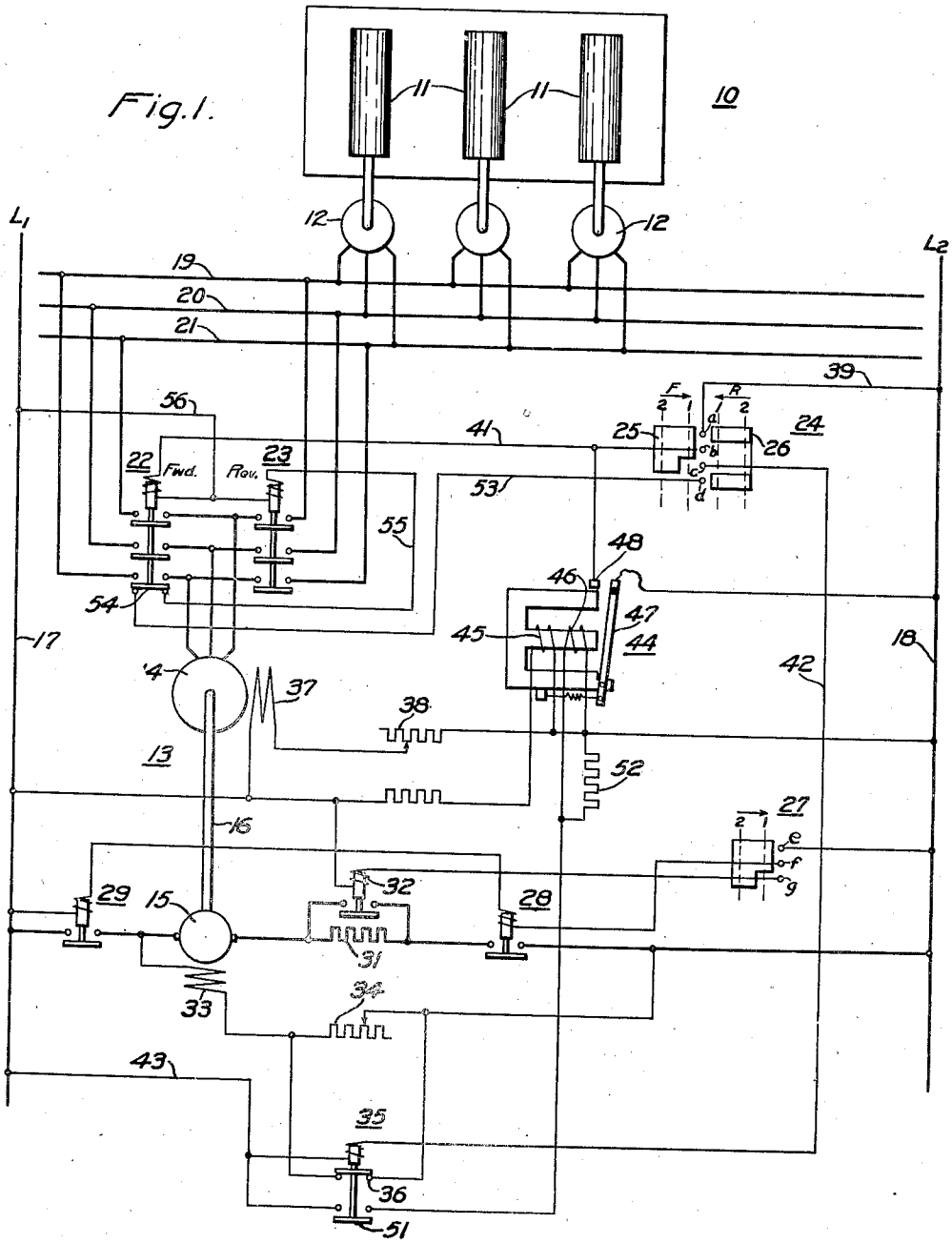
Nov. 7, 1933. R. M. KENAH 1,934,505

CONTROL SYSTEM FOR ROLL TABLE MOTORS

Filed March 2, 1931 2 Sheets-Sheet 1

Fig. 1.



