

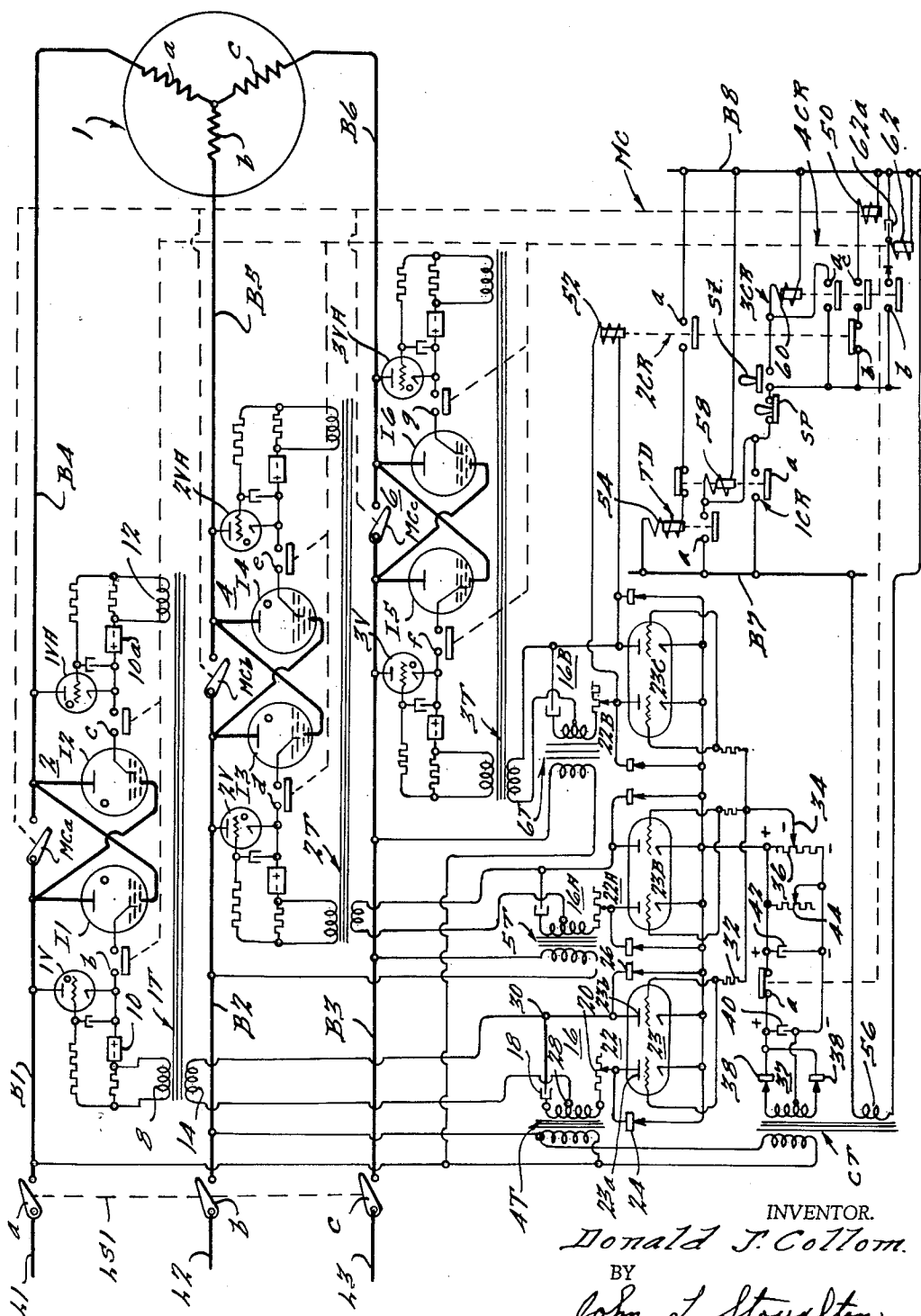
July 17, 1962

D. J. COLLOM

3,045,163

MOTOR CONTROLLING APPARATUS

Filed Sept. 9, 1957



INVENTOR.
Donald J. ColloM.
BY
John L. Stoughton
HIS ATTORNEY

1

3,045,163

MOTOR CONTROLLING APPARATUS

Donald J. Collom, Bloomfield Township, Oakland County, Mich., assignor to Weltronic Company, a corporation of Michigan

