Nov. 26, 1935.

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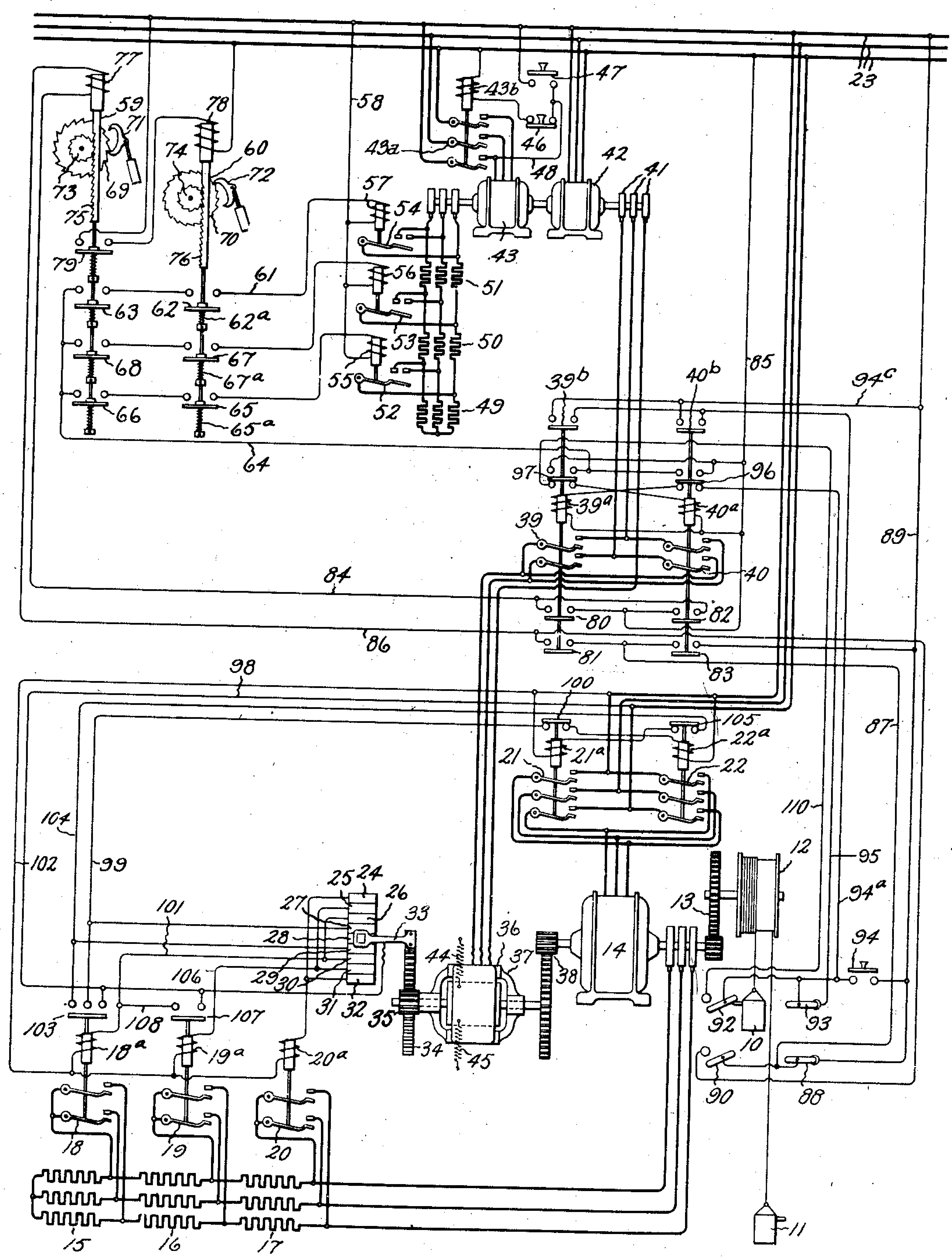
2,022,502

MOTOR CONTROL SYSTEM

Filed Feb. 1, 1930



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Patented Nov. 26, 1935

2,022,502

UNITED STATES PATENT OFFICE

2,022,502

MOTOR CONTROL SYSTEM

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Application February 1, 1930, Serial No. 425,301

14 Claims. (Cl. 172—152)

My invention relates to motor control systems, more particularly to control systems for hoists and the like, and has for its object the provision of a simple and reliable system of this character wherein the speed of the hoist is controlled independently of its load.

