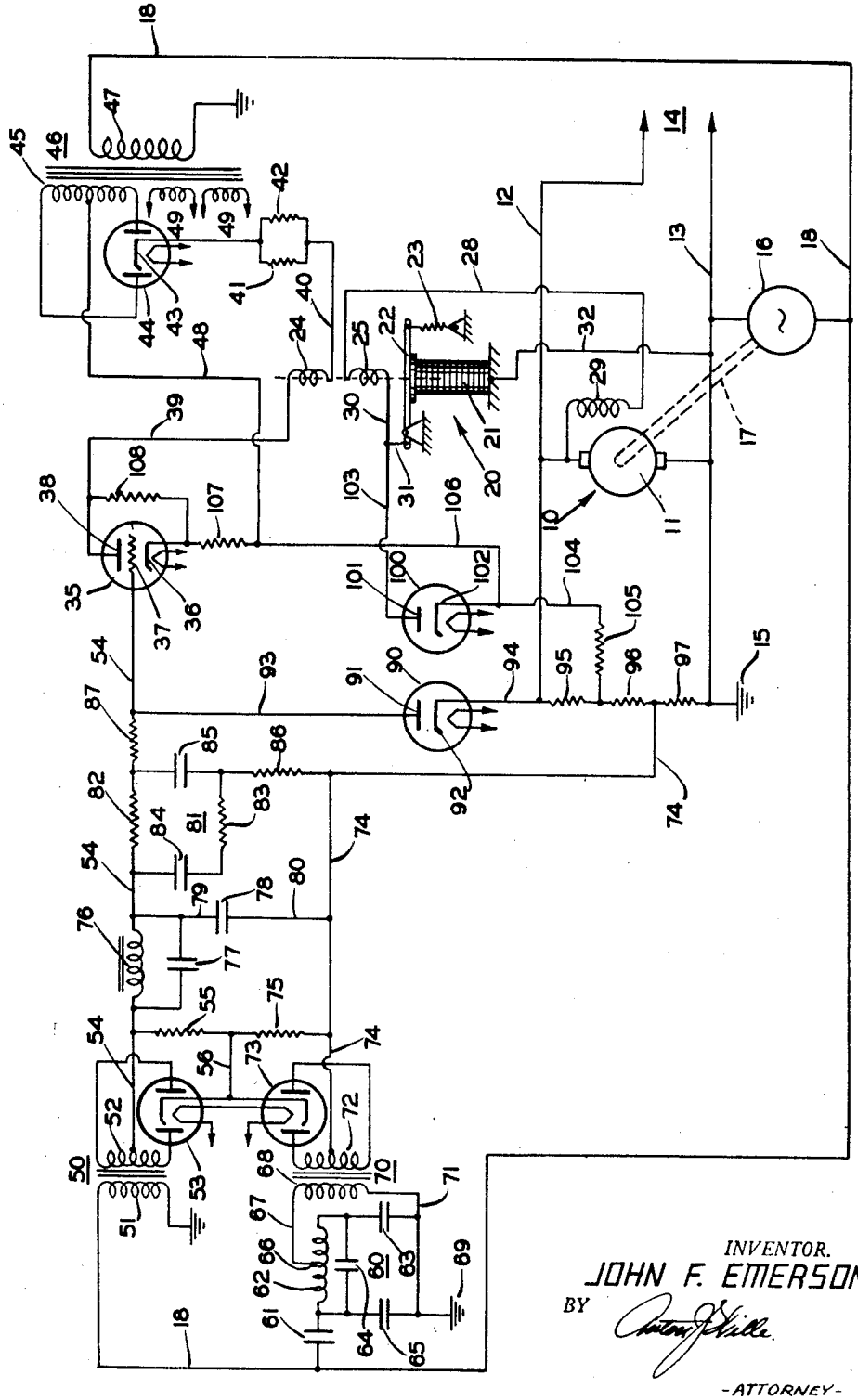
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FREQUENCY VOLTAGE REGULATOR

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FREQUENCY VOLTAGE REGULATOR

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This invention relates to a frequency regulator, and more particularly to a carbon pile regulator in which the carbon pile resistance is in the field circuit of a motor driving the generator developing the voltage, the frequency of which is to be regulated.

An object of my present invention is to provide a regulator in which the resistance of a carbon pile in the field circuit of the motor is varied in accordance with the frequency of the alternating current developed by the generator driven by the motor.

