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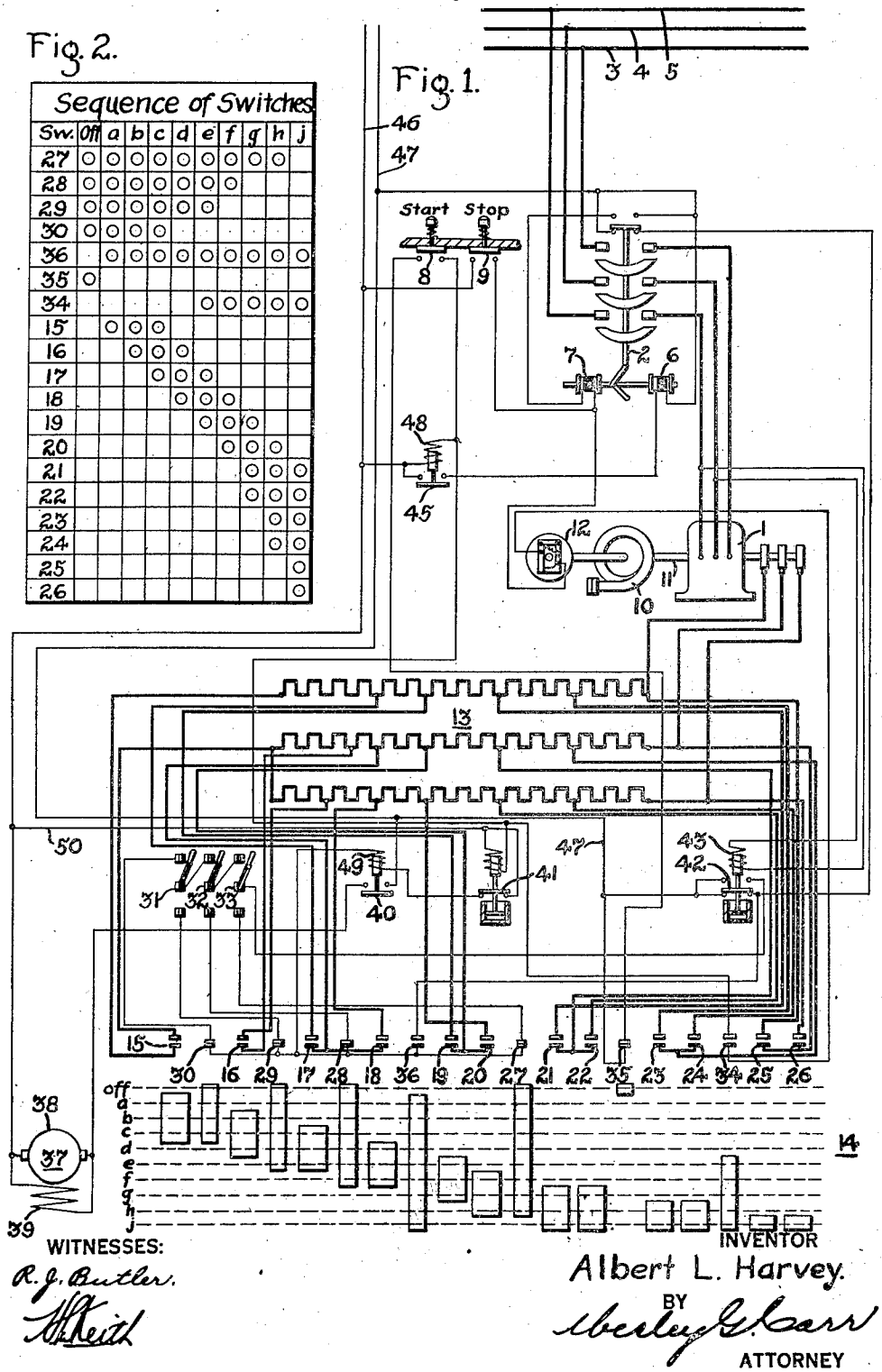
MOTOR CONTROL SYSTEM

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Fig. 2.

Sequence of Switches										
Sw.	Off	a	b	c	d	e	f	g	h	j
27	○	○	○	○	○	○	○	○	○	
28	○	○	○	○	○	○	○			
29	○	○	○	○	○	○				
30	○	○	○	○						
36		○	○	○	○	○	○	○	○	○
35	○									
34						○	○	○	○	○
15		○	○	○						
16			○	○	○					
17				○	○	○				
18					○	○	○			
19						○	○	○		
20							○	○	○	
21								○	○	○
22								○	○	○
23									○	○
24									○	○
25										○
26										○

Fig. 1.



WITNESSES:

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UNITED STATES PATENT OFFICE.

ALBERT L. HARVEY, OF WILKINSBURG, PENNSYLVANIA, ASSIGNOR TO WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY, A CORPORATION OF PENNSYLVANIA.

