

'A Control Circuit Arrangement for an
Induction motor with a Clutch/Brake Unit'

This invention relates to a control circuit arrangement for a drive consisting of an induction motor coupled to a clutch/brake unit, particularly, but not exclusively for use in electrically driven sewing machines.

Energy economy circuits for motors have attained interest particularly for mobile appliances which are fed from limited energy accumulators and particularly since the so-called energy crisis. A circuit arrangement is known from German Offenlegungsschrift 27 30 774, in which the energy consumption of an alternating-current induction motor is minimised under different service conditions by determining the loss factor ($\cos \varphi$) on the basis of current and voltage measurements at the motor and maintaining it constant by means of electronic circuitry at the level which it assumes at nominal speed and nominal load. This results in a reduction in the stable speed and torque range, so that such a circuit arrangement has only limited usefulness.

A motor control circuit for energy economy is also known from German Offenlegungsschrift 28 24 474, in which the speed of the motor is maintained constant irrespective of the load. A separate speed detection device is necessary for this purpose. When alternating current induction motors are used in the field of sewing machines, in which the output speed is controlled by clutch/brake units, the known energy economy circuits are unsuitable from the standpoints both of outlay and of use. This is because, by the use of

suitable alternating current induction motors, the speed thereof remains virtually stable in any case if such motors are kept in the stable speed range.

It is the aim of the invention to produce an energy-saving control circuit arrangement which provides optimum energy economy with reduced production costs.

According to the invention there is provided a control circuit arrangement for saving electrical energy in a drive comprising an induction motor and a clutch-brake unit, in which the motor has main and auxiliary windings which are so dimensioned that the motor speed remains, under normal service conditions, in an essentially constant speed range and in which the clutch-brake unit serves to control the drive speed so that the motor operates in alternate load and no-load phases, the clutch engagement initiating a clutch impulse; wherein switches are provided in the current path of the motor windings, said switches being actuated on engagement of the clutch by the clutch impulse so that they pass the full operating current to the motor windings and, following termination of the clutch engagement and the ending of the associated clutch impulse, are so switched through a modulation circuit that the auxiliary motor windings are completely switched off and the main motor windings are provided with only a part of the phase of the operating current.

The invention also provided a control circuit arrangement wherein the main motor winding is sub-divided and a plurality of switches is provided to control the switching of the current to the motor windings in dependence on the application of a clutch impulse by means of a modulation circuit, so that at least one of said switches closes to connect the parts of the main winding in parallel and under no-load conditions the or each said switch opens and a further switch closes to contact the parts of the main winding in series under a reduced current flowing therethrough.

The invention further provides a control circuit

arrangement for saving electrical energy in a drive comprising a three-phase induction motor and a clutch-brake unit, in which the windings of the induction motor are so dimensioned that the motor speed, under normal operating conditions, remains substantially constant within a stable speed range and the clutch-brake unit serves for the control of the driven output speed so that the motor operates in alternative load and no-load phases, the engagement of the clutch initiating a clutch impulse, wherein switches are provided in the current path of the windings of the three-phase induction motor, the switches being so actuated in response to the clutch impulse that, on the engagement of the clutch they conduct the full operating current for the motor windings and following the termination of the clutch engagement and of the associated clutch impulse by a control circuit, the switches are so actuated that one switch interrupts the current flowing in one of the windings and one switch, which is arranged between the other two windings, reduces the current flowing in said windings.

The invention enables the stable speed range to be attained as quickly as possible and maintained reliably, and the no-load losses are considerably reduced by the prescribed current reduction under no-load conditions.

In one embodiment of the invention, a modulation circuit is provided which contains a delay element which is triggered when the mains voltage is applied, the time constant of the delay element being determined to ensure

that the motor attains its stable speed range within the period determined by the delay element.

Since only switches and a modulation circuit are used to influence the current, the production outlay is small, for the same reason it is possible, e.g. for the circuit arrangement to be accommodated in the terminal board region of the motor, optionally as an attachment.

