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POWER SYSTEM

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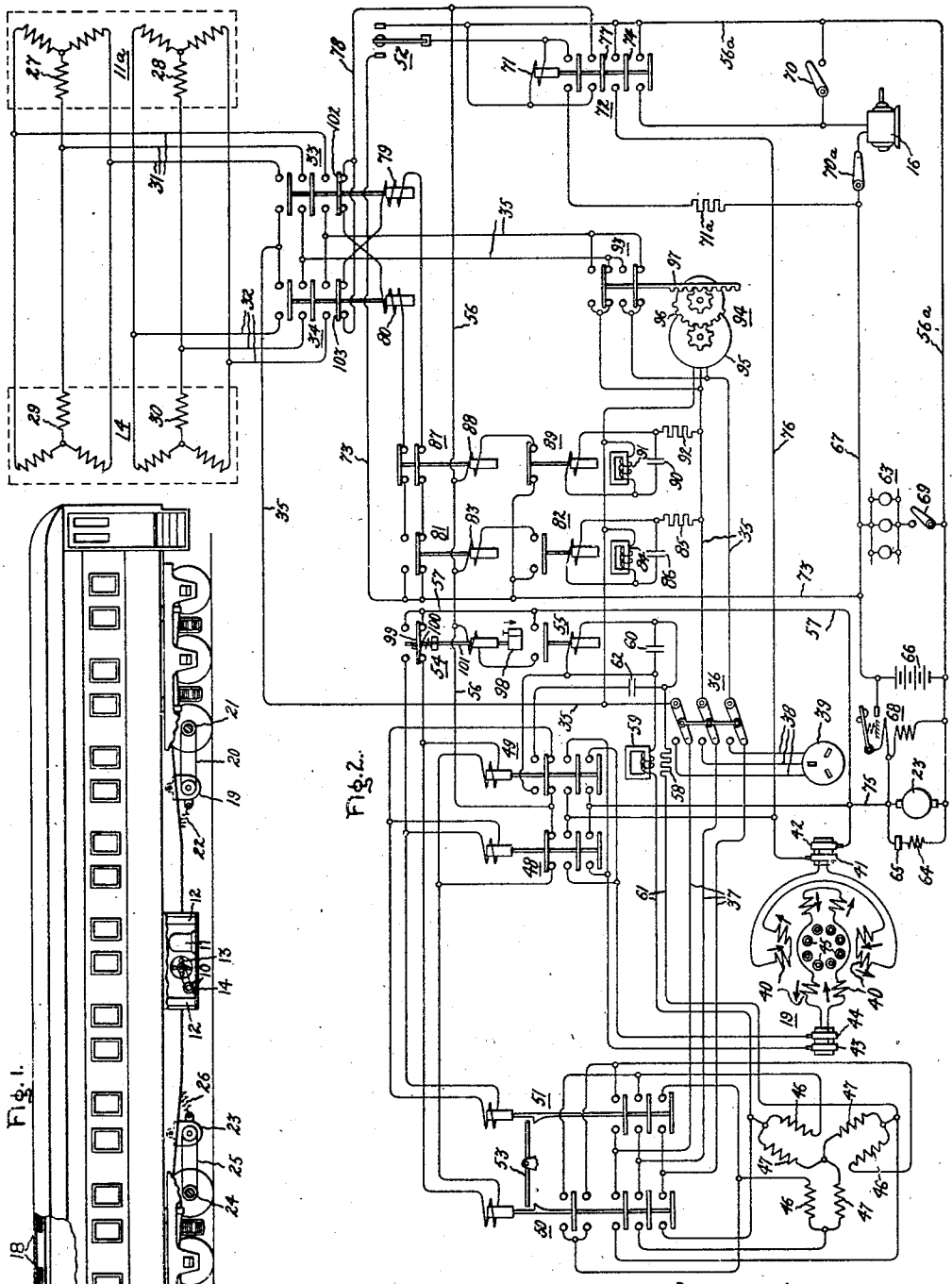


Fig. 2.

Fig. 1.

