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(54) Valve actuators

(57) The actuator includes a reversible polyphase electric motor (M) and an integral starter circuit including coupling means (4,5), through which the terminals for connecting the circuit to a polyphase electric supply are connected to the motor terminals and by means of which the sense of phase rotation at the motor terminals can be reversed relatively to the sense of phase rotation at the terminals. Also provided is a control circuit (7) for sensing the phase sequence of the electrical supply and which is operative such that the sense of phase rotation at the motor terminals is in a direction to cause rotation of the motor in a selected direction irrespective of the sense of phase rotation at said terminal means.

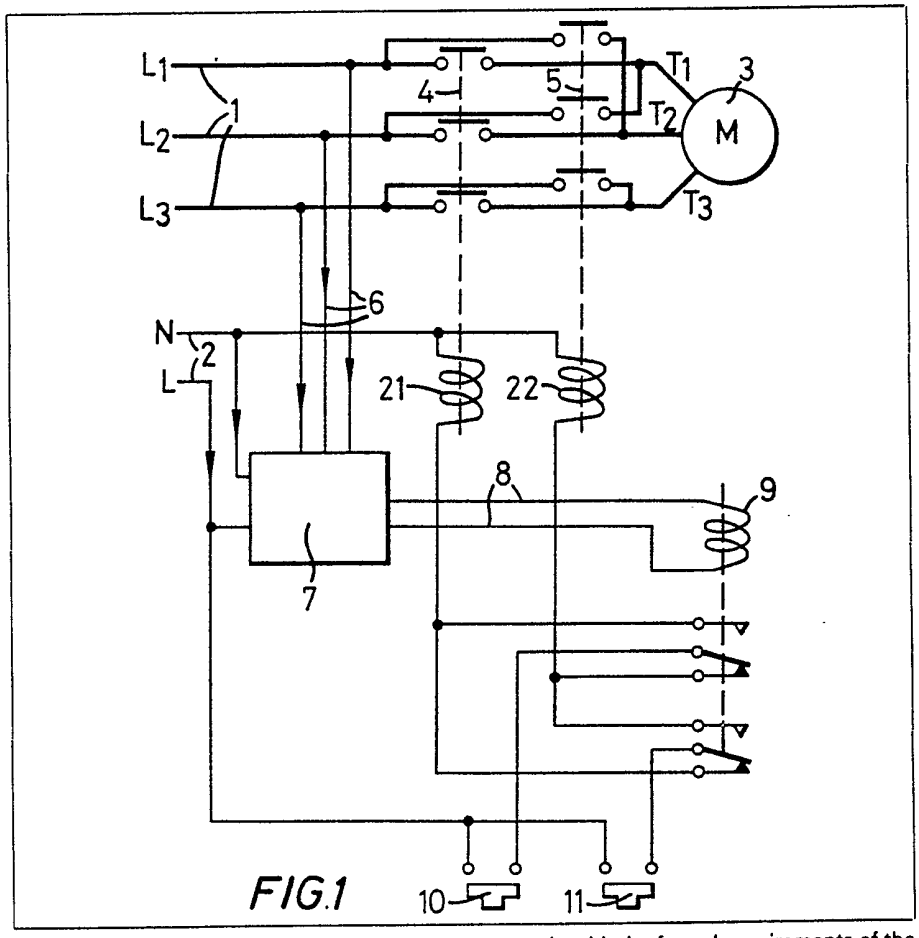

FIG.1

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This print takes account of replacement documents later filed to enable the application to comply with the formal requirements of the Patents Rules 1978.