A further object of the present invention is to provide a frequency regulator of the character indicated in which the average rectified value of the voltage developed by the generator is used as a reference and to which a voltage responsive to the frequency of the developed voltage is added to vary the resistance of a carbon pile in the circuit of the motor driving the generator to maintain the speed of the motor at a constant value.

Another object of my invention is to provide a frequency regulator of the general character indicated in which signal voltages responsive to the frequency and to the amplitude of the generated voltage, are applied to a vacuum tube circuit to control the output thereof for controlling the speed of a motor driving the generator developing the voltage.

Still another object of my invention is to provide a regulator of the character indicated in which the resistance of a carbon pile is varied in accordance with the output of a vacuum tube circuit controlled by the frequency and substantially independent of the voltage, in which the changes in the carbon pile resistance tend to stabilize the value thereof.

Still a further object of this invention is to provide a regulator of the character indicated in which the flow of excessive armature current is prevented by limiting the maximum value of the carbon pile resistance through a circuit attenuating excessive signal voltages.

Yet a further object of the present invention is to provide a regulator of the character indicated in which the flow of excessive armature current is further prevented by the change in carbon pile resistance affecting the bias voltage of the vacuum tube circuit.

Yet another object of this invention is to provide a regulator in which the amplitude and frequency of the generated voltage is unaffected by the changes in the motor voltage supply.

Still a further object is to provide a regulator

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of the character indicated in which "fail safe" provisions will reduce the speed of the motor upon failure n the regulating system.

Still another object of the invention is to provide a highly improved regulator of the character indicated which shall be simple in construction, relatively inexpensive to manufacture, positive in its action and automatic in its operation, which shall be unaffected by temperature changes in the circuits thereof and which is practical and efficient to a high degree in use.

Other objects of this invention will be obvious and in part hereinafter pointed out.

I accomplish the several objects of the invention by providing a carbon pile resistor in the field circuit of a shunt wound D. C. motor driving an A. C. generator. The resistance of the carbon pile is varied to control the speed of the motor by an electronic control circuit connected to the output of the generator. The control circuit is essentially in two sections, one section providing a signal voltage proportional to the generator voltage while the other section provides a signal voltage also proportional to the generator voltage but modified in response to the frequency of the generator voltage. The two signal voltages thus derived are applied to the input of the electronic circuit in series opposed relation. The components of the generated voltage tend to balance out, leaving the control of the electronic circuit sensitive to only the frequency variations in the generator voltage. The resistance of the carbon pile is thus varied in accordance with the frequency of the generator voltage to maintain the operation of the motor at a constant, predetermined speed.

Referring now in detail to the single figure of the accompanying drawing in which there is shown a schematic wiring diagram of an embodiment of my invention, the numeral 10 designates a shunt wound D. C. motor having its armature connected across the leads 12 and 13 of a D. C. power supply 14, the lead 13 being grounded as at 15. The motor 10 drives an A. C. generator 16 through a suitable shafting 17, said generator being connected at one side to the grounded lead 13 and at the other side to a power lead 18.

A carbon pile regulator 20 is provided to control the speed of the D. C. motor 10 in accordance with the A. C. output of the generator 16. The regulator 20 includes a resistance pile 21, a pivoted armature 22, and a coil spring 23; the bias of the spring being such as to increase the pressure of the armature 22 on the pile 21 to

decrease the resistance thereof. Two magnetizing coils 24 and 25 are also provided in aiding relation, the energization of which will attract the armature 22 against the bias of the spring 23 to reduce the pressure on the resistance pile 21. The coil 24 will hereinafter be referred to as the control coil, while coil 25 will be referred to as the stabilizing coil.

One end of the stabilizing coil 25 is connected by a lead 28 to the motor shunt field 29 connected to the D. C. supply line 12. The other end of the stabilizing coil is connected by two leads 30 and 31 to the armature 22 of the regulator. The armature 22 is electrically connected through the carbon pile 21 to a lead 32 connected at its other end to the grounded supply line 13.