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POWER SYSTEM

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4 Claims. (Cl. 172—289)

My invention relates to alternating current power systems having variable speed prime movers or other power devices and particularly to such systems for supplying power to drive auxiliary apparatus on railway cars or other vehicles.

Air conditioning systems and other auxiliary apparatus utilized on railway cars are commonly provided with power supplied from a suitable electric generator driven by one of the car axles. For most purposes, it is satisfactory to use a direct current generator. However, when air conditioning systems are provided with hermetically sealed compressor units; that is, units in which the motor and compressor are contained in a sealed casing, an induction motor should be used and it is necessary to provide a source of alternating current. The speed of an alternating current motor is dependent upon the frequency of the current supplied and this in turn is determined by the speed of the generator. In order to utilize alternating current supplied from a generator driven by the car axle, it is necessary to provide some arrangement for keeping the range of frequency of the generated current sufficiently narrow for satisfactory operation of the motors. This is particularly true when the motors are employed to drive apparatus such as refrigerant compressors, the refrigerating capacity of which varies with the speed. Accordingly, it is an object of my invention to provide an improved alternating current power system having a variable speed prime mover such as the axle of a railway vehicle and including an arrangement whereby the speed of the motors to which the power is supplied may be maintained within a range substantially narrower than the range of speed of the prime mover.

Further objects and advantages of my invention will become apparent as the following description proceeds, and the features of novelty which characterize my invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

For a better understanding of my invention, reference may be had to the accompanying drawing in which Fig. 1 shows a passenger railway car provided with an electrically driven air conditioning system and an alternating current power system embodying my invention for supplying energy to the air conditioning apparatus; and Fig. 2 is a wiring diagram of the power system utilized on the car shown in Fig. 1.

Referring now to the drawing, I have shown a railway car provided with a refrigerant condensing unit 10 including a hermetically sealed casing 11 in which is arranged a refrigerant compressor driven by an alternating current induction motor. The condensing unit 10 also includes condensers 12 and a fan 13 driven by an alternating current motor 14 for circulating air over the casing 11 and over the condensers. The condensing unit is arranged to supply liquid refrigerant to the cooling coils of an air conditioning system including a cooling chamber 15 within which the evaporator coils are arranged and a motor 16 for driving a fan to distribute the cooled air from a conduit 17 through openings 18 into the upper portion of the passenger space of the car. In order to supply alternating current for energizing the compressor motor and the motor 14, I provide an alternating current generator 19 driven by a belt 20 from one of the car axles 21, a spring 22 being provided to maintain tension in the belt 20. Other forms of mechanical drive may be used for transmitting power from the car axle to the generator, and any other suitable variable speed power device may be used to drive the generator 19. In order to provide field excitation for the generator 19 and also for energizing the lighting system of the car and such apparatus as the motor 16, I provide a direct current generator 23 of the type which is standard on railway cars. The generator 23 is connected to be driven from an axle 24 by a belt 25 or any other suitable arrangement, a spring 26 being provided to maintain the belt tension. The alternating current generator 19 is arranged, so that it may operate with a plurality of numbers of pairs of field poles in such manner that the frequency of the current produced thereby may be changed by changing the number of poles. A dynamo-electric machine of this type is disclosed and claimed in U. S. Letters Patent 1,491,451, April 22, 1924, Robert W. Wieseman, assigned to the General Electric Company, assignee of this invention. A frequency responsive device is provided for changing the number of poles of the alternating current generator 19 in accordance with the speed of the car, so that the frequency of the current produced by the generator 19 varies within a narrower range than the range of speeds of the car, and furthermore, the compressor motor and the motor 14 are designed to be operated at any one of a plurality of speeds, the speeds being selected in accordance with the frequency of the current produced by the generator 19, so that the speed of the motors varies within a narrower range than the range of frequency of the generated current. The variation in speed of the alternating current

motors is, therefore, much more narrow than the variation in speed of the generator 19, and the speed of the devices driven by the motors is, therefore, substantially uniform.