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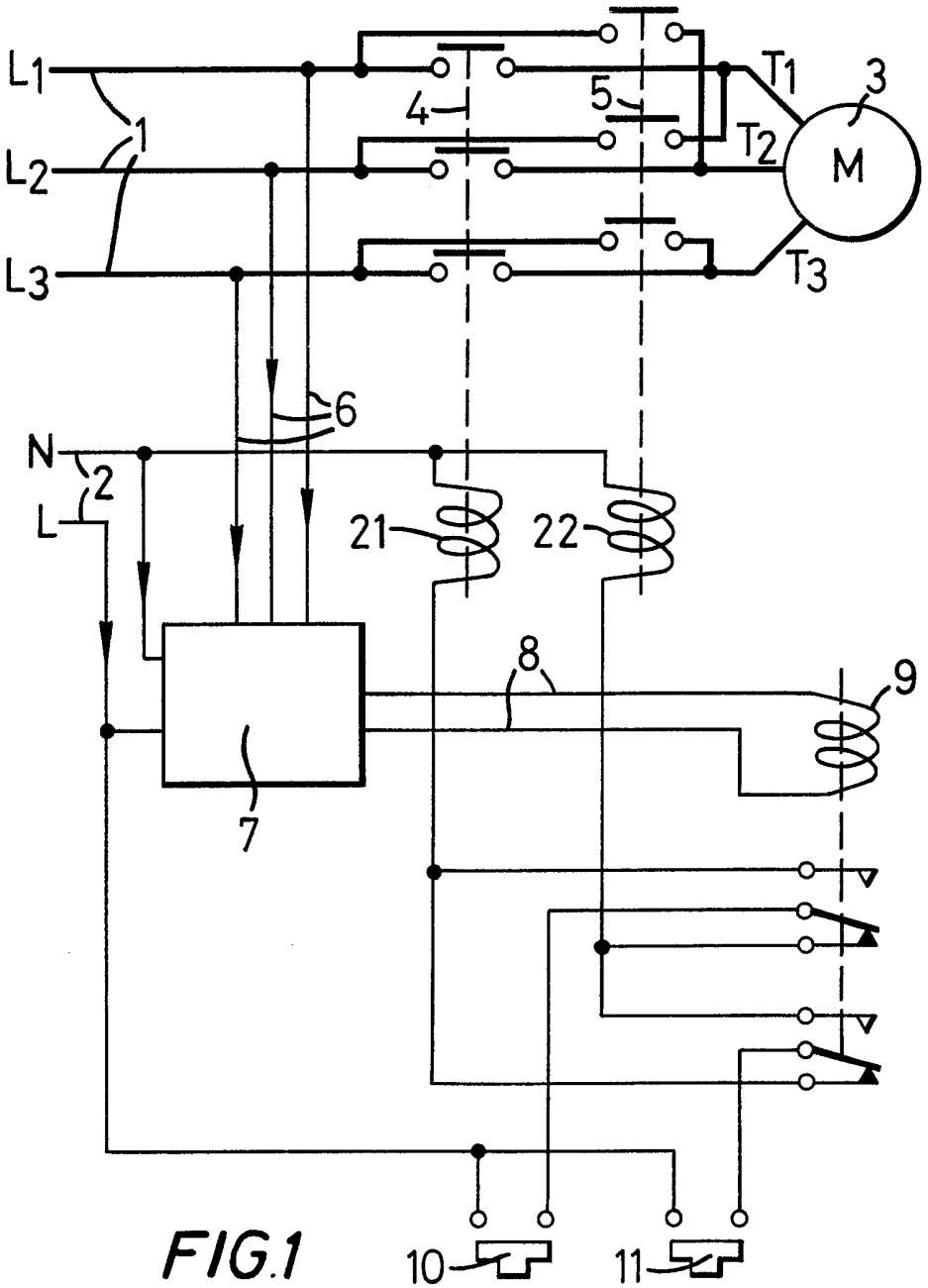

