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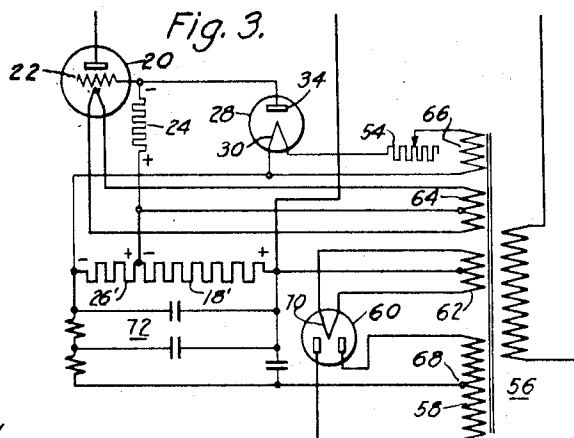
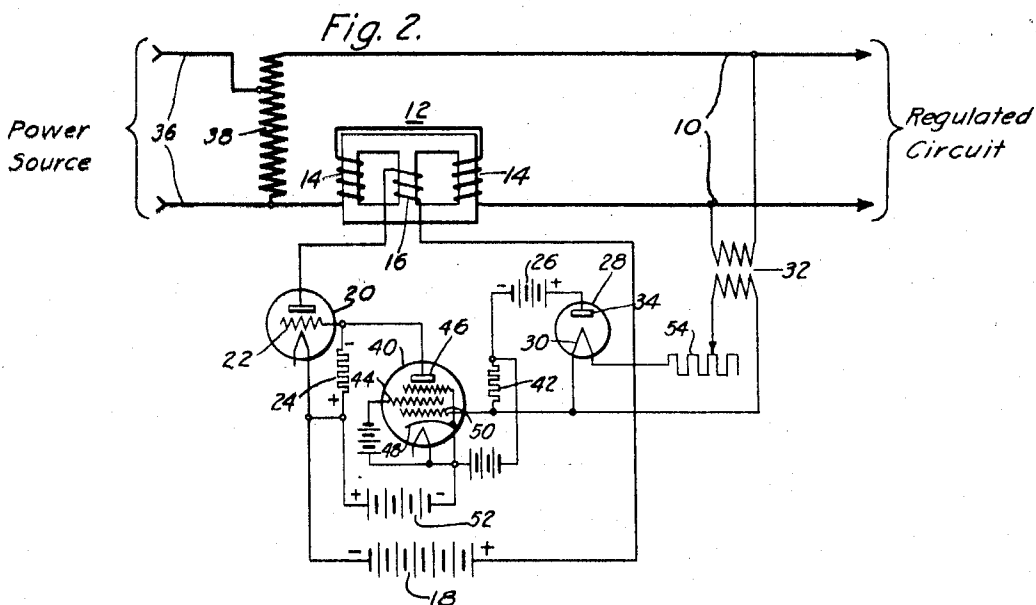
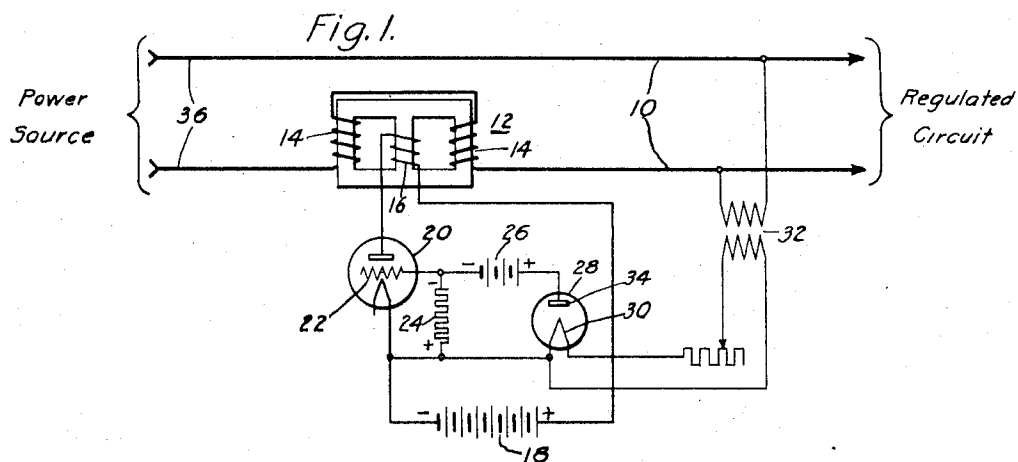
LA VERNE R. PHILPOTT

2,066,943

REGULATING SYSTEM

Filed July 31, 1935

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

Fig. 4.