Filed Sept. 9, 1957, Ser. No. 682,761

19 Claims. (Cl. 318-227)

This invention relates generally to motor controlling apparatus and, more particularly, to such an apparatus using electronic discharge tubes such as ignitrons for starting high horsepower electric motors.

A prime object of this invention is to provide an improved starter for large horsepower electric motors.

A further object of this invention is to provide such a starter using discharge devices to control the initial current flow to the motor, and embodying improved phase-shift control means for automatically increasing the effective voltage applied to the motor to thereby cause it to accelerate.

A still further object of this invention is to provide such a device in which the electronic discharge devices are not used during running periods of the motor.

Another object of this invention is to provide such a device in which a mechanical contactor is used to complete the energizing circuit to the motor after it has been initially actuated by means of the discharge devices.

A further object of the present invention is to provide an improved phase-shift control system.

Other objects of this invention will be apparent from the specification, the appended claims and the drawings, in which the sole FIGURE schematically illustrates a motor controlling apparatus embodying the invention.

Referring to the drawing, the numeral 1 indicates generally a conventional three-phase electric motor of relatively high horsepower energizable from a three phase source of alternating current as illustrated by the supply lines L1, L2, and L3. These lines are selectively connectible by means of a disconnect switch LS1 to busses B1, B2, and B3 respectively. The busses B1, B2, and B3 are connected respectively to busses B4, B5, and B6 through pairs of back-to-back or anti-parallel connected pairs of ignitrons 2, 4, and 6. Pair 2 comprises the ignitrons 11-12; the pair 4, the ignitrons 13-14; and the pair 6, the ignitrons 15-16. The anodes of the ignitrons 11, 13, and 15 are respectively connected to the busses B1, B2, and B3 while their cathodes are connected respectively to the busses B4, B5, and B6, which are directly connected to the input terminals of motor 1. The ignitrons 12, 14, and 16 are connected between the busses B1-B4; B2-B5; and B3-B6 in reverse relationship with respect to the ignitrons 11, 13, and 15 respectively, so that current may flow in either direction through the pairs of ignitrons. The busses B1-B4, B2-B5, and B3-B6 are individually and directly connectible together by means of the contacts a, b, and c of the running contactor MC.

The pairs of ignitrons 2, 4, and 6 are similarly energized and therefore a detailed description of only the pair 2 will be given, it being remembered that the pairs 4 and 6 are specifically the same, the only difference being that they are connected to different phases of the source. The ignitron 11 is fired by means of a firing tube 1V, the anode of which is connected to the bus B1 and the cathode of which is connected through contacts b of relay 4CR to the igniter of the ignitron 11. The firing valve 1V may be of the discontinuous control type, such as a thyatron, and the initiation of conduction there-through is determined by means of a bias voltage applied between its controlling grid and cathode. The controlling grid of the valve 1V is connected through the usual grid current limiting resistor to one terminal of the

2

secondary winding 8 of a control transformer 1T. The other terminal of this winding 8 is connected through a source 10 of bias potential to the cathode of the tube 1V. Similarly, ignitron 12 is fired by means of a firing tube 1VA, which is like valve 1V. The anode of valve 1VA is connected to bus B4 and its cathode is connected through contact c of relay 4CR to the igniter of ignitron 12. The grid of valve 1VA is connected through current limiting resistor to one terminal of the secondary winding 12 of transformer 1T. The other terminal of winding 12 is connected through an additional source 10a of bias voltage of the cathode of tube 1VA. Usual resistors are connected across the secondary windings 8 and 12 and usual filter condensers are connected between the grids and cathodes of valves 1V and 1VA.