FIG.1

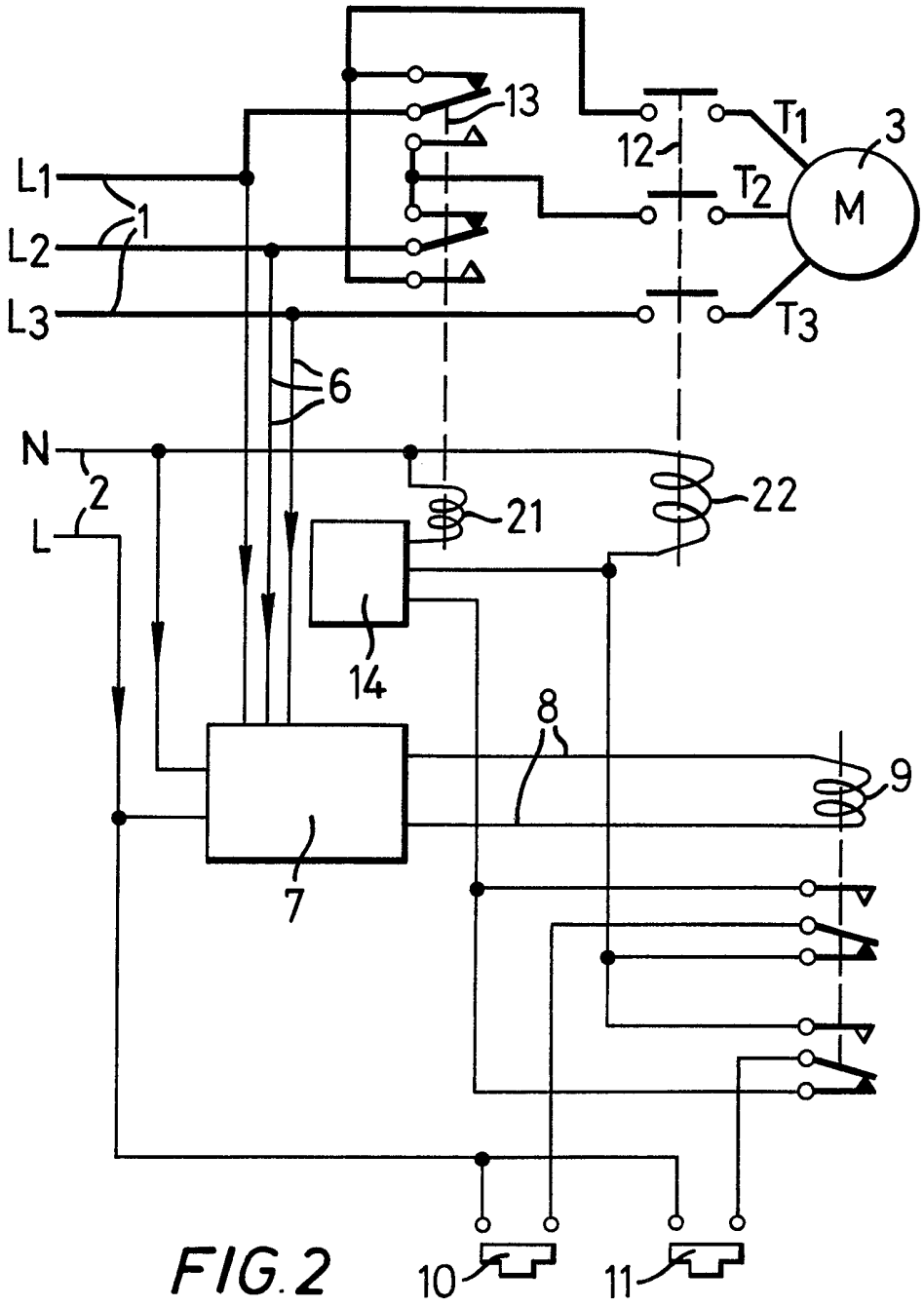

FIG. 2

POOR QUALITY

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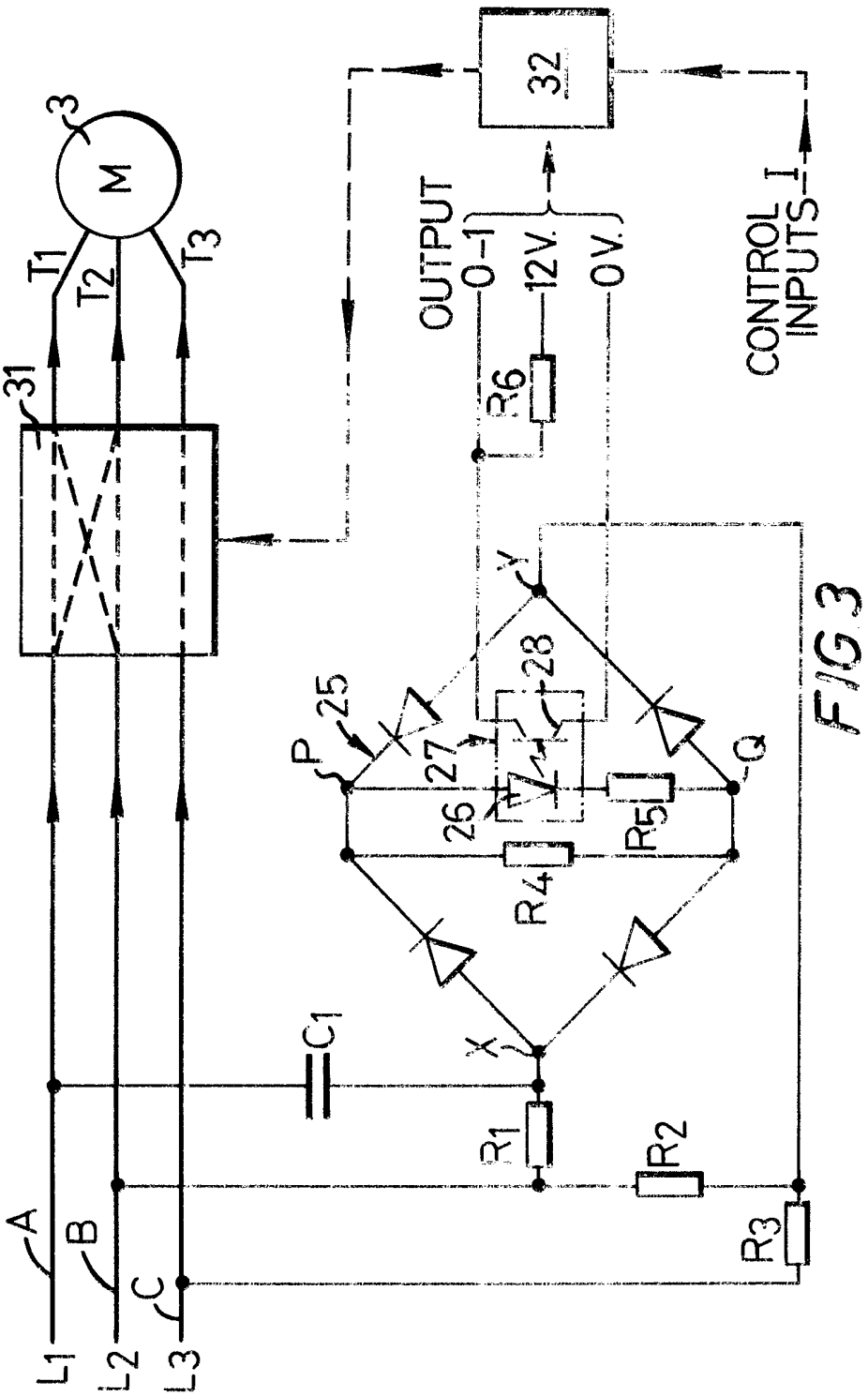

