

March 21, 1944.

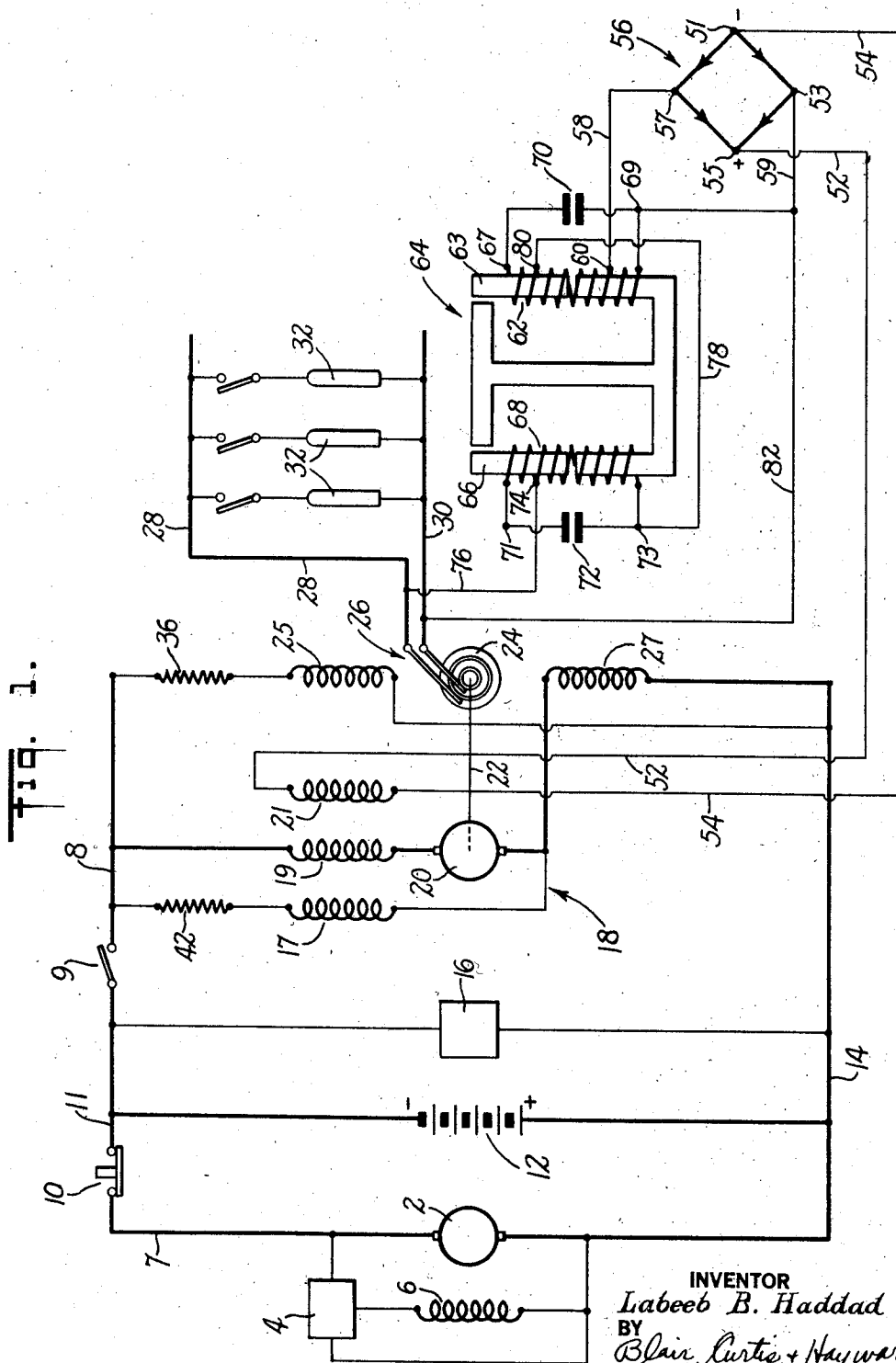
L. B. HADDAD

2,344,608

CONTROLLING SYSTEM

Filed Sept. 19, 1940

5 Sheets-Sheet 1



March 21, 1944.

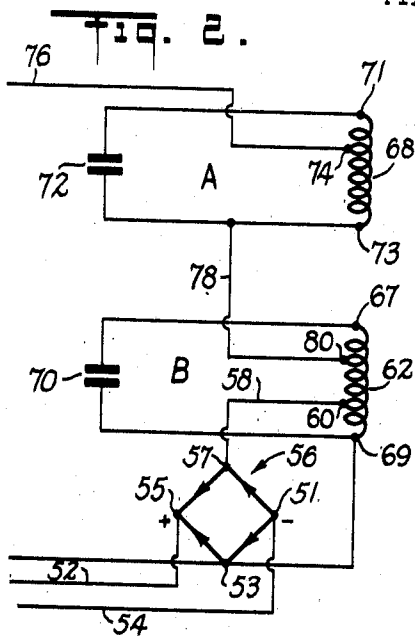
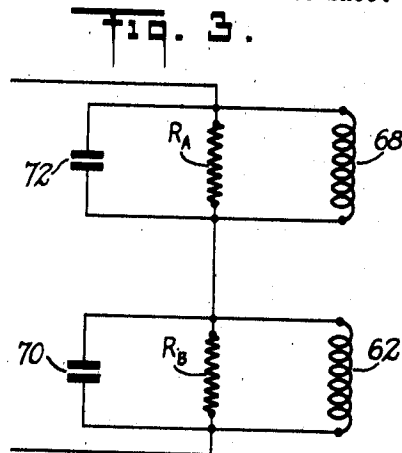
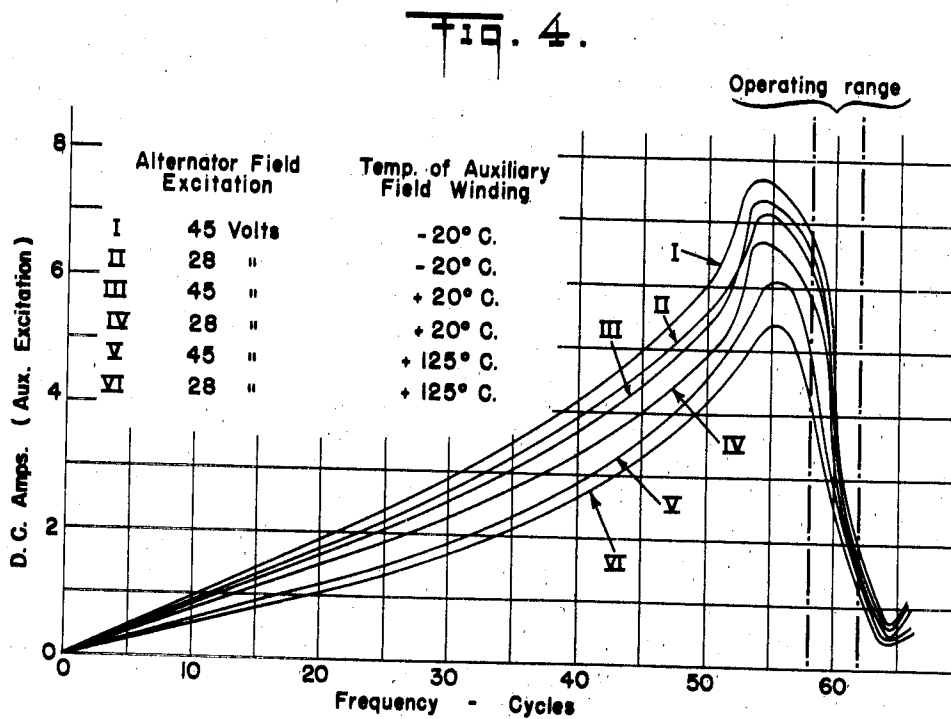
L. B. HADDAD