The stabilizing coil 25 is poled to aid the control coil 24. The stabilizing coil being in series with the carbon pile resistance 21, the magnetomotive force develeped by the coil is dependent on the ohmic value of the resistance. The magnetomotive force of the coil decreases as the value of the carbon pile resistance increases. Thus a magnetizing current flowing through the control coil 24 will attract the armature 22 of the regulator. The resistance of the pile 21 will increase due to the decrease in pressure. The increase in resistance of the pile will decrease the magnetizing effect of stabilizing coil 25, tending to increase the pressure of the armature 22 on the pile slightly. Similarly, if the magnetizing current in control coil 24 should decrease, the pressure on the pile 21 will increase tending to decrease the resistance of the carbon pile. The magnetomotive force of the stabilizing coil will increase tending to decrease the pressure on the pile slightly. Thus, the magnetomotive force developed by the control coil 24 is offset slightly by that developed by the stabilizing coil 25 to stabilize the resistance value of the carbon pile 21.

It will be apparent that fluctuations in the supply voltage 14 will be partially compensated by the stabilizing coil 25. A reduction of the supply voltage will reduce the magnetomotive force of the coil tending to decrease the resistance of the carbon pile 21. A greater current will then flow through the field winding 29. An increase in the supply voltage will tend to increase the magnetizing current through the coil 25 to increase the resistance of the carbon pile 21.

Thus the stabilizing coil 25 will stabilize the resistance of the carbon pile 21 with respect to the magnetizing current in the control coil 24, and also aid, as will hereinafter be described, in compensating for changes in motor speed due to fluctuations in the D. C. supply 14.

Means are now provided to energize the control coil 24 of the carbon pile regulator 20 for maintaining the speed of the motor 10 at a constant value.

To this end there is provided in the circuit illustrated a triode vacuum tube 35, having a cathode 36, a control grid 37, and a plate 38. The control coil 24 is connected to the plate 38 by a lead 39, and by a lead 40 through two resistors 41 and 42 connected in parallel to the cathode 43 of a full-wave rectifier tube 44. The rectifier tube is connected in a conventional manner across a centertapped secondary winding 45 of a transformer 46, the centertap being connected by a lead 48 to the cathode 36 of the control tube through a resistor 107 to supply the bias voltage thereof. The primary winding 47 of the transformer is grounded at one end and connected to the A. C. power lead 18 at the other end. The transformer 46 is provided with additional secondary windings 49 to supply the necessary filament voltages, as hereinafter described.

It is evident, that the conduction of the control tube 35 will cause an energizing current to flow through the control coil 24 to increase the resistance of the carbon pile 21 for varying the current through the field of the D. C. motor 10. The resistors 41 and 42 in series with the control coil 24 have a negative temperature coefficient of resistance. Since the heating of the control coil by the magnetizing current therethrough and variation in amibent temperature affects the resistance thereof, the two resistors being in series and in thermal contact therewith will compensate for the changes in resistance to maintain the resistance of the control coil circuit constant.

The operation of the triode tube 35 is controlled by the A. C. output of the generator 16 through two parallel circuits connected to the power lead 18. One circuit will develop a D. C. voltage proportional to the average voltage developed by the generator and independent of the frequency, while the second circuit will develop a D. C. voltage proportional to the generator voltage but also affected by the frequency thereof. The two signal voltages thus developed are combined and applied to the grid 37 of the control tube 35.

A transformer 50 having a grounded primary winding 51 is connected to the A. C. power line 18. The center-tapped secondary winding 52 of the transformer is connected in the conventional manner to the plates of a full-wave rectifier tube 53. The center tap of the secondary winding 52 is connected by a lead 54 to the grid 37 of the control tube, said lead serving as a connection to one end of a resistor 55. The other end of the resistor 55 is connected by way of a lead 56 to the cathode of the rectifier tube 53. The A. C. voltage developed by the motor driven generator 16 is thus applied to the rectifier circuit described and is impressed as D. C. across the resistor 55.

The D. C. component of the rectified generator voltage appearing across the resistor 55 is proportional to the average value of the A. C. voltage developed by the generator 16.

The second of the two control circuit for the tube 35 is by way of a frequency sensitive circuit connected to the A. C. power lead 18, generally designated by the numeral 60. This circuit comprises a series resonant circuit of a condenser 61, an inductance 62, and a second condenser 63, one plate of the condenser 63 being grounded as at 69. The resonant circuit described is resonant below the desired frequency of the A. C. voltage generated. To increase the control sensitivity of the resonant circuit near the regulated frequency, a condenser 64 is connected across the inductance 62. The inductance and the shunt condenser form a high impedance at anti-resonance which is arranged to occur at a slightly higher frequency than resonance for the series circuit. The overall effect of the addition of the condenser 64 is to cause a rapid change in the response characteristic curve of the circuit 60 in a relatively narrow frequency band extending on either side of the regulated frequency.

