United States Patent

[11] 3,551,740

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[21] Appl. No. **733,431**
[22] Filed **May 31, 1968**
[45] Patented **Dec. 29, 1970**

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[54] **LIMIT CONTROL FOR AN ALTERNATING CURRENT MOTOR**
6 Claims, 1 Drawing Fig.

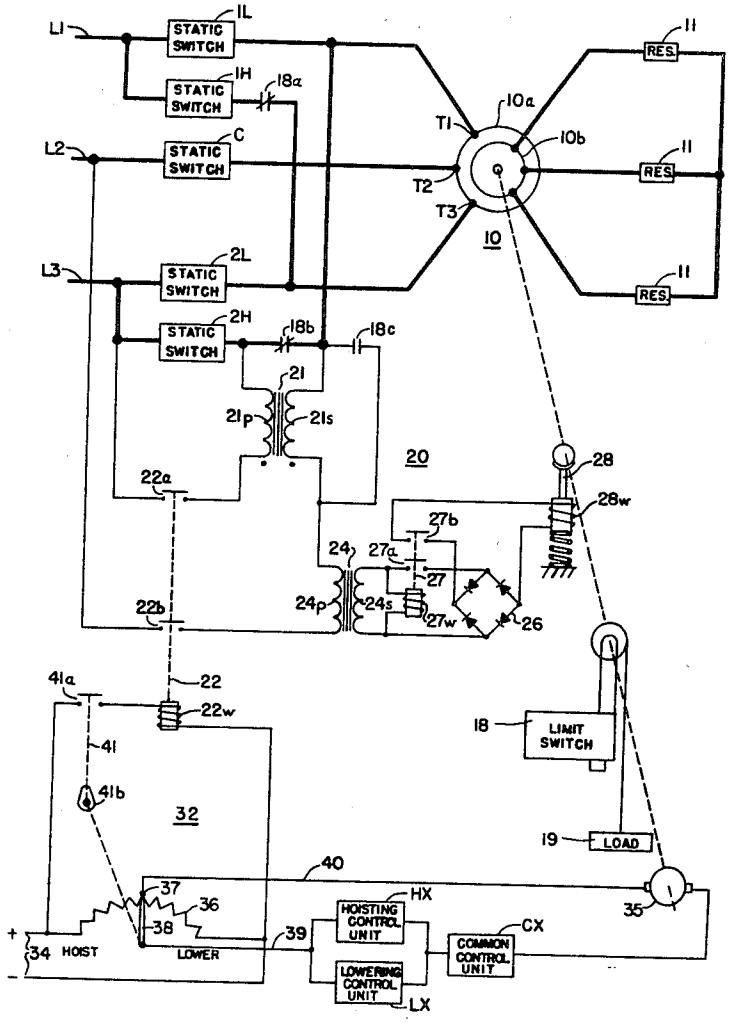
[52] **U.S. Cl.** **318/203,** 318/209, 318/372, 318/466
[51] **Int. Cl.** **H02k 17/02**
[50] **Field of Search** 318/203, 204, 209, 282, 286, 372, 466

