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(54) A SUPPLY SYSTEM FOR AN ASYNCHRONOUS MOTOR

(71) We, SAFT-SOCIETE DES ACCUMU-
 LATEURS FIXES ET DE TRACTION, a French
 Corporation, of 156, Avenue de Metz, 93230
 Romainville, France, do hereby declare the
 invention, for which we pray that a patent
 may be granted to us, and the method by
 which it is to be performed, to be particu-
 larly described in and by the following state-
 ment:—

The invention concerns a supply system
 for an asynchronous motor, comprising an
 alternating current source for normal use
 and a direct current source for alternative
 use, in combination with an inverter.

For reasons of continuity of operation or
 emergencies in the case of a breakdown of
 the power distribution system, two electrical
 supply systems are often provided. Known
 means consist in replacing the defective nor-
 mal power distribution system by a self con-
 tained supply system having a voltage and
 a frequency identical to those of the normal
 power distribution system. Electrical gen-
 erator units and charge-battery inverter
 assemblies are used, for example.

Often when any emergency arises it is only
 desired to complete an operation in progress.
 For example lifts may be brought to a se-
 lected level, and similarly power lifting de-
 vices, belt conveyors or bucket elevators may
 be stopped in a pre-determined position, or
 the closing of a swing-bridge railway turn-
 table, or rolling door may be completed.
 The lubricating of a turbo-alternator assem-
 bly may be continued until the complete
 stopping thereof. Given that the emergency
 operation often consists only in ending a
 movement in progress or resetting a device
 in its rest position, conventional solutions
 seem fairly expensive.

Moreover, speed variators for asynchron-
 ous motors which enable the speed of the
 operations carried out under the action of the
 motor to be reduced are known. Neverthe-

less, these speed variators are complicated
 and expensive.

According to the present invention there
 is provided a supply system for an asynchron-
 ous motor, comprising an alternating current
 source for use as a normal supply and a
 direct current source for use in combination
 with an inverter as an alternative supply, the
 inverter having an oscillation frequency which
 is appreciably lower than the frequency of the
 normal supply and the ratio between the out-
 put voltage of the inverter and its normal
 operating frequency being approximately
 equal to the ratio between the voltage and
 the frequency of the normal supply so as to
 maintain the torque provided by the motor
 substantially constant for both conditions of
 operation.

The inverter may comprise means enab-
 ling the over-voltages produced by the motor
 to be absorbed.

In the particular case where the direct cur-
 rent source is constituted by a battery, these
 means enable the battery to be recharged
 when the motor operates as a generator.

For several of the applications cited above,
 it is useful to provide means enabling the
 reversing of the rotation direction of the
 phase voltages and hence the reversing of
 the direction of movement of the motor.
 Thus, the most adequate rest position may be
 reached or the direction of movement for
 which the torque is the smallest may be
 chosen.

The torque of an asynchronous motor is a
 function of the voltage and of the frequency
 of the power distribution system. More par-
 ticularly, the torque is proportional to $1/f$ (f
 being the energising frequency of the motor)
 when the motor is in synchronism, that is,
 when the slip is very small. The torque is
 proportional to $1/f^2$ during starting up, that
 is, when the slip is very great, and it reaches
 a maximum at an intermediate stage.

For lifting motors, manufacturers generally arrange for the maximum torque to be close to the starting torque.

The supply system according to the present invention makes it possible to supply low-speed asynchronous motors from a low-voltage and low-power direct current source, which may be either a storage battery having low internal resistance or a low voltage alternating current source followed by a rectifier. It is possible, in many cases, to use frequencies in the vicinity of a tenth of the frequency of the normal supply system, without coming up against technological difficulties such as arise when the speed of the motor running idle becomes lower than the slip speed which is independent of frequency. A supply frequency too close to the resonance frequency of the motor must also be avoided, but in general, this resonance frequency is still lower than the minimum frequency fixed by the slip.