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CONTROL SYSTEM FOR ROLL TABLE MOTORS

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Fig. 2.

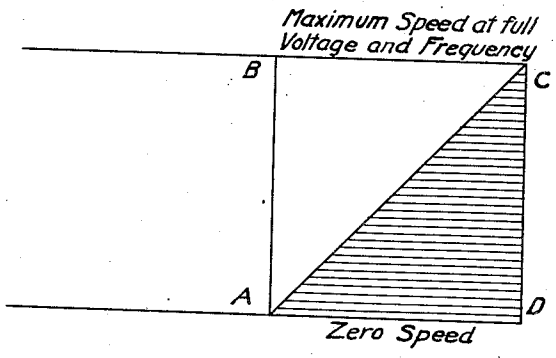


Fig. 3.

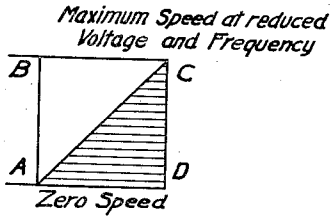


Fig. 4.

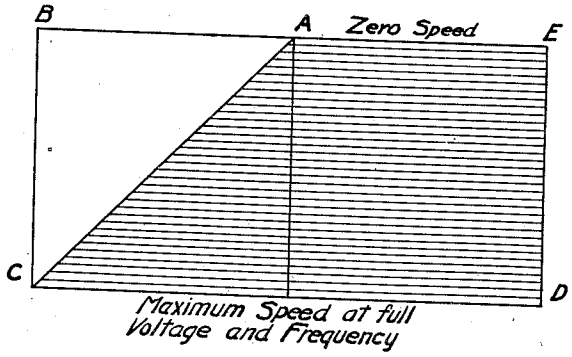
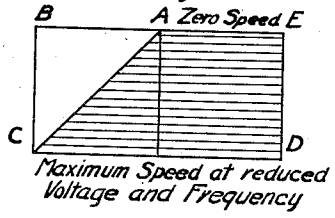


Fig. 5.



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UNITED STATES PATENT OFFICE

1,934,505

CONTROL SYSTEM FOR ROLL-TABLE MOTORS

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Application March 2, 1931. Serial No. 519,473

10 Claims. (Cl. 172—239)

My invention relates generally to motor-control systems and more particularly to systems for controlling the operation of electric motors which may be utilized for operating roll tables in connection with steel-rolling mills and other similar applications.

Heretofore, roll tables for handling metal, as it is fed to the rolling mill or delivered therefrom, have usually been operated by a single motor connected to all the roll members of the table by means of a lay shaft and suitable bevel gears.

In some instances, however, roll tables have been operated by individual motors, preferably of the induction type, connected to each roll of the table and all of the motors controlled, as a unit, from a single generator by varying the generator voltage.

However, in using the latter type of drive, considerable difficulty has been experienced in preventing injury to the roll motors from overheating, since their location naturally requires that they shall be almost entirely enclosed to prevent mechanical injury and to exclude dust, scale and other foreign matter which is found in steel mills in great quantities.

When the motors are placed under such adverse operating conditions, it becomes very difficult to operate them in such manner as to maintain their windings at safe temperature, since they are not only heated up by the high temperature of the air in their immediate vicinity caused by the hot metal which is carried on the roll table but also by the high currents which flow in their windings during the starting and plugging periods which may occur quite frequently where it is necessary to start and stop the roll table at frequent intervals.

Accordingly, the object of my invention, generally stated, is to provide a motor-control system which shall be simple and efficient in operation and easy and economical to manufacture and install.

A more specific object of my invention is to provide for so effecting the accelerating and plugging operation of motors operating under adverse temperature conditions as to prevent over-heating and consequent injury to the windings.