[56] **References Cited**
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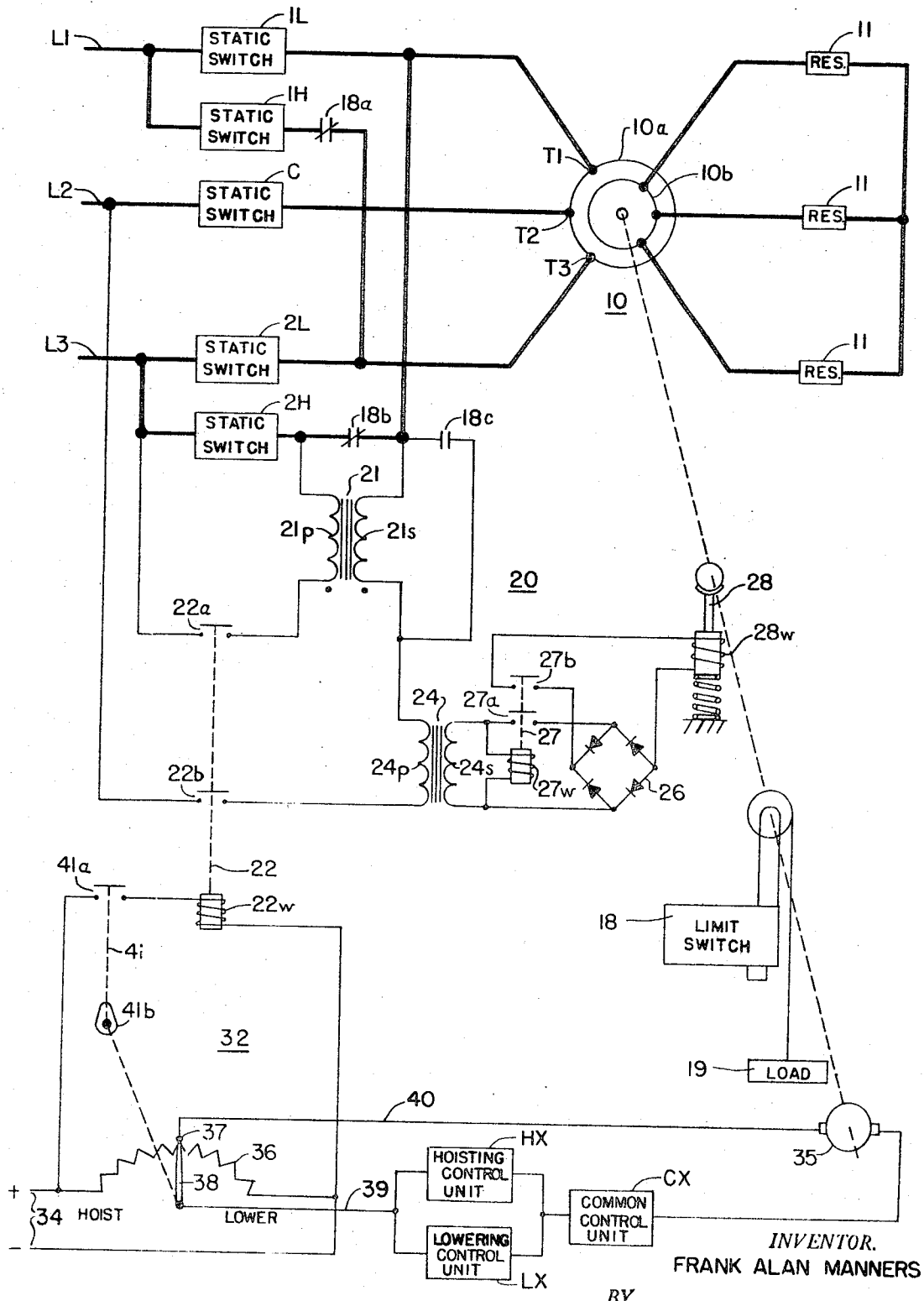
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ABSTRACT: An electrical control system for a polyphase motor driving a hoist mechanism and including a power circuit limit switch. The direction and magnitude of the torque of the motor are controlled by static variable impedance devices in the power circuit. The voltage across an operating coil of a brake is maintained constant during normal hoisting and lowering operation, regardless of the voltage at the motor terminals, by a brake control circuit including a control transformer which has its primary and secondary windings connected in series with each other through a normally closed contact of the limit switch. Upon overhoisting, the limit switch trips and the motor and brake are disconnected from the source and can be energized only to permit operation of the motor in the lowering direction.



PATENTED DEC 29 1970

3,551,740



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LIMIT CONTROL FOR AN ALTERNATING CURRENT MOTOR

This invention relates to a reversing control system for a polyphase induction motor and electroresponsive brake combination, and more particularly to such a control system having a power circuit limit switch operative to deenergize the motor and set the brake upon movement of a load driven by the motor beyond a predetermined limit in one direction.