Although the maximum transmission (resonance) and minimum transmission (anti-resonance) will be affected by change in the losses of inductor 62, a frequency approximately midway between the frequencies for these two conditions will be substantially independent of such

losses. This should be used for the regulated frequency to minimize temperature effect.

A condenser 65 is connected in series with the condenser 61 to form a capacity voltage divider. The response of the frequency sensitive circuit 60 described is the same as though the generator 16 developed a lower voltage and the two condensers were connected in parallel.

The output of the frequency sensitive circuit 60 is tapped off as at point 66 on inductance 62 and applied through a lead 67 to one side of the primary windings 68 of a transformer 70. The other end of the primary winding is connected by a lead 71 to the condenser 63 and to the ground connection 69. The center-tapped secondary winding 72 of the transformer 70 is connected in the usual manner to a full-wave rectifier tube 73. The output voltage of the rectifier is applied by way of a lead 74 itnerconnecting the center tap of the secondary winding 72 with one end of a resistor 75; said resistor being in series with the resistor 55. The lead 74 is grounded as at 15. The lead 56 connected to the cathode of the rectifier completes the rectifier circuit to the other end of the resistor 75.

The D. C. component of the rectified generator voltage appearing across the resistor 75 is proportional to the voltage generated as modified by the frequency circuit 60. As the frequency of the generated voltage increases from zero, the voltage output of the rectifier 73 also increases until a maximum voltage is obtained. Maximum voltage will occur when the frequency is slightly less than the regulated frequency of the circuit 60. The rectifier output voltage will thereafter decrease sharply with increase in frequency until the regulated frequency is obtained, at which point the voltage output of rectifiers 53 and 73 will be very nearly equal. With increase in frequency, the output of rectifier 73 will continue to decrease.

The resistors 55 and 75 being connected in series opposition, the algebraic sum of the rectifier voltages impressed thereon will provide the grid voltage for operating the control tube 35. The polarities of these voltages are in opposition so that the voltage across 55 acts as a reference from which the voltage across 75 subtracts a greater or lesser amount depending upon the frequency of the generator. Thus the grid voltage applied will be dependent upon the frequency of the generated voltage and substantially independent of the amplitude thereof.

In starting the motor 10 it is desirable to obtain a high torque with a minimum of armature current. Since the spring 23 creates a pressure on the carbon pile 21 through the armature 22 of the regulator, the resistance of the carbon pile is at a minimum. As the motor speeds up to a value consistent with the minimum resistance in the field circuit, the voltage developed by the generator 16 will operate the tube 35 to increase the resistance of the carbon pile. Since the peak of the output characteristic of the frequency sensitive circuit occurs at a frequency less than the regulated frequency, the output of the rectifier 73 applied across the resistor 75 will increase until the peak frequency is reached. Thus the grid voltage applied to the control tube 35 will increase in the positive direction with the voltage across the resistor 75. The plate current through the control coil 24 will likewise increase with the rise of motor speed. The energization of the coil 24 will decrease the pressure on the carbon pile 21 increasing the pile resistance in the motor field circuit causing the motor to continue to accelerate. When the speed of the motor approaches that of the desired speed, the carbon pile resistance will be rapidly decreased due to the decrease in the plate current of the control tube in the control coil 21. The decrease in carbon pile resistance will continue until the regulated frequency is attained.

Any deviation from the regulated frequency due to motor operation will increase or decrease the grid voltage applied to the control tube 35 to vary the pressure on the carbon pile 21. The change in the resistance in the circuit of motor field 29 will vary the speed of the motor 10 to bring the frequency of the generated voltage to the regulated frequency.

For purposes hereinafter appearing it is desirable to obtain substantially D. C. voltage from the rectifier circuits. To this end a filter is connected in the grid lead 54 which comprises a choke 76 with a condenser 77 in parallel therewith and a by-pass condenser 78. The choke and condenser 77 are anti-resonant at the principal ripple frequency in the output of the rectifiers. The by-pass condenser 78 connected by leads 79 and 80 to the leads 54 and 74 respectively, has the lowest capacity consistent with the permissible ripple voltage at the grid 37 of the control tube. Unncessary filtering is to be avoided since it will increase the recovery time and aggravate any tendency of the system to hunt.

To reduce the tendency of the circuit to hunt, an anti-hunt circuit, generally designated by the numeral 81 is connected into the grid circuit of the control tube.