The magnitude and polarity of the voltage of the bias sources is utilized to control the point on the alternating voltage wave of the transformer 1T at which the tubes 1V and 1VA are rendered conducting. The voltage magnitude will depend on the polarity and magnitude of the bias voltage required to render the tubes conductive and this in turn will depend upon the characteristic of the particular tube which may be utilized. I have found that in some instances the sources 10 and 10a may be omitted entirely. A blocking bias on the tubes 1V and 1VA during stand-by conditions with the limit switch LS1 closed is not necessary since the tubes 1V and 1VA are prevented from firing the ignitrons 11 and 12 respectively by the open contacts b and c of the relay 4CR in the control circuit to be described below.

The primary winding 14 of control transformer 1T is supplied with power from a transformer 4T through a phase-shifting network 16. The primary winding of transformer 4T is connected across busses B1 and B2 and, consequently, the outputs of secondary windings 8 and 12 bear a phase relation to the voltage wave appearing between busses B1 and B2 which is determined by the setting or condition of the phase-shifting network 16. In the broader aspects of the present invention, network 16 may be variously arranged. Preferably, and as illustrated, however, the end terminals of the secondary winding of transformer 4T are interconnected by a capacitor 18 (which may be either fixed or variable, but is shown as fixed), a variable but normally fixed calibrating resistor 20, and a variable resistance network 22. The resistance of network 22 is varied as described below, in accordance with a predetermined pattern, in order to provide a gradual increase in the voltage applied to the motor 1, to thereby control the starting currents drawn by it and its rate of acceleration.

Variable resistance network 22 comprises a dual triode 23, the corresponding anodes and cathodes whereof are shunted by usual dry rectifiers 24 and 26, respectively. One terminal of the primary winding 14 of control transformer 1T is connected to the secondary winding of transformer 4T at an intermediate tap 28 thereof. The other terminal of primary winding 14 is connected to a terminal 30 between the capacitor 18 and the resistances 20 and 22. During half cycles of one polarity, transformer 4T tends to cause current to flow through network 22 by way of, for example, anode 23a and its cathode and rectifier 26. During opposite half cycles, the current flow tends to be through anode 23b, its cathode and rectifier 24. It will be understood that the phase relation between the voltage output of winding 14 and that of transformer 4T is determined by the relative magnitudes of capacitor 18 and resistances 20 and 22. The grids of triode 23 are joined together and are connected, through a resistor 32, to tap 34 of potentiometer 36. Potentiometer 36 is supplied from any suitable direct current source 37, illustrated as comprising control transformer CT, rectifiers 38 and condenser 40. Source 37 is connected

3

to potentiometer 36 through contacts *a* of control relay 4CR. Potentiometer 36 is bridged by biasing condenser 42 and an adjustable resistor 44, the setting of which determines the length of the accelerating period of the motor.

With the system at rest, but with the disconnect switch LS1 closed, contacts *a* of relay 4CR are closed. Under these circumstances biasing condenser 42 is charged to the full potential of source 37 with the indicated polarity. Also under these conditions, the grids of the high vacuum dual triode 23 are biased negative with respect to their cathodes to a degree determined by the setting of tap 34 along potentiometer 36. Preferably this setting establishes a ratio between the resistance of triode 23 and condenser 18 such that the output of winding 14 is out of phase with respect to the voltage between buses B1-B2 to such a degree as to tend to cause valves 1V and 1VA respectively to become conductive at approximately the 90° point in the respective positive and negative half waves of the voltage between the buses B1 and B2; or stated otherwise, at approximately the 60° point in the positive half cycle of the voltage wave of bus B1, as measured in relation to the potential at the junction of the motor windings *a*, *b* and *c*. As is described below, as an incident to a motor starting operation, contacts *a* of relay 4CR open, enabling capacitor 42 to discharge through resistors 44 and 36 at a rate determined by the values thereof. This, of course, progressively reduces the negative biases between the grids and cathodes of the dual triode 23. Consequently, its conductivity progressively increases and its resistance to current flow correspondingly decreases. The progressive decrease in resistance of triode 23 decreases the phase displacement between the voltage of transformer 1T and the voltages of bus B1, and advances the firing points of valves 1V and 1VA. At the conclusion of the discharge operation of capacitor 42, substantially full firing of valves 1V and 1VA is provided.