Another object of my invention is to provide for controlling the operation of a plurality of roll-table motors by varying the voltage and frequency of the current supplied to them from a single generator to reduce the heating effect of the starting and plugging currents to a minimum value.

A still further object of my invention is to automatically delay establishment of plugging connections for the roll-table motors until the voltage and frequency of the generator, supplying current to the motors, have been reduced to predetermined values.

Other objects of my invention will become evident from the following description, taken in conjunction with the accompanying drawings in which,

Figure 1 is a diagrammatic view of a motor-control system embodying the principal features of my invention, and

Figs. 2 to 5, inclusive, are diagrams showing how the heating effect of the starting and plugging current may be materially reduced by the use of my invention.

Referring now to Fig. 1 of the drawings, 10 designates, generally, a roll table of conventional design having a plurality of roll members 11, all of which are disposed to be rotated at the same speed to convey metal, in the form of ingots or billets, to and from a rolling mill. In order to operate the rolls 11, I provide an individual motor 12 for each roll which may be connected to its roll in any suitable manner. These auxiliary or roll motors may be of any suitable type, but, in this embodiment of the invention, three-phase induction motors of the squirrel-cage type are utilized.

The roll motors 12 may be supplied with current from any suitable power source such, for example, as a motor-generator set 13, comprising an alternating-current generator 14 and a direct-current driving motor 15, having their rotating elements mechanically connected, by means of a shaft 16, in the usual manner.

Power for operating the motor-generator set 13, as well as the various control devices of the system, may be obtained from any suitable source of substantially constant voltage, direct-current power which, in this instance, is illustrated by line conductors 17 and 18.

As will be observed, the roll motors 12 are all connected, in parallel-circuit relation, to conductors 19, 20 and 21. The connection of the roll motors 12 to the alternating-current generator 13 may be controlled by switches 22 and 23.

The switch 22 functions to connect the generator terminals to conductors 19, 20 and 21 to effect a forward-running operation of the roll motors, and, therefore, may be conveniently termed the forward-running line switch.

The switch 23 connects the generator terminals to the conductors 19, 20 and 21, with the phase

connection between conductors 19 and 21 reversed, in order to energize the roll motors for reverse operation and may, therefore, be termed the reversing line switch or plugging switch, since, in this embodiment of the invention, actual reversed running operation of the roll motors is not effected, as will be more clearly set forth hereinafter.

The system may be controlled, and especially the operation of the line switches 22 and 23, by any suitable control device, however, in this embodiment of the invention, a manually-operated master switch, shown generally at 24, is utilized. As shown, the master switch comprises movable segments 25 and 26, each of which is disposed, when actuated in the forward running and plugging directions, respectively, to engage certain of the fixed contact fingers *a*, *b*, *c* and *d*.

In order that the novel features of my invention may be more readily understood, a detailed description of the operation of the system will now be given.

In applications to which my invention is particularly adapted, it is the usual practice to start and stop the roll table frequently. Since the starting and stopping operation must be effected within the shortest time possible, provision must be made for accelerating and retarding the roll motors in a rapid manner and still maintain the temperatures of the motors at the lowest possible value, even though they may be required to operate under the most adverse conditions, insofar as atmospheric temperature is concerned.

Therefore, in order to provide for quickly accelerating the roll motors and, at the same time, maintain their temperatures at the lowest possible value, provision is made for initially subjecting them to a voltage and frequency of reduced value, preferably from twenty-five to fifty percent of the full voltage and frequency value. If it is desired, the reduced voltage may be made slightly greater, in proportion, than the reduced frequency, in order to stabilize the voltage of the generator when the load is suddenly applied, as when in starting, and to cause the roll motors to develop a greater starting torque.

The motor-generator set 13 is first set in operation by actuating the manual controller 27 to the first operating position to bridge contact fingers *e* and *f* and thereby establish an energizing circuit for line switches 28 and 29, as shown. Upon the closure of switches 28 and 29, the direct-current motor 15 is connected across the line conductors 17 and 18 through the starting resistor 31.