My invention has particular application to automatic hoists, i. e, to hoists which when once started from one level operate to the next or predetermined level where the hoist is automatically slowed down and stopped. When the hoist is driven by a slip ring induction motor, or a motor of similar characteristics wherein the speed of the motor varies appreciably with the load, a varying rate of retardation results for varying loads on the hoist. Under these conditions the hoist would obviously be stopped at distances from the desired position varying in dependence upon the load.

One of the objects of my invention is to provide a control system for hoists driven by induction motors, or motors having similar characteristics, whereby the hoist will automatically approach the stopping point with a predetermined retardation, or leave that point with a predetermined acceleration regardless of the load. Another object is to reduce the speed of approach in a predetermined way to such a value that a predetermined method of landing is effected independently of the load.

In accordance with my invention I provide in one form thereof a pilot motor generator set which is used solely for the purpose of controlling the hoist motor. The motor of this motor generator set is automatically controlled to give the desired speed variations to the elevator driving motor and since the generator runs with a loading independent of the hoist driving motor these speed changes are predeterminable and independent of the load on the hoist. The control means for the hoist motor is made responsive to the frequency of the pilot generator so that the hoist motor is automatically controlled to follow the speed changes of the generator regardless of the load on the hoist.

For a more complete understanding of my invention reference should be had to the accompanying drawing the single figure of which shows in diagrammatic fashion a hoist control system embodying my invention.

Referring to the drawing, the hoist is illustrated as comprising two cages or floors 10 and 11 which are connected respectively to cables so arranged with respect to the hoisting drum 12 that one cable is wound up while the other is unwound, depending upon the direction of rotation of the drum, whereby the cages are alternately raised and lowered. The hoisting drum 12 is operatively connected through gearing 13 to the hoisting motor 14 shown as a three phase slip ring induction motor having a wound rotor connected to slip rings by means of which three sets of resistances 15, 16 and 17 may be connected in the rotor circuit to control its speed. These three sets of resistances are in turn controlled by the electromagnetic switches 18, 19 and 20 it being understood that when all three switches are open all three sets of resistances are in the secondary motor circuit whereas closure of switch 18 short circuits the section 15, closure of switch 19 short circuits the sections 15 and 16, while closure of the switch 20 short circuits all three sections.

The control of the electromagnetic switches 18, 19, and 20, and also of the electromagnetic reversing switches 21 and 22 for connecting the motor 14 to the three phase supply source 23 for the desired direction of rotation, is effected by means of a suitable control device shown as comprising a series of insulated conducting segments 24, 25, 26, 27, 28, 29, 30, 31 and 32 over which a contact arm 33 is movable. This contact arm, as shown is secured to a gear rack 34 which is connected to a pinion 35 on the rotatably mounted stator 36 of a regulating dynamometer device 37. This device 37 has its rotor connected through gearing 38 to the hoisting motor 14. The control device 37 may be synchronous or asynchronous. Preferably it is in the form of a squirrel cage induction motor having a squirrel cage rotor winding and a three phase distributed armature winding which may be connected electrically by electromagnetic reversing switches 39 and 40 to the slip rings 41 of a three phase wound rotor induction motor 42 driven as an induction generator by the motor 43, shown as a three phase wound rotor induction motor. The stator 36 of the control device 37 is biased to a predetermined central position as by suitable springs 44 and 45, whereby the contact arm 33 is maintained on the central segment 28 when the hoist is at rest.

In operation of the control device 37 it will be understood that its rotor will be driven by the hoisting motor 14 in the same direction as the field rotation in its stator when its stator is connected to the generator 42. Briefly stated, when the rotor is turning at the same speed as the field rotation, no torque will be applied to the stator and it will be held to its central position by the springs 44 and 45. Any difference in these two speeds, however, resulting from a change in speed of the generator 42 to produce a desired hoisting operation, produces a torque reaction between the stator and rotor of the device 37 whereby the stator is moved in one direction or the other to operate the contact arm 33 and thereby control the hoisting motor.