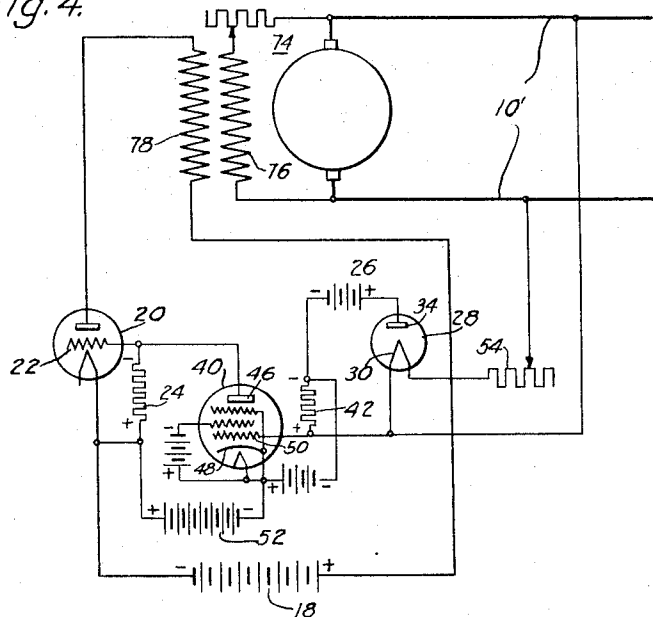
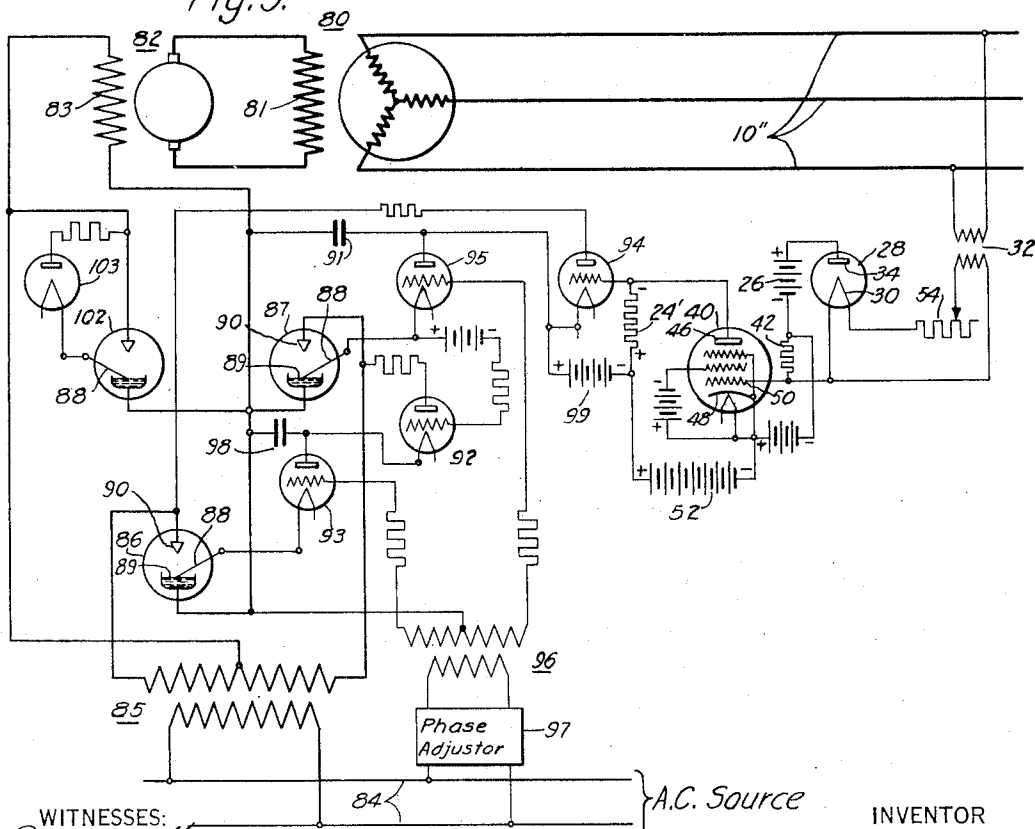


Fig. 5.