The speed of the motor-generator set may be further increased by operation of the manual controller 27 to the second position where contact fingers *e* and *g* are bridged to establish an obvious energizing circuit for an accelerating switch 32.

As will be observed, the motor 15 is provided with a shunt field winding 33, connected in series with a variable resistor 34 which may be adjusted to cause the motor 15 to operate at any desired speed.

In order, however, to cause the generator to develop a reduced voltage and frequency, provision is made for subjecting the motor 15 to full field excitation until the roll motors have been connected to the generator and have had sufficient time to accelerate to a speed proportional to the reduced voltage and frequency of the generator. This function is accomplished by the use of a switch 35 having contact members 36 which are closed when the switch is deenergized. At this time, the switch 35 is deenergized, since the master controller 24 is in the off position, and, therefore, the contact members 36 establish a shunt circuit for the field resistor 34 to impress full voltage of the line conductors 17 and 18 across the shunt field winding 33.

As will be readily understood, the generator 14 is now operating at reduced speed and, consequently, it can develop only a certain voltage and frequency with a given amount of field excitation. As shown, the field winding 37 of the generator is connected across the line conductors 17 and 18 through a variable resistor 38, which may be adjusted to cause the generator to develop the desired voltage.

If it now be desired to set the roll-table motors in operation, master switch 24 may be actuated to the first position in the forward-running direction, which causes a movable segment 25 to bridge contact fingers *a* and *b*. This establishes an energizing circuit for the forward-running switch 22 which extends from line conductor 18, through conductor 39, contact fingers *a* and *b*, conductor 41 of master switch 24, bridged by segment 25 and the operating coil of the switch 22, conductor 56 to the line conductor 17. Upon the closure of the switch 22, the roll motors are connected to the generator 14 in such phase relation as to cause them to run in a forward direction, and, since the voltage and frequency of the generator 14 are of reduced value, the roll motors will quickly accelerate to a speed proportional to the voltage and frequency values.

In order to further increase the speed of the roll motors 12 to their normal value, provision is made for increasing the speed of the motor-generator set 13 to such value as to cause the generator 14 to develop full voltage and frequency, thereby causing the roll motors to come up to maximum speed in accordance with the rise of generator voltage and frequency.

In this embodiment of the invention, this function is effected by decreasing the field excitation of the motor 15 through the operation of the shunting switch 35 which may be energized by actuating the master switch 24 to the second position in the forward-running direction. As shown, the circuit thus established extends from line conductor 18, conductor 39, through contact fingers *a* and *c*—bridged by the segment 25 of the master switch 24—conductor 42, operating coil of the switch 35 and conductor 43, to line conductor 17.

As described, in the preceding paragraph the operation of the shunting switch 35 to control the field excitation of the motor 15 is controlled directly through the master switch 24 which does not definitely provide for a time interval, between the operation of switches 22 and 35, of sufficient length to permit the roll motors to accelerate from stand-still to the reduced speed value before the speed of the motor generator set is increased, except that which is introduced by the operator in actuating the master switch.

It will be readily understood, however, that, if it were thought to be desirable or necessary, a suitable time-delay relay might be readily interposed between the master switch 24 and the switch 35 in order to provide this definite time interval between the operation of the switches 22 and 35.

In order to quickly stop the roll motors after they have been operating in a forward direction for the desired length of time, provision is made for plugging the motors in such manner as to effect a quick stopping operation and, at the same

time, very materially reduce the heating effect ordinarily caused by plugging operations.

In order to accomplish the foregoing purpose, provision is made for definitely maintaining the forward-running switch 22 in the closed position, regardless of the position of the master switch 24, until the speed of the motor-generator set 13 has been reduced to its initial value, where the generator only develops voltage and frequency at reduced value.