The generator 42 is constructed to have a predetermined synchronous speed for the frequency of the supply source 23, which frequency may be 60 cycles, for example a synchronous speed of 600 R. P. M., although if desired the generator may be provided with pole changing means or a multiple winding whereby different synchronous speeds may be obtained. When driven at this synchronous speed the generator will have zero frequency across the rings 41, and when the generator is driven above the synchronous speed the ring frequency increases, it being 60 cycles at 1200 R. P. M. and 120 cycles at 1800 R. P. M. It will be understood, of course, that this generator might be replaced by a synchronous generator having its speed varied from zero to synchronous speed or above in a similar manner to obtain the variable frequency from the stator instead of the rotor.

The motor 43 may be connected to the supply source 23 by means of an electromagnetic switch 43*a*, the operating coil 43*b* of which is controlled by means of push buttons 46 and 47. Closure of the normally open push button 47 connects the coil 43*b* through the push buttons 46 and 47 across the supply source 23 whereby the switch 43*a* is closed, a holding circuit for the coil 43*b* being thereby closed through the button 46 and the conductor 48 back to the supply source. To stop the motor 43 the button 46 is depressed to deenergize the coil 43*b*.

For controlling the speed of the motor 43, sections of resistance 49, 50 and 51 are provided in its secondary circuit, these resistances being controlled respectively by the electromagnetic switches 52, 53 and 54. The operating coils 55, 56 and 57 of these switches are each connected at one side to a conductor 58 leading to the supply source 23. The remaining terminals of these operating coils are connected to circuits leading through relay switches controlled by the timing devices 59 and 60 whereby a predetermined time sequence in the operation of the switches 52, 53 and 54 is obtained. Thus the remaining terminal of the coil 57 is connected through a conductor 61 and relay switches 62 and 63 controlled respectively by the timing devices 59 and 60 to a conductor 64 while the remaining terminals of the coils 55 and 56 are respectively connected through similar switches 65, 66 and 67, 68 controlled by the timing devices to the conductor 64.

Any suitable timing devices 59 and 60 may be used. As shown, the devices are provided with ratchet wheels 69 and 70 with which cooperate pendulum escaping devices 71 and 72 whereby the speed of rotation of the ratchets is held at some predetermined value so as to introduce a predetermined time interval. Driven by the ratchet wheels 69 and 70, and, as shown, secured thereto, are smaller ratchet wheels 73 and 74 with which cooperate racks 75 and 76. These two rack and ratchet devices are oppositely arranged, however, so that as indicated in the drawing the rack 75 is immediately pulled up upon energization of its operating coil 77, the teeth on the wheel 73 being inclined to slip past each other to permit this movement whereby the switches 63, 66 and 68 may be immediately closed upon the energization of the coil 77. The teeth on the rack 76 and the ratchet wheel 74 are oppositely arranged so that they engage during upward movement of the rack when the operating coil 78 is energized whereby a time interval is introduced as determined by the escapement device 72 in the closing of the switches 62, 65 and 67. It will be observed, however, that when the coil 78 is deenergized the rack 76 immediately drops down to open the switches 62, 65 and 67, whereas a time element is introduced in the opening of the switches 63, 66 and 68 due to the escapement device 71.

Furthermore, the switches 65, 67 and 62 are arranged to close in sequence with predetermined time intervals in the order mentioned while the switches 63, 68, 66 and 79 are arranged to open in predetermined sequence with time intervals in the order mentioned. In order to effect this the moving contacts of these switches are slidably mounted, as shown, on rods forming extensions of the racks 75 and 76, and are biased upward to predetermined positions on the rods by means of springs. Thus the moving contacts of the switches 65, 67 and 62 are biased upward by means of springs 65*a*, 67*a* and 62*a* to such positions that the contact of switch 65 closes first after which the spring 65*a* yields to permit the switch 67 to close after which both springs yield to allow for the closing of switch 62, any further upward movement of the rack 76 being taken care of by the springs. The arrangement of the switches 63, 68, 66 and 79 is similar, the springs being arranged to hold the moving contacts in such positions as to give the opening sequence heretofore referred to. Of course, these latter switches will actually close in the reverse sequence but since in closing no time interval is introduced by the escapement 71, the interval between this sequence is not appreciable so that the switches as a practical matter all close instantaneously. The same applies to the switches 62, 67 and 65 on their opening movement.