The invention will now be described in more detail by way of example and with reference to the accompanying drawings, in which:—

Figure 1 is a block diagram of a supply system;

Figure 2 shows the power circuit of the inverter;

Figure 3 is a diagram of the control circuit of the inverter;

Figure 4 shows representative curves describing the operation of the circuit according to Figure 3;

Figure 5 is a more detailed diagram of the circuit in Figure 1; and

Figure 6 shows the emergency supply installation of a lift.

With reference to Figure 1, a three-phase asynchronous motor 1 is supplied during normal operation by a three-phase 220 volt 50 Hz power distribution system 2.

A multiplex switch 3 makes it possible to cut off the connection between the power distribution system and the motor and establishes an electrical connection with an auxiliary source composed of a direct current source 4 and an inverter whose three outputs A_1 , A_2 , A_3 send out a three-phase voltage of 24 volts at about 6 Hz, for example, the voltage being measured from the positive to the negative maximum.

Because of the comparatively lower frequency of the supply system, the motor rotates at a lower speed than in normal operation, and the torque which the motor develops is practically identical to that which is observed in the case of normal operation. Thus, with a relatively low power source, it is possible to operate at a lower speed and in certain cases, to complete an operation should the system 2 fail.

The inverter is composed of a control

circuit 11 and a power circuit which comprises three identical parts 5 corresponding to the three phases.

The part 5 of the power circuit corresponding to the phase i ($i=1, 2$, or 3) has a positive control input P_i , a negative control input N_i and a power output A_i , the latter being connected to the switch 3. Figure 2 shows in detail a transistorised embodiment of the part 5, the circuit comprising two branches 6 and 7 which are almost identical, composed of amplification transistors and two power transistors in parallel. The two control inputs affect the two branches in a complementary way, that is, the two power transistors of one branch are conductive when those of the other branch are non-conductive.

The power transistors are shunted by reverse supply diodes 8 and 9, reverse connected, which become conductive when the motor operates and produces over-voltages at the terminal A_i . In this circumstance, power is sent back to the source 4.

The points B_i and C_i are connected to the terminals of the direct current source.

The inputs P_i and N_i are connected to the control circuit 11 which is shown in detail in Figure 3. It contains a time base circuit 12, which sends out pulses of a regular rhythm with a frequency of about 36 Hz. This pulse train is represented by the diagram I in Figure 4. The time base circuit will be described in detail further on.

The pulse train is sent out to a cyclic shift register 13 having three binary units whose output is connected to the input so as to allow a logic level "1" to circulate endlessly at the speed of the input pulse train. For the sake of clearness in the drawing, the resetting to zero of these binary units when the auxiliary supply system is brought into operation has been omitted. This resetting to zero may be defined by a "1" in the first binary unit and by "0" in the other two binary units.

An output of each binary unit of the shift register 13 is connected to one of the bi-stable flip-flops 14, 15 and 16 respectively, which changes its binary state each time it receives a positive rising wavefront at its input. The signals at the input of these three flip-flops are shown in Figure 4 by the diagrams II, III and IV and the signals they send out at their positive output are shown in diagrams V, VI and VII respectively. The flip-flops 14 and 16 are reset to zero when the auxiliary supply system is brought into operation whereas the flip-flop 15 is reset to the opposite state "1".

The three flip-flops are provided with complementary outputs N_1 , N_2 and N_3 respectively, whose signals are always logically reversed in relation to the signals on outputs 130

P1, P2 and P3. These outputs are connected to control inputs which are analogous to those of the power circuit according to Figure

2. The two branches of a phase are alternately conductive, that is, the output A_1 , A_2 , or A_3 respectively is connected either to the positive terminal or the negative terminal of the source 4 which is constituted by a battery. The signals shown in the diagrams V, VI and VII are therefore simultaneously significant for the logic state of the three flip-flops and for the voltage of the output A_i of the inverter. The last diagram in Figure 4 shows the voltage between the two output terminals A_1 and A_2 of the inverter which corresponds in form to the difference between the logic levels shown in diagrams V and VI. The same considerations may be applied to the other phases and the three difference signals UA_1-A_2 , UA_2-A_3 , UA_1-A_3 of which only UA_1-A_2 is shown in Figure 4, are phase shifted by 120° in relation to each other. The maximum voltage corresponds practically to the voltage of the direct current source 4 and the frequency is one sixth of the frequency of the time base circuit 12.