The speed of the motor-generator set 13 is reduced when the master switch 24 is actuated in the reverse direction from its last or second position in the forward-running direction which deenergizes the switch 35 to subject the motor 15 to full field excitation, as described hereinbefore. Therefore, it is evident that, as soon as the master switch 24 is moved from this second position, the motor-generator set 13 begins to slow down, with the roll motors still connected for forward running, which causes them to likewise reduce their speed in accordance with the changes in voltage and frequency of the generator. This provides for quickly reducing the speed of the roll motors to a low or reduced value where they may be finally stopped by a plugging operation.

In this embodiment of the invention, the forward-running connection of the roll motors is maintained by means of a time-delay relay 44 which functions to maintain an energizing circuit for the forward-running switch 22 for a predetermined time interval after the master switch has been actuated to the off or plugging positions. Any suitable type of time-delay relay may be used for this purpose, but, in this instance, I have illustrated a particular type of relay which is fully described in Letters Patent No. 1,753,983 granted to W. G. Cook, April 8, 1930.

Since the mechanical structure and principle of operation of the time-delay relay 44 are fully described in the patent designated in the preceding paragraph, it has been deemed unnecessary to set forth a detailed description in this specification. However, in a brief manner, it may be said that the relay is provided with magnetizing coils 45 and 46, both of which must be energized in order to cause the armature 47 to close the contact members 48. As shown, the coil 45 is permanently connected across the line conductors 17 and 18, while the energization of the coil 46 is controlled by auxiliary contact members 51 provided on the shunting switch 35 which, when closed, connect the coil 46 across line conductors 17 and 18 in parallel with a resistor 52. When the coil 46 is deenergized, it discharges through a local or discharge circuit formed by resistor 52 to control the time delay in the opening of armature 47 to effect disengagement of contact members 48.

Assuming that the master switch 24 has been actuated to the first position in the plugging direction, an energizing circuit for the reverse-running or plugging switch 23 is partially established from the line conductor 18, through conductor 39, contact fingers *a* and *d*—bridged by segment 26—and conductor 53, to back contact members 54 of the switch 22, which are now open, since the switch is held closed.

As soon as the time-delay relay 44 opens its contact members 48, the holding circuit for switch 22 is interrupted which causes the switch to open the forward-running connection between the roll motors and the generator and, at the same time, close its back contact members 54, to complete the partially established energizing circuit for the reverse-running or plugging switch 23, through conductors 55 and 56. to line conductor 17, as shown.

As will be readily understood, the closure of switch 23 reverses the connection of the roll motors to the generator 14, while the motors are still running in a forward direction at reduced speed, thereby performing what is commonly known as a plugging operation, which quickly reduces the speed of the roll motors to zero value, whereupon the master switch 24 may be returned to the off position.

It will be apparent from the foregoing description that my invention provides for always starting and plugging the roll motors at reduced voltage and frequency and that, by the use of such a system as provided by my invention, the roll motors may be operated under the most adverse operating conditions from both the mechanical and temperature standpoint. By reducing the heating effect of the starting and plugging current to a minimum, motors of standard or ordinary construction may be used to operate a roll table, thereby making it unnecessary to use motors specially constructed to withstand high operating temperatures.

The manner in which my invention provides for reducing the heating effect of the starting and plugging currents may be more fully understood by considering the diagrams shown in Figs. 2 to 5.

Fig. 2 shows, graphically, the conditions existing in a motor of the induction type when it is connected to full generator voltage and frequency, at standstill, and accelerated to synchronous or normal speed. The energy stored in the rotating parts of the motor and load is represented by the area A, B, C. The secondary loss under such conditions is represented by the shaded area A, C, D. Fig. 3 shows the conditions existing in the same motor when started on voltage and frequency of reduced value, preferably about one half the maximum value for full speed operation. It will be observed that the shaded area A, C, D, in Fig. 3, which represents the secondary losses is only about one quarter in size to that of Fig. 2, when the motor is started on maximum voltage and frequency.