The operating coil 78 is connected to the supply source 23 through a relay switch 79 operated by the rack 75 while the operating coil 77 is connected to the supply source 23 in dependence upon the closure of the switches 39 and 40 and the operation of the cages 10 and 11. Thus the closure of the switch 39 closes its two relay switches 80 and 81 while the closure of the switch 40 closes its relays 82 and 83 all four of which are in the control circuit for the coil 77. The closure of either of relays 80 and 82 connects one side of the coil 77 to the supply source 23 through conductors 84 and 85, while the closure of relay 81 connects the other side of the coil 77 through the conductor 86 and conductor 87 to a limit switch 88 operated to a closed position by the hoist cage 11 on downward movement, whereby the other side of the coil 77 is connected through the conductor 89 to the opposite terminal of the supply source 23 and the coil energized. When the relay 83 closes, a circuit is closed for this opposite side of the coil 77 from conductor 86, a switch 90, which is closed when the hoist cage 10 is moved downward, thence through a conductor 87, and the relay 83 to the opposite side of the supply source 23, through the conductor 89.

Two other hoist cage operated switches 92 and 93 are provided to control the operating coils 39*a* and 40*a* of the switches 39 and 40, these switches 92 and 93 being operated respectively by the hoist cages 10 and 11. As indicated on the drawing, the switches 90 and 92 are situated adjacent the upper limit of travel of the cage 10 which is provided with a suitable cooperating projection which opens switch 90 as the cage passes by in the upward direction, the switch 90 remaining open, and which opens the switch 92 when the cage reaches its uppermost position. The switch 92, however, is normally biased to a closed position, as by a suitable spring not shown, so that when the cage 10 starts downward again the switch 92 closes, and the switch 90 is so arranged that when the cage passes downward past it the switch remains in closed position. Similar provisions are made for the operation of the switches 88 and 93 by the cage 11, these two switches being both closed when the cage starts downward and being both open when the cage is in its uppermost position.

In the operation of the system as disclosed each cage has but two positions, that is, a lower and an upper position, and the control is such that when the hoist is started by means of the push button 94 it continues in operation until the positions of the cages have been reversed. Assuming that the hoist is to be started and with the control parts in the positions shown in the drawing, button 47 is first pressed to start the pilot motor 43 driving the pilot generator 42. For frequent use of the elevator this pilot motor generator set may of course remain in operating condition continuously as desired, in which case the only operation necessary to start the motor is the depression of the button 94. With the cage 11 in its lower position, as shown in the drawing, the depression of the button 94 closes the circuit from conductor 89 through the button, switch 93, conductor 95, relay 96, and operating coil 39*a*, through conductor 85, back to the opposite side of the supply source whereby the switch 39 is closed to connect the slip rings of the generator 42 to the control device 37 for the proper field rotation in the stator of that device. At this time the resistances 49, 50 and 51 will be in the rotor circuit of the motor 43 so that the generator 42 is driven at its synchronous speed whereby the output from the generator 42 has a zero or nearly zero frequency. Any increase in the speed of generator 42 sets up a slowly rotating field in the stator 36 of the control device 37 which, due to the fact that its rotor is stationary, produces a reaction turning the stator slowly in the proper direction as determined by the closure of the switch 39. The switch arm 33 is moved in the proper direction to close one or the other of the switches 21 and 22 so as to connect the motor 14 to operate in a direction to raise the cage 11 and lower the cage 10. For example, assuming that the contact arm 33 is moved upward, it first engages the segment 27 whereby the circuit is closed from the supply source through conductor 98, the contact arm, segment 27, conductor 99, relay 100, which is closed since switch 21 is open, thence through coil 22*a* of the switch 22, back to the opposite side of the supply source. This closes the switch 22 whereby the motor 14 is started in the desired direction. The motor 14 is now operating at a slow speed with the resistances 15, 16 and 17 included in its rotor circuit and driving with it the rotor of the control device 37. If the speed of the rotor is equal to the speed of the field rotation in the stator of the device 37 then no further movement of the contact arm 33 takes place until a further increase in frequency in the generator 42 occurs.