FIG 3

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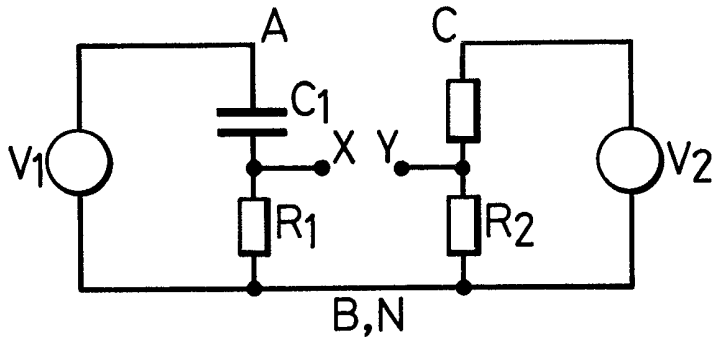

FIG.4

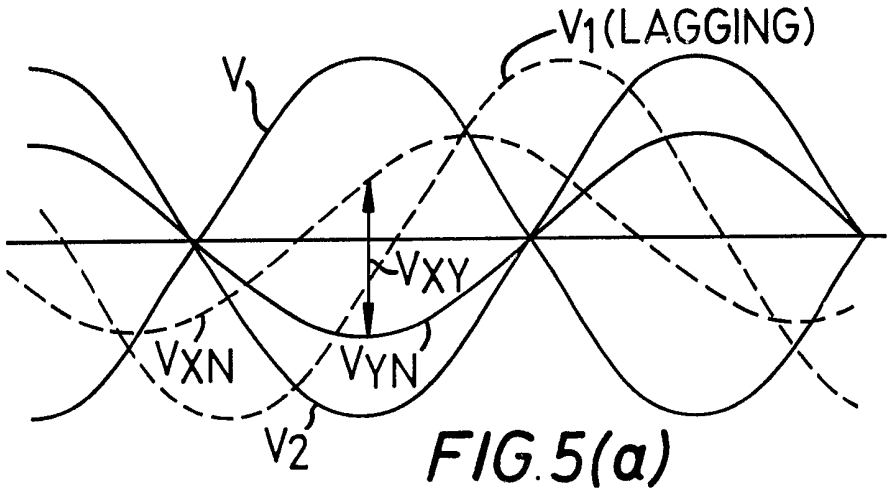

FIG.5(a)