Fig. 4 shows the conditions in the same motor when it is plugged, on full voltage and frequency, from maximum running speed to standstill, while Fig. 5 shows the conditions existing in the same motor when it is plugged, on reduced generator voltage and frequency, from approximately half speed to standstill. The secondary losses in both cases are indicated by the shaded areas AEDC. As in the case of the starting operation, the secondary losses when the motor is plugged at reduced voltage and frequency are about one quarter of the losses which result when the same motor is plugged on full voltage and frequency.

In the foregoing discussion of the motor losses, only the secondary losses have been considered. These losses, which occur during the starting period, are fixed by the inertia of the moving parts of the motor. The primary losses of the motor, during starting and plugging operations, depend largely upon the secondary resistance and, for the ordinary motor, having a low-resistance secondary, the primary losses may be assumed to be equal to the secondary losses.

In the above description, nothing has been said in regard to the heat losses in the motors during the period in which the motor-generator set is accelerated after the roll motors have been

connected during the starting operation and during the period before they have been disconnected when the motor generator set is being slowed down preparatory to performing a plugging operation. It has been found in actual practice that the latter losses are not great, since the motors are operating on the lower part of the current-torque curve. However, when all the losses have been taken into consideration, actual experience has demonstrated that the total temperature loss during one cycle of operation of the system according to my invention is only about one-third of the losses which result when the system is operating constantly on full voltage and frequency.

It may be stated, in conclusion, that, while the illustrated example constitutes a practical embodiment of my invention, I do not wish to limit myself strictly to the exact details herein illustrated, since modifications of the same may be made without departing from the spirit of the invention, as defined in the appended claims.

I claim as my invention:

1. In a motor-control system, in combination, a work motor, a generator for supplying power of variable voltage and frequency for said motor, means for driving the generator at variable speeds, means for causing the generator-driving means to drive the generator at such speed as to develop a voltage of low value and frequency, means initially operable to connect the work motor to the power source to accelerate the motor to a speed corresponding to the voltage and frequency of the power source, and means, dependent upon the further operation of said last named means, for increasing the speed of the generator driving means and thereby the voltage and frequency of the generator to effect the acceleration of the work motor to full speed, whereby the work motor is started and accelerated to full speed with minimum heating.

2. In a motor-control system, in combination, a plurality of work motors, a motor-generator set for supplying power to said motors, a source of power for the motor-generator set, means for causing the motor-generator set to operate at reduced speed, a master switch, means responsive to the operation of the master switch for connecting the work motors to the generator in group relation to accelerate the motors to a speed corresponding to the generator speed, and means responsive to further operation of the master switch for increasing the speed of the motor-generator set to maximum, whereby the work motors are accelerated to full speed from the reduced speed in accordance with the gradual increase in generator voltage, thereby to reduce their temperature rise to a minimum.

3. In a motor-control system, in combination, a plurality of work motors, a motor-generator set for supplying power to said motors, a source of power for the motor-generator set, means for causing the motor-generator set to operate at reduced speed, a master switch, means responsive to the operation of the master switch for connecting the work motors to the generator in group relation to accelerate the motors to a speed corresponding to the generator speed, and means dependent upon the further operation of the master switch for increasing the voltage and frequency of the generator, thereby to cause the work motors to reach full-speed operation with a minimum rise of internal temperature.

4. In a motor-control system, in combination, a motor, a motor-generator set for supplying variable-voltage alternating-current power to the motor, a source of power, means for connecting the motor of the motor-generator set to the source of power to cause the generator to develop a voltage of predetermined value and frequency, a master switch disposed to be actuated to a plurality of positions, means responsive to the operation of the master switch to one position to connect the motor to the generator to accelerate the motor to a speed proportional to the voltage and frequency of the generator, and means disposed to respond to the further operation of the master switch for increasing the speed of the motor-generator set to cause the motor to increase its speed to maximum value in accordance with the rise in voltage and frequency of the generator.

