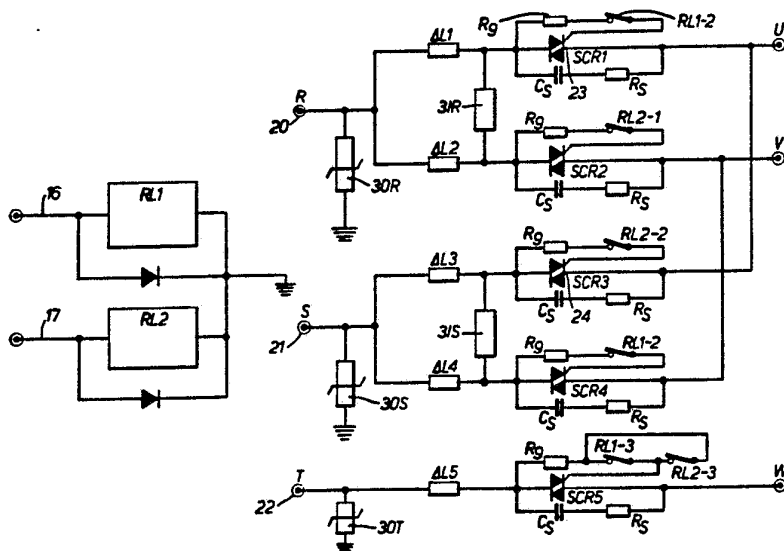




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(54) Title: ELECTRICAL CIRCUIT FOR SWITCHING A MULTI-PHASE A.C. SUPPLY TO A LOAD (57) Abstract An electrical switching circuit for a multi-phase a.c. supply uses semiconductor rectifier switches SCR1 to 5 to reversibly switch power to a multi-phase electric motor so that the motor can be run in a forward or a reverse direction. The SCRs are provided in two sets, one for switching power to forward run the motor, and the other set for the reverse running of the motor. Inductor elements ΔL are connected in series with the SCRs. In certain situations gross spurious over voltages may occur at the input phases, when subjected to lightning strikes, for example, which may result in spurious firing of the SCRs. It has been found by the provision of varistors between the input phases and ground, the input voltage can be clamped a maximum preset value, so preventing spurious firing of the SCRs. Also disclosed is the provision of further varistors in order to reduce the effects of voltage standing waves which may be produced due to the internal capacitances of the first mentioned set of varistors.		



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ELECTRICAL CIRCUIT FOR SWITCHING A
MULTI-PHASE A.C. SUPPLY TO A LOAD

This invention relates to an electrical circuit for switching a multi-phase a.c. supply to a load, and has particular application to reversibly switching a three phase a.c. supply to an electric
5 motor, for running, stopping and reversing the motor.

The invention can be used with particular advantage to control an electric motor used to drive a valve actuator.

Electrically driven valve actuators are
10 well known and have been used for many years to drive valves for controlling hydraulic and pneumatic flows in industrial process plants, for example in the operation of butterfly valves used in oil refineries. A known valve actuator, for example our Limitorque
15 Model SMC 2005, comprises a three phase electric motor which drives a reduction gearing having an output for connection to a valve to drive its valve member. The reduction gearing and the motor are mounted in a heavy explosion proof cast metal housing. Mounted in
20 a compartment within the housing is a set of electrical contactors which switch a three phase electrical supply to the motor so that the motor can be stopped, started and reversed. The contactors are operated by relay coils themselves driven from a single phase of the a.c.
25 supply.



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An improved circuit for controlling such an arrangement is disclosed in our European Patent Application 82303368.3 which circuit utilises a non-linear inductance in series with a controlled
5 rectifier device for each phase in order to prevent spurious operation of the controlled rectifier devices.

While this circuit is effective in normal operation, there are some exceptional circumstances
10 when even the improved circuit will not prevent spurious operation e.g. a lightning strike.

It is an object of the present invention to improve upon the circuit disclosed in our European Patent Application 82303368.3 and to that end a
15 variable resistance device is connected between one end of each non-linear inductance and ground.

Preferably, a further variable resistance device is connected across the downstream ends of the non-linear inductances of one or more phases.