MOTOR-CONTROL SYSTEM.

Application filed September 12, 1922. Serial No. 587,655.

My invention relates to systems of control and it has particular relation to systems employed in connection with centrifugal pumps and the like.

The object of my invention is to provide novel and effective means for accelerating and controlling a motor and for operating the motor at predetermined selective speeds in accordance with the varying service requirements.

I preferably employ a controller of the cam-operated type, similar to that illustrated in the patent to H. D. James, No. 1,362,003, assigned to the Westinghouse Electric & Mfg. Company. The controller referred to, however, is manually operated, whereas I provide electro-responsive means for actuating the controller. In my system, a number of selective switches provide means for predetermining the running speed of the main motor, and a time-element relay is so connected as to permit the initial operation of the main motor for any desired period at greatly reduced torque, prior to the starting up of the speed-controlling means. A low-voltage relay is also provided with a time-limiting device, whereby the motor-starting resistors are reconnected into circuit in case low voltage obtains for such a period as to cause an undesirable reduction in the motor speed. This arrangement protects the motor against overload upon the sudden return of normal line voltage.

A centrifugally operated switch is provided to disconnect the motor from the line should the speed thereof fall below a desired value.

My invention will be described with reference to the accompanying drawing, in which Fig. 1 is a diagrammatic representation of circuits and apparatus embodying my invention, and

Fig. 2 is a table or chart indicating the sequence of operation of the main controller switches.

Referring to Fig. 1, a three-phase induction motor 1 is connected, by means of a remotely-controlled circuit-breaker 2, to line conductors 3, 4 and 5. The circuit-breaker 2 is provided with a closing coil 6 and an opening coil 7, which are respectively controlled by a start button 8 and a stop button 9. I have illustrated a centrifugal pump 10 directly connected to the driving motor 1, and, on the same operating shaft 11, is mounted a speed-governing switch 12.

Accelerating resistors 13 are connected, in the customary manner, to the secondary winding of the motor 1. A cam-operated controller 14 having a number of operative positions *a* to *j*, inclusive, is provided with a plurality of switches 15 to 26, inclusive, for controlling the resistors 13. The controller 14 is also provided with a plurality of auxiliary switches 27, 28, 29 and 30, which co-operate with selector switches 31, 32 and 33. Additional auxiliary switches 34, 35 and 36 are actuated by the controller 14, as will be described later. The controller 14 is operated by means of a pilot motor 37 having an armature 38, and a field-magnet winding 39.

A relay 40 controls the operating circuit of the motor 37. A time-element relay 41 is arranged to be opened, by means of the start button 8, to prevent the initial operation of the motor 37, for a purpose to be hereinafter set forth. A low-voltage relay 42 is provided with an operating coil 43 that is normally energized through the circuit-breaker 2. This relay is, therefore, normally in its upper position and, in case of low voltage, it slowly returns to its lower or illustrated position. A control relay 45 is operated by means of the start button 8 for closing the circuits of the circuit-breaker 2 and the relay 41. As a matter of convenience, an auxiliary circuit, including conductors 46 anl 47, is provided for the operating coils of certain of the control switches.

Assuming the apparatus and various switching devices in their illustrated positions, the system is operated by momentarily pressing the start button 8, thereby closing relay 45, the operating coil 48 of the relay being connected to conductors 46 and 47 through switch 35 of the controller 14. The closure of relay 45 completes a circuit for the closing coil 6 of the circuit-breaker 2. This coil is also connected to conductors 46 and 47. When closed, the circuit-breaker 2 is adapted to remain in its closed position independently of the closing coil 6.

The main motor 1 is now supplied with energy from conductors 3, 4 and 5 to start with only one of its secondary phase windings in circuit, since the switch 15 for connecting re-

sistor sections 13 is open. The low-voltage relay 42 "picks up" and maintains its upper position during normal operation.

As is well understood, an induction motor operating with a single-phase secondary connection delivers a torque of comparatively low value. The resistor sections 13 are of suitable value to insure gradual starting, which is best adapted to the operation of a centrifugal pump. The relay 41, initially "picked up" by means of the start button 8, is released when the start button is released and slowly returns to its lower or illustrated position, whereby a circuit is established for the operating coil 49 of the relay 40. It may be assumed that selector switch 33 occupies its lower closed position, completing the circuit extending from conductor 46, through conductor 50, relay 41, coil 49, switches 27 and 33 and relay 42, to conductor 47.

The relay 40 closes to connect the pilot motor 37 to line conductors 46 and 47. The operation of the motor 37 effects the successive closing of switches 15 to 26, inclusive. Switch 15 completes the connection of the secondary-resistor circuit of the motor 1, and the switches 16 to 26, inclusive, gradually shunt the resistors 13, after which the motor 1 operates at full speed, and the pump 10 delivers its maximum output.