Ignitrons 13 and 14 are provided with firing valves 2V and 2VA, and firing networks, and a phase-shifting network 16A which corresponds in all respects to the arrangement described with respect to ignitrons 11 and 12, with the exception that the supply transformer 5T which supplies the phase-shifting network 16A is connected between busses B2 and B3. During starting operations, accordingly, valves 2V and 2VA are first fired late in the respective positive and negative voltage waves appearing between busses B2 and B3 and thereafter are fired at progressively earlier stages of such voltage waves. Similarly, ignitrons 15 and 16 are provided with firing valves 3V and 3VA, the firing networks of which are like those described above, with the exception that the supply transformer 6T for the associated phase-shifting network 16B is connected between busses B3 and B1 and, consequently, valves 3V and 3VA are controlled in timed relation to the voltage between phase conductors B3 and B1. The grid cathodes of all of the dual triodes of networks 16, 16A, and 16B are tied together and the bias voltages applied therebetween are controlled by a potentiometer 36, resistor 44 and bias condenser 40 in the manner described above relative to triode 22.

In accordance with the present invention the ignitrons 11 through 16 supply the motor current only during the starting and acceleration operations. Under running conditions, these ignitrons are shunted by normally open contacts MC*a*, MC*b* and MC*c* of motor controlling contactor MC. The contactor MC is provided with an energizing coil 50, the circuit for which is controlled by a relay 2CR having a coil 52 which is automatically controlled by the accelerating operation. More particularly, coil 52 is connected directly across the variable resistance network 22B and the voltage applied across coil 52 is consequently a maximum at start and a minimum at the end of each accelerating operation.

It is believed that the remaining details of the present

4

system may best be understood from a description of operation thereof, which is as follows:

The apparatus is conditioned for operation by closure of the line switch LS1, which energizes the busses B1, B2, and B3 from the lines L1, L2, and L3, which are connected to a suitable source of three phase alternating potential supply. The energization of the busses B1, B2, and B3 also energizes the phase-shift supply transformers 4T, 5T, and 6T, which in turn energize the associated networks 16, 16A, and 16B, respectively. This action causes grid transformers 1T, 2T, and 3T to apply firing impulses to the grids of valves 1V-1VA, 2V-2VA, and 3V-3VA.

Closure of the disconnect switches LS1, LS2, and LS3 also energizes control transformer CT which thereupon charges bias condenser 42 to the full voltage of source 37. As previously described, this action, through potentiometer 36, applies such a negative bias between the grids and cathodes of triodes 23, 23B, and 23C as to tend to fire valves 1V-1VA, 2V-2VA, and 3V-3VA late (for example, about the ninety (90°) degree points) of the corresponding voltage waves. No firing of these valves occurs, however, since their anode-cathode circuits are open at contacts *b* through *g* of relay 4CR.

As previously described, and with the resistance of triode 23C at a maximum, the voltage drop appearing across coil 52 of relay 2CR is at a maximum and this relay, consequently, assumes the energized position, closing its contacts *a* and opening its contacts *b*. The latter action prevents completion of an energizing circuit for the motor controlling contactor MC. This ensures that the starting circuits for the motor 1 shall be through the ignitrons 11 through 16.

Closure of contacts *a* of relay 2CR completes an energizing circuit for the coil 54 of the time delay relay TD, it being understood that the control busses B7 and B8 are now energized from the secondary winding 56 of control transformer CT. At the expiration of a predetermined time after energization of its coil 54, relay TD closes its contacts *a*. This action completes a circuit for the energizing coil 58 of control relay 1CR which thereupon closes its contacts *a*. This action completes a self-holding circuit for the coil 58 and also makes it possible to start the motor 1 by closure of the usual start switch *St*. It will be understood that the delay interposed by time delay relay TD is sufficient to permit the usual heaters (not shown) associated with the various thyratrons and the triodes 23, etc. to reach operating temperatures. These heater circuits (also not shown) may be completed in conventional fashion by closure of the disconnect switch LS1.