2,344,608

CONTROLLING SYSTEM

Filed Sept. 19, 1940

5 Sheets-Sheet 2



INVENTOR
Labeeb B. Haddad
 BY
Blau, Curtis + Hayward
 ATTORNEYS

March 21, 1944.

L. B. HADDAD

2,344,608

CONTROLLING SYSTEM

Filed Sept. 19, 1940

5 Sheets-Sheet 3

Fig. 5.

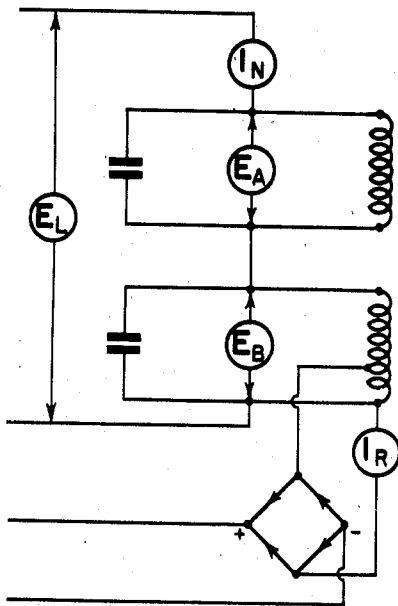


Fig. 6.

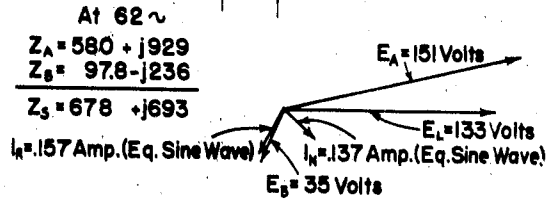


Fig. 7.

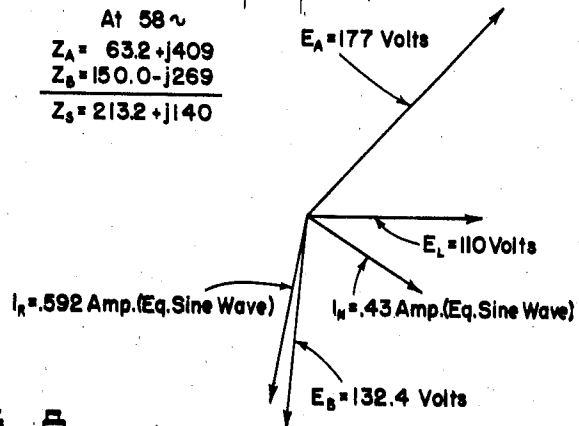
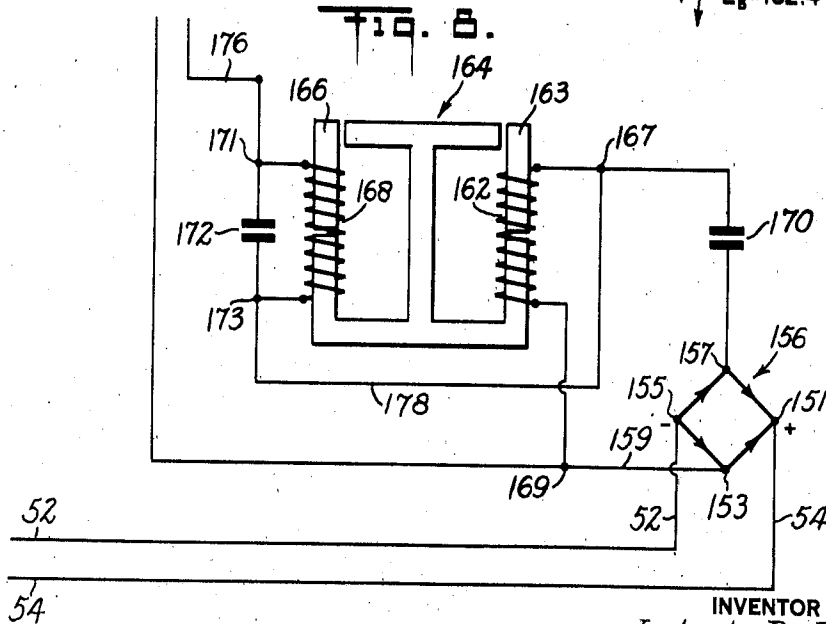


Fig. 8.