The arrangement and mode of operation of the power system will readily be understood by reference to Fig. 2, in which I have indicated at 11a the motor within the casing 11 shown in Fig. 1 to drive the compressor of the refrigerating machine. The motor 11a is provided with a low speed field exciting winding 27 and a high speed field exciting winding 28. The fan motor 14 is provided with a low speed field exciting winding 29 and a high speed field exciting winding 30. The two windings are connected to be supplied in parallel, the low speed windings being connected to three-phase supply lines 31, and the high speed windings to three-phase supply lines 32. Lines 31 and 32 are arranged to be connected by switches 33 and 34 respectively, to three-phase alternating current supply lines 35, which are connected to three terminals of a manually operable switch 36. Three-phase alternating current power is supplied to the switch 36 either from three-phase lines 37 connected to the alternating current generator 19 or from three-phase lines 38 connected to receive power from a receptacle 39 when the train is in the station.

The generator 19 comprises a salient pole rotor having a plurality of field exciting windings 40, which are connected so that opposite pairs of windings are in series, the pairs shown on the vertical axis being connected to slip rings 41 and 42 at the right end of the rotor, and the pairs on the horizontal axis to slip rings 43 and 44 at the left end of the rotor. The field exciting winding has been illustrated with eight coils 40 providing a full number of eight field poles. When the generator is operating with its full number of poles, the magnetic flux in adjacent poles is in opposite directions as indicated by the arrows. When it is desired to operate the generator with one-half its full number of poles, the current in the group of coils connected in the left-hand rings 43 and 44 is reversed, it being evident that then the polarity of each of the coils of the reversed group is the same as that of the adjacent coil of the other group. This connection provides four groups of coils, each group comprising two coils in which the direction of magnetic flux is the same and there are, therefore, four effective field poles. Each of the salient poles is provided with a short-circuiting ring or jacket 45 to damp the flux changes produced by the reversal of the fields when changing the number of poles of the generator. The stator of the generator 19 is provided with a plurality of field exciting windings 46 and 47 arranged to provide either a single-Y connection for the lower range of speeds, or a double-Y connection for the upper range of speeds. This change in the connection of the stator windings compensates for the change of voltage due to the change in speed. In order to change the number of pairs of poles on the rotor of the generator 19, I provide solenoid operated switches 48 and 49; and in order to change the connection of the windings of the stator, I provide solenoid operated switches 50 and 51.

In the railway air conditioning system illustrated, the switches 50 and 51 in addition to effecting a change of the connection of the generator field exciting windings, also connect the alternating current supply to the lines 37 thereby making power available at the switch 36. Energy for actuation of the switches 48, 49, 50 and 51 is available upon operation of a thermostat 52 which is arranged in the passenger space of the car, and is responsive to the temperature of the air in the car and all of the switches are maintained open until there is a demand for cooling of the air in the car. The switches 48 and 51 are operated as a pair concurrently, and the switches 49 and 50 are operated as a pair concurrently. Concurrent operation of the two pairs of switches is prevented by interlock contactors comprising the top arms of switches 48 and 49. Operation of the pair of switches 48 and 51 connects the generator 19 with its full number of poles and with its stator winding in single-Y. This is the connection for the lower range of train speeds. The pair of switches 49 and 50 connects the generator with one-half its full number of poles and with its stator winding in double-Y. This is the connection for the upper range of train speeds. In addition to an electrical interlock effective through the top arms of the switches 48 and 49 to prevent concurrent actuation of the two pairs of switches, a mechanical interlock 53 is provided to prevent concurrent actuation of the switches 50 and 51.