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REGULATING SYSTEM

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Application July 31, 1935, Serial No. 34,011

4 Claims. (Cl. 171-119)

My invention relates to electrical regulators of the electronic tube type and it has particular relation to means for improving electronic tube regulators which are adapted to maintain constant the voltage or other characteristic of an electrical machine or circuit.

One object of my invention is to simplify the construction, improve the reliability, and lower the cost of systems of this character.

Another object of my invention is to provide error-detecting means capable of affording high regulatory sensitivity without the use of the source of reference control potential heretofore required in high-sensitivity applications.

A further object is to provide detecting means of the above class which are suited for use with both alternating and direct current circuits the voltage or other characteristic of which is to be regulated.

A still further object is to provide an improved form of electronic tube regulator for dynamoelectric machines which in operation simulates the ratio-regulated on and off the form of control provided by vibratory-contact regulating devices.

My invention itself, together with additional objects and advantages thereof, will best be understood by the following description of specific embodiments when taken in conjunction with the accompanying drawings, in which:

Figure 1 is a diagrammatic representation of an elementary form of the regulating system of my invention shown as being applied to control the voltage of an alternating-current feeder circuit;

Fig. 2 is a reproduction of the system of Fig. 1 showing how amplifying means may be utilized to increase the sensitivity thereof;

Fig. 3 is a partial reproduction of Fig. 1 illustrating one manner in which the direct-current voltages required to energize the electronic tube circuits may be supplied from a source of alternating-current power;

Fig. 4 is a diagrammatic representation of the regulating apparatus of Fig. 2 applied to control the voltage of a direct-current generator; and

Fig. 5 is a diagrammatic view of apparatus and circuits comprised by an alternating-current generator voltage regulator arranged in accordance with my invention to provide a form of on and off excitation adjustment control which simulates that afforded by a vibratory-contact regulator.

Referring to the drawings, I have illustrated in Fig. 1 the improved system of my invention as being applied to maintain constant the voltage

of an alternating-current circuit 10 which is energized from a suitable source of power through an adjusting device consisting of a saturable core reactor 12. This reactor is of a well-known construction comprising two outer core legs, upon which are positioned windings 14 connected intermediate the power source and the regulated circuit, and a central leg which carries a saturation control winding 16. The effective impedance of windings 14, and hence the voltage drop which the flow of current from the power source to the regulated circuit produces thereacross, is determined by the magnitude of a unidirectional current circulated through winding 16.

This current is supplied from a suitable source of power, indicated as a battery 18, through a circuit which includes one or more electronic tubes 20 of the grid-controlled variety. The current passed by each of these tubes is determined by the voltage impressed upon the grid element 22 thereof by a resistor 24, through which a second source of power 26 circulates a current determined by the conductivity characteristics of an error-detecting tube 28. This last-named tube is of the two-element type having a filamentary cathode 30 which is energized, through a connection which includes a transformer 32, by a measure of the voltage appearing between regulated circuit conductors 10.

The illustrated use as a detector of the two-element tube eliminates the necessity for the standard potential battery or other equivalent source of reference voltage which heretofore has been required in all high-sensitivity electronic-tube voltage-control applications. This tube is preferably operated with a voltage upon its anode 34 which is sufficiently high to saturate or place the tube in a condition in which all of the electrons emitted by the cathode are attracted to the anode. For such a condition, a change in the magnitude of the filament heating potential effects a highly amplified change in the magnitude of the current which the tube draws through the resistor 24. Essentially, such a filament controlled detector is a temperature actuated device and functions to indicate the root-mean squared value, instead of the average as does a grid voltage control tube, of the alternating-current voltage which energizes its cathode. Thus in addition to being highly sensitive, such a tube provides a type of response which is especially desirable when the generator voltage wave is subject to deviation from the usual sinusoidal form.

In operation of the system of Fig. 1, as long as the voltage of circuit 10 remains of the desired value, the illustrated electronic tube control maintains the voltage adjusting reactor 12 at that intermediate degree of saturation required to hold this desired voltage. The drop across windings 14 then reduces the power source voltage appearing between conductors 36 by an intermediate amount necessary to properly supply circuit 10. If desired an auto-transformer may, as shown at 38 in Fig. 2, be utilized to boost the power supply voltage by an amount which compensates for the drop through the adjusting reactor 12.