Connected in the grid lead 54 is a resistor 82 having a second resistor 83 connected in parallel therewith through two condensers 84 and 85. A third resistor 86 is connected in series with the resistor 83, the other end thereof being connected to the grounded lead 74.

The resistor 82 will conduct the steady state current to the grid 37 of the control tube. If the motor 10 accelerates or hunts about the regulated condition, the changes in the signal voltage due to the changing condition of the generated voltage will charge the condenser 84 and discharge through the resistors 83 and 86. Thus an increment of the grid voltage determined by the values of the resistors 83, 86 and condensers 84 and 85 will be added to the grid lead 54 through the condenser 85. The voltage applied will depend upon the rate of change of the frequency of the generated voltage. The anti-hunt component of the signal voltage will lead the signal voltage, so that a leading component of the signal voltage is applied to the grid lead 54 to correct for the inherent lagging response of the rest of the system. Hunting, therefore, by the motor 10 will be eliminated by the slight decrease or increase of the plate current flowing through the control coil 24, to decrease or increase the value of the carbon pile resistance in the motor field circuit in anticipation of the final signal voltage.

In order to prevent the flow of excessive armature current the maximum value of the carbon pile resistor 21 is limited by a limiting circuit provided in the grid circuit of the control tube 35 to limit the plate current thereof.

To this end a resistor 87 is connected in the lead 54 in series with the resistor 82. A diode 90 is also provided having a plate 91 and an indirectly heated cathode 92. The plate of the diode is connected by a lead 93 to the lead 54 while the cathode is connected by a lead 94 through the

series connected resistors 95, 96, and 97 to the ground connection 15.

Should the signal voltage applied to the grid 37 increase to a point where plate 91 becomes positive with respect to the cathode 92, the diode 99 will conduct. The excess voltage will drop across the resistor 97 thereby limiting the grid voltage applied to the control tube 35. The plate current of the control tube is thus limited, limiting the maximum value of the carbon pile resistor 21.

A further limiting circuit is provided to limit the maximum value of the carbon pile resistance 21 by developing a bias voltage in the control tube circuit to limit the plate current thereof.

To this end a second diode 100 is provided having a plate 101 and an indirectly heated cathode 102. The plate 101 is connected by a lead 103 to the junction point of the leads 30, 31 at the regulator armature 22. The cathode 102 is connected by a lead 104 through a resistor 105, and through the resistors 96, 97 to the ground point 15. The cathode 102 is further connected by lead 106 to the lead 48, and through a resistor 107 to the cathode 36 of the control tube 35. A resistor 108 is interconnected between the plate 38 and the cathode 36 of the control tube to carry a portion of the plate current thus permitting the use of a smaller tube for the control tube.

Examination of the circuit for the diode 100 will reveal a bridge circuit in which the resistance pile 21 forms one arm thereof, and the stabilizing coil 25 and motor field winding 29 form a second and adjacent arm of the bridge. The resistor 95 forms a third arm opposite the resistance pile, while resistors 96 and 97 form the fourth arm opposite the coil 25 and winding 29.

Should the resistance of the carbon pile 21 increase so that

$$\frac{R_{21}}{R_{96}+R_{97}}$$

is greater than

$$\frac{R_{25}+R_{29}}{R_{95}}$$

wherein R is the resistance of the element identified by the subscript, the plate 101 of the diode will become positive with respect to its cathode. The diode 100 will then conduct to develop a bias voltage across the resistor 105. The bias voltage for the control tube being obtained from the plate current flowing through the resistor 107 and the voltage drop across the resistor 96, the development of a third bias voltage by the diode 100 across the series resistor 195 will increase the bias of the control tube 35. The plate current is thus limited, limiting the maximum value of the carbon pile resistor 21.

A further feature of the cathode circuit of the control tube described, is that compensations are made therein upon fluctuations in the D. C. supply 14.

Since the bias voltage drop across the resistor 96 is proportional to the D. C. supply voltage, a reduction in supply voltage will reduce the bias voltage of the control tube. The plate current will thus increase, to decrease the pressure of the armature 22. The carbon pile resistance will thus be increased to maintain the speed of motor 10. The decrease in field current under these conditions is correct in view of the decrease in armature current. An increase in the supply voltage on the other hand, will increase the bias of the control tube to decrease the carbon pile resistance to minimize the increase in motor speed.