Up till now, it has been considered that the shift register is directly connected to these three flip-flops 14, 15, 16, this being justified if only one direction of rotation of the vector of the three phase system is required. Sometimes, however, it is required to set up on order the opposite direction so as to be able to reverse the direction of rotation of the asynchronous motor.

This reversing may be effected at the level of the shift register, whose shift direction could be reversed. Nevertheless, a simpler solution is shown diagrammatically in Figure 3 and consists in crossing the connections of two binary units at the input of the flip-flops 15 and 16. To this end a reversing relay 17 is provided, controlled by a control signal applied to the winding 18. As a function of the position of the contacts of this relay, the last two binary units are thus connected to the flip-flops 15 and 16 in the order drawn or else in a crossed order.

It is known that on starting up, the torques should, in many cases, be greater than the torques which are observed when the slip of the motor is at its minimum and that these torques increase when the supply frequency decreases. With a view to providing a greater torque on starting up, the time base circuit 12 shown in Figure 3 includes means for progressively increasing the repetition rate of the pulse train on starting up until at the end of the starting period, an operating frequency of 36 Hz is reached. Instead of a multivibrator, a monostable flip-flop 19 which becomes an oscillator by an external negative feedback is used. The negative feedback circuit comprises a resistor 20 and

a capacitor 21 which define the oscillation frequency during the starting up.

It comprises additionally a resistor 22 in series with a transistor 23. The base of the transistor is connected to a terminal 24 for the supply voltage through a capacitor 25 which, on application of voltage to the terminal 24, makes the transistor 23 non-conductive during a certain period and thus disconnects the resistor 22 from the negative feedback. When the transistor 23 becomes progressively conductive with a time constant defined by the capacitor 25 and the base resistor 26, the emitter resistor 22 and the collector-emitter path of the transistor 23 progressively shunt the resistor 20 causing a progressive increase of the oscillator frequency, starting from the starting up frequency which is approximately 10 Hz, to the operation frequency of 36 Hz which is obtained after a few seconds.

In Figure 5 the direct current source is constituted by an alternating current source followed by a rectifier; like elements bear the same reference as in Figure 1.

A three-phase asynchronous motor 1 which is supplied, during normal operation, by a three-phase 220 volt 50 c/s power distribution system is shown. When it is desired to operate the motor at low speed, it is switched by means of a multiplex switch 3 to a three-phase system comprising the terminals A_1 , A_2 , A_3 having an appreciably lower frequency and voltage. The voltages at the terminals A_1 , A_2 , A_3 are derived from a three-phase power distribution system 34 through a transformer 35, a rectifier 36 and an inverter. The system 34 may, in this case where low-speed operation only is being provided for, be the normal power distribution system 2.

The inverter is composed of three power circuits 5 which connect the outputs A_i alternately to the two terminals of the rectifier 36 under the control of complementary signals applied to the control inputs P_i and N_i as shown in Fig. 2. These signals are produced in a control circuit 11 which comprises the time base circuit and other components, as has been described with reference to Figure 3.

The auxiliary supply system may be used for electrical braking. The power provided by the motor operating as a generator may be absorbed by the inverter. In this case, a storage battery or a resistor is connected in parallel with the rectifier 36. To avoid a continuous charge of this battery or a loss of power in a resistance absorber when the motor operates normally, the battery or absorber is connected to the circuit through a switch 38.

The battery may be used to provide an emergency power supply in the event of

failure of the normal power distribution system.

Such an embodiment is applied, to great advantage, to a system such as a crane or bridge, which operates at a certain speed and which uses a reduced speed for delicate movements, for example, for approaching or drawing alongside.

