Nov. 28, 1933. H. C. NYCUM 1,936,801

REGULATING APPARATUS

Filed Feb. 19, 1932

Fig. 1.

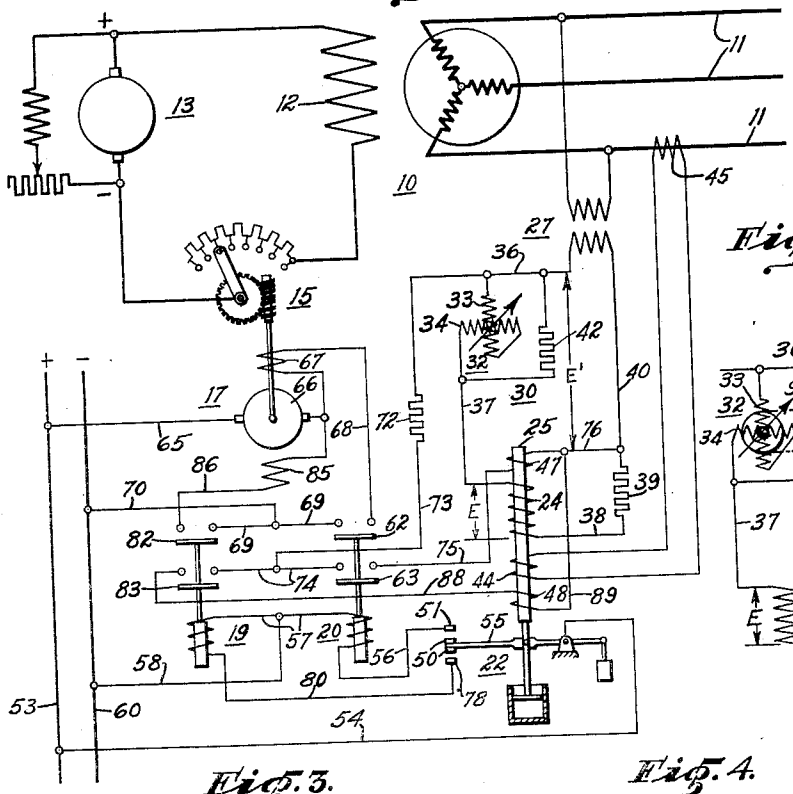


Fig. 2.

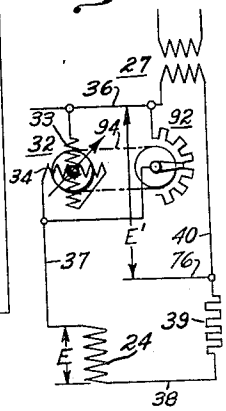


Fig. 3.

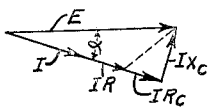


Fig. 4.

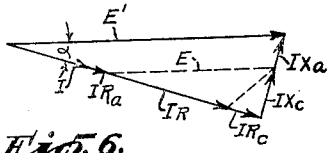


Fig. 5.

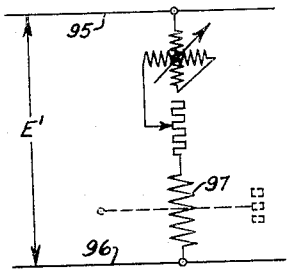
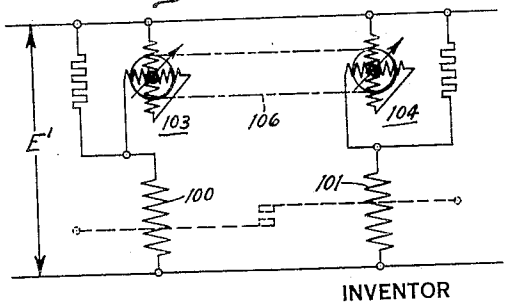


Fig. 6.



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REGULATING APPARATUS

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6 Claims. (Cl. 171—119)

My invention relates to regulating apparatus and has particular relation to voltage-adjusting means for electrical regulators which control the voltage of alternating-current circuits and machines.

In the past it has been customary to insert an adjustable resistance in the energizing circuit of the voltage regulator for the purpose of adjusting the magnitude of voltage at which the regulator will maintain the regulated circuit or machine. Recalibration by this method is found in practice to be subject to a number of disadvantages. The sliding contacts which must be utilized in such an adjusting device in themselves cause considerable difficulty because of the oxidation of the surfaces and because dirt may readily collect and also introduce extraneous resistance into the circuit.