In order to actuate the pair of switches 48 and 51 during the lower range of train speeds and the pair of switches 49 and 50 during the upper range of speeds, I provide a switch 54 operated by relay contactor 55 in accordance with the frequency of the voltage supplied by the generator to the lines 37. In its upper position, the switch 54 connects the solenoids of the switches 48 and 51 in parallel between lines 56 and 57 through the top arm of switch 49, so that the switches 48 and 51 will be actuated upon closing of the thermostat 52. The line 57 is connected to one of the terminals of the direct current generator 23 and the line 56 is connected to the other terminal through a line 56a when the thermostat is operated. The pole changing operation can be effected only when the generator 23 is in operation, so that operation of the thermostat 52 when the system is being supplied from the station source through the lines 38 does not operate the pole changing switches. In its lower position, the switch 54 connects the coils of switches 49 and 50 across the lines 56 and 57 through the top arm of switch 48. The switch 54 is actuated by a relay employing a series non-linear resonant circuit including a resistance element 58, a saturable inductance element 59 and a capacitance element 60 arranged in series across lines 61, which are connected to be energized across one phase of the windings of the generator 19. A second capacitance element 62 is provided to change the critical frequency for operation of the relay in such manner that the relay may effect a change in the connections of the generator in accordance with the speed of the train although the relay itself is responsive to the frequency of the voltage produced by the generator. A relay of this type is described and claimed in a copending application, Serial No. 182,268, filed December 29, 1937, in the name of Chauncey G. Suits and assigned to the same assignee as the present application. I do not, therefore, claim herein anything described or claimed in the said Suits application. The operation of the frequency responsive relay will be explained more fully hereinafter.

Direct current is supplied by the generator 23 for energizing the control circuits and the field of the alternating current generator 19 and any

auxiliary apparatus, such as the motor 16 and a plurality of lights 63. The generator 23 is of the type commonly employed on railway cars, and is provided with a shunt field winding 64, and a field regulator 65. A storage battery 66 is provided to supply direct current when the train is not in motion. The battery is permanently connected across the supply line 56a and a line 67. A cutout 68 is provided to connect the battery to the generator for changing whenever the voltage of the generator is greater than that of the battery, this arrangement being standard for railway lighting circuits. The lights 63 may be connected across the lines 56a and 67 by a switch 69, and the motor 16 may be connected across the lines 56a and 67 by a switch 70 in the event it is desired to run the motor continuously. A switch 70a is provided so that the circuit of the motor 16 may be opened to prevent automatic starting of the motor and draining of the battery when the car is out of service.

When the thermostat 52 calls for cooling, it moves to the left and connects a coil 71 across the battery to actuate a switch 72, the coil 71 being across the battery through the line 56a and a line 73. The upper contact of the switch 72 closes a holding circuit for the coil 71. The bottom contact connects the motor 16 across the battery, and an intermediate contact 74 connects the field exciting winding of the generator 19 across the direct current generator 23 between the line 56a and a connection 75 through a line 76. The other intermediate contact indicated at 77 connects a line 78 to the line 56a to energize one side of coils 79 and 80 of the switches 33 and 34 respectively. One of the coils 79 and 80 is energized by being connected between lines 73 and 78, the coil selected depending upon the position of a switch 81, and the corresponding one of the switches 33 and 34 is, therefore, operated to connect either the high or low speed windings of the motors 11a and 14 to the supply line 35.

When the thermostat 52 is satisfied, it will engage its right-hand contact and short-circuit the coil 71 thereby causing the switch 72 to drop out and deenergize the circuit of the coils 79 and 80 thereby stopping operation of the motors. Operation of the fan 16 is also stopped and the field exciting winding of the generator 19 is deenergized. A resistance 71a is provided in the holding circuit of the coil 71 to prevent short-circuiting the battery when the coil is short-circuited by the thermostat.

The speed of the alternating current motors depends on the frequency of the current supplied by the generator 19. The arrangement for changing the number of poles of the generator 19 makes it possible to supply current at a frequency varying within a range more narrow than the range of speed of the car. It will be understood that as the speed of the car is increased on starting, the frequency of the generator 19 will increase proportionately. The pole-changing operation may be effected at about one-half full speed, so that the frequency of the generator 19 is halved and the generator supplies current at a frequency which increases with the increase of speed up to full car speed. It is readily apparent that even with this reduction the range of the alternating current generator frequencies, there is still a wide variation of frequency and it is in order to reduce still further the range of motor speeds that the alternating current motors are provided with the two speed windings, as shown, making it possible to operate the motors within a range of speed more narrow than the range of frequency of the current supplied by the generator. In this manner, it is possible to operate the compressors or fans driven by the motors with relatively small speed variation.