Certain "fail safe" provisions are incorporated in the circuits hereinbefore described.

If a loss in current through the control coil 24 exists, the spring 23 will increase the pressure of the armature 22 on the carbon pile 21. The spring thus minimizes the resistance of the carbon pile to reduce the motor speed.

Under normal operating conditions, the correct regulated speed of motor 10 will provide a voltage drop across the resistor 75 about 10% greater than the drop across the resistor 55. If no signal voltage appears across the output circuits of the rectifiers 53 and 73, the conduction of the control tube 35 is reduced, thereby reducing the magnetizing current through the control coil 24.

Further, with the series connection of the rectifier filaments to the secondary winding 49 of the transformer 46, failure of either tube will cause both to stop conducting, permitting the control coil 24 to become deenergized to decrease the resistance of the carbon pile 21.

It will thus be seen that there is provided a regulator in which the several objects of this invention are achieved and which is well adapted to meet the conditions of practical use.

As various possible embodiments might be made of the above invention, and as various changes might be made in the embodiment above set forth, it is to be understood that all matter herein set forth, or shown in the accompanying drawings, is to be interpreted as illustrative and not in a limiting sense.

Having thus described my invention, I claim as new and desire to secure by Letters Patent:

1. A control system comprising a direct current motor, an alternating current generator driven by said motor, a carbon pile resistor in the field circuit of said motor, a resiliently biased armature for said resistor for maintaining the ohmic value of said pile at a minimum, electromagnetic means for increasing the ohmic value of the resistor upon energization thereof, a vacuum tube for controlling the energization of said electromagnetic means, a frequency sensitive circuit for said generator including resonant and anti-resonant circuits to provide a signal voltage responsive to the frequency and amplitude of the generated voltage, a circuit to provide a signal voltage proportional to the generated voltage and circuit means including a filter circuit for applying the rectified signal voltages to the input of said tube to control the energization of said electromagnetic means.

2. A control system comprising a direct current motor, an alternating current generator driven by said motor, a carbon pile resistor in the field circuit of said motor, a resiliently biased armature for said resistor for maintaining the ohmic value of said pile at a minimum, electromagnetic means for increasing the ohmic value of the resistor upon energization thereof, a vacuum tube for controlling the energization of said electromagnetic means, a frequency sensitive circuit for said generator including resonant and anti-resonant circuits, the output of which is peaked at a frequency other than that of the desired frequency to provide a signal voltage responsive to the frequency of the generated voltage, a circuit to provide a signal voltage proportional to the voltage generated, and circuit means for applying the rectified signal voltages across the input circuit of said tube, said circuit including an anti-

hunt circuit to add an increment of the combined signal voltages to the input of said tube at a leading or lagging phase angle dependent upon the rate of change of the frequency of the generated voltage for stabilizing the speed of said motor.

3. A control system comprising a direct current motor, an alternating current generator driven by said motor, a carbon pile resistor in the field circuit of said motor, a resiliently biased armature for said resistor for maintaining the ohmic value of said pile at a minimum, electromagnetic means for increasing the ohmic value of the resistor upon energization thereof, a vacuum tube for controlling the energization of said electromagnetic means, a frequency sensitive circuit for said generator including resonant and anti-resonant circuits, the output of which is peaked at a frequency other than that of the desired frequency to provide a signal voltage responsive to the frequency and amplitude of the generated voltage, a circuit to provide a signal voltage proportional to the voltage generated, and circuit means for applying the rectified signal voltages across the input circuit of said tube, said circuit including an anti-hunt circuit to add an increment of the combined signal voltages to the input of said tube at a leading or lagging phase angle dependent upon the rate of change of the frequency of the generated voltage for stabilizing the speed of said motor, said circuit including a diode tube for limiting the conduction of said first tube to prevent the flow of excessive armature current in said motor.

4. A control system comprising a direct current motor, an alternating current generator driven by said motor, a carbon pile resistor in the field circuit of said motor, a resiliently biased armature for said resistor for maintaining the ohmic value of said pile at a minimum, electromagnetic means for increasing the ohmic value of the resistor upon energization of said electromagnetic means, a frequency sensitive circuit for said generator including resonant and anti-resonant circuits, the output of which is peaked at a frequency other than that of the desired frequency to provide a signal voltage responsive to the frequency and amplitude of the generated voltage, a circuit to provide a signal voltage proportional to the voltage generated, and circuit means for applying the rectified signal voltages across the input circuit of said tube, said circuit including an anti-hunt circuit to add an increment of the combined signal votages to the input of said tube at a leading or lagging phase angle dependent upon the rate of change of the frequency of the generated voltage for stabilizing the speed of said motor, said circuit including a diode tube for limiting the conduction of said first tube to prevent the flow of excessive armature current in said motor, a second diode tube, and a bridge circuit including said carbon pile resistor in one arm thereof, the unbalance of said bridge operates said second diode to increase the bias of said first tube to further limit the flow of motor armature current.