Although having other applications, the invention will be described as embodied in a control system for a motor driving a hoist mechanism of a crane. The substitution of variable impedance static switching devices for the electromagnetic contactors previously used in alternating current crane hoist control systems has presented problems related to the interposition of the contacts of an overhoist limit switch in the supply lines to the motor and to a brake for the hoist mechanism. Such a limit switch must be so connected that when it is in its normal, i.e. untripped, position, the motor can be operated in the hoisting and lowering directions, selectively. Upon tripping of the limit switch by reason of the hoist mechanism being driven too far in the hoisting direction, the motor must be effectively disconnected from the power source so that hoisting power is removed from the motor, and the operating winding of the brake must be disconnected from the source so that setting of the brake is assured. It is also necessary that the limit switch, upon tripping, complete auxiliary circuits making it possible to release the brake and to cause the motor to rotate in the lowering direction in order to reset or return the limit switch to its normal position. Additionally, the control system should provide safe operation of the hoist in the lowering direction while the limit switch is tripped regardless of the overhauling or nonoverhauling nature of the load and regardless of whether or not the limit switch resets promptly. Upon resetting of the limit switch, the motor and brake should be controllable in the same manner as they were prior to tripping of the limit switch.

A limit control system having the foregoing capabilities is described in U.S. Pat. No. 3,183,423, issued May 11, 1965, and assigned to the same assignee as the present invention. However, in the control system of this prior patent, the circuit to the operating winding of the brake is not interrupted directly by a limit switch contact upon tripping of the limit switch. Also, in lowering out of a tripped limit switch, driving down torque is provided by unbalanced three-phase voltage obtained from only a single phase of the source. Although this previous system has been and is still used successfully in an extensive number of industrial applications, the limit control system of the present invention constitutes an improvement in that the limit switch, upon tripping, directly interrupts the circuit to the brake, and the system provides balanced three-phase power to the motor for lowering out of a tripped limit switch.

It is an object of this invention to provide an improved control system for a polyphase induction motor and electroresponsive brake combination including a limit switch having contacts interposed in the supply circuits for the motor and brake.

Another object is to provide an improved control system for an alternating current motor in which an electroresponsive brake for the motor is energized through a transformer controlled by a limit switch.

Another object is to provide a limit control system for a polyphase alternating current motor and electroresponsive brake combination in which the brake is connected for energization from one phase of the source through series-connected primary and secondary windings of a transformer.

Other objects and advantages of this invention will become apparent from the following specification wherein reference is made to the drawing, in which:

The single FIG. is a schematic wiring diagram of a control system embodying this invention.

Referring to the drawing, the invention is disclosed for purposes of illustration as applied to a three-phase-wound rotor induction motor **10**, its use with squirrel cage and other types of motors being readily apparent from the illustrative example. The motor **10** has a primary winding **10***a* provided with terminals T1, T2, and T3 and supplied from a suitable three-phase power source indicated by supply conductors L1, L2, and L3. A secondary winding **10***b* of the motor **10** is connected to a balanced Y-connected network, each leg of which includes a resistor **11** which, if desired, may be adjustable.

The effective connection of the primary winding **10***a* to the supply conductors L1, L2, and L3, and the direction of phase rotation and magnitude of the voltages applied to the primary winding **10***a*, are controlled by a plurality of variable impedance static switching devices **1H**, **2H**, **1L**, **2L**, and **C**, hereinafter called static switches, which are connected in the usual reversing arrangement for a three-phase motor. The impedances of the static switches **1H** and **2H** are controlled by a hoisting control unit HX, the impedance of the static switches **1L** a and **2L** are controlled by a lowering control unit LX, and the impedance of the static switch C is controlled by a control unit CX, designated common control unit in the drawing. The static switches **1H**, **2H**, **1L**, **2L**, and **C** may be thyristors arranged in an inverse-parallel bridge arrangement, magnetic amplifiers, or saturable reactors, all of which are well-known in the art.

An overhoist limit switch **18** of the power circuit type is arranged to be operated by a load **19** driven by the motor **10**. The limit switch **18** has two normally closed contacts **18***a* and **18***b* and one normally open contact **18***c*. The contact **18***a* is interposed between the static switch **1H** and the motor terminal T3, the contact **18***b* is interposed between the static switch **2H** and the motor terminal T1, and also forms part of a brake control circuit **20** to be described, and the contact **18***c* is included in the brake control circuit **20**.

