOR.

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This invention relates to means for regulating the voltage of a source of electric current.

The object of the invention is to provide a voltage regulator which is sufficiently sensitive and of sufficiently steady sensitivity to be efficient and yet requires only cheap standard relays.

In general, I provide, in association with a source of electric current having a resistance associated with it and controlling its voltage, an arrangement whereby resistances are automatically bridged in parallel with the controlling resistance. Heretofore, regulation has been effected by inserting or cutting out resistances in series with the controlling resistance.

Since with the arrangement of the invention no set of relay contacts is required to carry more current than is suitable for the contacts of the ordinary flat type relays, the arrangement has the advantage that it permits a considerable economy of construction without a sacrifice of efficiency.

The invention will be more clearly understood when the following detailed description of a desirable embodiment thereof is read with reference to the accompanying drawing.

Figure 1 of the drawing shows diagrammatically the apparatus and circuit connections of my novel regulator system.

Fig. 2 indicates, in a simplified and schematic form, the essential features of my regulator arrangement.

It is believed that the invention will be best understood if consideration is given first to Fig. 2 of the drawing. For the purpose of illustration, the generator is assumed to be one having a resistance, variable from 2.5 to 1.0 ohms, in series with the field. A voltmeter relay, shown in Fig. 1, causes the resistance in series with the field of the generator to vary by actuating a relay train which shunts various resistances around a 2.5-ohm resistance which is permanently connected in the circuit. The desired regulation could be obtained by causing one or more of a group of 120 resistances to be shunted around this 2.5-ohm resistance. This would necessitate 120 relays. To save a portion of this expense, two banks of relays are provided, the "A" bank to give fine steps and the "B" bank to give coarse steps. The relays in the "A" bank are operated one by one until all are operated, if the voltage of the battery is low. Then, the next nonoperated relay in the "B" bank is op-

erated and all relays in the "A" bank released. The voltage of the battery continuing low, the relays in the "A" bank are operated again successively and when all are operated, the next relay in the "B" bank is operated. In this way the resistance in series with the field is decreased until the voltage of the battery is restored to normal. Similarly, if the voltage of the battery is too high, the resistance in series with the field is increased by the successive release, one by one, of the relays in the "A" bank. When all are released, the relay in the "B" bank which was last operated is released and all relays in the "A" bank operated. If the battery voltage continues high, the "A" relays are released again, one by one, and when all are released another of the "B" relays is released. Means are provided as shown in Fig. 1, to move the "A" bank of relays from one step to another of the "B" bank.

Each resistance in the "B" bank is shown divided into two parts, one part consisting of 6 ohms and the other differing for each step. The reason for this is that the total resistance of the resistances in the "A" bank when they are connected in parallel is very nearly 6 ohms. This 6 ohms is in series with the residual resistance of the next coarse step to be operated. Therefore, when this operation takes place, the fixed 6-ohm resistance is switched in to take the place of the 6 ohms in "A" which is removed. Instead of these particular values of resistance which assume about 6 coarse steps and 20 fine steps, a more economical arrangement probably would be to have 12 coarse steps and 10 fine ones.

Consideration will now be given to the details of Fig. 1. A voltmeter relay, 4, is shown bridged across the battery whose voltage is to be regulated. Its armature is in series with a contact, 5, which is operated at any desired interval, say once a minute, by a clock mechanism or slow-operating relay chain. When it operates, if the voltage of the battery is outside of the limits, the armature of the voltmeter relay will be making contact with one of the two contacts. Assuming that the voltage is too low, it will be touching the top contact. The battery connected through contact 5, will be impressed through a condenser in parallel with a high resistance on the winding of relay *d*, through contacts of relays *a*, *b*, and *c* in series, operating relay *d*. The object of the condenser shunted by a fixed resistance is to prevent more than one

of the relays in the chain *a* to *t* from operating at one time. The resistance discharges the condenser when contact 5 opens; relay *d* locks up through its left contact and a separate winding. Its second armature from the left prepares a circuit so that relay *e* will operate when the voltmeter relay next touches its upper contact. The third armature from the left connects the winding of relay *c* solidly to ground, preventing its release, by the opening of the common ground circuit through the operation of relay 29, as explained hereinbelow, before the release of relay *d*. The fourth armature inserts resistance 25 in parallel with resistances 22—24. These four parallel resistances, which form four of the fine steps described above, are, in series with resistance 20, bridged across the fixed resistance 21 which is in series with the field circuit. Upon succeeding operations of contact 5, if the voltage remains low and, therefore, the armature of the voltmeter relay continues to touch the upper contact, succeeding relays, *e*, *f*, *g*, etc. will be operated until finally *t* is operated. Upon the succeeding operation of 5, relay 6 will operate. Its left armature removes the holding battery from all of the relays *a* to *t* inclusive, releasing these relays. The right-hand armature causes the operation of relay 10 through a condenser bridged by a high resistance and through contacts of relays 7, 8, and 9. The object of the condenser is to prevent more than one of the relays 7 to 13 from operating at one time. The left armature of 10 bridges resistances 19 and 20 in series around resistance 21. The second armature from the left disconnects resistances 22 to 27 from resistance 20 and prepares a circuit so that upon the operation of the relays *a*—*t* associated with them they will be connected to resistance *v*, which is one of the resistances in the coarse step controlled by relay 11. The third armature from the left of relay 10 connects the winding of relay 9 directly to ground, thus preventing an interruption of the common ground circuit from releasing relay 9 until 10 has been released. The fourth armature prepares a circuit so that relay 11 will be operated the next time relay 6 is operated—after all of the relays controlling the fine steps have operated once more. The fifth armature locks 10 in the operating position.