Acceleration of the motor is thus reliably ensured, and can be realised with a very small outlay, particularly under the services conditions existing during sewing operations. Such a circuit arrangement provides a particularly simple type of the modulation circuit, by means of which the motor remains in the stable speed range even in the case of brief and frequent load changes.

This embodiment of the invention provides an advantageous dual use of the current switch, which achieves a reduction in the components used in the circuit arrangement.

Some embodiments of the invention will now be described by way of example and with reference to the accompanying drawings, in which;

Figure 1 shows a circuit according to the invention of a single-phase alternative current induction motor provided with a main winding and an auxiliary winding,

Figure 2 shows a circuit of a single-phase alter-

nating current induction motor provided with a divided main winding and with an auxiliary winding,

Figure 3 shows a circuit of a three-phase induction motor in star circuit,

Figures 4 to 6 show various embodiments of current switches, and

Figures 7 and 8 show various embodiments of current switches when additionally used as current reducing valves.

The embodiments relate to sewing machine drives, in which an alternating current induction motor is coupled with a clutch/brake unit, by means of which the instantaneous output speed is adjusted by the interplay of clutch and brake. The clutch is excited electromagnetically. From the clutch modulation an electrical signal can be tapped, which indicates the presence of this modulation. It is designated hereinbelow the clutch impulse. Such drives with clutch/brake units are known, e.g., from German Auslegeschrift 22 63 259 (corresponding to United States Patent 3 885 175). These generally known devices are therefore not explained in detail hereinbelow.

In the circuit illustrated in Figure 1 an alternating current induction motor with a main winding 1 and with an auxiliary winding 2 is used. A phase shift capacitor 3 ensures a virtually circular rotating field for motor starting and operation under load; the auxiliary winding 2 is switched on not only during the acceleration, but is also energised during service under load. The windings receive the service current from two bus-bars 4 and 5 and for the phase and the

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neutral conductor. An earth connection 6 is also provided. Mains current passes through a switch to the auxiliary winding 2 and current also passes through a current control means 8 including a switch to the main winding 1.

The switches 7 and the current control means 8 are connected to a modulation circuit 9 in which a delay element 10 is connected on the input side to an initiating lead 11 and has an output lead 12. An impulse prolongation element 13 connected to an input lead 14 has an output lead 15 which, like the output lead 12 of the delay element 10 constitutes the input for an OR-gate 16. The output 17 of the OR-gate leads to the control inputs 18, 18' respectively of the switch 7 and of the current control means 8.

The current control means 8 comprises a switch 8a modulable through the control input 18, and a phase shift circuit 19 which is responsible for the ~~valve~~ action of the switch 8a.

The bus bars 4 and 5 are passed through a mains filter 20 which is also connected to the earth connection 6.

The circuit operates as follows:

An initiating impulse on the initiating lead 11, which is generated when the mains supply is turned on by a mains switch, (not shown) triggers the delay element 10. Its output impulse passes through the OR-gate 16 to the inputs of the switch 7 and the current control means 8 and closes both switches. Full operating current therefore flows through the motor windings 1 and 2. The motor accelerates and tends towards its no-load speed. The time constant of the delay element is adjusted so that the motor, with

flywheel mass, attains its no-load speed within the running time of the delay element 10. As soon as the clutch on the motor engages, a clutch impulse appears on the lead 14. It is transmitted through the impulse prolongation element 13 to the OR-gate 16 and therefore, by the closing of both the switches produces full current through main winding 1 and auxiliary winding 2. After the end of the clutch impulse, which persists as long as the clutch transmits torque from the motor to the drive output side, the action of the impulse prolongation element 13 commences. As soon as its delay time has expired, the switch 7 and the switch element of the control means 8 open. The motor runs at no-load speed. The current through the auxiliary winding 2 is no longer required, because no-load conditions exist after the release of the clutch. At the no-load speed, the current through the main winding 1 finds such a torque in the motor that the rotary movement of the motor is maintained. With the elimination of the modulation of the current control means 8, the latter becomes a current controlling valve modulated by the phase shifter circuit 19 structurally combined with it, inasmuch as it now conducts only during a part of the full mains cycle. In the no-load case the motor losses are considerably reduced by the reduction of the motor current. Measurements have shown a reduction in consumption by approximately 80% when the valve action of the current control means 8 was optimally adjusted in accordance with the motor type. Because high frequency perturbations may reach the bus-bars 4 and 5 due to the valve action of the current control means 8 when mod-

ulated by the phase shifter circuit 19, the filter 20 is provided to attenuate these perturbations.