The static switches are connected as follows: static switch **1L** directly between the conductor L1 and the terminal T1; static switch **1H** between the conductor L1 and the terminal T3 through the contact **18***a;* static switch C directly between the conductor L2 and the terminal T2; static switch **2L** directly between the conductor L3 and the terminal T3; and static switch **2H** between the conductor L3 and the terminal T1 through the contact **18***b*, the contact **18***b* being interposed between the static switch **2H** and the terminal T1.

The brake control circuit **20** comprises a 1 to 1 ratio transformer **21** having a primary winding **21***p* and a secondary winding **21***s* connected in series with each other through the contact **18***b*. The series combination thus formed is connected across the supply conductors L2 and L3 in a circuit from the conductor L3 through a normally open contact **22***a* of an electromagnetic control relay **22**, the primary **21***p*, of an electromagnetic the contact **18***b* of the limit switch **18**, the secondary **21***s*, a primary winding **24***p* of a transformer **24**, and a normally open contact **22***b* of the relay **22** to the supply conductor L2. The relay **22** has an operating winding **22***w*. The limit switch contact **18***c* is connected across the secondary **21***s*.

A secondary winding **24***s* of the transformer **24** is connected to the input terminals of a full wave rectifier bridge **26** through a circuit including a normally open contact **27***a* of an electromagnetic relay **27** having a second normally open contact **27***b* and an operating winding **27***w*, the operating winding **27***w* being connected across the secondary **24***s*. A spring-applied, electromagnetically-released friction brake **28** having an operating winding **28***w* is provided for the motor **10**. The output terminals of the rectifier bridge **26** are connected to supply the brake winding **28***w* through a circuit including the normally open contact **27***b*. The circuit elements including the transformer **24**, the relay **27**, the rectifier bridge **26** and the brake winding **28***w* are arranged to provide an electroresponsive means for operating the brake **28**.

Although a spring-applied electromagnetically-released brake is illustrated, it will be understood that other suitable types of electroresponsive brakes can be used.

The control units HX, LX, and CX are normally turned off and are arranged to be selectively turned on in response to a

net signal voltage which is the resultant of a reference voltage and a feedback voltage in series opposition. The reference voltage is obtained from a reversing master control element **32** supplied from a unidirectional voltage source **34**. The feedback voltage is obtained from a tachometer generator **35** driven by the motor **10** so that the feedback voltage is proportional to the speed of the motor **10** and of a polarity dependent upon the direction of motor rotation. When the hoisting control unit HX is turned off, the static switches 1H and 2H are nonconducting, and when the control unit HX is turned on, the static switches 1H and 2H conduct to a degree related to the magnitude of the net signal voltage. Similarly, when the lowering control unit LX is turned off, the static switches 1L and 2L are nonconducting, and when the control unit LX is turned on, the static switches 1L and 2L conduct to a degree related to the magnitude of the net signal voltage. The common control unit CX similarly controls the static switch C, and is connected in series with the control units HX and LX so as to be nonconducting and conducting in relation to the magnitude of the net signal voltage but not sensitive to the polarity of the net signal voltage.

The master control element **32** includes a potentiometer resistor **36** connected across the source **34**, a center tap **37** on the resistor **36**, and a manually operable slider **38** movable along, and in electrical contract with, the resistor **36** and electrically engageable with the center tap **37**. The polarity of the reference voltage provided by the master control element **32** is determined by the position of the slider **38** with respect to the center tap **37**, and the magnitude of the reference voltage is proportional to the distance of the slider **38** from the center tap **37**. Thus the polarity of the potential between a conductor **39**, connected to the slider, and a conductor **40**, connected to the center tap **37**, can be selected and its magnitude adjusted or varied by movement of the slider **38**.

The master control element **32** also includes a contact mechanism **41** including a contact **41***a* which is opened, as by a cam **41***b*, when the slider **38** is in its central or OFF position is engagement with the center tap **37** and is released by the cam **41***b* and closes whenever the slider **38** is moved from its central position to an ON position.