If the voltage continues low, the relays *a* to *t*, which control the fine steps, will operate once more in order, causing the operation of relay 11, which will insert another coarse step, and after that, relays 12 and 13 in order. If the battery voltage still remains too low, bell 28 will ring, summoning an attendant.

Now, assuming that the equipment is restored to the original condition shown on the drawing and that the battery voltage increases to the upper limit, the voltmeter relay arma-

ture will touch the lower contact, causing relay 29 to operate when relay 5 next operates and thus disconnecting the ground from the winding of relay *c*, releasing it. The condenser in series with relay 29 causes it to operate only momentarily. The release of *c* disconnects resistance 24 thus increasing slightly the resistance in series with the field winding and, therefore, decreasing the voltage of the generator. If the voltage continues high, relays *c*, *b* and *a* will be released upon successive operations of contact 5 and then relay 30 is released. The release of 30 causes the operation of 31 which connects battery to relays *a* to *t* in turn, operating them. 6 is prevented from operating because the left armature of 31 opens its winding circuit. Relay 31 must release slowly enough so that all relays, *a* to *t*, will have time to operate. If this is not easily done by one relay, it is obviously easy to do it by a chain of 2 or 3 relays. The right contact of 30 removes ground from the winding of relay 9, releasing it and removing resistances 17 and 18 from the parallel circuit shunted around 21. The functions of the other contacts of 9 have been described for 10 above. If the voltage of the generator remains high, relays *t* to *a* will be released in succession again and cause the release of relay 8. If the cycle is repeated again relay 7 will be released and after that relay 33, causing bell 32 to ring, summoning an attendant.

From the above description it is obvious that at any time a circuit is in such condition that if the voltage of the generator increases or decreases beyond the allowable limits, a compensating change automatically takes place in the resistance in series with the field winding.

While the invention has been specifically disclosed in one embodiment, which is deemed desirable, it is to be understood that it is capable of embodiment in other and different forms, within the true scope of the invention, as defined in the appended claims.

What is claimed is:

1. In association with a source of electric current having a resistance associated therewith and controlling the voltage thereof, a system for regulating the voltage of said source, said system comprising a voltmeter relay associated with the source, a resistance in shunt around said voltage controlling resistance, circuit-making means responsive to the operation of the voltmeter relay due to a deficiency of the voltage of the source for decreasing said shunt resistance by gradual steps until the level is restored, and circuit-breaking means responsive to the operation of the voltmeter relay due to an excess of the voltage of the source for increasing said shunt resistance by gradual steps until the level is restored.

2. In association with a source of electric

current having a resistance associated therewith and controlling the voltage thereof, a system for regulating the voltage of said source, said system comprising a voltmeter
 5 relay associated with the source, a resistance in shunt around said voltage controlling resistance, circuit-making means responsive to the operation of the voltmeter relay due to a deficiency of the voltage of the source
 10 for decreasing said shunt resistance by gradual steps until the level is restored, circuit-breaking means responsive to the operation of the voltmeter relay due to an excess of the voltage of the source for increasing said
 15 shunt resistance by gradual steps until the level is restored, and means for giving an alarm if either the maximum increase or the maximum decrease of the shunt resistance fails to restore the voltage level.

20 3. In association with a source of electric current having a resistance associated therewith and controlling the voltage thereof, a system for regulating the voltage of said source, said system comprising a voltmeter
 25 relay associated with the source; a plurality of relatively small resistances; a plurality of relatively large resistances; means responsive to the operation of said voltmeter relay due to a deficiency of the voltage of the source
 30 for connecting the large resistances successively in shunt around the voltage controlling resistance until the level is restored, then if the level is not restored, connecting one of the small resistances in parallel with the voltage
 35 age controlling resistance and disconnecting the large resistances, and adding the large resistances successively to the shunt resistance, and repeating the operation until the level is restored; and means responsive to the

operation of the voltmeter relay due to an excess of the voltage of the source for similarly increasing the resistance in shunt with the voltage controlling resistance by steps until the voltage level of the source is restored. 45

4. In association with a source of electric current having a resistance associated therewith and controlling the voltage thereof, a system for regulating the voltage of said source, said system comprising a voltmeter
 50 relay associated with the source; a plurality of relatively large resistances; a plurality of relatively small resistances; means responsive to the operation of said voltmeter relay due to a deficiency of the voltage of
 55 the source for connecting the large resistances successively in shunt around the voltage controlling resistance until the level is restored, then if the level is not restored, connecting one of the small resistances in
 60 shunt around the voltage controlling resistance and disconnecting the large resistances, and adding the large resistances successively to the shunt resistance, and repeating the operation until the level is restored, means
 65 responsive to the operation of the voltmeter relay due to an excess of the voltage of the source for similarly increasing the resistance in shunt with the voltage controlling resistance by steps until the voltage level of the
 70 source is restored, and means for giving an alarm if either the maximum increase or the maximum decrease of the shunt resistance fails to restore the voltage level.

In testimony whereof, I have signed my
 name to this specification this 2nd day of
 September, 1927.

LELAND C. ROBERTS.