20 Features and advantages of the present invention will become apparent from the following description of an embodiment thereof given by way of example with reference to the accompanying drawing which shows a circuit diagram of a switching circuit
25 according to the present invention.

A three phase motor switching circuit will now be described in detail with reference to the embodiment thereof shown in the drawing. The three input phases R.S.T. of an a.c. supply are fed to input
30 terminals 20, 21, 22 and the three phase inputs of a three phase motor are connected to terminals U.V. and W. Semiconductor rectifier switches in the form of triacs SCR1 - 5 control the connection of the input phases R.S.T. to the terminals U.V.W. To run the
35 motor in a forward direction the phases are connected



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as follows:-

R to U, S to V and T to W.

To reverse the motor the connection of the R and S phases is reversed, and the connections are

5 as follows:-

R to V, S to U, and T to W.

Thus, to run the motor forwardly, triacs SCR1, 4 and 5 need to be fired to a conductive state, which is achieved by means of a relay comprising a
10 coil RL1 and switching contacts RL1 - 1, 2 and 3. The relay coil RL1 is energised in response to a control signal on line 16 from the control logic circuit (not shown), the control signal being indicative that the motor is to be run forwardly. Each of the relay
15 contacts is connected in series with a dropping resistor Rg so that when the contacts are closed a suitable gate potential is derived from the a.c. supply and applied to the gates of SCR1, 4 and 5 to fire them to a conductive state. When the control signal on line
20 16 ceases, the relay RL1 is released, thus opening the contacts RL1 -1 to RL1 - 3, thus causing the SCRs 1, 4 and 5 to switch off and stop the motor.

Reverse running of the motor is controlled in a similar way by means of a relay RL - 2 having a
25 coil energised by a reverse running signal on line 17 from the control logic circuit (not shown). The relay RL2 has contacts RL2 - 1, 2, 3 which when closed, fire SCRs 2, 3 and 5 to a conductive state.

It will be appreciated that the electric
30 motor connected to the terminals U V and W essentially comprises an inductive load. Considering for the moment the triac SCR1, when it has been conductive and is then switched off, transients occur which would produce spurious firing of the triac if the following
35 precautions were not taken. Upon switching off of the



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triac SCR1 a substantial rapidly rising transient back emf is developed in the motor coils and the back emf is applied to SCR1. In response to such rapid transients, the impedance presented by the switched off triac SCR1, is defined predominately by the capacitances of the pn junctions on either side of the SCR's gate and thus, in the presence of the transient the SCR's equivalent circuit is two capacitors connected in series and on opposite sides of the gate electrode. The rapidly rising back emf can cause charge to build up in the capacitors defined by the triacs pn junctions so as to raise the gate potential sufficiently retrigger the triac into conduction. To prevent such spurious retriggering of the triacs, a snubber circuit comprising a snubber resistor R_s and a snubber capacitor C_s , provides a by-pass for the transient back emfs. The time constant of the snubber circuit is selected so that at the a.c. frequency of the supply, the snubber circuit presents a high impedance, but at the high frequency of the transient back emfs the transient currents pass preferentially through the snubber circuit so as to by-pass SCR1, thereby to prevent the spurious firing. Each of the SCRs 1 to 5 is provided with its own snubber circuit $C_s R_s$.

Another problem of spurious firing of the triacs occurs at switch on of the motor. It is to be noted that each of the input phases R and S can be selectively connected to the terminals U V by means of the SCRs 1 to 4, so that the motor can be run both forwardly and backwardly. An SCR behaves as a capacitor when in its "off" condition which means that the input circuit is a capacitively terminated line when the motor is de-energised or is running in one direction. There is a danger that the transients produced on switching on of say SCR1 will produce spurious firing of SCR3, which would result in a short circuit being produced across the phases R and S. A similar short circuit could be



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established if SCRs 2 and 3 became conductive simultaneously.