The motor 1 may be stopped by momentarily pressing the stop button 9, thereby energizing the opening coil 7 of the circuit-breaker 2. When it is desired to reduce the output of the pump 10, it may be accomplished by means of certain of the selector switches, as, for example, by the closure of switch 32 in its lower position and the closure of switch 33 in its upper position. The pilot motor 37 is started by the closure of relay 40, as previously described, and continues to operate until the opening of relay 40 by means of switch 28 is effected in position *g* of controller 14, in which position switches 21 and 22 are closed to shunt a major portion of the starting resistors 13.

Similarly, a still lower operating speed is obtained with selector switches 32 and 33 in their upper positions and switch 31 in its lower position. The pilot motor 37, in this case, operates until switch 29 is opened in position *f* of controller 14, in which position switches 19 and 20 are closed, and the succeeding resistor switches remain open, thereby leaving additional sections of the resistors 13 in circuit with the motor 1.

The minimum selective speed of motor 1 is obtained when selector switches 31, 32 and 33 occupy their upper closed positions, in which case, the pilot motor operates controller 14 until it occupies position *d*, in which position, switch 30 is opened to interrupt the pilot-motor circuit. In this position, the secondary switches 17 and 18 are closed, the subsequent switches remaining open.

Upon the occurrence of low voltage for a considerable period, relay 42 returns to its lower illustrated position. It will be noted that switch 36 is closed in any of the operating positions *a* to *j*, inclusive. The pilot motor 37 is now started by the closure of relay 40 and continues its operation until controller 14 occupies the "off" position. The circuit for the operating coil 49 of the relay 40, in this latter instance, extends from conductor 46 through conductor 50, relay 41, coil 49, switch 36 and relay 42, to conductor 47. When controller 14 attains the "off" position, switch 36 is again opened, thereupon de-energizing coil 49, opening the relay 40 and stopping the pilot motor 37. Following the operation just described, the main motor 1 continues to operate at reduced speed. With controller 14 now in its initial starting position, upon a sudden restoration of normal voltage, the motor or other equipment cannot suffer damage.

At normal voltage, relay 42 returns to its upper position, permitting the energization of coil 49 of relay 40, which again starts the pilot motor, as previously described, returning the controller 14 to its selected operating position.

During the low-voltage period, if the speed of the motor 1 falls below a predetermined desirable value, the switch 12, which is open during normal operation of the motor, closes to complete a circuit for the opening coil 7 of the circuit-breaker 2, extending through the switch 34. This operation effects the opening of the circuit-breaker 2, causing an interruption of the main operating circuit and restoring controller 14 to its initial position. It may be noted that switch 34 is open during a portion of the starting period, when the speed switch 12 is closed. After the main motor is up to the proper speed, corresponding to position "*e*" of controller 14, the switch 34 closes to render the switch 12 effective.

I have described a system for accelerating and controlling the speed of an induction motor. Any other suitable motor may be likewise controlled, and it is believed that my system of control will lend itself to applications other than that which I have described.

Various changes in detail and arrangement may be made without departing from the spirit and scope of the invention, as defined in the accompanying claims.

I claim as my invention:

1. The combination with an alternating-current motor and a normally open circuited accelerating resistor therefor, of means for automatically connecting and excluding the resistor in successive steps, and a relay for delaying the initial operation of said means for any desired period.

2. The combination with an alternating-current motor and an accelerating resistor

therefor, of means for automatically rendering a portion of the motor winding ineffective and for excluding the resistor in successive steps, a relay for delaying the initial operation of said means for any desired period, and a time-limit low-voltage relay effective to cause said resistor to be re-inserted.

3. The combination with an alternating-current motor and an accelerating resistor therefor, of means for automatically controlling a portion of the motor winding, a relay for initially delaying the operation of said means for any desired period, and a plurality of selector switches for predetermining the motor speed.

4. The combination with an alternating-current motor and an accelerating resistor therefor, of means for automatically excluding the resistor in successive steps, a relay for rendering one phase-winding ineffective for any desired period, a time-element low-voltage relay effective to cause said winding to be re-inserted, and a plurality of selector switches for predetermining the motor speed.

5. The combination with an alternating-current motor and remotely controlled starting means therefor, of an accelerating resistor, means for automatically shunting said resistor in successive steps, selective means for controlling the shunting means, means for delaying the functioning of said shunting means, speed-responsive means, for controlling said starting means and remotely controlled means for rendering said speed-responsive means ineffective during starting.

6. The combination with a main motor and remotely controlled starting means therefor, of an accelerating resistor, a motor-operated controller for progressively shunting the resistor; selective means for arresting the operation of said controller to limit the main motor speed, a time-relay for controlling said controller, speed responsive means for controlling the starting means, and a switch for rendering the speed-responsive means ineffective when starting the main motor.

In testimony whereof, I have hereunto subscribed my name this 19th day of August, 1922.

ALBERT L. HARVEY.