In order to select the motor speeds and make the range of speeds of the motors more narrow than the range of frequency of the supplied current, I provide a relay 82 for energizing a coil 83 to operate the switch 81. Any suitable frequency responsive device or relay may be utilized to operate the switch 81 and select the one of the switches 33 and 34 which is to be operated. I prefer, however, to employ a relay utilizing a series non-linear resonant circuit of the type disclosed and claimed in U. S. Letters Patent No. 2,021,753, Chauncey G. Suits on November 19, 1935, and assigned to the General Electric Company, assignee of this invention. The relay 82 is connected to be responsive to the frequency of the voltage across one phase of the lines 35, and comprises a non-linear resonant circuit including a saturable inductance element 84, a resistance element 85, and a capacitance element 86 connected in series between two of the lines 35. The operating coil of the relay 82 is connected across the capacitance 86. A circuit of this type may be designed to have a characteristic such that the voltage across the capacitance falls suddenly at a critical value of frequency. On an increase of frequency from minimum to maximum, the relay 82 will be picked up to energize the coil 83 and pick up the switch 81 thereby actuating the switch 34 and connecting the high speed windings of the motors 11a and 14. When the critical value of frequency is reached, the relay 82 will drop out thereby causing the switch 81 to drop out and actuate the switch 33 to connect the low speed windings of the motors to the lines 35. It will be evident that the operation of the motors with their high speed windings at frequencies in the lower portion of the range of frequency will approximate the speeds of operation of the motors with the low speed windings at frequencies in higher portion of the range of frequencies. Any suitable arrangement for providing two speed ranges for the motors may be employed. However, I prefer to use motors provided with two windings as shown, the windings being arranged to provide a different number of effective poles. For example, in the system illustrated in which the generator is provided with an arrangement for halving the number of its field poles, I prefer to provide motors having high and low speed windings giving a ratio of speeds of 3:2. For example, the motors might be provided with a four-pole high speed winding and a six-pole low speed winding.

In order to prevent excessive speed of the motors; for example, in the event the train speed should become excessive, I provide a switch 87 having an operating coil 88 arranged to be actuated by a relay 89 when in its drop out position. The relay 89 is connected across a capacitance 90 of a non-linear resonant circuit including a saturable inductance element 91 and a resistance element 92 connected in series with the capacitance 90 across one phase of the supply lines 35. The non-linear resonance circuit is designed to pick up the relay 89 at all normal frequencies of the voltage across the lines 35, so that the coil 88 is normally deenergized. The critical frequency of the non-linear circuit is selected so that the relay drops out at a value of frequency

corresponding to the maximum frequency permissible for energization of the motors. When the relay 89 drops out the coil 88 of the switch 87 is energized and the switch 87 is picked up to open the circuits of the coils 79 and 80 thereby preventing actuation of either of the switches 33 and 34 so that the motors 11a and 14 cannot be energized.

In order to prevent a reversal of the direction of rotation of the motors 11a and 14 due to a reversal of the direction of phase rotation of the current supplied to the motors, I provide a reversing switch 93, which is arranged to reverse two of the supply lines 35, and I provide a phase rotation responsive device 94 for actuating the switch 93. The device 94 comprises a small polyphase induction motor 95 having a relatively high resistance squirrel cage rotor, or it may be any other suitable device having similar characteristics. The three phase windings of the motor are connected to the lines 35. When the phase rotation is in one direction the motor 95 rotates in a clockwise direction and moves the switch 93 to its upper position through a train of gears 96 and a rack 97. When the phase rotation is in the opposite direction, the motor turns in a counter-clockwise direction and moves the switch to the position shown in the drawing. It will, therefore be evident that the same direction of phase rotation will be maintained in the lines 35 leading to the motors regardless of the direction of phase rotation at the terminals of the switch 36.