5. A control system comprising a direct current motor, an alternating current generator driven by said motor, a carbon pile resistor in the field circuit of said motor to control the speed thereof, a resiliently biased armature for said resistor for maintaining maximum pressure on said pile resistor, electromagnetic means adapted to decrease the pressure of said armature upon energization thereof, means for energizing said electromagnetic means by signal voltages responsive

to the frequency substantially independent of the amplitude of the generated voltage to control the motor speed at a predetermined value, and a second electromagnetic means for decreasing the pressure of said armature on said carbon pile, in series with said carbon pile resistor in the field circuit of said motor, to stabilize the speed of said motor at the predetermined speed.

6. A control system comprising a direct current motor, an alternating current generator driven by said motor, a carbon pile resistor in the field circuit of said motor, a resiliently biased armature for said resistor for maintaining the ohmic value of said pile at a minimum, electromagnetic means for increasing the ohmic value of the resistor upon energization thereof, a vacuum tube for controlling the energization of said electromagnetic means, means for controlling the conduction of said tube in accordance with the frequency substantially independent of the amplitude of the voltage developed by said generator to control the speed of said motor, and a second electromagnetic means for decreasing the pressure of said armature on said carbon pile, in series with said carbon pile resistor in the field circuit of said motor, to stabilize the speed of said motor at the predetermined speed.

7. A control system comprising a direct current motor, an alternating current generator driven by said motor, a carbon pile resistor in the field circuit of said motor, a resiliently biased armature for said resistor for maintaining the ohmic value of said pile at a minimum, electromagnetic means for increasing the ohmic value of the resistor upon energization thereof, a vacuum tube for controlling the energization of said electromagnetic means, a frequency sensitive circuit for said generator including resonant and anti-resonant circuits, the output of which is peaked at a frequency other than that of the desired frequency to provide a signal voltage responsive to the frequency and amplitude of the generated voltage, a circuit to provide a signal voltage proportional to the voltage generated, circuit means for applying the rectified signal voltages across the input circuit of said tube, said circuit including an anti-hunt circuit to add an increment of the combined signal voltages to the input of said tube at a leading or lagging phase angle dependent upon the rate of change of the frequency of the generated voltage for stabilizing the speed of said motor, said circuit including a diode tube for limiting the conduction of said first tube to prevent the flow of excessive armature current in said motor, and a second electromagnetic means for decreasing the pressure of said armature on said carbon pile, in series with said carbon pile resistor in the field circuit of said motor, to stabilize the speed of said motor at the predetermined speed.

8. A control system comprising a direct current motor, an alternating current generator driven by said motor, a carbon pile resistor in the field circuit of said motor, a resiliently biased armature for said resistor for maintaining the ohmic value of said pile at a minimum, electromagnetic means for increasing the ohmic value of the resistor upon energization of said electromagnetic means, a frequency sensitive circuit for said generator including resonant and anti-resonant circuits, the output of which is peaked at a frequency other than that of the desired frequency to provide a signal voltage responsive to the frequency and amplitude of the generated voltage, a circuit to provide a signal voltage pro-

portional to the voltage generated, circuit means for applying the rectified signal voltages across the input circuit of said tube, said circuit including an anti-hunt circuit to add an increment of the combined signal voltages to the input of said tube at a leading or lagging phase angle dependent upon the rate of change of the frequency of the generated voltage for stabilizing the speed of said motor, said circuit including a diode tube for limiting the conduction of said first tube to prevent the flow of excessive armature current in said motor, a second diode tube, and a bridge circuit including said carbon pile resistor in one arm thereof, the unbalance of which operates said second diode to increase the bias of said first tube to further limit the flow of motor armature current, and a second electromagnetic means for decreasing the pressure of said armature on said carbon pile, in series with said carbon pile resistor in the field circuit of said motor, to stabilize the speed of said motor at the predetermined speed.

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