Upon a decrease in this regulated voltage, however, the temperature of detector cathode 30 is lowered, its electronic emission reduced, and the current passed by tube 28 through resistor 24 correspondingly diminished. The lowered voltage drop across resistor 24 changes in the positive direction the potential applied to the grid 22 of tube 20, and correspondingly raises the conductivity of this tube. As a result, more current is passed to the saturation control winding 16, the degree of core saturation of device 12 raised, and the reactance of and hence the voltage appearing across windings 14 reduced. This correctively raises the voltage supplied to circuit 10 back to the desired value.

In a similar manner, when the regulated voltage rises, the electron emission and hence the conductivity of tube 28 is raised, the grid potential applied to grid 20 changed in the negative direction and the saturation of reactor 12 correspondingly lowered. In this manner, the voltage supplied to circuit 10 is correctively decreased back to the desired value.

Where unusually high precision of regulation is desired, an amplifying electronic tube, indicated at 40 in Fig. 2, may be interposed between the filament controlled detector 28 and the reactor saturation control tube 20. In the connection shown in Fig. 2, the current passed by detector tube 28 is circulated through a resistor 42 the voltage drop across which determines the potential impressed upon the grid 44 of the amplifier tube 40. In addition to this grid and the usual anode and cathode elements 46 and 48, this tube is shown as being provided with a screen grid 50.

A suitable source of unidirectional potential indicated as a battery 52 circulates through the grid-bias determining resistor 24, associated with the voltage-adjusting tube 20, a current determined by the impedance of this amplifying tube 40. Small changes in the output of detector 28 are converted by means of the amplifier into considerably larger changes in the current supplied to resistor 24 which, through tube 20, functions in the manner already explained to adjust the voltage of circuit 10.

The operation of the system of Fig. 2 is thus essentially the same as that of Fig. 1, with the exception that greater sensitivity is afforded. In both systems, the magnitude of the regulated voltage may be adjusted by changing the setting of a rheostat 54 preferably connected in the manner shown in the energizing circuit of the detector filament.

Instead of utilizing batteries or other separate sources of unidirectional potential, the electronic-tube circuits comprised by my regulating system may, by the use of the rectifying equipment illustrated in Fig. 3, be energized from a source of alternating-current power which, if

desired, may be the regulated circuit 10 of Figs. 1 and 2. The equipment of Fig. 3 comprises a transformer 56 energized by the alternating-current power source and provided with a main secondary winding 58, the two ends of which are respectively connected with the anodes of a full-wave rectifying tube 60. The cathode of this rectifier may be supplied from another secondary winding 62, while still additional sections 64 and 66 may be utilized to energize the cathodes of the electronic tubes 20 and 28 comprised by the regulating system. Tube 60 rectifies both waves of the voltage impressed thereon by transformer winding 58, and causes to appear between the midtap connection 68 of this winding and the connection with cathode 70 a unidirectional voltage, the ripples in which are by means of equipment 72 filtered out before this voltage is impressed upon resistor sections 18' and 26', which respectively serve to supply the anode circuits of the tubes 20 and 28.

In addition to the alternating-current feeder circuits represented in Figs. 1 and 2, my improved regulating system may also be utilized to control the voltage of a dynamo-electric machine, a direct-current generating type of which is indicated in Fig. 4 at 74. The armature winding of this machine is directly connected with the conductors 10' of a direct-current circuit the voltage of which is to be maintained constant, and the main field winding 76 is self-excited by the machine. An auxiliary or regulating field winding 78 is supplied from power source 16 with an energizing current determined by tube 20 which, through amplifier 40, is controlled by detector 28, the cathode 30 of which is shown as being energized directly by the voltage of circuit 10'.

In operation of the system of Fig. 4, when the voltage of circuit 10' is of the desired value, the illustrated equipment functions to supply to field winding 78 an intermediate value of exciting current which maintains the voltage of generator 74 at this desired value. When the circuit voltage falls, however, detector 28 responds in the manner explained in connection with Figs. 1 and 2 to cause amplifier 40 to increase the exciter current passed by voltage adjusting tube 20 and thereby correctively raise the generator voltage back to the desired value. In a similar manner, when the voltage rises, the electronic tube equipment correctively reduces the generator excitation.

In Fig. 5 I have illustrated a further extension of the basic regulating system of the preceding figures which in operation simulates a vibratory type of regulator in that adjustment in a quantity-determining current is, under certain circumstances, effected by rendering electronic tubes which control this current alternately fully conductive and fully non-conductive. The relative values or ratios of these conducting and non-conducting periods are varied in such manner as to maintain the regulated quantity at its desired value.