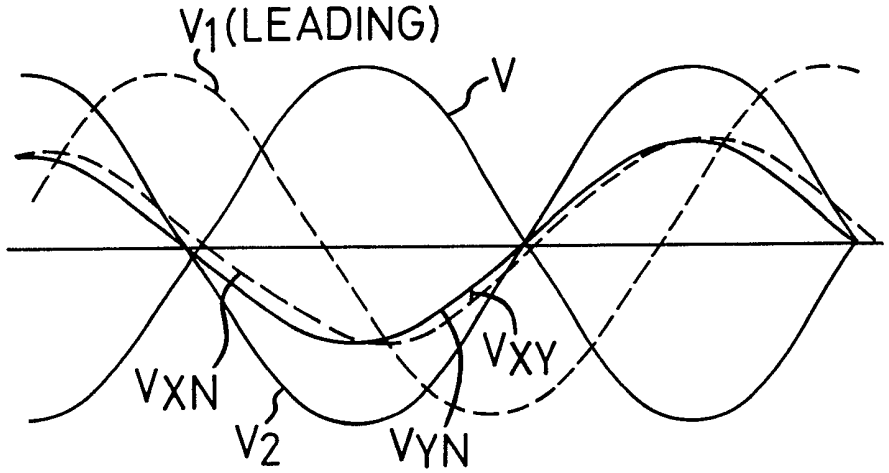

FIG.5(b)

SPECIFICATION

Valve actuators

This invention relates to valve actuators and particularly to the control aspects of such valve actuators.

The invention is more particularly concerned with relatively large sized valve actuators which even at the smaller end of the range are capable of providing a valve operating torque typically of the order of 3 kg.m and at the larger end of the range are capable of providing a valve operating torque of the order of 1000 kg.m. Such valve actuators find wide application for example in the thermal power generation, gas storage and oil storage industries as well as having marine, penstock and other specialised applications. When such actuators are in use their designed operating speed and torque requirements are very important, as is their back-up control system to ensure safe and reliable operation.

Such valve actuators have an output shaft driven by a reversible motor through gearing, e.g. worm and worm-wheel gearing, and which can rotate the output shaft in either direction to open or close a valve drivingly connected to the output shaft. Opening and closing of the valve, i.e. starting of the motor in either direction is initiated by a switch for example a push button. The stopping of the electric motor is under the control of "open" and "close" travel and torque limit switches.

The operation of the switches to initiate opening or closing of the valve causes the appropriate energisation of the motor starter circuit, e.g. reversing contactors or equivalent static switching components, so that the motor starts to rotate in the desired direction. The present invention is particularly, but not exclusively concerned with actuators in which the starter circuit is integral with the actuator, i.e. is located within the housing of the actuator. Depending upon the environment in which the actuator is to be used the housing may be either flame-proof or fluidtight.

The reversible electric motor usually comprises a three phase induction motor. With three phase induction motors the direction of rotation of the motor is determined by the phase rotation of the electrical supply to the motor. If the electrical power leads to the actuator are incorrectly connected the phase rotation of the electrical supply will not be in the selected direction. This can have serious consequences. For example when the "close" button is pressed the motor will rotate in the valve opening direction and vice versa. Furthermore the travel limit and torque switches may fail to protect the actuator because these switches are normally wired to stop the motor when travel is in the selected direction, e.g. the "open" limit switch circuit will only stop the motor when it is rotating to drive the actuator in the "open" direction.

In U.K. Patent Specification No. 1 144 188 there is described a valve actuator whose integral motor starter circuit is provided with a control circuit for preventing the polyphase electric motor from starting in the event that the phase rotation of the electrical supply is in the wrong direction. A visual warning is also given if an attempt is made to start the motor with supply incorrectly connected.

The disadvantage of this control circuit is that if a wrong connection has been made, a skilled engineer must than be brought into correct the fault. Correction of the fault can be very expensive because the actuator is out of commission until the fault is corrected, and time consuming.

An object of the present invention is to provide a control circuit which is so arranged that the reversible polyphase motor will always operate in a selected direction irrespective of the sense of phase rotation of the incoming supply at the input terminals of the actuator.

According to the present invention in a valve actuator having a reversible polyphase electric motor and including terminal means for connection to a polyphase electrical power supply, means coupling the terminal means to the motor such that the sense of phase rotation of the power supply at the motor terminals can be reversed and control means operable on said coupling means to permit selection of the direction of rotation of the motor, a control circuit is provided for sensing the phase sequence of the electrical supply and operative such that the sense of phase rotation at the motor terminals is in the direction to cause rotation of the motor in either selected direction irrespective of the sense of phase rotation at said terminal means.

The coupling means may comprise contactor means in the supply lines between said terminal means and said motor terminals and whose energisation is selectively controlled.

The coupling means may alternatively comprise contactor means and a change-over relay connected in the supply lines between said terminal means and said motor terminals, energisation of the relay coil being selectively controlled and a time delay circuit being provided to delay energisation of said contactor means relative to said change-over relay.