Figure 6 shows the application of an emergency supply system according to Figure 1 to a lift. The direct current source 4 is a battery and the inverter consists of the power circuit according to Figure 2 and the control circuit 11 which is shown in detail in Figure 3. The three-phase asynchronous motor 1 constitutes the main motor of a lift cabin (not shown). During normal operation, this motor is supplied through a control block 30 by the three-phase 220 V 50 Hz power distribution system 2. That same network also feeds a charger 27 which keeps the battery charged outside the emergency periods. The switch 3 in Figure 1 is replaced here by a system of two relays 28 and 29 which are mechanically and electrically locked in relation to one another to prevent them from both being energised simultaneously.

The relay 28 is energised by the distribution system 2: during the energising thereof, it cuts off the supply to the coil of the other relay 29 and connects the power distribution systems 2 through the control block 30 to the motor.

The relay 29 is supplied by the emergency battery when the power distribution system 2 fails and a switch 31 is closed automatically by the lack of power. By three sets of contacts the relay 29 disconnects the supply to the coil of relay 28, energises the inverter and connects the output of the latter to the motor 1.

One particularity of this installation is the fact that the reversing of the direction of motor rotation is obtained automatically when the starting up of the cabin in one direction requires of the battery a current which exceeds a chosen threshold. The reversing of the direction is ensured in the case where the load on the lift will not allow starting up in a predetermined direction. A measurement shunt circuit 32 is connected between the battery and the inverter. The drop in voltage at the terminals of that shunt is supplied to a direction control circuit 33 which produces the direction reversing signal applied to the winding 18 (Figure 3).

The direction control circuit 33 may comprise a threshold amplifier and a bistable element which changes its binary state as soon as the voltage on the shunt 32 exceeds a pre-determined threshold. It can, moreover, comprise a time delay element which delays the energising of the circuit to remove the effect of the inrush current on starting up.

If necessary amplifier stages may be pro-

vided between the outputs of the flip-flops and the input of the power circuit to amplify the logic levels before they are applied to the input of the power circuit. Also the starting up of the emergency system may be made dependent on certain safety conditions being fulfilled, for example in the case of a lift by the closing of the storey contacts, gate contacts and end of run contacts.

WHAT WE CLAIM IS:—

1. A supply system for an asynchronous motor, comprising an alternating current source for use as a normal supply and a direct current source for use in combination with an inverter as an alternative supply, the inverter having an oscillation frequency which is appreciably lower than the frequency of the normal supply and the ratio between the output voltage of the inverter and its normal operating frequency being approximately equal to the ratio between the voltage and the frequency of the normal supply so as to maintain the torque provided by the motor substantially constant for both conditions of operation.

2. A system as claimed in claim 1, in which the inverter comprises overvoltage protection means enabling the overvoltages produced by the motor to be absorbed.

3. A system as claimed in claim 2, in which when the direct current source is a battery, the overvoltage protection means enable the battery to be recharged when the motor operates as a generator.

4. A system as claimed in claim 3, in which the overvoltage protection means consist of diodes reverse connected to the terminals of the power switching elements of the inverter and having a current capacity exceeding the current supplied by the motor when acting as a generator.

5. A system as claimed in any one of the preceding claims, in which the inverter includes a time base circuit controlling the operating frequency which comprises a starting up means enabling said circuit to operate during a first period after the energising of the inverter at frequencies lower than the operating frequency, and to progressively reach the operating frequency.

6. A system as claimed in any one of the preceding claims, in which for use with a polyphase motor, the inverter comprises means enabling the reversing of the direction of rotation of the phase voltages.

7. A system as claimed in claim 1 wherein the inverter comprises three switching circuits for alternately connecting the positive and negative terminals of the D.C. source to three respective outputs of the inverter, and a control device for activating the switching circuits to provide a three-phase output.

8. A system as claimed in claim 7 wherein the control device includes a circulating

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failure of the normal power distribution system.

5 Such an embodiment is applied, to great advantage, to a system such as a crane or bridge, which operates at a certain speed and which uses a reduced speed for delicate movements, for example, for approaching or drawing alongside.