If now it is desired to start the motor, the start button *St* may be momentarily closed thereby completing an obvious energizing circuit for the coil 60 of relay 3CR which thereupon closes its contacts *a*, *b* and *c*. Closure of contacts *a* of relay 3CR completes a self-holding circuit for the coil 60 enabling the start switch to be reopened without effect. Closure of contacts *c* of relay 3CR is preparatory only, but closure of contacts *b* completes an obvious energizing circuit for the coil 62 of relay 4CR which thereupon opens its contacts *a* and closes its contacts *b*, *c*, *d*, *e*, *f* and *g*. Opening of contacts *a* of relay 4CR disconnects the biasing condenser 42 from the source 37 and initiates its discharge through resistors 36 and 44, as aforesaid.

Closure of contacts *b-g* of relay 4CR starts the motor. More particularly, let it be assumed that contacts *b* through *g* close just prior to the aforesaid 60° point in a positive half cycle of the voltage wave of bus B1. Under these conditions, at the 60° point of bus B1, valve 1V becomes conductive. At this time, valve 2VA associated with bus B2 is already conductive since the time in question is later than the 60° point in the negative half cycles of the voltage of bus B2. Consequently the rendering conductive of valve 1V completes firing circuits for both ignitrons 11 and 14, which extend from bus B1 through valve

5

1V, contacts *b* of relay 4CR, igniter and cathode of ignitron I1, bus B4, windings *a* and *b* of motor 1, bus B5, valve 2VA, contacts *e* of relay 4CR and thence through the igniter and cathode of ignitron I4 to bus B2. Completion of these firing circuits ignites ignitrons I1 and I4 and supplies starting current to the motor 1. At this same time, bus B3 is positive with respect to bus B2 and since the tube 3V at this time will be biased conductive, ignitron I5 will conduct and current will flow from bus B3 through windings *c* and *b* to bus B2.

Thereafter the polarity of the voltage between busses B3 and B2 will reverse. The current through ignitron I5 will not immediately cease since it lags the voltage. Subsequently however the current flow ceases. At about the 150° point on the voltage wave between busses B1 and B2, the valve 3VA will be rendered conductive and current will flow from the bus B1 through motor windings *b* and *c* and ignitron I6 to the bus B3. Subsequently the bus B2 becomes positive with respect to busses B1 and B3. When the inductive current flow ceases ignitron I4 will go out. Thereafter valve 2V conducts to cause ignitron I3 to conduct and current flow from bus B2 through motor windings *b* and *c* to bus B3.

The various ignitrons I1-I6 are continually rendered conductive in accordance with the operation of the phase-shift networks 16, 16A and 16B in the manner set forth with the current flow through the fired ignitrons terminating after the voltage thereacross reverses as a consequence of the reversing of the line voltages and the termination of the inductive current flow therethrough.

As previously described the progressive discharge of bias condenser 42 progressively advances the firing points of valves 1V, 1VA, 2V, 2VA, 3V, 3VA with respect to the voltages of their associated busses B1, B2 and B3 to progressively advance the point in the half cycles of the voltage waves of these busses at which the ignitrons I1 and I6 become conductive and consequently increases the effective voltage applied to the motor as it accelerates to full speed.

When a condition of substantially full firing of ignitrons I1 through I6 has been attained, which corresponds to a substantially fully discharged condition of condenser 42, the resistance of, and consequently the voltage drop across the triodes 23C becomes so low that coil 52 of relay 2CR is no longer able to maintain this relay in the energized condition. When this occurs relay 2CR resumes the illustrated position closing its contacts *b* and completing an obvious energizing circuit through the now closed contacts *c* of relay 3CR for the coil of the motor controlling switch 50. Completion of this circuit causes switch MC to close, closing its contacts MCa, MCb, and MCC. These contacts directly shunt the respective pairs of ignitrons and complete direct metallically conductive circuits for the motor windings.