Likewise, in alternating current applications, the introduction of additional resistance in the regulator energizing circuit is found to produce very noticeable and frequently objectionable phase shifts in the current flowing in the control winding of the regulator, these shifts being caused by the dissimilar changes in the resistance and reactive components of winding-circuit impedance which rheostat types of adjustors introduce.

The phase displacement is found to be particularly pronounced when regulator control windings of high impedance are used, and may subject the regulator to appreciable error in response when other windings, such as the anti-hunting or compensating variety, are inductively associated with the main control winding in well known and extensively applied manner.

My invention is directed to the provision of voltage-adjusting means which overcome the above-mentioned and other disadvantages, and which possess additional desirable features to be pointed out later.

One object of my invention is to provide a voltage adjustor for an electrical regulator which utilizes no sliding contacts and which is capable of varying its impedance in infinite steps.

Another object of my invention is to provide a voltage adjustor which is capable of maintaining constant, or of varying in a predetermined manner, the phase relation between the current flowing in the regulator control winding and the voltage of the regulated circuit or machine from which the winding is energized.

A further object of my invention is to provide adjusting means of the type described which are low in cost, simple in design, effective in operation, and compact in construction.

A still further object of my invention is to provide a voltage adjustor of the type described, which is readily applicable to known types of regulators.

I have discovered that these and other objects may be attained through the use of an adjustable reactance device, such as a small induction regulator or variometer, in the control-winding energizing circuit of the regulator to be adjusted. This variometer may be of the well-known type comprising two coils or windings disposed in rotatable relation with respect to each other in a manner that the inductive interaction therebetween may be varied in infinite steps. Such a device utilizes no sliding contacts and is capable of changing its effective reactance throughout a wide range, which change in reactance may be utilized to adjust or recalibrate the regulator in a manner to be more completely explained.

An adjustable-reactance device of this type is not only simple in design and low in cost, but it may be very compactly constructed, a feature which is especially valuable in certain well known applications of regulating equipment.

In many applications of the voltage-adjusting device, I have found that the variometer alone is sufficient, while in others, a combination of a resistor in circuit with the variometer is decidedly desirable and advantageous. Thus, for example, such a voltage-adjustor combination can be so designed to turn in any desired amount of either resistance or reactance or both in the control winding circuit of the regulator so that the phase position of the winding current may be maintained under complete control. Such a combination, furthermore, is readily applicable to the characteristics of either high or low impedance windings of regulators of practically all known designs so that its range of application is practically unrestricted.

My invention itself will best be understood through the following description of specific embodiments thereof, when taken in connection with the accompanying drawing, in which:

Figure 1 is a diagrammatic view of apparatus and circuits showing my invention applied to an alternating-current generator voltage regulator of a well known rheostatic type.

Fig. 2 is a diagrammatic view illustrating a modification of the voltage-adjustor equipment shown in Fig. 1.

Figs. 3 and 4 are vector diagrams illustrating the manner in which the adjustor of my inven-

tion may be caused to maintain constant the phase position of the regulator-control-winding current throughout a wide range of voltage adjustment.

Fig. 5 is a simplified diagrammatic view showing a third modification of my invention disposed in the control-winding circuit of a regulator; and

Fig. 6 is a similar simplified diagrammatic representation of the voltage adjusting means of my invention applied to a double winding regulator such as of the well known vibrating type.

Referring to the drawing, and particularly to Fig. 1 thereof, the regulating system with which my invention is illustrated is of a well known rheostatic type shown as being disposed to control the voltage of an alternating-current generator 10 having armature windings connected with conductors 11 of a power circuit and a field winding 12 disposed to be energized by an exciting generator 13 or other source of direct-current energy.

To control or adjust the voltage of generator 10, a rheostat 15 is disposed in the field-winding circuit of the generator and operated by means of a suitable motor 17. Motor 17 is shown as being of the series split-field type which may be energized in the voltage-raising and voltage-lowering directions, respectively, by the actuation of control relays 19 and 20. Energization of these motor-control relays is controlled by a contact-making voltmeter or primary relay device 22 which is responsive to the voltage of regulated generator 10.