During the operation of the power system described above, when the car leaves the station, manual switch 36 is closed in its lower position thereby connecting supply lines 35 to the alternating current generator leads 37. As soon as the car attains sufficient speed, the voltage of the direct current generator 23 will build up, and will rise to a value sufficient to close the cutout 68 and connect the generator to charge the battery 66. Should there be a demand for cooling, the thermostat 52 will pick up the switch 71 and, since the switch 54 is in its drop out position, the coils of the switches 49 and 50 will be connected across the generator between the lines 56 and 57 and the switches 49 and 50 will be picked up. The actuation of the switches 49 and 50 connects the generator with its minimum number of poles, so that a relatively low frequency voltage is produced. However, at the speed at which the direct current generator 23 builds up, this frequency will be sufficient to actuate the relay 55 and pick up the switch 54 thereby transferring the generator connections from the switches 49 and 50 to the switches 48 and 51 and connecting the generator with its maximum number of poles and with its stator windings in single-Y. It will be noted that the switch 54 is provided with a dashpot or other time delay device 98 arranged to delay the dropping out of the switch and, furthermore, the switch arm is retained against a stop 99 by a spring 100, so that in its pick up position the switch rod indicated at 101 will continue to move upwardly a short distance after the switch arm has engaged the upper contacts. This arrangement assures the maintaining of switch arm in engagement with the upper contacts during the interval when the generator connections are being changed and, therefore, prevents the dropping out of the switch due to the decrease of voltage during the interval of change. The generator is now connected to supply the motor lines 35, and the relay 82 will be picked up to actuate the switch 81 and connect the coil 80 between the lines 78 and 73 through an interlock arm 102 of switch 33. The switch 34 is, therefore, actuated to connect the high speed windings 28 and 30 of the motors to the power supply. The motors 11a and 14 will then operate the condensing unit 10 to supply refrigerant to the coils within the cooling chamber 15 and the cooled air will be circulated by operation of the fan 16 and delivered to the passenger compartment. As the train speed increases, the frequency of the current supplied by the generator will increase until the critical frequency of the relay 82 is reached when the relaly 82 will drop out deenergizing the coil 83 to cause the switch 81 to drop out and deenergize the coil 80. When the coil 80 is deenergized, the high speed switch 34 opens. Switch 81 in its drop out position energizes the coil 79 of the switch 33 through an interlock arm 103 of the switch 34 and the switch 33 is, therefore, actuated to connect the low speed windings of the motors to the supply lines 35. The increase in frequency of the supplied current is, therefore, compensated by the reduction of the speed of the motors and the refrigerating apparatus is, therefore, driven at about the same range of speed as was effective with the high speed windings during the lower range of frequency. As the generator frequency increases, it will increase to a value which is the critical value for the resonant circuit of the relay 55 when only the condenser 60 is connected therein. Relay 55 will, therefore, drop out thereby deenergizing the switch 54 which drops out disconnecting the switches 48 and 51 and energizing the switches 49 and 50, so that the generator is connected with one-half its full number of poles and with its windings in double-Y. When the switch 49 is picked up, the upper arm thereof connects the capacitance 62 in parallel with the capacitance 60 of the relay 55 and thereby changes the characteristic of the non-linear resonant circuit, so that the relay 55 will not be picked up until the frequency is reduced and a frequency is reached less than one-half the critical frequency of the circuit with only the capacitance 60. The reduction of the frequency due to the halving of the number of effective poles of the generator causes the relay 82 to be picked up since the frequency has fallen below its critical drop out value and the motors are, therefore, connected so that their high speed windings are energized by picking up of the switch 34. As the train speed continues to increase, the frequency of the current supplied by the generator 19 will again reach the critical frequency of the relay 82 and the relay will drop out to transfer the motors from their high speed to their low speed windings thereby lowering the speed of the motors and compensating for the increase in frequency of the generator 19. The system will continue to operate with the generator 19 connected with its minimum number of poles and the motors connected with their low speed windings until the train speed is again reduced or until the train speed becomes excessive and causes operation of the over-frequency relay 89 to disconnect the motors from the lines 35. When the train speed is decreased from the normal full speed, the motors and generator will be connected in a sequence which is the reverse of that just described. The motor windings will change from low to high speed when the frequency of the generator decreases to the critical pick up frequency of the relay 82. When there is a further decrease of train speed, the critical speed for the relay 55 will