Considering now the switching on of SCR1, when the relay RL 1 is operated, a gate potential is applied to SCR 1 and it switches on. Consequently the potential at its cathode 23 rises to the potential of the input phase R. Thus, a very rapid rise of voltage could occur which if the precautions discussed hereinafter were not taken, would produce spurious firing of SCR 3. It will be appreciated that a substantially rectangular step wavefront could be established at the cathode 23 of SCR 1, which would be applied to cathode 24 of SCR 3. This step wavefront has a substantially greater rate of rise than the back emfs developed upon switching off of the SCRs and consequently the snubber circuit Cs Rs associated with SCR 3 would be unable to suppress the rapid voltage rise at the cathode 24. As a result, the rapid voltage rise associated with the switching on of SCR 1 would be likely to produce spurious firing of SCR 3 as a result of the transient voltage rise raising the gate potential of SCR 3. Similarly, firing on SCR 3 could produce spurious firing of SCR 1 and SCRs 2 and 4 would interact in a similar manner.

A similar problem arises when the phases R S and T are initially connected to the terminals 21, 22 and 23. Again, a step wavefront would be applied to the SCRs 1 to 5 which could produce simultaneous spurious firing of the SCRs, thereby producing a short circuit across the phases.

Such spurious firing and short circuiting of the phases is prevented by providing in series with the SCRs 1 to 5 respective inductor coils $\Delta L_1 - 5$ each provided with a core of a material exhibiting a non-linear permeability. The permeability of the core



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varies as a non-linear function of the frequency and magnitude of the applied field, and the core is typically made of ferrite material i.e. sintered carbides or iron powder material. The core may also be
5 made of permalloy, for example, Mulypermalloy manufactured by Magnetics, a division of Spang Industries Inc., P.O. Box 391, Butler Pa, 16001, U.S.A. or powdered soft iron.

The inductor coils ΔL have the effect of reducing the rate of rise of current to which the
10 SCRs are subjected so that no spurious firing occurs. By using a non-linear permeability core, the inductors appear to operate preferentially on the rapid transients which occur upon switch on; if a solid soft iron bar is used, the core inductors are heated by the a.c. supply
15 whilst the motor is running. Conversely if no core is used in the inductors, resonance at radio frequencies may be produced in response to switching of the SCRs
1 to 5.

The provision of the inductors $\Delta L1$ to 5 has
20 been found to provide reliable switching of the SCRs 1 to 5.

Thus far the circuit is as described in our European Patent Application 82303368.3. We have found, however, that in certain situations gross spurious
25 over-voltages may occur at the input phases R,S,T, e.g. when subjected to lightning strikes or other fault conditions. These over-voltages may also cause spurious firing of the semiconductor rectifier switches which cannot be cured by the inductor coils $\Delta L1-5$.

30 We have found that if a variable resistance device 30R, 30S, 30T is connected between the upstream end of the inductor coils in each phase respectively and ground then the effects of this particular problem can be ameliorated. Preferably, each device 30R,
35 30S, 30T is a varistor which operates to clamp the



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input voltage to a maximum preset value, say V_{trm} of its associated rectifier device. Varistors have the advantage of preventing sharp dv/dt changes such as might exist with an air gap arrestor.

- 5 For many instances, this addition to the circuit is sufficient but with presently available varistors, each varistor has an internal capacitance which is larger than the capacitance of each rectifier device and the presence of this upstream non-negative capacitance
- 10 could result in a reflected or standing wave signal being generated when varistor 30R, 30S, 30T operates. The signal may also be the result of manufacturing tolerances which cause a mismatch. The magnitude of this signal could be such as to cause spurious firing of the rectifier
- 15 devices. To overcome this difficult we provide each phase which is capable of being switched to reverse the motor with a further variable resistance device 31R, 31S which is connected between the downstream ends of the inductor coils of that phase. The effect of the
- 20 further resistance device 31R and 31S is to cause a circulating current to flow around the loop comprising L1, 31R and L2 for the R phase if the magnitude of the reflected or standing wave signal is greater than a preset value which for convenience is the same as that for
- 25 the varistors 30, in this case V_{trm} of the rectifier device.