If it is desired to stop the motor, the stop button *Sp* may be momentarily opened. This action de-energizes relay 3CR which in turn opens its contacts *b* to de-energize relay 4CR, and the opening of contacts *c* of the relay 3CR de-energizes the motor switch MC causing its contacts MCa, MCb, and MCC to open and again insert the ignitrons I1 to I6 in the motor circuit. De-energization of relay 4CR re-establishes the original negative bias on the grids of the triodes 23, 23B, and 23C and the opening of contacts *b*, *c*, *d*, *e*, *f*, and *g* opens the igniting circuits for all of the ignitrons I1 through I6, and thereby prevents further firing thereof. The restoration of the original bias on triode 23C re-energizes relay 2CR which opens its contacts *b* to control recompletion of the energizing circuit for the coil 50 of the motor controlling switch MC when the contacts *c* of relay 3CR close as a consequence of the reclosure of the start switch *St* in restarting the motor 1. If desired, a conventional timing mechanism may be applied to the contacts *b* through *g* of relay 4CR so that the reopening thereof does not occur until after the phase-shifting circuits 16, 16A and 16B have reduced

6

the voltage supplied to the motor. The foregoing stopping actions restore the system to its original condition, in readiness for another starting operation, which may be initiated and controlled as aforesaid.

Although only a single embodiment of the invention has been described in detail it will be appreciated that various modifications in the form, number and arrangement of parts may be made without departing from the spirit and scope of the invention.

What is claimed is:

1. In a control circuit for supplying power to a load device from a three-phase power line, said load device having a plurality of input terminals, the combination which comprises two banks of electronic tubes connected between said line and said input terminals to provide going and return current paths for load current, each said tube having a control electrode, firing means connected in circuit with the control electrodes of the tubes in both of said banks for initiating the conduction periods of such tubes, the firing means for at least one of said banks being adjustable so as to effect the firing of the corresponding tubes in predetermined adjustable phase relation to the power-line voltage, a contactor connected in shunt with the tubes of a first of said banks, and terminating means for opening said contactor to remove the shunt around said tubes of said first bank and for thereafter rendering said firing means ineffective to fire said tubes.

2. In a motor-control circuit for supplying power to a three-phase motor from a three-phase power line, said motor having a plurality of input terminals, the combination which comprises three pairs of electronic tubes, the tubes in each pair being connected back-to-back and each such pair being connected between one of the conductors of said power line and one of said input terminals, each tube having a control electrode, and voltage-supply means connected in circuit with the control electrode of both tubes of each of said pairs for initiating conduction periods in said tubes, the voltage-supply means for one tube of each pair being adjustable so as to controllably vary the positions of half cycles of conduction of the corresponding tubes, a contactor having a circuit controlling portion connected in shunt with at least one pair of said tubes, and means actuated by said voltage-supply means for actuating said contactor.

3. In a control circuit for supplying power to a load device from a three-phase power line, said load device having a plurality of input terminals, the combination which comprises two banks of electronic tubes connected between said line and said input terminals to provide going and return current paths for load current, each said tube having a control electrode, firing means connectible in circuit with the control electrodes of the tubes in both of said banks for initiating the conduction periods of such ignitrons, the firing means for at least one of said banks being adjustable so as to effect the firing of the corresponding tubes in predetermined adjustable phase relation to the power-line voltage, a contactor having circuit controlling elements connected in shunt with each of said tubes of a first of said banks, an initiating device, and sequencing means responsive to the operation of said initiating device for connecting said firing means in circuit with said control electrodes and for thereafter energizing said contactor.

4. In a control circuit for supplying power to a load device from a three-phase power line, said load device having a plurality of input terminals, the combination which comprises two banks of electronic tubes connected between said line and said input terminals to provide going and return current paths for load current, each said tube having a control electrode, firing means connected in circuit with the control electrodes of the tubes in both of said banks for initiating the conduction periods of such tubes, the firing means for at least one of said banks being adjustable so as to effect the firing of the corre-

sponding tubes in predetermined adjustable phase relation to the power-line voltage, mechanical contactor means operable to by-pass said banks of tubes and provide direct conductive connections between said source and between said power-line and said load device, switch means for initiating the operation of said firing means, and means effective a preselected period after actuation of said switch means and independent of the back electromotive force of the load device for actuating said mechanical contactor means.