The control circuit may include a phase discriminator circuit which detects the phase sequence at said terminal means and produces a first output signal when the phase sequence of the power supply is in a first sense and a second output signal when said phase sequence is in the opposite sense said first and second output signals being operative such that the phase connections at said motor terminals when said first output signal is present are the reverse of when said second output signal is present. The phase discrimina-

tor circuit may include an opto-isolator circuit whereby said first and second signals are derived from a photo-detector.

The invention will be described now by way of example only with particular reference to the accompanying drawings. In the drawings:–

Figure 1 is a block diagram illustrating one embodiment of the present invention as applied to a reversing contactor starter of a valve actuator,

Figure 2 shows a second embodiment of the invention applied to a single three-phase contactor having a phase reversing power relay, of a valve actuator.

Figure 3 shows a third embodiment of the invention as applied to a valve actuator and having a phase discriminator employing an opti-isolator,

Figure 4 shows the equivalent of the phase discrimination circuit included in the embodiment of Fig. 3 for the purpose of explaining its operation, and

Figure 5 shows the voltage wave-forms as derived from Fig. 4.

The drawings have been simplified and do not show for example the related control circuits concerned with sustaining the contactors in a desired state until the valve travel limit or torque limit switch has been operated.

Referring now to Fig. 1, a three-phase power supply circuit has power supply terminals 1 which in use are connected to a three-phase source and which are designated "L1", "L2", "L3" and control supply terminals 2 which are designated "L" and "N". The control supply may be independent or may be obtained from the main three-phase supply by means of a step-down transformer with its primary winding connected to two of the three supply phases.

The power supply is fed to terminals T1, T2 and T3 of a polyphase induction motor 3 via a pair of reversing contactors of standard design. One contactor set 4 is arranged to couple the three-phases direct to the motor and the other set 5 is arranged to reverse two of the three phases in a known manner as illustrated. Three signal leads extend from the power suppy lines to a phase discriminator circuit shown as a block 7. The circuit within this block comprises a resistance and capacitance network so arranged that if the phase rotation of the power supply is in one direction, a control current appears on lines 8 leading to the coil of a control change-over relay 9. If the phase rotation is in the other direction, no current flows in the lines 8 and relay coil 9 remains de-energised as shown in Fig. 1. A typical phase discriminator circuit is described in U.K. Patent Specification No. 1 144 188.

Open and close buttons 10, 11 are connected to a contactor coil 21 and to a contactor coil 22 via the control change-over relay such that the open button 10 operates on coil 22 and the close button 11 on the coil 21 when the control change-over relay 9 is de-energised, and vice versa when the relay is energised.

The circuit operates in the "close" direction of the valve actuator as follows:–

Suppose that the motor 3 is required to rotate clockwise for the "valve close" operation, and that this direction is obtained when the phases at the supply terminals L1, L2 and L3 are in a clockwise sense and the connections required are L1 to T1, L2 to T2, L3 to T3. In this state the phase discriminator circuit is not passing current to the control change-over relay 9 via the lines 8 so that, when the "close" button is depressed, coil 21 of the contactor 4 is energised thereby connecting L1 to T1 and so on.

If two of the power supply leads are reversed at the terminals 1 the incoming supply phases will be in an anti-clockwise sense. This causes the phase discriminator circuit 7 to energise the coil of the control change-over relay 9 so that if the "close" button 11 is now depressed, coil 22 of the contactor 5 is energised instead of coil 21 as previously described. Since contactor set 5 reverses the phase rotation, the motor connection will now be L1 to T2, L2 to T1 and L3 to T3.

As the incoming mains leads have been reversed, the motor will still rotate in the desired clockwise direction. A similar description applies to the "valve open" operation.

As previously stated, the various travel limiting and monitoring parts of the control circuit have not been illustrated as these do not affect the operation of the circuit being described. It will also be appreciated that the functions of the control change-over relay and the main motor contactors would be achieved by the use of solid state electronic devices.

Referring to Fig. 2 the conventional pair of reversing contactors has been replaced by a single three phase contactor 12 and a power change-over relay 13. A time delay circuit 14 has also been added to the circuit. The purpose of the time delay circuit is to allow the power change-over relay 3 to operate and its contacts to be closed before the main contactor 12 operates, so that the relay contacts never close with current passing. Also the time delay circuit 14 prevents the power change-over relay from opening its contacts before the contactor has disconnected the current.

The operation of the circuit of Fig. 2 is similar to the operation described and illustrated in Fig. 1, except that the push buttons 10, 11 operate either the contactor 12 directly or the power change-over relay 13 depending on the state of the control change-over relay 9. When the power change-over relay 13 is operated, the time delay circuit is activated and pulls in the main contactor 12 a

short time after the power change-over relay contacts have been made.