be reached and the relay 35 will pick up and energize the switch 54 which will change the generator connections from the lower number of poles to the full number of poles. This change will increase the frequency of the current supplied and the relay 32 will drop out thereby reconnecting the motors with their low speed winding energized. As the train speed is decreased still further, the critical pick up value of frequency for the relay 32 will be reached again, the relay will pick up, energize the switch 31 and transfer the motors from their low speed to their high speed connection. When the train speed is still further reduced, the voltage of the direct current generator 23 will fall sufficiently to open the cutout 60 and deenergize the control circuits thereby stopping operation of the power system.

The previous description has been based on the assumption that the thermostat 52 was continuously calling for cooling. It will be understood, however, that under normal operation of the air conditioning system, the thermostat may not call for cooling until the car has attained substantial speed. However, as soon as there is a demand for cooling and the thermostat operates to pick up the switch 72, the generator and motors will be connected in the necessary relation to provide the desired speed of the motors at the car speed existing when the thermostat is operated.

From the foregoing, it is apparent that I have provided a power system for railway cars and other vehicles which makes possible the operation of alternating current auxiliary devices on the car at speeds within ranges materially less than the range of speeds of the car and, furthermore, that the desired speed of the motors is maintained regardless of the changes of speed of the vehicle.

While I have described my invention in connection with an air conditioning system for railway cars, other applications will readily be apparent to those skilled in the art. I do not, therefore, desire my invention to be limited to the particular construction shown and described, and I intend in the appended claims to cover all modifications within the spirit and scope of my invention.

What I claim as new and desire to obtain by Letters Patent of the United States is:

1. A power system including an alternating current generator, a variable speed device arranged to drive said generator, said generator having a plurality of pairs of field poles, an alternating current motor, said motor having field exciting windings providing two ranges of speed, means for supplying to said motor current produced by said generator to energize said motor, means dependent upon the speed of said device for changing the effective number of pairs of said field poles to vary the frequency of the current produced by said generator and for maintaining the range of frequency of the current produced by said generator more narrow than the range of speed of said device, and means dependent upon the frequency of the current produced by said generator for selecting either of said ranges of speed of said motor.

2. A power system including an alternating current generator, a variable speed device arranged to drive said generator, said generator having a plurality of pairs of field poles, means for changing the effective number of pairs of said field poles to provide a range of frequency of the current, produced by said generator more narrow than the range of speed of said device, an alternating current motor having windings providing two ranges of speed, means dependent upon the speed of said device for actuating said pole changing means, and means dependent upon the frequency of the current produced by said generator for selecting either of said ranges of speed of said motor during operation of said generator with either number of effective pairs of field poles.

3. A power system including an alternating current generator, a variable speed device arranged to drive said generator, said generator having a plurality of pairs of field poles, an alternating current motor, said motor having windings providing two ranges of speed, means for supplying to said motor current produced by said generator to energize said motor, means responsive to the frequency of the current produced by said generator for changing the effective number of pairs of said field poles to vary the frequency of the current produced by said generator and for maintaining the range of frequency of the current produced by said generator more narrow than the range of speed of said device, and means dependent upon the frequency of the current produced by said generator for selecting either of said ranges of speed of said motor.

4. A power system including an alternating current generator, a variable speed device arranged to drive said generator, said generator having a plurality of pairs of field poles, an alternating current motor, said motor having windings providing two ranges of speed, means for supplying to said motor current produced by said generator to energize said motor, means responsive to the frequency of the current produced by said generator for changing the effective number of pairs of said field poles to vary the frequency of the current produced by said generator and for maintaining the range of frequency of the current produced by said generator more narrow than the range of speed of said device, means dependent upon the frequency of the current produced by said generator for selecting either of said ranges of speed of said motor, and means for connecting to said motor a source of alternating current other than said generator and for rendering inoperative said generator pole changing means.

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