Assuming the motor **10** to be at rest and the brake **28** to be set, movement of the slider **38** of the master control element **32** in the clockwise direction from its OFF position provides a reference voltage of a polarity to turn on the lowering control LX. This movement of the slider **38** also causes closure of the contact **41***a* resulting in energization of the winding **22***w* of the relay **22** from the source **34** so as to close the contacts **22***a* and **22***b*.

Upon turning on of the lowering control unit LX, the impedance of the static switches 1L and 2L is lowered. The current flowing through the unit LX also passes through the unit CX so that the impedance of the static switch C is concurrently lowered. The reduction of the impedance of the static switches 1L, 2L, and C causes a balanced polyphase voltage to be impressed on the motor terminals T1, T2, and T3 of such a phase rotation that the motor **10** exerts a torque in the lowering direction. Because the brake **28** is released, as will be described, the load **10**, whether overhauling or not, now starts to move downwardly and the tachometer generator **35** starts to generate a feedback voltage.

As the speed of the motor **10** increases, the feedback voltage from the tachometer generator **35** increases, causing the net signal voltage to decrease, and thereby resulting in a gradual increase in the impedance of the static switches 1L, 2L, and C. Should the feedback voltage exceed the reference voltage from the master control element **32**, as under an overhauling load condition, the polarity of the net signal voltage reverses. Thereupon, the phase rotation of the voltage at the motor terminals T1, T2, and T3 reverses because the lowering control unit LX becomes turned off and concurrently the hoisting control unit HX becomes turned on to cause a reduction in impedance of the static switches 1H and 2H. This causes the motor **10** to exert a hoisting torque while still rotating in the lowering direction, and thereby to provide a countertorque which maintains a lowering speed of the motor **10** determined by the distance of the slider **38** from the center tap **37**.

In event the load **19** is not overhauling, the phase rotation of the polyphase voltage at the terminals T1, T2, and T3 remains in such direction that the motor **10** continues to exert a lowering torque to drive the load **19** downwardly at a speed determined by the position of the slider **38**.

Upon return of the slider **38** to the OFF position at the tap **37**, the contact **41***a* opens, the brake **28** sets, the reference voltage becomes zero, and the feedback voltage is such that the impedances of the static switches 1H, 2H, and C are reduced to cause the motor to exert a counter or hoisting torque, thereby to aid in stopping the motor quickly. When the motor comes to a standstill, the feedback voltage is zero and all of the static switches are at maximum impedance so that there is no voltage at the motor terminals T1, T2, and T3.

Upon movement of the slider **38** in a counterclockwise direction from the OFF position, the brake **28** is released as will be described, and the reference voltage turns on the control unit CX and is of such polarity that the hoisting control unit HX is also turned on. The turning on of the units HX and CX causes the impedance of the static switches 1H, 2H, and C to be reduced thereby to cause the polyphase voltage at the terminals T1, T2, and T3 to be of such phase rotation as to cause the motor **10** to exert a hoisting torque. When the motor **10** starts to rotate in the hoisting direction, the interaction of the reference and feedback voltages causes the torque of the motor **10** to be sufficient to hoist the load **19** at a speed determined by the position of the slider **38**. The speed of the motor **10** stabilizes when the reference voltage from the master control element **32** and the feedback voltage from the generator **35** effectively combine to indicate to the control units HX and CX that the motor is operating at the desired hoisting speed.

At all times during normal operation of the motor **10** with the limit switch **18** untripped, substantially full line voltage is impressed across the primary **24***p* of the transformer **24** thus insuring that the brake **28** is released. The reason for this will now be explained. Because the primary **21***p* and secondary **21***s* are interconnected at their upper ends, as viewed in the drawing, through the contact **18***b*, and have the same number of turns and are wound as indicated by the dots, it follows that their lower ends, as viewed in the drawing, are substantially at the same potential. Thus, there is substantially no voltage drop across the series combination including the primary **21***p* and the secondary **21***s*. Hence, because the lower end of the primary **21***p* is connected to the supply conductor L3 through the contact **22***a*, the lower end of the secondary **21***s* is likewise effectively connected to the supply conductor L3. Because the lower end of the secondary **21***s* is also connected directly to one end of the transformer winding **24***p* and the other end of the transformer winding **24***p* is connected to the supply line L2 through the contact **22***b*, substantially the full line voltage of the source is applied across the winding **24***p* irrespective of the impedances of the static switches 1L and 2H. Consequently wherever the contacts **22***a* and **22***b* are closed and the limit switch **18** is untripped, substantially full operating voltage is applied on the brake winding **28***w* and the brake **28** is released.