If it is absolutely necessary to avoid high frequency perturbations which may appear during the valve action of the current control means 8, the circuit arrangement for a single-phase alternating current induction motor as shown in Figure 2 should be adopted. The motor has a divided main winding 1a and 1b and an auxiliary winding 2 with the phase shift capacitor 3, the capacitor 3 and the winding 2 being placed in parallel with the partial main winding 1b. Switches 7a, 7b, 7c are placed in the current paths to the windings 1a, 1b, 2. The switches 7b, 7c are modulated in common and simultaneously. They connect the two partial main windings 1a, 1b in parallel as soon as they are closed. By closing the switch 7a with the switches 7b, 7c simultaneously opened, the two partial main windings 1a, 1b are connected in series.

A modulation circuit 21 serves for the functionally correct modulation of switches 7a, 7b and 7c. It contains a delay element 10 connected on the input side to the initiating lead 11, with an output lead 12, an impulse prolongation element 13 with an input lead 14 and an output lead 15. The two output leads 12, 15 are connected to the inputs of an OR-gate 16, the output of which is connected to the output lead 17. Signals appearing on this lead 17 are fed both to an AND-gate 22 and also, after inversion by the inverter 23 to an AND-gate 24. The output of the AND-gate 22 is connected to a lead 25 which leads to the switches 7b, 7c. The output of the AND-gate 24 is fed to a lead 26 which

connects it to the switch 7a. The output of the impulse prolongation element 13 is connected through the lead 15, not only to the OR-gate 16, but also to a lead 27 to a monoflop 28 and to an inverter 29. The output of the inverter is fed to a monoflop 30. A discrete construction of the inverter may be omitted if the monoflop 30 already contains an integrated inverter. The monoflops 28, 30 are connected on the output side through leads 31, 32 to an OR-gate 33 which is connected on its output side through the lead 34 to the inputs of the AND-gates 22, 24.

The function of this circuit is as follows:

With an initiating impulse on the initiating lead 11 to the delay element 10, the two switches 7b, 7c are closed through the OR-gate 11 and the AND-gate 22. The two partial main windings 1a, 1b together with the auxiliary winding 2 are placed in parallel between the bus bars 4 and 5. The motor receives full current and accelerates during the time prescribed by the delay element 10. A clutch impulse likewise passes to the switches 7b, 7c through the lead or wire 14, the impulse prolongation element 13, the OR-gate 16 and the AND-gate 22. The partial main windings 1a, 1b are therefore connected in parallel during the clutch impulse. At the end of the clutch impulse the running time of the impulse prolongation element 13 commences and maintains the switches 7b, 7c closed until the end of the period. With each switching of the impulse prolongation element 13, i.e., both at the initial flank of the clutch impulse and upon its decay, one of the monoflops 28, 30 is triggered. The output signals of

these monoflops 28, 30 are combined by the OR-gate 33 and control the AND-gates 22, 24, namely in the sense that the gates 22, 24 are blocked to modulation signals of the switches 7a, 7b, 7c during the period of the monoflops 28, 30. The switches 7a, 7b, 7c are then opened, or open not later than the expiry of the halfwave of the mains phase present at that time. The monoflops 28, 30 therefore exhibit periods which are greater than or equal to half a mains cycle. Under no-load, when the clutch impulse has decayed, no modulation passes through the gate 22 to the switches 7b, 7c. Then a modulation signal passes from the inverter 23 through the AND-gate 24 to the switch 7a. The partial main windings 1a, 1b are therefore connected in series. The current flux through the motor is reduced. The losses become smaller. Measurements have revealed an energy economy in the region of 60%.