10 Figure 6 shows the application of an emergency supply system according to Figure 1 to a lift. The direct current source 4 is a battery and the inverter consists of the power circuit according to Figure 2 and the control circuit 11 which is shown in detail in Figure 3. The three-phase asynchronous motor 1 constitutes the main motor of a lift cabin (not shown). During normal operation, this motor is supplied through a control block 30 by the three-phase 220 V 50 Hz power distribution system 2. That same network also feeds a charger 27 which keeps the battery charged outside the emergency periods. The switch 3 in Figure 1 is replaced here by a system of two relays 28 and 29 which are mechanically and electrically locked in relation to one another to prevent them from both being energised simultaneously.

20 The relay 28 is energised by the distribution system 2: during the energising thereof, it cuts off the supply to the coil of the other relay 29 and connects the power distribution systems 2 through the control block 30 to the motor.

25 The relay 29 is supplied by the emergency battery when the power distribution system 2 fails and a switch 31 is closed automatically by the lack of power. By three sets of contacts the relay 29 disconnects the supply to the coil of relay 28, energises the inverter and connects the output of the latter to the motor 1.

30 One particularity of this installation is the fact that the reversing of the direction of motor rotation is obtained automatically when the starting up of the cabin in one direction requires of the battery a current which exceeds a chosen threshold. The reversing of the direction is ensured in the case where the load on the lift will not allow starting up in a predetermined direction. A measurement shunt circuit 32 is connected between the battery and the inverter. The drop in voltage at the terminals of that shunt is supplied to a direction control circuit 33 which produces the direction reversing signal applied to the winding 18 (Figure 3).

35 The direction control circuit 33 may comprise a threshold amplifier and a bistable element which changes its binary state as soon as the voltage on the shunt 32 exceeds a pre-determined threshold. It can, moreover, comprise a time delay element which delays the energising of the circuit to remove the effect of the inrush current on starting up.

40 If necessary amplifier stages may be pro-

vided between the outputs of the flip-flops and the input of the power circuit to amplify the logic levels before they are applied to the input of the power circuit. Also the starting up of the emergency system may be made dependent on certain safety conditions being fulfilled, for example in the case of a lift by the closing of the storey contacts, gate contacts and end of run contacts.

WHAT WE CLAIM IS:—

1. A supply system for an asynchronous motor, comprising an alternating current source for use as a normal supply and a direct current source for use in combination with an inverter as an alternative supply, the inverter having an oscillation frequency which is appreciably lower than the frequency of the normal supply and the ratio between the output voltage of the inverter and its normal operating frequency being approximately equal to the ratio between the voltage and the frequency of the normal supply so as to maintain the torque provided by the motor substantially constant for both conditions of operation.

2. A system as claimed in claim 1, in which the inverter comprises overvoltage protection means enabling the overvoltages produced by the motor to be absorbed.

3. A system as claimed in claim 2, in which when the direct current source is a battery, the overvoltage protection means enable the battery to be recharged when the motor operates as a generator.

4. A system as claimed in claim 3, in which the overvoltage protection means consist of diodes reverse connected to the terminals of the power switching elements of the inverter and having a current capacity exceeding the current supplied by the motor when acting as a generator.

5. A system as claimed in any one of the preceding claims, in which the inverter includes a time base circuit controlling the operating frequency which comprises a starting up means enabling said circuit to operate during a first period after the energising of the inverter at frequencies lower than the operating frequency, and to progressively reach the operating frequency.

6. A system as claimed in any one of the preceding claims, in which for use with a polyphase motor, the inverter comprises means enabling the reversing of the direction of rotation of the phase voltages.

7. A system as claimed in claim 1 wherein the inverter comprises three switching circuits for alternately connecting the positive and negative terminals of the D.C. source to three respective outputs of the inverter, and a control device for activating the switching circuits to provide a three-phase output.

8. A system as claimed in claim 7 wherein the control device includes a circulating

shift register, each element of which is connected to a flip-flop controlling one of the switching circuits.

9. A supply system for an asynchronous motor, substantially as herein described with reference to the accompanying drawings.

10. An emergency installation for a device driven by a reversible asynchronous motor, comprising a supply system as claimed

in claim 5 and means enabling, on starting up, the direction of rotation of the motor to be maintained or reversed according to the value of the current supplied by the d.c. source to the inverter. 10

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