The closure of switch 39 closes its relay switch 39*b* whereby a holding circuit is established around the button 94 so that the button can be released. This holding circuit leads through the conductor 94*a*, the relay 39*a* and conductor 94*c* to the conductor 89.

Furthermore, the closure of the switch 39 at the same time closed the relays 80 and 81 whereby the operating coil 77 is connected across the supply source 23 through these switches and the switch 88. The coil 77 immediately pulls up the rack 75, whereby the switches 63, 66, 68 and 79 operated by the rack are instantaneously closed, the closure of the switch 79 energizing the operating coil 78 which exerts a pull on the rack 76 moving it up at a speed determined by the escapement device 72. Since the switches 65, 67 and 62 actuated by rack 76 are arranged to close in sequence in the order named, the switch 65 will close after a predetermined interval to energize the coil 55 to close the switch 52 whereby the resistor 49 is short circuited and the speed of the motor 43 thereby increased. This circuit from the coil 55 may be traced from the supply source 23 through the conductor 58, the coil, relays 65 and 66, conductor 64, relay 97, moved to its upper position by the closure of switch 39, and conductor 85 to the opposite side of the supply source. In this position of the relay 97 the circuit for the coil 40*a* of switch 40, closed by the relay in its lower position, is maintained open so that it is not closed when switch 92 closes in accordance with its bias as the elevator 10 moves downward.

By reason of the increase in speed of the motor 43, the frequency of the generator 42 is increased, whereby the control device 37 moves the contact arm 33 still further, for example, into engagement with the segment 26 whereby a circuit is completed from the contact arm through the operating coil 18*a* to close the switch 18 and short circuit the resistance 15. This circuit for the coil 18*a* is traced from the segment 26 through the conductor 101, the coil, conductor 102, back to the opposite side of the supply source. The motor 14 thereupon follows the increase in speed of the generator 42. Upon the closure of the switch 18, a relay 103 operated by it is also closed whereby a holding circuit is established for the operating coil 22*a* so that the contact arm 33 can move off of the segment 27 without opening the switch 22. This holding circuit leads from the conductor 98 through the relay 103 to the conductor 99.

It might be mentioned at this point that the relay 103 also connects the conductor 93 with the conductor 104 whereby a holding circuit would be established through the relay 105, operated by the switch 22, for the coil 21*a* of the switch 21 provided the hoist motor 14 were operated in the opposite direction. At the present time, however, this circuit is not closed since the relay 105 was opened by the closing of switch 22.

After a predetermined time interval, however, the relay 67 is closed by the timing device 60 whereby the coil 56 is energized thereby closing the switch 53 and short circuiting an additional section 50 of the starting resistance for the motor 43 whereby the motor speed increases and likewise the frequency of the generator 42. This causes the control device 37 to move the contact member 33 upward still further into engagement, for example, with the segment 25 which closes a circuit from the contact arm through the conductor 106 to the coil 19a to conductor 102, thereby closing the switch 19 and short circuiting the resistance section 16. The closing of the switch 19 at the same time closes a relay switch 107 which establishes a holding circuit through the conductor 108 for the coil 18a.

Again after a predetermined time interval the relay 62 is closed by the time element device 60 whereby the coil 57 is energized to close the switch 54 and short circuit the remaining resistor section 51. The motor 43 now accelerates to its highest operating speed thereby increasing the frequency of the generator 42 which causes the control device 37 to move the contact arm into engagement with the segment 24 whereby the coil 20a is energized to close the switch 20 and thereby short circuit the last resistance section 17 for the motor 14. This step is arranged to cause the motor 14 to accelerate to a speed corresponding to the frequency of generator 42, even under the most extreme load conditions. It will be understood that for light loads the contact arm 33 may not be moved far enough to come into engagement with the segment 24 or even with the segment 25 in order to bring the hoisting motor up to the desired maximum speed.