As shown, relay 22 comprises a main control winding 24 which is disposed to exert an upwardly acting pull upon an elongated armature member 25, the magnitude of this pull being determined by the winding-energizing voltage which, in the system shown, is supplied from generator-circuit conductors 11 through a potential transformer 27.

In the operation of voltage regulating systems, of which the regulator shown in Fig. 1 may be taken as being generally representative, the regulator functions to maintain constant the potential impressed upon the regulator-control winding, deviations from a given value causing operation of voltage-adjusting means associated with the regulated machine or circuit to restore the potential impressed upon the control winding to the original value.

Hence, as is known, a change in the impedance of the circuit through which the regulator control winding is energized by the regulated voltage effects a change in the value of voltage at which the regulator will maintain the regulated machine or circuit. As previously pointed out, however, if only the resistance component of this adjustable impedance is changed, a noticeable shift in the phase position of the control-winding current may result, and, if additional windings are inductively related to this main control winding, the operation of the regulator may be objectionably affected by this phase shift.

To change the impedance of the control-winding circuit of the regulator shown in the system of Fig. 1, the voltage-adjusting means of my invention may be disposed, in some manner such as is shown at 30, intermediate the regulated generator and the primary relay of the regulator. In the past, as has been pointed out, it has been customary to provide an adjustable resistance in position 30 for the purpose of recalibrating the regulator. My invention, by replacing this resistance, provides the numerous advantages already mentioned.

As illustrated, the voltage-adjusting means 30 may comprise a variometer 32 having a stator or stationary winding 33 and a rotor or movable winding 34, the two windings being interconnected in some manner such as is shown. A change in the inductive relation of these two windings, such as may be effected by rotating winding 34, changes the effective reactance of the variometer and thus modifies the potential impressed from the circuit conductors 11 upon the regulator primary-relay winding 24.

In practice it will usually be found preferable to provide magnetic core material in association with these windings to increase the effectiveness of the variometer and to permit of wider adjustment in the characteristics of the device, the latter feature for a purpose to be later made evident. Since such core construction is well known in the art, it being the same as that employed in movable coil induction regulators, a detailed showing of it is deemed unnecessary.

It will be observed that in Fig. 1 the energizing circuit for the regulator control winding 24 extends from the left side of the secondary winding of potential transformer 27 through conductor 36, windings 33 and 34 of the variometer 32, conductor 37, the control winding 24, conductor 38, a resistor 39 and conductor 40 back to the other side of the potential transformer winding.

In parallel circuit relation with the variometer, an additional resistor 42 may, if desired, be disposed to bridge both the stator and rotor windings, in the manner shown, or to bridge only one of these windings. Tests indicate that such a combination is capable of varying, when the variometer alone is adjusted, not only the effective reactance of the adjusting means, but the effective resistance as well, and by the use of such a modification, the phase position of the regulator control winding current may be maintained within given limits. Tests further indicate that the relation between resistance and reactance variation is a function of the variometer design, particularly the air gas dimensions of the core structure which carries the windings; as well as being dependent upon the size and connection of the paralleling resistor.

To more clearly illustrate the situation above-mentioned in which the primary relay utilizes a plurality of windings, primary relay 22 is shown as being additionally provided with a load-compensating winding 44 energized through a current transformer 45 by the output current of regulated generator 10 in a manner that changes in the value of generator current may be caused to change the value of voltage which the regulator will maintain between circuit conductors 11. Likewise, to prevent overshooting of the corrective action, anti-hunting windings 47 and 48 are also associated with the armature member 25 of the primary relay and arranged to be respectively energized by the closure of motor control relays 20 and 19.

In the operation of the regulating system illustrated, a rise in the voltage of generator 10 moves contact member 50 upward into engagement with contact member 51 of primary relay 22 and thus completes an energizing circuit for motor-control relay 20 which extends from positive control conductor 53 through conductor 54, contact-carrying arm 55 and contacts 50 and 51 of primary relay 22, conductor 56, the operating winding of

motor control relay 20, and conductors 57 and 58 back to negative control conductor 60.

Under the influence of this energization, relay 20 moves contact members 62 and 63 upwardly completing through member 62 an energizing circuit for rheostat motor 17 which extends from positive control conductor 53 through conductor 65, the armature and field windings 66 and 67 respectively, of motor 17, conductor 68, relay contact member 62 of relay 20 and conductors 69 and 70, back to negative control conductor 60. Contact member 63 of relay 20 at the same time completes an anti-hunting winding energizing circuit which extends from the left side of potential transformer 27 through conductor 36, a resistor 72, conductors 73 and 74, relay contact member 63, conductor 75, the anti-hunting winding 47, and conductors 76 and 40 back to the right side of potential transformer 27.