The system is shown as being adapted to maintain constant the voltage of an alternating-current generator 80, the armature windings of which are connected with a three-phase circuit represented by conductors 10'' and the field winding 81 of which is energized from a separate exciter 82. The exciter field winding 83 is supplied with a unidirectional energizing current derived from a source of alternating-cur-

rent power, which, as shown, may be in the form of a separate circuit 84, or which may constitute the generator output circuit 10'. The represented energizing connection includes a transformer 85 and a pair of rectifiers 86 and 87 which are connected in a well-known manner to effect full-wave rectification.

These rectifiers are of a well-known type having a make-alive element or firing rod 88 arranged in contact with the cathode, which comprises mercury or other vaporizable reconstructing material 89, in such manner that a current passage therethrough renders the rectifier conductive. Once instituted, this conduction persists during the remainder of the positive half cycle in which it was started. In the absence of make-alive element excitation, the device remains an insulator during both half cycles of voltage impressed upon its anode element 90.

In the system disclosed, I utilize for the purpose of exciting the make-alive element of each of these two rectifiers a capacitor with which there is associated a charging circuit. In the case of rectifier 86 this capacitor is shown at 98 and its charging circuit is energized by the voltage supplied to rectifier 87. This circuit is controllably completed through an electronic tube 92. When another electronic tube 93 is rendered conductive capacitor 98 is discharged through the make-alive element 88 of rectifier 86 to thereby render that rectifier conductive. In a similar manner, a charging circuit for capacitor 91 associated with rectifier 87 is energized by the voltage supplied to the anode of rectifier 86 and is controllably completed through an electronic tube 94. A circuit for discharging this capacitor through the make-alive element of rectifier 87 is completed when an additional electronic tube 95 is rendered conductive.

Tubes 92, 93, 94 and 95 are each of a three-element type which may be maintained non-conductive by impressing thereon a grid bias in excess of a certain critical negative value. When this bias is reduced below this value, tube conductivity will result when a proper value of anode voltage is supplied to the tube. Tubes 93 and 95 are supplied with grid voltage of proper character to cause them to break down when the capacitors 91 and 98 are charged to a proper voltage by means of a transformer 86 energized from source 84 through a phase shifting device 97 the adjustment of which is initially fixed to obtain most satisfactory operation.

Tube 92 is so interconnected with tube 95 that whenever this last-named tube breaks down to discharge capacitor 91 through the make-alive element of rectifier 87, tube 92 will be rendered conductive to charge capacitor 98 during the same half cycle. Capacitor 98 then discharges during the succeeding half cycle to render rectifier 86 conductive.

Tube 94 is in turn controlled by the potential appearing across a resistor 24' connected in its grid circuit. This potential is determined by amplifier tube 40 controlled, as in the systems of the preceding figures, by a detector tube 28 upon the filamentary cathode 30 of which is impressed a measure of the voltage acting in regulated circuit 10'.

In operation of the complete regulating system of Fig. 5, the control is such that the main rectifiers 86 and 87 are alternately conductive for a few cycles and non-conductive for the next succeeding few cycles, the ratio of these conducting to non-conducting periods being deter-

mined by the voltage acting in regulated circuit 10'. When this voltage is low, this ratio is caused to rise to thereby increase the excitation of generator 80, and when the voltage is high, the ratio is correspondingly reduced to lower the excitation and hence the voltage of machine 80.

At all times, therefore, it is necessary that the voltage of circuit 10' very slightly fluctuate above and below the desired mean or average value. When below, the detector 28 adjusts in the negative direction the grid bias of amplifier 40. This lowers the tube conductivity and, by decreasing the drop across the output resistor 24', lowers the grid bias supplied by this resistor, and the battery 99, to tube 94 to less than the aforementioned critical value.

This renders the tube conductive allowing it to pass to capacitor 91 a charging current during each of the negative half cycles of anode voltage supplied to rectifier 87. This current passage persists as long as tube 94 remains conductive. During each succeeding positive half cycle of anode voltage, tube 95 discharges the capacitor 91 through the make-alive element 88 of rectifier 87, thereby rendering it conductive. With each passage of discharge current through tube 95, tube 92 is rendered conductive to pass charging current to capacitor 98 associated with rectifier 86, and tube 93 in turn discharges this capacitor through the make-alive element of rectifier 86 during each succeeding half cycle. As a result, for each half cycle that rectifier 87 is maintained conductive, rectifier 86 is also rendered in the same condition during the succeeding half cycle. Consequently, the rectifier conducting periods are always multiples of two half cycles.