INVENTOR

Labeeb B. Haddad

BY Blair, Curtis & Hayward
ATTORNEYS

March 21, 1944.

L. B. HADDAD

2,344,608

CONTROLLING SYSTEM

Filed Sept. 19, 1940

5 Sheets-Sheet 4

Fig. 9.

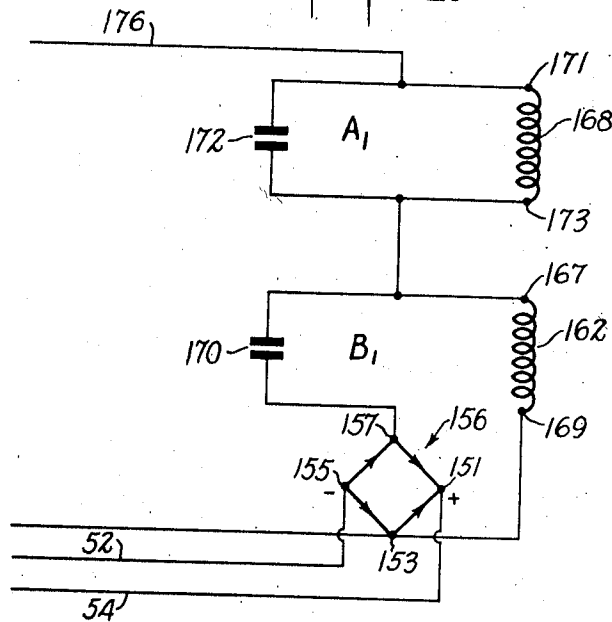
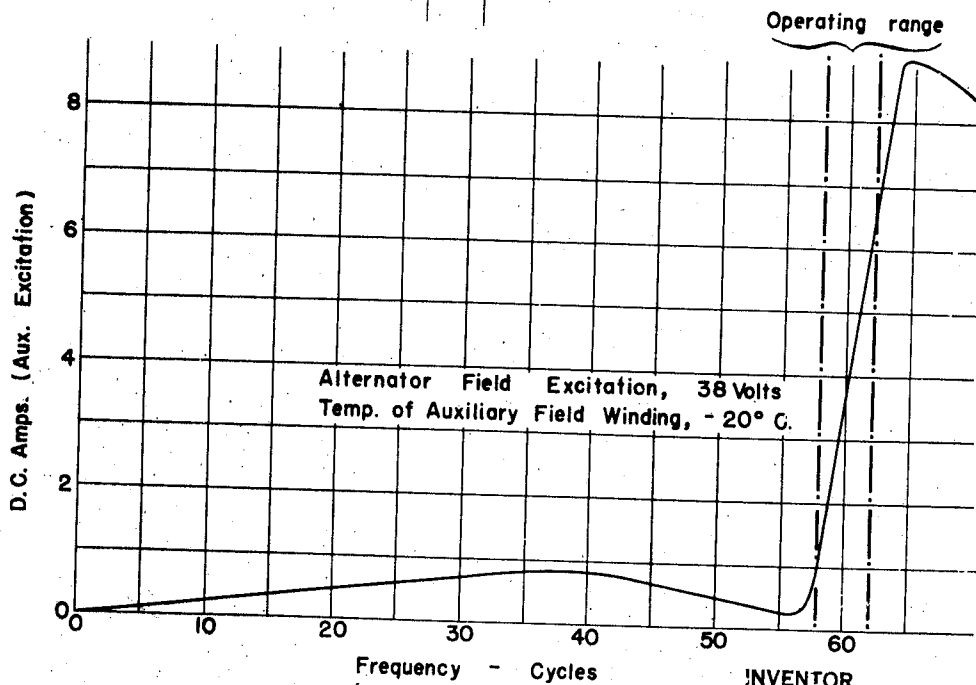


Fig. 10.



INVENTOR
Labeeb B. Haddad
BY
Blair, Curtis & Hayward
ATTORNEYS

March 21, 1944.

L. B. HADDAD

2,344,608

CONTROLLING SYSTEM

Filed Sept. 19, 1940

5 Sheets-Sheet 5

Fig. 11.

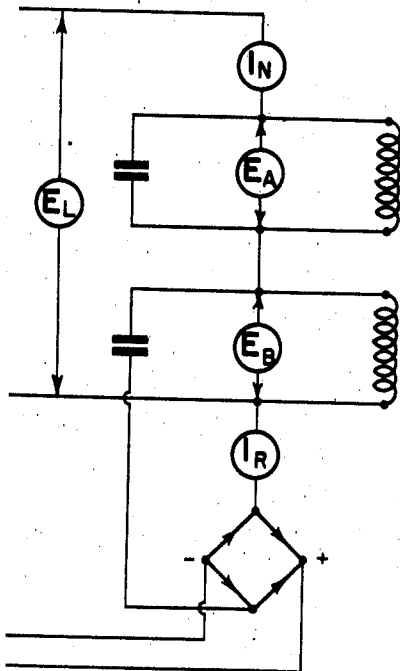


Fig. 12.

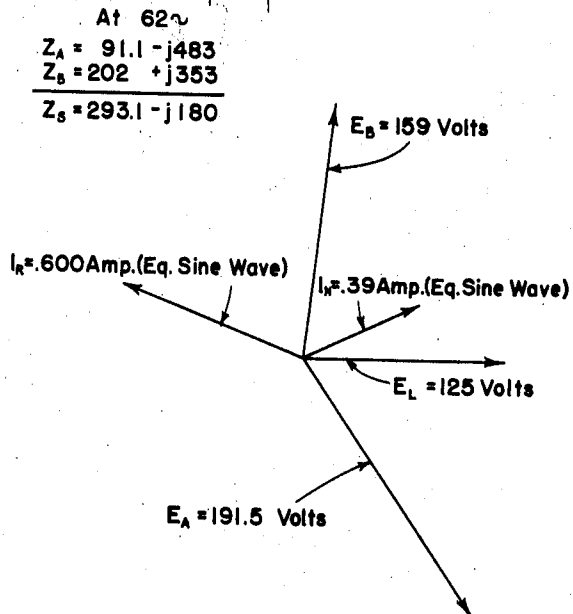


Fig. 14.