The hoisting motor will now continue to operate at the predetermined running speed until the two cages approach their terminal landings at which time the cage 11 will first open the switch 88 which opens the circuit of the coil 77 whereupon the rack 75 starts to drop down at a speed predetermined by the escapement device 71. The switches 63, 68 and 66 are thereupon opened in a predetermined time sequence in the order mentioned whereby the switches 54, 53 and 52 are opened to gradually insert the resistances in the secondary of the motor 43 and thus reduce its speed so that the frequency of the generator 42 is gradually reduced. This operation causes a reversal of the functions previously performed by the control device 37 whereby the contact arm 33 is moved back toward the central segment 28, thereby gradually cutting the resistor sections 15, 16 and 17 into the secondary of the motor 14 to reduce its speed. This operation, like the accelerating operation, is not dependent upon the load on the motor and consequently the motor will be decelerated at a predetermined rate so that its speed will be reduced to a predetermined slow speed when the cage reaches its upper limit and opens the switch 93, which drops out the switch 39 whereupon the stator 36 is moved back to the central position on contact 28 by the springs 44 and 45 and the motor 14 thereby deenergized. Consequently the two cages will be stopped accurately at their limits of travel.

With the cage 11 uppermost it will be observed that the switches 88 and 93 will be open while the switches 90 and 92 will be closed so that a closure of the button 94 to again start the elevator will energize the coil 40a and thus close the reversing switch 40. This circuit may be traced from the conductor 89 through switch 94, switch 92, conductor 110, relay 97 which is now in its lowermost position since the switch 39 is open, and thence through coil 40a to the conductor 85. The closure of switch 40 also closes the contacts 40b which closes a holding circuit around the button 94, this circuit leading through the conductor 94a through the relay and conductor 94c to the conductor 89. This causes the field rotation in the device 37 to be in the opposite direction whereby the contact arm 33 will be lowered to first engage segment 28 and a circuit established through the conductor 104 and relay 105 for the coil 21a whereby the switch 21 is closed for the opposite direction of rotation of the motor 14. Subsequently the contact arm 33 is lowered under the control of the timing device 60 to accelerate the motor and thereafter raised under the control of the timing device 59 to decelerate the motor as will be understood from the previous description.

It will be understood that suitable automatic braking devices will be provided to secure the hoist in position at the landings. These devices are well known in the art, and have not been disclosed in the present instance in order that the disclosure may be simplified.

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

1. Means for controlling a driving motor so as to maintain a predetermined speed independently of the load on the motor comprising a pilot motor, means for varying the speed of said pilot motor at a predetermined rate, and means responsive to the change in speed of said pilot motor for controlling the speed of said driving motor so as to maintain a predetermined relation between the speeds of said motors.

2. A system for controlling a driving motor to cause said motor to operate at predetermined speeds independently of its load comprising in combination with a driving motor, a pilot motor, means for varying the speed of said pilot motor at a predetermined rate, speed control means for said driving motor, and means differentially responsive to the speeds of said driving motor and said pilot motor for operating said speed control means to maintain a predetermined relation between the speed of said driving motor and the speed of said pilot motor.

3. A control system for hoists and the like comprising a generator, means for varying an electrical characteristic of said generator at a predetermined rate, a driving motor for the hoist, speed control means for said driving motor, and means responsive to variations in the electrical characteristic of said generator for operating said speed control means to control the acceleration and deceleration of said motor.

4. A control system for hoists and the like comprising a pilot motor, time element means for controlling said pilot motor so as to vary its speed at a predetermined rate, a driving motor for the hoist, means responsive to the speed of said pilot motor and the speed of said driving motor for controlling the speed of said driving motor so as to maintain a predetermined relation between them and means actuated by the hoist for initiating the operation of said time element means.

5. A control system for hoists and the like comprising a pilot motor, time element control means for controlling said pilot motor to cause said pilot motor to operate at a predetermined sequence of speeds, a driving motor for the hoist, means responsive to the speed of said pilot motor for controlling said driving motor so as to cause said driving motor to maintain a predetermined speed relation with said pilot motor, and means actuated by said hoist for initiating the operation of said time element control means.