5. In a motor-control system, in combination, a motor, a motor-generator set for supplying variable-voltage alternating-current power to the motor, a source of power, means for connecting the motor of the motor-generator set to the source of power to cause the generator to develop a voltage of predetermined value and frequency, a master switch disposed to be actuated to a plurality of positions, means responsive to successive operation of the master switch for first connecting the motor to the generator and subsequently increasing the speed of the motor-generator set to cause the motor to operate at full speed, and means responsive to the operation of the master switch in the opposite direction for causing the speed of the motor-generator set to be reduced to the initial speed and for reversing the connection of the motor to the generator after a predetermined time interval to effect plugging operations of the motor only when its speed has been reduced to a value corresponding to the initial voltage and frequency of the generator.

6. In a motor-control system, in combination, a plurality of induction motors disposed to operate as a group, an alternating-current generator for supplying power at variable voltage and frequency to the induction motors, a motor for driving the generator, a source of power of said motor, means for connecting the motor to the power source to obtain operation of the generator at reduced speed, reversing switches for connecting the induction motors to the generator, a master switch for controlling the operation of the reversing switches, said master switch being disposed, when actuated to successive positions in one direction, to first connect the induction motors to the generator while operating at reduced speed and to subsequently increase the voltage and frequency of the generator to full value, thereby to effect the acceleration of the induction motors to full speed with a minimum of heat losses.

7. In a motor-control system, in combination, a plurality of motors disposed to be operated as a group, a motor-generator set for supplying power to the group of motors, means for effecting the operation of the motor-generator set at reduced speed, means including a master switch for first connecting the motors to the generator and for subsequently effecting an increase in speed of the motor-generator set, and means dependent upon the operation of the master switch in the opposite direction for first reducing the speed of the motor-generator set and for subsequently reversing the connection of the group of motors to the generator a predetermined time interval after the operation of the master switch

from the initial position to the opposite position.

8. The combination with a plurality of induction motors and a motor-generator set for supplying variable voltage and frequency power to the motors, of means for effecting the operation of the motor generator set at a predetermined speed less than maximum, control means operable to connect the induction motors to the generator to effect their energization in either direction, means operable to increase the speed of the motor-generator set, said means being responsive to the operation of the control means to a predetermined position in one direction, and means rendered effective by the operation of the control means in the opposite direction to delay the reversal of the generator connection to the induction motors until the motor-generator set has reduced its speed to the initial value less that maximum, thereby to reduce the time during which a heavy current flows in each induction motor during the decelerating period to a minimum value.

9. In a motor-control system, in combination, a plurality of work motors, a generator for supplying power to the work motors, a motor for driving the generator, switches for connecting the work motors to the generator, a master switch having forward and plugging positions for controlling the operation of the connecting switches to effect forward running and plugging operations of the work motors, means for energizing the generator-driving motor to effect the operation of the generator at reduced speed, means disposed to be energized by the master switch only subsequent to the energization of the forward-running connecting switch for increasing the speed of the generator-driving motor to cause the generator to develop full voltage, and a time-delay relay rendered effective by the subsequent operation of the master switch to the plugging position for maintaining the forward running connection between the work motors and the generator until the generator voltage has returned to the original low value, thereby to provide for plugging the work motors only on low voltage.

10. In a motor-control system, in combination, a plurality of induction motors, an alternating-current generator for supplying power to the induction motors, reversing switches for connecting the induction motors to the generator, a motor provided with a field winding for driving the generator, a source of power for said motor, a variable resistor for controlling the excitation of the motor, a normally closed shunting switch for the resistor, means operable to connect the generator-driving motor to the power source, with its field winding fully energized to cause the generator to develop a voltage and frequency less than maximum, a master switch operable in one direction to first effect the closure of one reversing switch to connect the induction motors for operation in a forward direction and for subsequently effecting the opening of the resistor-shunting switch to increase the speed of the generator to maximum, said master switch being disposed, when actuated in the opposite direction, to partially establish an energizing circuit for the other reversing switch, and means rendered effective upon the closing of the resistor-shunting switch for delaying the final energization of said other reversing switch until the voltage and frequency of the generator has been reduced to the initial value.

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