Thus energized, motor 17 rotates in a direction to raise the resistance of rheostat 15 and thus lowers the voltage of generator 10. Anti-hunting winding 47 opposes the action of regulator control winding 24 and thus effects premature opening of the primary relay contacts in the usual well known manner so that voltage-adjusting rheostat 15 will not over-travel.

In a similar manner a decrease in the voltage of generator 10 allows primary relay contact 50 to move downwardly into engagement with contact member 78 thereby completing an energizing circuit for motor control relay 19 which extends from positive control conductor 53 through conductor 54, contact-carrying arm 55, contact members 50 and 78 of the primary relay, conductor 80, the operating winding of motor control relay 19 and conductors 57 and 58 back to negative control conductor 60.

Thus energized, relay 19 moves contact members 82 and 83 upwardly to effect the completion of a rheostat motor-energizing circuit by member 82, and of an anti-hunting circuit by member 83. The motor-energizing circuit extends from positive control conductor 53, through conductor 65, the armature and field windings 66 and 85 respectively of motor 17, conductor 86, relay contact member 82, and conductors 69 and 70 back to negative control conductor 60. The anti-hunting circuit extends from one side of potential transformer 27 through conductor 36, resistor 72, conductors 73 and 74, contact member 83 of relay 19, conductor 88, the anti-hunting winding 48, and conductors 89, 76 and 40 back to the other side of potential transformer 27.

Thus energized, motor 17 operates rheostat 15 in the resistance lowering direction and raises the voltage of regulated generator 10. Anti-hunting winding 48 aids the action of main control winding 24 of the regulator and thus effects premature opening of the contacts to prevent over-travel of the voltage-adjusting rheostat.

As has been mentioned, compensating winding 44 of the regulator acts with changing values of regulated generator current to change the value of voltage, which must be maintained upon main control winding 24 in order to maintain its contact member 50 in the disengaged position. Likewise, the anti-hunting windings 47 and 48 respectively oppose and assist the main control winding 24 in its upwardly acting pull.

In order that these compensating and anti-hunting actions may be independent of and unaffected by changes in the position of the voltage-adjusting means, which condition is particularly desirable in any applications in which exceedingly close regulation is required, it is necessary that the phase relations of the currents, which respectively energize the several windings named, remain unchanged for different positions of the voltage adjusting means. The voltage adjustor of my invention shown in Fig. 1 will in ordinary applications be found to provide this requirement, while in special cases where unusual requirements are imposed the modification illustrated in Fig. 2 may be utilized.

In the diagram of Fig. 2, which will be seen to include only that portion of the system of Fig. 1 directly connected with the voltage adjusting equipment, I have illustrated a rheostat 92 connected in parallel circuit relation with variometer 32 in the energizing circuit of the main control winding 24 of the regulator. I have further provided means whereby the variometer and the rheostat may be simultaneously operated, such means being illustrated by broken lines at 94 in the form of a chain or other suitable mechanical interconnection between the rotating members of the two devices. By properly designing the two devices, it will be apparent that changes in the resistance and reactance components of circuit impedance may be produced simultaneously at any predetermined relative rate.

The vector diagrams of Figs. 3 and 4 more clearly illustrate the manner in which the voltage adjusting means shown may function to maintain constant the phase position of the regulator-control-winding current for changes in the position of the voltage adjustor, and hence, for adjustment in the value of regulated voltage. In Fig. 3, the horizontal vector E designates, at some given instant, the voltage impressed upon the regulator energizing circuit by the regulated machine or circuit. When the voltage adjustor is turned to the position of minimum impedance, a current I flows in the circuit of the regulator winding. In phase position, this current lags voltage E by angle alpha, because of the reactance of the regulator winding, in which reactance the voltage IX_c takes place. Voltage drops IR_c and IR, in phase with current I, are set up in the circuit due, respectively, to the resistance of the regulator winding and to the presence in the circuit of an external resistance shown at 39 in Figs. 1 and 2.