As mentioned, if the motor **10** while operating in the hoisting direction raises the load **19** too high, the limit switch **18** trips closing its contact **18***c* and opening its contacts **18***a* and **18***b*. Normally, at the time of entering the limit switch zone, the static switches 1H and 2H are conductive. Opening of the contacts **18***a* and **18***b* removes power from the motor primary **10***a*, and opening of the contact **18***b* also interrupts the series circuit feeding the primary winding **24***p* so that the voltage across the coil **28***w* goes to zero resulting in setting of the brake **28** to stop the motor **10** and hold the load **19** suspended. Closure of the contact **18***c* is of no immediate effect because the static switch 1L is nonconductive and the contact **18***b* is open.

To operate the motor **10** in a lowering direction with the limit switch **18** tripped, it is necessary for the brake **28** to be released and for the motor **10** to produce only sufficient driving down torque in order to overcome friction when lowering an empty hook. A load **19** of any size on the hook assists the motor in this operation.

With the limit switch **18** tripped, the motor **10** can no longer be operated in the hoisting direction as just explained. The load **19** can be lowered out of the limit switch zone, however, by moving the slider **38** of the master control element **32** to the lowering position. The resultant conduction of the static switches 1L, 2L, and C applies a balanced three-phase voltage to the motor primary **10***a* with a phase rotation causing the motor **10** to exert torque in the lowering direction. The primary winding **24***p* is connected across the conductors L1 and L2 through the now-closed contact **18***c* and the static switch 1L so that upon the static switch 1L reaching a predetermined low impedance, the brake **28** releases and the motor **10** rotates in the lowering direction. Normally, after a few revolutions of the motor **10**, the limit switch **18** resets to establish normal lowering connections. When the limit switch **18** resets, the connections to the motor **10** and to the brake winding **28***w* are the same as described above for the normal lowering operation.

If the motor should be plugged at the instant of entering the limit switch zone, the brake **28** does not set, but the motor is then connected to supply torque in the lowering direction so that the load is safely brought to a standstill and then lowered out of the limit switch zone.

An additional safety feature prevents and overspeed condition when lowering out of the limit switch zone even if the limit switch **18** should fail to reset and remains tripped. If the load **19** is overhauling, the feedback voltage from the tachometer generator **35** causes the net signal voltage to increase the impedance of the static switches 1L, 2L, and C so that the voltage impressed on the brake winding **28***w* is reduced to a value which will cause the brake **28** to reset and stop the motor **10**. When the motor stops, the feedback voltage disappears, and the remaining reference voltage causes the impedance of the static switches 1L, 2L, and C to decrease again. The brake **28** is consequently released and the load **19** again accelerates and then stops as before. Therefore, if the limit switch **18** fails to reset, the motor **10** alternately accelerates and stops, thus safely lowering the load **19** even if the operator holds the master switch **32** in a lowering position.

I claim:

1. A limit control system for a polyphase motor and electroresponsive brake therefor, said system comprising a 1 to 1 ratio transformer having a primary winding and a secondary winding, variable impedance means for completing a motor supply circuit from a polyphase source to the motor thereby to apply a polyphase voltage of variable magnitude to the motor, said primary and secondary windings being connected to said motor supply circuit whereby voltages of variable magnitude are impressed on the primary and secondary windings, respectively, during operation of the motor, and electroresponsive means for controlling the brake, limit control means having a first normally closed contact connecting the primary and secondary windings in series with each other to form a series combination, and means connecting the series combination thus formed in a series circuit with the electroresponsive means across one phase of the source, said transformer windings being so wound and interconnected that substantially no voltage drop occurs across said series combination whereby the voltage across the electroresponsive means remains substantially constant independently of said voltages impressed on the primary and secondary windings, and said limit control means being operative upon said motor reaching a limit of operation in one direction to interrupt the connection between the primary and secondary windings.