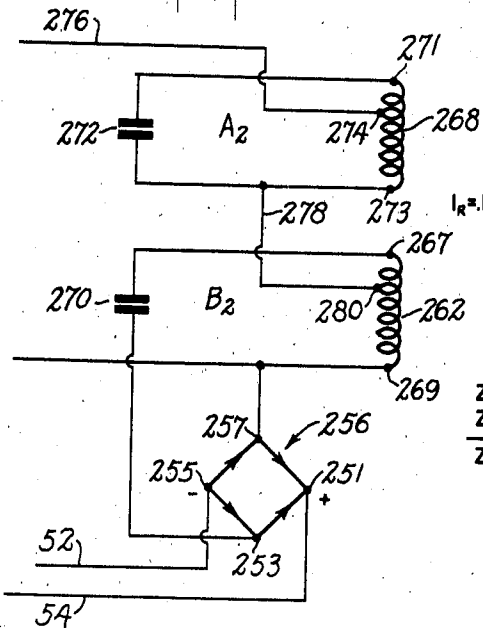
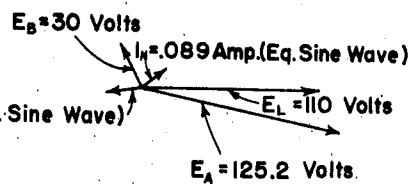


Fig. 13.



At 58~

$$Z_A = 750 - j1195$$

$$Z_B = 126 + j315$$

$$Z_S = 876 - j880$$

INVENTOR
Labeed B. Haddad
BY
Blair, Curtis & Hayward
ATTORNEYS

UNITED STATES PATENT OFFICE

2,344,608

CONTROLLING SYSTEM

Labeeb B. Haddad, New Haven, Conn., assignor
to The Safety Car Heating and Lighting Com-
pany, Inc., a corporation of Delaware

Application September 19, 1940, Serial No. 357,430

10 Claims. (Cl. 171-119)

This invention relates to control, and more particularly to the control of the speed of a motor alternator which receives power from a direct current source and delivers alternating current to fluorescent lights on railway cars.

An object of this invention is to provide a reliable and dependable source of alternating current of constant frequency and voltage. A further object is to provide a motor alternator which is capable of delivering alternating current having a minimum range of variation of frequency and voltage when the voltage of the direct current source of power varies over a wide range. A further object is to provide apparatus of the above character which is light in weight and efficient in operation and which is thoroughly practical in use. A still further object is to provide a control for the effective magnetic field of the motor of a motor alternator. A further object is to provide a source of current on a motor-alternator set which current may be used to automatically regulate the driving speed depending upon the output frequency of the alternator. A further object is to provide a method of control and control means for a motor alternator of the above character which will receive alternating current from the alternator and deliver current which tends to maintain constant speed. Other objects will be in part obvious and in part pointed out hereinafter.

The invention accordingly consists in the features of construction, combinations of elements, arrangements of parts and in the several steps and relation and order of each of the same to one or more of the others, all as will be illustratively described herein, and the scope of the application of which will be indicated in the following claims.

In the drawings:

Figure 1 is a schematic showing of one embodiment of the invention;

Figure 2 is a diagrammatic representation of a portion of the apparatus shown in Figure 1;

Figure 3 is a simplified equivalent alternating current circuit of the speed regulating circuit of Figures 1 and 2;

Figure 4 is a set of curves showing the variation with frequency of the direct current output of the control unit shown in Figures 1 and 2, with the various curves representing various conditions of operation;

Figure 5 is a diagrammatic representation similar to Figure 2, but showing a different embodiment;

Figures 6 and 7 are vector diagrams showing

the voltage and current relationships in the embodiment of Figure 5 at alternator frequencies of 62 and 58 cycles per second respectively.

Figure 8 is a view similar to the right-hand portion of Figure 1, but showing another embodiment of the invention;

Figure 9 corresponds to Figure 2 and relates to the circuit of Figure 8.

Figure 10 is similar to Figure 4, and shows the variation in direct current output as the output frequency varies in the embodiment of Figure 8;

Figure 11 is similar to Figure 5, but shows the currents and voltages of Figures 12 and 13;

Figures 12 and 13 are vector diagrams showing the voltage and current relationships in the circuit of Figure 8 at the alternator frequencies of 62 and 58 cycles per second, respectively; and

Figure 14 is a view similar to Figures 2 and 9, but showing another embodiment of the invention.

This application is a continuation-in-part of my copending application Serial Number 186,306, filed January 22, 1938, entitled Voltage control, which has issued as Patent No. 2,236,173, dated March 25, 1941.

As conducive to a clearer understanding of the present invention, it should be noted that the present embodiments are particularly suited for use on railway cars in providing a source of power for fluorescent lights. It is therefore important that the equipment be light in weight and sturdy in construction and that it be adaptable for use under varying conditions. On railway cars such as coaches, pullman cars and the like each car is provided with its own individual electrical system. This system generally includes a set of storage batteries, lighting and other equipment, and an axle-driven direct current generator to supply power for the equipment and for charging the batteries. In the present invention, direct current power is taken from the system to drive a motor and this motor in turn drives an alternator which supplies alternating current to fluorescent lights. Railway equipment should be dependable in action and it should not require constant adjustment or repairing as it is difficult to insure that the equipment will receive proper attention during use.

The voltage in the usual direct current electrical system varies during operation between 28 volts and 45 volts depending upon the condition of charge of the batteries and upon whether or not current is being supplied by the direct current generator. Furthermore, the voltage may

vary when there are changes in the load, and thus with the present system, a change in the lighting load may tend to cause a change in the speed of the motor alternator. It is an object of this invention to provide apparatus of the above character which will constitute a reliable source of alternating current under the above conditions.