In the case of a three-phase alternating current induction motor with the type of circuit shown in Figure 3, its three star connected windings 35, 36, 37 are switched on fully by a switch 7 and a control means 8 for acceleration or during torque delivery. The control means 8 acts conjointly with a phase shift circuit 19 as a current valve when the motor is operating under no-load.

The switch 7 and the current control means 8 are controlled by a modulation circuit 9 which corresponds to the modulation circuit illustrated in Figure 1 and which has already been described.

The function of the winding circuit is as follows:

An incoming impulse on the initiating wire 11 triggers the delay element 10 which closes the switches 7, 8a through the OR-gate 16. A clutch impulse on the input wire 14 of the impulse prolongation element 13 likewise closes the switches 7 8a through the OR-gate 16. These switches still remain closed for some time after the end of the clutch impulse in conformity with the period of the impulse prolongation element 13. Then they open. The switch 7 interrupts the current flux through the winding 37. The phase shift circuit 19 acts after the elimination of the modulation of the current control device 8, so that it operates as a current valve in accordance with the phase shift circuit 19 and is closed only during brief times within each mains cycle. The windings 35, 36 are connected in series together with the current control means 8. An energy economy in the region of 60% is obtained in this case due to the reduction of the current flux.

An impulse prolongation element 13 is contained in each of the modulation circuits 9, 21. It causes the respective connected motor to continue to receive full current for some time after the release of the clutch i.e., after the end of the clutch impulse. It is thereby achieved that the motor speed is maintained even in the case of frequent load changes, because the torque of the motor does not fall below its breakdown torque. The period of the impulse prolongation element must accordingly be arranged so that the attainment of the stable speed range and consequently its maintenance is ensured after brief heavy loading of the motor.

Such impulse prolongation elements 13 are commercially available as integrated circuits.

In the context of the alternating current induction motors used here, breakdown torque is understood to mean the torque which is attained after their acceleration, when starting torque and acceleration torque occur. The breakdown torque has a maximum value which decreases to zero during the further acceleration of the motors. The speed range between the breakdown torque and the diminishing torque which follows it in speed is designated the stable speed range. Normal service conditions exist when the motor can accelerate from standstill into the region of the stable speed range and if, after acceleration, load and supply conditions exist in such combination that the motor is not constrained to leave the stable speed range. Because it is necessary for acceleration under load to be possible, the modulation prolongation of the switch 7 and the current control means 8 acts in the sense that, even when the speed falls below that pertaining to the breakdown torque, when the load is disconnected the motor rises back above the breakdown torque into the stable speed range.

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The delay element 10, which is present in both modulation circuits 9, 21, commonly available as an integrated component, serves for acceleration control. During acceler-

ation the stable speed range has not yet been attained. By a sufficiently long application of the full service voltage of the motors through the delay element 10 the breakdown torque is exceeded during acceleration and the stable speed range is therefore attained under normal service conditions. Normal also means here that the breakdown torque can be exceeded, i.e., that the motor is not subject to such heavy loads that its rotation is blocked.

Figures 4, 5 and 6 show three possible embodiments of a potential free current circuit. The simplest possibility (Figure 4) is that a modulation signal through the relevant control input 18 makes a relay 38 react. The latter operates a contact 39, which directly assumes the current circuit. An RC-combination 40 placed in parallel with the contact 39 counteracts sparking.

Over longer periods of time the embodiment shown in Figure 5 operates more reliably than the circuit illustrated in Figure 4; in this variant a contact 39 of the relay 38 switches, not the full motor current, but only a small auxiliary current for a triac 41. The triac is protected by an RC-combination 40.