2. A limit control system according to claim 1 wherein said limit control means includes an additional normally closed contact, both of said contacts being interposed in the motor supply circuit and operative, upon operation of said limit control means, to interrupt the motor supply circuit, and said first normally closed contact interrupts the connection between the primary and secondary windings upon operation of the limit control means thereby to interrupt the series circuit to the electroresponsive means so as to disconnect the electroresponsive means from said one phase of the source.

3. A limit control system according to claim 1 wherein the transformer has an iron core.

4. A limit control system according to claim 1 wherein the variable impedance means comprises a plurality of static switch means connected to supply three-phase voltage of selective phase rotation to the motor so as to cause operation of the motor selectively in two directions of rotation, a first group of the static switch means when conductive supplying three-phase voltage of one-phase rotation to cause operation of the motor in one direction and a second group of the static switch means when conductive supplying three-phase voltage of another phase rotation to cause operation of the motor in the other direction, said limit control means has an additional normally closed contact, said contacts being interposed in the motor supply circuit and operative, upon operation of the limit control means, to disconnect the motor from the source regardless of the conductivity of said first group of static switch means, said second group of static switch means when conductive supplying three-phase voltage of said another rotation to the motor regardless of the operative condition of said limit control means.

5. In a control system for a polyphase motor and a spring-applied electromagnetically-released brake therefor including variable impedance means for completing a motor supply circuit from a three-phase source to the motor thereby to apply a three-phase voltage of variable magnitude and selective phase rotation to the motor so as to cause operation of the motor at variable speeds in two directions of rotation, selectively, limit control means having two normally closed contacts, said normally closed contacts being interposed in the motor supply circuit and being closed during normal operation of the motor and operative to open, thereby to interrupt said motor supply circuit, upon said motor reaching a limit of operation in one direction, and a brake control circuit responsive to operation of the motor beyond said limit of operation and including an electroresponsive means for releasing the brake when energized and a 1 to 1 ratio transformer having a primary and a secondary winding, the improvement comprising means connecting said primary and secondary windings in series with each other through one of the normally closed contacts of the limit control means during normal operation of the motor, and means connecting the series combination thus formed in a series circuit with the electroresponsive means across a single phase of the three-phase source, said primary and secondary windings being so wound and interconnected that substantially no voltage drop occurs across said series combination whereby a substantially constant voltage is provided across the electroresponsive means regardless of the magnitude or the phase rotation of voltage applied to the motor thereby to insure positive release of the brake during normal operation of the motor in either direction, said one contact, upon opening, directly interrupting the series circuit to the electroresponsive means thereby positively insuring application of the brake, and said limit control means additionally including a normally open contact in said brake control circuit and operative upon opening of said normally closed contacts to provide a circuit to said electroresponsive means which is completed upon operation of the motor in the other direction.

6. In a limit control system for a three-phase motor and electroresponsive brake therefor, a source of three-phase voltage, an electroresponsive means connected to control the operation of the brake, a transformer having primary and secondary windings, means connecting one of the transformer windings in series with the electroresponsive means to form a series combination, means connecting the other transformer winding in series with said series combination across a first

phase of the source, and variable impedance means for impressing variable three-phase voltage on the motor, said variable impedance means impressing a variable voltage from a second phase of the source across said series combination and not across said other winding, said variable impedance means also impressing a variable voltage from a third phase of the source across the other transformer winding and not across said series combination, and said transformer windings having substantially the same number of turns and being so wound and interconnected that substantially no voltage drop occurs across the serially-connected transformer windings whereby the voltage across the electroresponsive means remains substantially constant irrespective of variations in voltages impressed from said second and third phases of the source upon the respective transformer windings.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,551,740 **Dated** December 29, 1970

Inventor(s) Frank Alan Manners

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 17, after the reference number "1L" cancel "a"; lines 48 and 49, after "the primary 21p," cancel "of an electromagnetic". Column 3, line 38, before "engagement" for "is" read --in--. Column 5, line 30, after "prevents" for "an read --an--. Column 6, line 27, after "another" insert --phase--.

Signed and sealed this 11th day of May 1971.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

WILLIAM E. SCHUYLER,JR.
Commissioner of Patents