5. In a control circuit for supplying power to a load device from a three-phase power line, said load device having a plurality of input terminals, the combination which comprises two banks of electronic tubes connected between said line and said input terminals to provide going and return current paths for load current, each said tube having a control electrode firing means connected in circuit with the control electrodes of the tubes in both of said banks for initiating the conduction periods of such tubes, the firing means for at least one of said banks being adjustable so as to effect the firing of the corresponding tubes in predetermined adjustable phase relation to the power-line voltage, mechanical contactor means operable to by-pass said banks of tubes and provide direct conductive connections between said power-line and said load device, initiating means for actuating said firing means to initiate a supply of power to the load device and for thereafter varying said adjustable firing means in accordance with a predetermined pattern to increase said supply of power, and means operable in timed relation to said increase for actuating said mechanical contactor means.

6. In a control circuit for supplying power to a load device from a three-phase power line, said load device having a plurality of input terminals, the combination which comprises two banks of electronic tubes connected between said line and said input terminals to provide going and return current paths for load current, each said tube having a control electrode firing means connected in circuit with the control electrodes of the tubes in both of said banks for initiating the conduction periods of such tubes, the firing means for at least one of said banks being adjustable so as to effect the firing of the corresponding tubes in predetermined adjustable phase relation to the power-line voltage, a contactor having three switch portions individually connected in shunt with the tubes of a first of said banks of tubes, initiating means for actuating said firing means to initiate a supply of power to the load device and for thereafter varying said adjustable firing means in accordance with a predetermined pattern to correspondingly increase the said supply of power to said load device, said initiating means thereafter being operable to actuate said contactor to close said switch portions.

7. In a control circuit for supplying power from a source of alternating current to a load device which has a pair of terminals, the combination which comprises a pair of electric valves connected in back-to-back relation to pass alternating current therethrough, firing means operatively associated with said valves for controlling current flow therethrough, said firing means including a control device having a first condition in which said firing means is effective to permit current to flow through said valves, said control device having a second condition in which said firing means is effective to prevent current flow through said valves, an electric switch having circuit open and circuit closed positions connected in shunt circuit with said valves, and control means to sequentially actuate said electric switch and said control device.

8. In a control circuit for supplying power from a source of alternating current to a load device which has a pair of terminals, the combination which comprises a pair of electric valves connected in back-to-back relation to pass alternating current therethrough, firing means operatively associated with said valves for controlling cur-

rent flow therethrough, said firing means including a control device having a first condition in which said firing means is effective to permit current to flow through said valves, said control device having a second condition in which said firing means is effective to prevent current flow through said valves, an electric switch having circuit open and circuit closed positions connected in shunt circuit with said valves, and control means to sequentially actuate said electric switch to its circuit open position and thereafter actuate said control device to its said second condition.

9. The combination of claim 8 in which said control means includes a timing apparatus for determining the time interval between the actuation of said electric switch and the actuation of said control device.

10. The combination of claim 8 in which said control means is effective to sequentially actuate said control device to its said first condition and thereafter actuate said electric switch to its circuit closed position.

11. In a control circuit for supplying power to a load device from a three-phase power line, said load device having a plurality of input terminals, the combination which comprises two banks of electronic tubes connected between said line and said input terminals to provide going and return current paths for load current, each said tube having control means, a firing network connected to said control means for controlling the initiation of current flow through said tubes, said network including a phase controlling circuit for varying the point of firing of said tubes of at least one of said banks, a contactor having circuit controlling portions individually connected in shunt with said tubes of a first of said banks, an initiating means for rendering said firing network effective to fire said tubes of said one bank at one firing point and for thereafter rendering said phase controlling circuit effective to shift the phase at which said tubes of said one bank fire, means responsive to said phase controlling network for actuating said contactor to shunt said tubes of said one bank, a terminating means, means responsive to said terminating means for rendering said contactor ineffective to shunt said tubes of said one bank and for thereafter rendering said firing network ineffective to initiate current flow through said tubes.