It is also possible to provide an auxiliary contact on the power change-over relay 13. This auxiliary contact can be arranged to activate the time delay circuit 14 so that the main contactor 12 cannot operate until the power change-over relay has operated, when selecting a motor direction which requires the latter to be operated. It may be possible to dispense with the time delay circuit if the natural time response of the control circuit is sufficiently long to ensure that full contact pressure on the power change-over relay has been obtained by the time the main contactor closes its contacts following the closing of the power change-over auxiliary contact. It will be appreciated that, although an electro-mechanical mechanism is illustrated in Fig. 2 for the power change-over relay, a solid state device could be used as an alternative.

In both Figs. 1 and 2, the phase discriminator circuit 7 is shown permanently coupled to the incoming supply. This has the effect of permanently energising the coil of the control change-over relay 9 if the incoming supply connections are connected with the phase rotation in one direction. In certain situations it may not be desirable to have this coil possibly energised permanently or not depending on the manner the incoming supply is connected. Accordingly, it may be required in certain situations to provide an extra contact on the "open" and "close" buttons 10, 11 the arrangement being such that this contact closes before the main button contact. These extra contacts would be wired in parallel at the buttons and arranged to complete the circuit between lines 8 and the control change-over relay 9. In these circumstances the relay coil can only be energised if either one of the open or close buttons is pressed and the phase discriminator circuit is calling for the change-over relay to be operated.

The present circuit may also be used in applications where the motor is required to rotate always in one direction, and where the motor shaft cannot be viewed or its directon of rotation otherwise determined—for example, in sealed wet rotor chemical pumps provided with a polyphase stator winding and fitted with an integral starter and protection circuits. In such an application the circuit illustrated in Fig. 1 or Fig. 2 can be used, but omitting the close button 11 and its associated change-over contact on the control change-over relay 9 and retaining button 10 as a motor start button.

Referring to Fig. 3 the power supply circuit has power supply terminals L1, L2 and L3 which in use are connected to a three-phase source and from which lines A, B and C extend via a phase reversing contactor set 31 to motor terminals T1, T2 and T3. The contactor set 31 in one state connects line A and B to motor terminals T1 and T2 respectively to cause the motor 3 to rotate in one direction and in its other state connects lines A and B to terminals T2 and T1 respectively to reverse the sense of phase rotation at the motor terminals and cause the motor to rotate in the reverse direction.

The state of the contactor set 31 is controlled by control inputs I fed via a logic board 32 to the contactor set 31. Thus a first control input 1 will cause the motor 3 to rotate in one direction and a second input I will cause the motor 3 to rotate in the reverse direction. To ensure that for each of the first and second inputs the motor always rotates in a predetermined direction, even if the terminals L, L2, L3 have been wrongly connected to the three phase supply source a control circuit including a phase discriminator circuit as will be described is connected across the lines A, B and C and supplied either a logic 0 or 1 to the logic board 32 depending upon the phase sequence detected by the control circuit. In this way the phase sequence is corellated to the operative input signal I so that the output from the logic board 32 sets the state of contactor set 31 and hence sense of phase rotation at the terminals T1, T2, T3 to cause motor 3 to rotate in the prdetermined direction irrespective of the sense of phase rotation at the terminals L1, L2 and L3. Thus in the case of a valve actuator the first input I can with security be arranged to cause rotation of the motor 3 to drive the valve actuator for example in the valve closing direction and the second input I can be arranged to cause rotation of the motor 3 to drive the valve actuator in the valve opening direction.

The control circuit includes a rectifier bridge 25 whose input terminals X, Y are connected to the lines A, B and C through resistors R_1, R_2 and R_3 and capacitor C1 as shown. Fig. 4 shows the equivalent circuit of the connections of the lines A, B, C to the terminals X,Y.

V1 as represented in Fig. 4 is the voltage between lines A and B, i.e. between line A and common point N and is given by Vsin

$$(\omega t \pm \frac{2\pi}{3})$$

where V is the rms value of the three phase supply and V2 is the voltage between lines C and B, i.e. between line C and common point N and is given by (− V sinwt).

The open circuit voltage, V_{xy} appearing between terminals X and Y is given by:–

$$V_{xy} = V_{xN} - V_{yN}$$

V_{xN} leads V1 by $\tan^{-1}X_{C1}/R_1$ and has an rms magnitude equal to $VR_1/(R_1^2 + X^2_{C1})^{\frac{1}{2}}$ where X_{C1} is the reactance of capacitor C1. V_{yN} is in phase with V2 and has an rms magnitude

$(VR_2/(R_2 + R_3)$. If V1 is lagging V2 the voltage waveforms shown in Fig. 5a are produced. If V1 is leading V2 the voltage waveforms shown in Fig. 5b are produced.