6. A control system for hoists and the like comprising a pilot generator, a pilot motor for driving said generator, means for controlling said pilot motor to drive said generator at a range of speeds simulating the desired operating conditions of the hoist, a driving motor for said hoist, means

responsive to an operating condition of said generator for controlling said driving motor to cause said driving motor to repeat the speed changes of said generator, and means driven by said hoist for initiating the operation of said pilot motor control means.

7. A control system for hoists and the like comprising an alternating current generator, a pilot motor for driving said generator, control means for said pilot motor whereby said pilot motor is caused to drive said generator through a predetermined range of speeds, a driving motor for said hoist, control means for said driving motor, an alternating current control device provided with a pair of rotatably mounted elements, a driving connection between one of said elements and said driving motor, a driving connection between the other element and said control means, a winding on one of said elements, and electrical connections between said winding and said generator.

8. A control system for hoists and the like comprising an alternating current generator, a pilot motor for driving said generator, control means for said pilot motor whereby said pilot motor is caused to drive said generator through a predetermined range of speeds, a driving motor for said hoist, an alternating current control device having an armature element energized from said pilot generator so as to have a field rotating in accordance with the frequency of said generator, a field element for said control device driven by said driving motor, said armature member being rotatably mounted so as to be displaced by a difference in the speeds of said field and said field element, and control means for said driving motor operated by movement of said armature element.

9. A control system for hoists and the like comprising an alternating current generator, a motor for driving said generator, time element means for controlling the acceleration and deceleration of said motor so as to vary the frequency of said generator, a driving motor for operating said hoist, and means responsive to the frequency of said generator for controlling said driving motor.

10. A control system for hoists and the like comprising an alternating current generator, a motor for driving said generator, time element means for controlling the acceleration and deceleration of said motor in accordance with a predetermined rate, a driving motor for operating said hoist, an induction device for controlling the acceleration and deceleration of said driving motor, and connections between said induction device and said generator whereby said induction device is caused to control said motor in accordance with said predetermined rate of acceleration and deceleration.

11. A control system for hoists and the like comprising a polyphase alternating current generator, a pilot motor for driving said generator, time element means for controlling said motor so as to maintain a predetermined rate of acceleration and deceleration thereof, a driving motor for said hoist, control means for said motor, a dynamometer device, said dynamometer device being provided with a pair of rotatably mounted elements, a driving connection between one of said elements and said driving motor, a driving connection between the other element and said control means, a winding on one of said elements, and electrical connections between said winding and said generator including switching means for selectively controlling the phase rotation in said winding to control the acceleration and deceleration of said motor for each direction of rotation.

12. A control system for hoists and the like comprising a polyphase alternating current generator, a pilot motor for driving said generator, time element means for controlling said motor to maintain a predetermined rate of acceleration and deceleration thereof, a driving motor for said hoist, control means for said motor, a dynamometer device provided with a pair of inductively cooperating elements, a driving connection between one of said elements and said driving motor, a driving connection between the other element and said control means, a winding on one of said elements, switching means for connecting said winding to said generator for each direction of phase rotation, means controlled by the operation of said switching mechanism for initiating the operation of said time element mechanism to accelerate said pilot motor whereby said dynamometer accelerates said driving motor in the desired direction of rotation, and means operated by said hoist for initiating operation of said time element mechanism to decelerate said pilot motor whereby said driving motor is decelerated.

13. In a motor control system, a main motor, a source of excitation for said main motor, an auxiliary motor, a control switch for said auxiliary motor, means rendered effective upon each operation of said control switch to effect a predetermined rate of change of speed of said auxiliary motor, and means comprising a differential device responsive to the ratio of the speeds of said main and said auxiliary motors for controlling said excitation source to thereby maintain said ratio substantially constant throughout said change in speed of said auxiliary motor.

14. A control system for hoists and the like comprising a generator, means for varying an electrical characteristic of said generator at a predetermined rate, a driving motor for the hoist, speed control means for said driving motor, means responsive to variations in the electrical characteristic of said generator for operating said speed control means to control the acceleration and deceleration of said motor, and means comprising a switch for rendering said varying means effective.

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