Referring particularly to the left-hand side of Figure 1 of the drawings, a generator 2 is provided with a controller 4 which maintains the proper current in the generator field 6. One side of the generator is connected through a line 7 and a switch 10 to a line 11 and a set of batteries 12; this line 11 is connected through a manual switch 9 to a line 8. The other side of the generator is connected through a line 14 to the other side of the batteries. Lines 11 and 14 are the main power lines of the battery-generator system which carries a load 16 consuming direct current. When switch 9 is closed, the voltage across lines 8 and 14 is the same as that of lines 11 and 14, and this voltage varies depending upon the state of charge of the set of batteries and the starting and stopping of the charging action of the generator. Connected across lines 8 and 14, and thus adapted to be energized by the voltage of the battery-generator system, is a direct current motor 18 having a main shunt field winding 17, a starting winding 19 for producing high starting torque and an armature 20. Armature 20 is connected through a shaft 22 to drive the armature 24 of an alternator indicated at 26 and having a main field winding 25 and an auxiliary field winding 27. The alternator output brushes are connected to a pair of alternating current lines 28 and 30 which supply alternating current to a load 32 which, in this embodiment, is a bank of fluorescent lights and their attendant auxiliaries.

The main alternator field winding 25 has one side connected directly to line 14 and the other side connected through a resistor 36 to line 8. The alternator auxiliary field winding 27 is connected in series with the motor armature 20 and the starting winding 19, so that both of the windings 19 and 27 carry the motor armature current. Accordingly, winding 19 is effective during the starting period to supply the proper field flux, and winding 27 is effective during the running period to exert control upon the alternator voltage. When there is a load on the alternator, any increase in the load causes an increase in motor armature current which flows through winding 27 and causes a corresponding increase in the alternator field excitation. In this way, winding 27 compensates the alternator for armature reaction, and the alternator voltage tends to remain constant with changes in the load.

The main motor field winding 17 has one side connected through a resistance unit 42 to line 8, and the other side connected to the juncture of armature 20 and winding 27 and thus through winding 27 to line 14. Winding 27 is a low resistance current winding and has a very small voltage drop across it, and therefore, the voltage across winding 17 and resistance unit 42 is substantially the same as the voltage across lines 8 and 14. Resistance unit 42 is made as large as possible in proportion to the resistance of winding 17 and the resistance unit has a substantially zero temperature-resistance coefficient. Thus, variations in the resistance of winding 17 due to temperature changes have a minimum effect.

As indicated above, the magnetic field of alter-

nator 26 is produced by the main alternator field winding 25 and the auxiliary alternator field winding 27. Main field winding 25 is connected across lines 8 and 14 in series with a resistance unit 36 which has a substantially zero temperature-resistance coefficient, and which reduces the effect of changes in resistance of winding 25 in the manner that resistance unit 42 reduces the effect of such changes in the motor field winding 17. The iron core of alternator 26 is such that the flux produced by alternator field winding 25 is substantially constant even though the voltage between lines 8 and 14 varies. Thus, the flux produced by main field winding 25 tends to produce a constant voltage across the output lines 28 and 30.

As indicated above, it is important that the motor alternator be maintained at substantially constant speed, even though there are changes in the applied voltage, the motor temperature, and the load. In the illustrative embodiments of the present invention, the motor field is varied to control the speed with the result that when the motor starts to slow down, the motor field decreases; and when the motor starts to speed up, the motor field increases. This regulation of the field is dependent upon changes in the frequency of the alternator output voltage and, for all practical purposes, is independent of load and within the operating frequency range is much more sensitive to frequency variations than to voltage variations.

In carrying out this system of speed control, motor 18 is provided with an auxiliary speed-regulating field winding 21 which derives its current from the alternator output lines 28 and 30 through a resonant control circuit. In the illustrative embodiments, the resonant control circuit is formed by two reactors, two condensers and a rectifier; one of the reactors and one of the condensers are connected in a parallel resonant circuit, referred to as "circuit A," and the other reactor and the other condenser are connected in another resonant circuit, referred to as "circuit B." The rectifier unit has its output leads connected to the auxiliary field winding 21 of motor 18 and its input leads connected into circuit B. Thus, from an electrical standpoint the parallel resonance "circuit B" includes the rectifier unit and the auxiliary field winding 21.

Referring particularly to the right-hand side 30 of Figure 1, a double-sided iron core assembly 64 has a right-hand leg 63 upon which is inductance coil 62 which is the reactor of circuit B. Core assembly 64 has a left-hand leg 66 upon which is inductance coil 68 which is the reactor of circuit A. Circuit B also includes condenser 70 which is connected in parallel with inductance coil 62 at terminals 67 and 69. Circuit A includes a similar condenser 72 which is connected in parallel with inductance coil 68 at terminals 71 and 73. Inductance coil 68 is provided with a tap 74 which is connected through a lead 76 to line 28 of alternator 26, and terminal 69 is connected through a lead 82 to line 30 of alternator 26. Inductance coil 62 is provided with a tap 80 which is connected through a lead 78 to terminal 73. Rectifier unit 56 has one of its input terminals 53 connected through lead 59 to terminal 69, and its other input terminal 57 connected through a lead 58 to a tap 60 on inductance coil 62. The output terminals 55 and 51 of rectifier unit 56 are connected, respectively, through leads 52 and 54 to the auxiliary field winding 21 of motor 18. In this embodiment, condensers 70 and 72 are

each of fifteen microfarads capacity and inductance coils 62 and 68 are of .8 and .412 henries, respectively. The number of turns between terminal 71 and tap 74 would be 29.3 per cent of the total number of turns of inductance coil 68 if there were no flux leakage between the turns. In order to compensate for the effect of leakage reactance resulting from leakage flux, the number of turns between terminal 71 and tap 74 is less than the above-mentioned value. Similarly, the number of turns between terminal 67 and tap 80 would be 13.4 per cent of the total number of turns of the conductance coil 62, but is sufficiently less than 13.4 per cent to compensate for the effect of the leakage flux. The number of turns between tap 60 and terminal 69 is 34 per cent of the total number of turns of inductance coil 62.