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CLAIMS:

1. An electrical circuit for multi-phase switching of an a.c. electrical supply to a load, comprising input terminals (20,21,22) for receiving respective different phases (R,S,T) of an a.c. supply, output
5 terminals (U,V,W) for supplying the different phases to the load, means defining current paths between said input and said output terminals, said paths being arranged to connect the input terminals to respective ones of the output terminals in a first or a second
10 different predetermined relationship, each of said current paths including a respective semiconductor rectifier switching means (SCR1,SCR2,SCR3,SCR4,SCR5) for rendering the path conductive or non-conductive, said paths further including respective inductors
15 ($\Delta L_1, \Delta L_2, \Delta L_3, \Delta L_4, \Delta L_5$) each comprising a coil having associated therewith a core, wherein a respective variable resistance device (30R,30S,30T) is connected between each input terminal and ground, each variable resistance device being operable to clamp the input
20 voltage to a maximum preset value.
2. An electrical switching circuit according to claim 1 wherein said core is arranged to have a non-linear characteristic.
- 25
3. An electrical switching circuit according to claims 1 or 2 wherein an input terminal (20,21) has a first current path to a first output terminal (U) and a second current path to a second output terminal (V)
30 and wherein means are provided for selectively enabling



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the respective semiconductor rectifier switching means of each current path whereby to connect the input terminal to the respective first or second output terminal by the enabled semiconductor rectifier
5 switching means.

4. An electrical switching circuit according to claim 3, wherein a further variable resistance device (31R,31S) is provided between said first and second
10 current paths, said further variable resistance device being operable to prevent spurious firing of the respective semiconductor rectifier switching means which may otherwise occur as a result of the effect of the voltage standing wave produced due to the inherent
15 internal capacitance of said first variable resistance device.

5. An electrical switching circuit according to claim 4 wherein each of said current paths said
20 inductor is connected between said input terminal and said semiconductor rectifier switching means and said further variable resistance device has a first terminal connected to said first path between the inductor and the semiconductor rectifier switching
25 means and a second terminal connected to said second path between the inductor and the semiconductor rectifier switching means.



INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 84/00209

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) ³		
According to International Patent Classification (IPC) or to both National Classification and IPC		
IPC ³ : H 02 P 7/00 ; H 02 H 9/00		
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁴		
Classification System	Classification Symbols	
IPC ³	H 02 P 7/00; H 02 H 9/00; H 03 K 17/00	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁵		
III. DOCUMENTS CONSIDERED TO BE RELEVANT ¹⁴		
Category ⁶	Citation of Document, ⁸ with Indication, where appropriate, of the relevant passages ¹⁷	Relevant to Claim No. ¹⁸
Y	FR, A, 2204087 (LICENTIA PATENT VERWALTUNGS G.M.B.H.) 17 May 1974 see page 4, line 21 - page 6, line 11; figures 3,5,6 --	1-3
Y	FR, A, 2468527 (DIXON AUTOMATIC TOOL, INC.) 8 May 1981 see page 8, lines 34-38; figure 2 --	1
Y	EP, A, 0070633 (LIMITORQUE LTD.) 18 May 1983 see page 7, line 15 - page 10, line 35; figures 2,3 (cited in the application) --	1,2,3,4,5
A	US, A, 4259705 (F.J. STIFTER) 31 March 1981 see column 2, line 41 - column 3, line 26; figures 2,3 -----	1,4,5
¹⁵ Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search ²	Date of Mailing of this International Search Report ³	
12th September 1984	01 OCT. 1984	
International Searching Authority ¹	Signature of Authorized Officer ²⁰	
EUROPEAN PATENT OFFICE	G.L.M. Huydenberg	

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON

INTERNATIONAL APPLICATION NO. PCT/GB 84/00209 (SA 7429)

This Annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 24/09/84

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
FR-A- 2204087	17/05/74	DE-A,B,C 2251839 GB-A- 1427435	09/05/74 10/03/76
FR-A- 2468527	08/05/81	GB-A,B 2065388 DE-A- 3038685 JP-A- 56065706 CA-A- 1124819	24/06/81 14/05/81 03/06/81 01/06/82
EP-A- 0070633	26/01/83	BE-A- 889496 JP-A- 58044518	03/11/81 15/03/83
US-A- 4259705	31/03/81	None	

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