In the embodiment of a switch 7 as shown by Figure 6, switching contacts are avoided. The modulation signal through the input 18 switches on, through an optocoupler 42, a thyristor 43 which is inserted across a diode bridge 44. Here again an RC-combination 40 protects the switching element, the thyristor 43. The optocoupler 42 switches to the gate of the thyristor 43 a current which is prescribed by a resistor

45 and is limited by a Zener diode 46 so that, in the event of the nonmodulation of the optocoupler 42, no voltage which might damage the latter is applied to it.

If the switches shown in Figures 5 and 6 are extended by a phase shift circuit 19, then this results in the embodiments illustrated in Figures 7 and 8. Here triac 41 and thyristor 43 are supplied, even during opening times of the contact 39 or of the optocoupler 42, with modulation signals which appear when such a high voltage has been attained at a capacitor 47 through a resistor 48 by charging from the mains halfwave, that a diac 49 ignites and therefore delivers a powerful impulse to the gates of triac 41 and thyristor 43.

CLAIMS

1. A control circuit arrangement for saving electrical energy in a drive comprising an induction motor and a clutch-brake unit, in which the motor has main and auxiliary windings which are so dimensioned that the motor speed remains, under normal service conditions in an essentially constant speed range and in which the clutch-brake unit serves to control the drive speed so that the motor operates in alternate load and no-load phases, the clutch engagement initiating a clutch impulse; wherein switches are provided in the current path of the motor windings, said switches being switched on engagement of the clutch by the clutch impulse so that they pass full operating current to the motor windings and, following termination of the clutch engagement and the ending of the associated clutch impulse, are so switched through a modulation circuit that the auxiliary motors windings are completely switched off and the main motor windings are provided with only a part of the phase of the operating current.
2. A control circuit arrangement for saving electrical energy in a drive comprising an induction motor and a clutch-brake unit, in which the motor has main and auxiliary windings which are so dimensioned that the motor speed remains, under normal service conditions in an essentially constant speed range and in which the clutch-brake unit serves to control the drive speed so that the motor operates in alternate load and no-load phases, the clutch



engagement initiating a clutch impulse; wherein the main motor winding is sub-divided and a plurality of switches is provided to control the switching of current to the motor windings in dependence on the application of a

5 clutch impulse by means of a modulation circuit so that at least one of said switches closes to connect the parts of the main winding in parallel and under no-load conditions the or each said switch opens and a further switch closes to connect the parts of the main winding in series

10 under a reduced current flowing therethrough.

3. A control circuit arrangement for saving electrical energy in a drive comprising a three-phase induction motor and a clutch-brake unit in which the windings of the induction motor are so dimensioned that the motor-speed,

15 under normal operating conditions, remains substantially constant within a stable speed range and the clutch-brake unit serves for the control of the driven output speed so that the motor operates in alternate load and no-load phases, the engagement of the clutch initiating a clutch

20 impulse, wherein switches are provided in the current path of the windings of the three-phase induction motor, the switches being so actuated in response to the clutch impulse that, on the engagement of the clutch they conduct the full operating current for the motor windings and

25 following the termination of the clutch engagement and of the associated clutch impulse by a control circuit, the switches are so actuated that one switch interrupts the current flowing in one of the windings and one switch.



which is arranged between the other two windings, reduces the current flowing in said windings.

4. A control circuit arrangement according to claim 1 or claim 2, wherein the modulation circuit is provided
- 5 which includes a delay element that is triggered on the application of a mains voltage, the time constant of the delay element being selected so that the motor attains the constant speed range within the period of time established by the delay element.
- 10 5. A control circuit arrangement according to any one of claim 1, 2 or 4, wherein the modulation circuit includes an impulse-extending element, the time constant of which is selected so that the motor remains in its constant speed range under all operating conditions.
- 15 6. A control circuit arrangement according to any one of claims 1 to 5, wherein a phase shifting circuit is associated with at least one of the switches.
7. A control circuit arrangement for a drive including an induction motor and a clutch-brake unit, substantially
- 20 as hereinbefore detailed with reference to Figure 1, or Figure 1 modified as shown in Figure 2, Figure 3, Figures 4 to 6, Figure 7 or Figure 8 of the accompanying drawings.

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