Core assembly 64 is provided with air gaps, there being one gap at the center of each of legs 63 and 66 and there being a gap at the top of each of these legs, and the core assembly is so constructed that the iron of the core is not saturated during normal operation. Alternator 26 normally operates at approximately sixty cycles per second and circuit A is so proportioned and constructed that it is in resonance at sixty-four cycles per second, while circuit B is in resonance at forty-six cycles per second. By providing an unsaturated core for each of the reactances, the resonance curves for circuits A and B are far more sensitive to changes in frequency than to changes in voltage. The output of the rectifier varies very rapidly with changes in frequency and comparatively slowly with changes in voltage.

The circuit resulting from connecting these various units in the manner of Figure 1 is shown in Figure 2, there being a series circuit extending between the alternator output lines 28 and 38 which series circuit is formed by two parallel inductance-capacitance circuits A and B. Inductance-capacitance circuit A is formed by condenser 72 and inductance coil 68, and circuit B is formed by condenser 70, inductance coil 62 and the circuit of rectifier unit 56. It should be noted in considering the operation of the apparatus that the circuit may be considered as shown in Figure 3, which is a simplified equivalent circuit. Due to the use of taps on the inductance coils 68 and 62, the operation is the same as if condenser 72 were of thirty microfarads capacity and condenser 70 were of twenty microfarads capacity. In Figure 3, the copper and iron losses of circuit A are represented by the central leg R_a , and those of circuit B are represented by R_b . In circuit B, the leg R_b includes the equivalent resistances of rectifier unit 56 and the speed-regulating field coil 21 as well as the equivalent resistances of the losses of condenser 70 and inductance coil 62.

The embodiment of Figure 5 differs from that of Figures 1 and 2 in omitting taps 74 and 80 on the inductance coils, and the inductance coils and the condensers are different in sizes. Accordingly in Figure 5, condensers 70' and 72' are of 20 microfarads and 30 microfarads capacity respectively, and inductance coils 62' and 68' are of .6 henry and .206 henry, respectively. In this embodiment, results are obtained similar to the results of the embodiment of Figures 1 and 2, and because of its greater simplicity the circuit of Figure 5 is used wherever possible for illustration purposes. Accordingly the voltage and current designations of Figure 5 are represented by vector diagrams in Figures 6 and 7, though similar representations may be provided for the other embodiment.

During operation, the output voltage of the alternator which is impressed across the speed-regulating circuit is distributed within the circuit depending upon the relative reactances. Referring to Figure 5, the total impressed voltage is represented by E_L , while the line current is represented by I_L . The voltages across circuits A and B are represented by E_A and E_B , respectively, and the current through the rectifier unit is represented by the notation I_r . As the speed of the alternator changes, the voltage and current relationships within the circuit change so that a different voltage is effective on the input leads of the rectifier unit and there is a change in the value of current I_r . The circuits are so constructed and proportioned that the maximum current flows in the speed-regulating field coil 21 at a frequency slightly below the minimum operation speed, and as the speed increases, the value of this current drops off rapidly. As the speed and frequency increase toward and slightly beyond the maximum operating speed, the reduction in the current I_r continues to decrease at a rapid rate and reaches a value near zero. As indicated above, the speed-regulating field coil 21 is wound so that it tends to set up a flux opposing the main field flux of the motor, and when I_r is at a high value, the effect of this current in coil 21 is sufficient to materially reduce the effective field flux of the motor. A decrease in the effective field flux of the motor causes an increase in speed, and an increase in effective field flux causes a decrease in motor speed. At substantially the maximum motor speed, the effect of current in field winding 21 is negligible and the motor speed depends upon the main field flux produced by the shunt field winding 17. When the alternator speed starts to decrease, the current I_r increases at a rapid rate with the result that the field coil 21 becomes effective to neutralize some of the effect of the main field winding. The immediate effect is a reduction in the effective field flux which tends to increase the motor speed. The net result is to minimize the change in speed.

In practice, variations in the speed of the motor alternator are caused by changes in the voltage driving the motor, changes in the motor temperature, which result in variations in field resistance and field current, and changes in load. For example, at 28 volts a standard shunt motor may have a speed of 3200 R. P. M., and at 45 volts the same motor may have a speed of 4000 R. P. M. Changes in motor temperature may result in an increase of twenty per cent in the resistance of the shunt field coil when the temperature of the field coil is raised from a "cold" condition to a "hot" condition, and this results in an increase in motor speed of approximately eight per cent. An increase in load on a shunt motor or a cumulatively compounded motor causes a decrease in speed. In the present embodiment, a cumulatively compounded motor is shown, and accordingly the total field flux of the motor is the sum total of the effect of the shunt field winding plus the effect of the series field winding and minus the effect of the speed-regulating field coil. Omitting the effect of the speed-regulating field coil, the maximum speed would be reached when the temperature of the field winding is at a limiting temperature of 125° C. and at a maximum voltage of 45 volts with no load. The minimum speed would be reached at a minimum temperature of minus 20° C., a minimum voltage of 28

volts and a full load. Accordingly, the field windings are so proportioned and the current values are so regulated that the speed variation of the motor alternator is maintained within permissible limits throughout the ranges of these extreme conditions. Figure 4 shows a set of curves designated I, II, III, IV, V and VI, showing the variation in current in the speed-regulating field winding 21 as the frequency varies and under the various extreme conditions outlined. The normal speed of the motor alternator is 3600 R. P. M. so that the normal output voltage is at 60 cycles per second. During operation it is permissible that the speed and frequency vary within limits of plus and minus 3.3 per cent. Thus the operating range is between the approximate limits of 58 and 62 cycles per second.

During actual operation, these limits are automatically maintained with the maximum speed at 3720 R. P. M. and with the minimum speed at 3480 R. P. M. At this maximum speed, the ratio of the magneto motive force of coil 21 to the magneto motive force of the main shunt field winding 17 is of the order of 74 to 1000 ampere turns per pole. This ratio changes as the motor speed decreases and at the minimum speed of 3480 R. P. M., this same ratio is 300 to 750 ampere turns per pole. Thus, if field coil 21 were not used, the ampere turns per pole at the minimum speed compared to the maximum speed would be of the order of 750 to 1000 or 75 per cent. By using winding 21, the ampere turns per pole are reduced from 926 to 450, which is a reduction from 100 per cent to 48.5 per cent.