Operation of the voltage adjustor in the voltage-raising direction may be caused to produce the set of conditions depicted by the vector diagram of Fig. 4 in which the regulated circuit voltage has been increased from the value given by E to that given by E', this increase being produced by the introduction of additional resistance into the circuit of the control winding which introduces the additional voltage drop IR_a, and the simultaneous introduction of additional reactance which produces voltage drop IX_a. By properly proportioning these added values of resistance and reactance, the phase relation between the coil current I and the regulated circuit voltage E' may be maintained constant as is indicated in the diagram of Fig. 4, or may be caused to change in any predetermined manner desired.

It will be apparent that the variometer type of voltage adjustor of my invention may, in applications in which the phase position of regulator winding current is not critical, be used alone or in combination with a single resistor as is indicated in Fig. 5 in which the horizontally drawn lines 95 and 96 designate the conductors of a circuit whose voltage is to be regulated the control

winding of the regulator to be adjusted being represented at 97.

Likewise, in the case of regulators of the vibrating type, for example, in which a pair of control windings are utilized, a variometer-voltage adjustor may be inserted in circuit with each of the windings and the two adjustors mechanically interconnected for simultaneous operation as is shown in Fig. 6. In Fig. 6, the two windings of the regulator are represented at 100 and 101, the two variometers at 103 and 104, and the interconnecting means for parallel operation are designated at 106.

It will thus be apparent that the voltage-adjusting means of my invention may be applied to practically all types of alternating-current regulators now known in the art so that while I have only completely illustrated an adjustor as being combined with the rheostatic generator voltage regulator shown in Fig. 1, it will be understood that its application is in no way limited to this specific system.

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

I claim as my invention:

1. Voltage-adjusting means for an alternating-current voltage regulator comprising, in combination, a variometer and a rheostate disposed in the circuit through which the regulator is energized by the voltage to be regulated, and means whereby the said variometer and rheostat may be adjusted simultaneously to effect predeterminedly related changes in the reactance and the resistance components of impedance introduced into the regulator-energizing circuit by the said voltage-adjusting means.

2. In combination with an alternating-current voltage regulator comprising a magnetic core member having associated therewith a main control winding and an auxiliary winding, a circuit for energizing said main control winding by the alternating-current voltage to be maintained constant, and voltage-adjusting means disposed to change the value of voltage which the regulator will maintain, said adjusting means comprising an equipment which simultaneously varies the resistance and inductance characteristics of said energizing circuit in a manner to maintain constant the power factor of main control winding current.

3. In combination with an alternating-current voltage regulator comprising a magnetic core member having associated therewith a main control winding and an auxiliary winding, means for supplying to said auxiliary winding a compensating current of substantially unvarying power factor, a circuit for energizing said main control winding by the alternating-current voltage to be maintained constant, and voltage-adjusting means, disposed to change the value of voltage which the regulator will maintain, comprising an equipment which simultaneously varies the resistance and reactance characteristics of said energizing circuit in a manner to maintain constant the power factor of main control winding current.

4. In combination with an alternating-current voltage regulator comprising a magnetic core member having associated therewith a main control winding and an auxiliary winding, a circuit for energizing said main control winding by the alternating-current voltage to be maintained constant, and voltage-adjusting means disposed to change the value of voltage which the regulator will maintain, said adjusting means comprising a resistance device and an adjustable inductance device disposed in said energizing circuit, said devices having characteristics so related that the power factor of main control winding current will be maintained constant throughout the entire range of regulator voltage adjustment.

5. In combination with an alternating-current voltage regulator comprising a magnetic core member having associated therewith a main control winding and an auxiliary winding, means for supplying to said auxiliary winding a current of substantially unvarying power factor, a circuit for energizing said main control winding by the alternating-current voltage to be maintained constant, and voltage-adjusting means disposed to change the value of voltage which the regulator will maintain comprising a variometer adjustable-inductance device and a resistor disposed in said energizing circuit, the characteristics of said variometer and resistor being such as to maintain constant the power factor of main control winding current.

6. In combination with an alternating-current voltage regulator having a main control winding, a circuit for energizing said winding by the alternating-current voltage to be maintained constant, and a voltage-adjuster disposed to change the value of voltage which the regulator will maintain, said adjuster comprising means for simultaneously varying the resistance and inductance components of the impedance of said energizing circuit in a manner to maintain constant the power factor of main control-winding current while adjusting the regulator voltage.

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