It can be seen that V_{xy} can be zero when V1 is leading V2 by 120°, if tan $^{-1}X_{C1}/R_1$ is 60° and if the magnitudes of V_{xN} and V_{yN} are the same. Under these conditions V_{xy} has a considerable amplitude when V1 is lagging V2 by 120°. These conditions can be achieved by suitable choice of the components R_1, R_2 and R_3 and C1.

Connected across the output terminals PQ of the bridge is a light emitting diode 26 forming part of an opto-isolator 27, the opto-isolator 27 also having a photo-detector 28d. Thus when the voltage V_{xy} is zero indicating a sense of phase rotation ABC, no light is output from the diode 26 and the detector 28 produces a binary 1 output. However, when the voltage V_{xy} is greater than zero light is output from diode 26 and detector 28 produces a binary 0 output indicating a sense of phase rotation ACB.

As previously described if the correct connection of the terminals L1, L2 and L3 is to produce the sense of phase rotation ABC and by mistake the connection has been made to produce the sense of phase rotation ACB, then the binary 0 output from the control circuit will be correlated with the operative control input I to produce the same phase rotation at the motor terminals T1, T2 and T3 as if the sense of phase sequence at the terminals L1, L2 and L3 had been ABC.

Thus it will be seen that the present invention provides an arrangement which ensures that a polyphase motor operates in the required direction irrespective of the phase sequence of the power supply.

CLAIMS

1. A valve actuator having a reversible polyphase electric motor and including terminal means for connection to a polyphase electrical power supply, means coupling the terminal means to the motor such that the sense of phase rotation of the power supply at the motor terminals can be reversed and control means operable on said coupling means to permit selection of the direction of rotation of the motor, wherein a control circuit for sensing the phase sequence of the electrical supply and operative such that the sense of phase rotation at the motor terminals is in the direction to cause rotation of the motor in either selected direction irrespective of the sense of phase rotation at said terminal means.

2. A valve actuator according to Claim 1, wherein said control circuit includes a phase discriminator circuit which detects the phase sequence at said terminal means and produces a first output signal when the phase sequence of the power supply is in a first sense and a second output signal when said phase sequence is in the opposite sense said first and second output Signals being operative such that the phase connections at said motor terminals when said first output signal is present are the reverse of when said second output signal is present.

3. A valve actuator according to Claims 2, wherein said control means is operable to control said coupling means so that the phase connections at said motor terminals are revesed when a reversal of motor direction is selected.

4. A valve actuator circuit according to Claim 3, wherein said pulse discriminator circuit includes an opto-isolator circuit whereby said first and second output signals are derived from a photo-detector.

5. A valve actuator according to Claim 4, wherein said opto-isolator circuit comprises a rectifier bridge circuit having a photo emitter device connected across the output terminals of the bridge, the input terminals of the bridge being connected across said terminal means in such a manner that when the sequence of phase rotation is in a first sense said photo emitter device is "on" and when in the opposite sense said photo emitter device is "off".

6. A valve actuator according to any one of Claims 2 to 5, wherein said coupling means comprises contactor means in the supply lines between said terminal means and said motor terminals and whose energisation is selectively controlled by said first and second output signals.

7. A valve actuator according to Claim 6, wherein said control means for determining the direction of motor rotation are arranged to control the energisation of said contactor means in combination with said control circuit for sensing the phase sequence of the electrical supply at said terminal means.

8. A valve actuator according to any one of Claims 2 to 5, wherein said coupling means comprises contactor means and a change-over relay connected in the supply lines between said terminal means and said motor terminals, energisation of the relay coil being selectively controlled by said first and second output signals and a time delay circuit being provided to delay energisation of said contactor means relative to said change-over relay.

9. A valve actuator according to Claim 8, wherein said control means for determining the direction of motor rotation are arranged to effect energisation of said contactor means and to control the enrgisation of said change-over relay in combination with said control circuit for sensing the phase sequence of the electrical supply at said terminal means.

10. A valve actuator according to any preceding claim, wherein said control means exerts a control on said control circuit such that said control circuit is rendered operative only

upon the operation of said control means and just prior to the control means exerting its effect upon the coupling means.

11. A valve actuator substantially as hereinbefore described with reference to the accompanying drawings.

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