12. The combination of claim 11 in which said terminating means actuates said phase controlling network to shift the phase at which said tubes of said one bank fire.

13. The combination of claim 11 in which there is provided a timing means for determining the time interval between the time of actuation of said contactor by said terminating means and the time of rendering said firing network ineffective to initiate current flow through said tubes.

14. The combination of claim 13 in which said terminating means actuates said phase controlling network to shift the phase at which said tubes of said one bank fire.

15. In a control circuit for supplying power from a source of alternating current to a load device which has a pair of terminals, the combination of which comprises means including an electric valve connected to pass alternating current from the source to the load device, firing means operatively associated with said valve for controlling current flow therethrough, said firing means including a control device having a first condition in which said firing means is effective to permit current to flow through said valve, said control device having a second condition in which said firing means is effective to prevent current flow through said valve, an electric switch having circuit open and circuit closed positions connected in shunt circuit with said valve, and control means to sequentially actuate said electric switch and said control device.

16. In a control circuit for supplying load to a load device from a power line, said load device having a plurality of input terminals, the combination of which comprises means including electronic valve means connected between said line and said input terminals to provide

9

going and return current paths for load current, said electronic valve means having a control element, firing means connected in circuit with said control element for initiating the conduction periods of said electronic valve means, the firing means being adjustable so as to effect the firing of the electronic valve means in predetermined adjustable phase relation to the power-line voltage, mechanical contactor means operable to by-pass said electronic valve means and provide direct conductive connections between the power line and the load device, initiating means for actuating said firing means to initiate a supply of power to the load device and for thereafter varying the adjustable firing means in accordance with a predetermined pattern to increase said supply of power, and means operable in timed relation to said increase for actuating said mechanical contactor means.

17. The combination of claim 16 in which said initiating means includes a phase shifter including a pair of impedance elements one of which includes controllable electronic valve means, and means for varying the conductivity of said controllable electronic valve means in accordance with a predetermined time pattern, and in which said means operable in timed relation to said increase is controlled by said controllable electronic valve means.

18. The combination of claim 17 in which said controllable electronic valve means includes a pair of tubes having anodes energized from a source of electrical energy, and in which said means operable in timed relation to said increase includes a current responsive device connected between said anodes of said tubes and effectively shunted by said tubes at a preselected conductivity of said tubes.

19. In a motor control system for supplying power to

10

a three-phase motor from a source of three-phase alternating voltage, said motor having three input terminals, the combination which comprises three pairs of reversely connected periodically conductive electronic tubes, each said pair being connected between said source and an individual one of said motor terminals, said pairs providing going and return current paths for motor current, each of said tubes having a control electrode, and means for controlling conduction of said tubes comprising phasing means connected in circuit with the control electrodes of at least one of the tubes of each of said pairs for rendering said ones of said tubes conductive for portions of half periods of said voltage, a starting switch, circuit means including said phasing means and operative in response to and after operation of said switch for progressively increasing said portions as a continuous function of time and at a selectable and controlled time rate, a contactor having a circuit controlling portion connected in shunt with at least one pair of said tubes, and means actuated by said circuit means for actuating said contactor.

References Cited in the file of this patent

UNITED STATES PATENTS

25	2,299,911	Logan	Oct. 27, 1942
	2,444,186	Elliot et al.	June 29, 1948
	2,663,834	Large et al.	Dec. 22, 1953
	2,681,428	Rockafellow	June 15, 1954
	2,703,860	Large et al.	Mar. 8, 1955
30	2,726,356	Rockafellow	Dec. 6, 1955
	2,731,594	Rockafellow	Jan. 17, 1956

FOREIGN PATENTS

386,992	Great Britain	Jan. 23, 1933
---------	---------------	---------------