When thus rendered conductive, rectifiers 86 and 87 supply the field winding 83 with an energizing current which boosts the voltage of exciter 82 and thereby raises the voltage supplied by machine 80 to circuit 10'. When this rise has continued to slightly above the desired average or mean value, the detector 28 causes amplifier 40 to increase its conductivity and thereby raise the grid bias applied to tube 94 to above the critical value required to maintain this tube non-conductive. Charging current is then no longer supplied to capacitor 91, the make-alive element 88 of rectifier 87 is no longer excited, and conductivity by the rectifier is accordingly discontinued. Because of the before explained interconnection with rectifier 86, its conductivity is also discontinued.

As a result, energizing current is no longer supplied to field winding 83, the voltage of exciter 82 starts to drop causing machine 80 to lower the voltage supplied to regulated circuit 10'. This lowering continues until tube 94 is again rendered conductive when the above described cycle is caused to repeat itself.

The circuit of field winding 83 supplied by the rectifiers is highly inductive, so that the current through it cannot be interrupted suddenly. Hence in the supply circuit shown in Fig. 5 the normal tendency is to maintain conductive the rectifier 86 which last supplied current preceding a discontinuance by the control system of the rectifier conducting period. Such a condition is undesirable because it produces a high saturation in the main supply transformer 85, and to prevent this, I connect in shunt with the field winding 83 a bypass rectifier 102, which functions to complete a return circuit for the

inductive voltage of winding 83 upon a discontinuance of current supply thereto through the rectifiers 86 and 87.

The construction of this bypass rectifier may be similar to the before described tube rectifiers, and I have shown it as comprising a starting element 88 in circuit with which is connected an auxiliary rectifier 103 which insures that device 102 will conduct current only in the proper direction. By means of this arrangement, tube 102 remains non-conductive as long as current is supplied through rectifiers 86 and 87. As soon as this supply is cut off, however, the bypass device becomes conductive, allowing rectifiers 86 and 87 immediately to revert to the non-conducting state when the control system so supervises.

Although I have shown and described certain specific embodiments 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. In a system for regulating the voltage of a dynamo-electric machine, the combination of a circuit for supplying exciting current to the machine, a rectifier tube for adjusting the magnitude of said current, means, comprising a two-element tube having a filamentary cathode energized by a measure of the machine voltage, for supplying a control potential determined by said voltage, a triode electronic tube rendered conductive or non-conductive by changes in said potential, and means controlled by said triode tube for rendering said rectifier tube fully conductive or fully non-conductive, regulation being effected through variation in the ratio of the conductive to non-conductive periods of said rectifier tube.
2. In a system for regulating a characteristic of a dynamo-electric machine, the combination of a circuit for supplying exciting current to the machine, a rectifier, having a conductivity instituting make-alive element, for adjusting the magnitude of said current, means for supplying

a control potential determined by the said machine characteristic, a triode electronic tube rendered conductive or non-conductive by changes in said potential, a capacitor and a charging circuit therefor which includes said tube, and a circuit for discharging said capacitor through the make-alive element of said rectifier to thereby render the rectifier conductive, regulation being effected through variation in the ratio of the conductive to non-conductive periods of said rectifier.

3. In a system for regulating a characteristic of a dynamo-electric machine, the combination of an alternating-current source of power, a rectifier, a machine-excitation determining circuit of inductive character supplied from said source through said rectifier, means for supplying a control potential determined by said machine characteristic, means responsive to changes in the magnitude of said potential for rendering said rectifier fully conductive or fully non-conductive, and a second rectifier connected in parallel-circuit relation with said machine-excitation determining circuit to bypass the current of induction which results when the first-named rectifier is rendered non-conductive.

4. In a system for regulating a characteristic of a dynamo-electric machine, the combination of an alternating-current power source, a pair of rectifiers, a machine-excitation determining circuit of inductive character supplied from said source through a full-wave rectifying connection of said rectifiers, means for supplying a control potential determined by said machine characteristic, means responsive to changes in the magnitude of said potential for rendering one of said rectifiers fully conductive or fully non-conductive, means responsive to the conductivity of said initially controlled rectifier for controlling the conductivity of the other rectifier, and a third rectifier connected in parallel-circuit relation with said machine-excitation determining circuit to bypass the current of induction which results when said first-named rectifiers are rendered non-conductive.

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