In Figures 6 and 7, the voltages and currents of Figure 5 at 62 and 58 cycles per second, respectively, are represented vectorially. Within this range of frequencies, circuit A has an inductive reactance and circuit B has a capacitive reactance. As shown in Figure 4, the current reaches a minimum value at approximately 64 cycles per second and at this point, the impedance of circuit A is very high and in effect is pure resistance, whereas the impedance of circuit B is very low and is capacitive.

In the embodiment of Figures 8 to 13, the motor alternator is the same as in the embodiment of Figures 1 to 7 but the speed-regulating circuit supplies current to field coil 21 in the reverse direction. Thus, field coil 21 tends to assist the main field winding so that the motor speed is kept down by increasing the current in coil 21, and the motor speed is kept up by decreasing the current in coil 21. Accordingly, within the operating speed and frequency range of the apparatus, the current to field coil 21 changes at a rapid rate with the speed, increasing when the speed starts to increase and decreasing when the speed starts to decrease. The resonant control circuit of this embodiment is formed by circuits A₁ and B₁ in series across lines 28 and 30. Circuit A₁ comprises condenser 172 connected at terminals 171 and 173 in parallel with inductance coil 168 which is positioned on a leg 166 of a double-sided iron core assembly 164. The other leg 163 of the iron core assembly 164 carries an inductance coil 162 and a condenser 170 has one side connected to one side of inductance coil 162 at terminal 167. The other side of condenser 170 is connected to the input terminal 157 of the rectifier unit 156, the other input terminal 153 of the rectifier unit being connected through lead 159 and terminal 169 to inductance coil 162. Terminal 169 is connected to line 30 and terminal 171 is connected to line 28.

The output terminals 155 and 151 of rectifier unit 156 are connected respectively through leads 52 and 54 to the auxiliary field winding 21 of motor 18. It should be noted that leads 52 and 54 are of reversed potential in Figure 8 with respect to their potentials in Figure 1, and this is due to the fact that in operation rectifier unit 156 is reversed relative to rectifier unit 56. Core assembly 164 is provided with air gaps in the same manner as is core assembly 64 of Figure 1.

In this embodiment, condensers 170 and 172 are of 10 microfarads and 30 microfarads capacity, respectively, and inductance coils 162 and 168 are of .445 henry and .265 henry, respectively. The normal operating speed of the motor generator is 3600 R. P. M., with sixty cycle output voltage, and the permissible frequency variation is from 58 to 62 cycles. Circuit A₁ is in parallel resonance at 56.7 cycles per second, and circuit B₁ is in parallel resonance at 80 cycles per second.

Figure 9 is a simplified showing of the circuit of Figure 8. Thus, circuit B₁ is shown as having one branch formed by inductance coil 162 and the other branch formed by condenser 170 in series with rectifier unit 156 and its output circuit, and circuit A₁ is shown as having branches formed by inductance coil 168 and condenser 172. Circuits A₁ and B₁ are parallel resonant circuits similar to the embodiment of Figures 1 to 7, and may be represented by the equivalent circuit of Figure 3.

Figure 10 is a curve showing the variation in the current supplied to coil 21 as the speed and the output frequency change. Assuming that the motor alternator is operating at 3600 R. P. M., if there is an increase in speed and frequency, this increase is accompanied by a sharp increase in the current to coil 21. This increase in current materially strengthens the motor field and tends to hold the motor speed down. Conversely, as the motor speed starts to fall, there is a sharp reduction in the current of field coil 21, and an accompanying decrease in the strength of the motor field.

In Figure 11, the notations correspond to those of Figure 5, with the total impressed voltage represented by E_L and line current represented by I_N; the voltages across circuits A₁ and B₁ are represented by E_A and E_B, respectively, and the current through the rectifier unit is represented by the notation I_R. In Figures 12 and 13 the voltages and currents of Figure 11 are represented vectorially at 62 and 58 cycles per second, respectively. Within this range of frequencies, circuit A₁ has a capacitive reactance, and circuit B₁ has an inductive reactance.

Referring again to Figure 10, at substantially 57 cycles, the current through field coil 21 is three-hundredths amperes, whereas at 64 cycles, it is nine-tenths amperes, and the change is substantially straight-line variation between these limits. The apparatus is carefully adjusted to respond to this change, and accordingly, field coil 21 has sufficient turns to limit the variation in frequency due to all causes to plus or minus 3.3 per cent from the normal 3600 R. P. M., 60 cycle, speed. This is accomplished with current not exceeding six-tenths amperes. As an example, the slowest speed during operation of a standard shunt motor having no speed control means occurs when the voltage is 28 volts, the temperature of the shunt field winding coil is minus 20° C., and the motor is fully loaded; at this point there are 750 field ampere turns per pole. The fastest motor speed

of operation is when the voltage is 45 volts, the temperature of the shunt field coil is 125° C., and the equipment is carrying no load; at this point there are 1000 field ampere turns per pole. As a result, when the present device is not used, the speed variation under these circumstances would be from 3720 R. P. M. to 2900 R. P. M. When the present device is used, the total field ampere turns per pole remains at 1000 at the high speed of 3720 R. P. M., but the ampere turns per pole is reduced to 480 at 3480 R. P. M. which is the lowest speed attained.

Under some circumstances, it may be desirable to combine the features of the tapped inductance coils of the embodiment of Figures 1 to 7 with the features of circuit B₁ of Figures 8 to 13. Accordingly, in Figure 14, an embodiment of this nature is shown. In this embodiment, the results attained are similar to the results of the other embodiments. The elements represented in Figure 2 and corresponding to elements of the other figures have been given corresponding numerals in the 200 range. Hence, line 28 is connected through lead 276 to tap 274 of inductance coil 268 which is in parallel with condenser 272, and this comprises circuit A₂. Circuit B₂ includes condenser 270, inductance coil 262, and rectifier unit 256 with its output circuit, and circuits A₂ and B₂ are connected by lead 278. The results attained are similar to the results of the other embodiments, and by properly proportioning the values of the various parts of the equipment, the operation of the motor generator is held within permissible limits. In this embodiment condensers 270 and 272 are of 7.5 microfarads and 15 microfarads respectively, and inductance coils 262 and 268 are of .595 henry and .530 henry respectively. Tap 280 is such that an effect is obtained of there being 13.4 per cent of the turns between tap 280 and terminal 267; likewise, tap 274 is such that an effect is obtained of there being 29.3 per cent of the turns between tap 274 and terminal 271.

As many possible embodiments may be made of the mechanical features of the above invention, and as the art herein described might be varied in various parts, all without departing from the scope of the invention, it is to be understood that all matter hereinabove set forth, or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

I claim:

1. In an electrical system of the class wherein a motor alternator receives power from a direct current source and supplies alternating current power to a load and wherein the motor of said motor alternator is provided with the major portion of its field flux by a shunt field winding, the combination with said shunt field winding of an auxiliary field winding which carries current to thereby tend to effect a change in the total magnetic flux of the motor, and means to supply auxiliary field current to said auxiliary field winding comprising two parallel resonant circuits connected in series across the output terminals of the alternator.

2. In an electrical system of the class wherein a motor alternator receives power from a direct current source and supplies alternating current power to a load and wherein the motor of said motor alternator is provided with the major portion of its field flux by a shunt field winding, the combination with said shunt field winding of an auxiliary field winding which carries current to thereby tend to effect a change in the total mag-

netic flux of the motor, and means to supply auxiliary field current to said auxiliary field winding comprising two parallel resonant circuits connected in series across the output terminals of the alternator, one of said resonant circuits including a rectifier unit having its output leads connected to deliver the auxiliary field current.

3. In an electrical system of the class wherein a motor alternator receives power from a direct current source and supplies alternating current power to a load and wherein the motor of said motor alternator is provided with the major portion of its field flux by a shunt field winding, the combination with said shunt field winding of an auxiliary field winding which carries current to thereby tend to reduce the total magnetic flux as the motor generator speed falls, and means to supply current to said auxiliary field winding comprising two parallel resonance circuits connected in series across the output lines of the alternator, each of said resonance circuits including an inductance coil having an unsaturated iron core and having a tap intermediate its ends.

4. In a system in which an alternator supplies power of substantially constant frequency and voltage to a load and the alternator is driven by a motor, the combination with said motor and said alternator of means to supply auxiliary field current to said motor comprising a series circuit connected across the output terminals of said alternator and including a rectifier having its output terminals connected to deliver auxiliary field current to the motor, said series circuit comprising a first circuit and a second circuit with said rectifier forming a part of said second circuit, said first circuit comprising an impedance means and said second circuit including a parallel resonance unit which is in resonance at a frequency substantially near but other than the normal operating range of frequencies of the alternator.

5. In a system in which an alternator supplies power of substantially constant frequency and voltage to a load and the alternator is driven by a motor, the combination with said motor and said alternator of means to supply auxiliary field current to said motor comprising a series circuit connected across the output terminals of said alternator and including a rectifier having its output terminals connected to deliver auxiliary field current to the motor, said series circuit comprising a first circuit and a second circuit with said rectifier forming a part of said second circuit, said first circuit comprising a condenser unit and an inductance unit which are connected in parallel and are in resonance at a frequency which is substantially one of the limits of the range of operating frequencies, and said second circuit comprising an inductance unit and a condenser unit connected in parallel and said rectifier circuit having its input terminals connected across a portion of said inductance unit.

6. A system as claimed in claim 4, wherein said auxiliary field current tends to set up magnetic flux which adds to the main magnetic flux and wherein said first circuit is a resonant circuit and is in resonance at a frequency above the normal operating frequency and said second circuit is in resonance at a frequency below the normal operating frequency with the result that said auxiliary current is decreased as the motor speed increases.

7. A system as claimed in claim 4, wherein said auxiliary field current tends to set up magnetic flux which opposes the main magnetic flux and wherein said first circuit is a resonant circuit and is in resonance at a frequency below the normal

operating frequency and said second circuit is in resonance at a frequency above the normal operating frequency with the result that said auxiliary current is increased as the motor speed increases.

8. A system as claimed in claim 4, wherein said first circuit comprises a condenser unit and an inductance unit which are connected in parallel and are in resonance at a frequency which is substantially the lower limit of the range of operating frequencies, and wherein said second circuit comprises an inductance unit connected in parallel with a condenser and the rectifier circuit, said rectifier circuit having its input terminals connected in series with said condenser with said second circuit in parallel resonance at a frequency which is substantially above the upper limit of the range of operating frequencies.

9. A system as claimed in claim 5, wherein said first circuit has a tap on its inductance unit which is connected to one of the output terminals of the alternator and one side of said first circuit is connected to a tap on the inductance unit of said second circuit, and wherein said first circuit is in resonance at a frequency which is substantially the upper limit of the range of operating frequen-

cies and said second circuit is in resonance at a frequency which is substantially below the lower limit of the range of operating frequencies.

10. In an electrical system in which an alternator supplies power of substantially constant frequency and voltage to a load and the alternator is driven by a direct current motor the speed of which varies with variations in field flux, the combination with said motor and said alternator of auxiliary means to supply auxiliary field current to the field winding assembly of the motor comprising a series circuit connected across the output terminals of said alternator and including a rectifier having its output terminals connected to deliver the auxiliary field current, said series circuit comprising a first circuit and a second circuit with said rectifier forming a part of the said second circuit, said first circuit comprising an impedance means and said second circuit including a resonance unit which is in resonance at a frequency substantially near but other than the normal operating range of frequencies of the alternator whereby a departure from said normal operating range of frequencies causes a rapid change in the auxiliary field current.

LABEEB B. HADDAD.