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(54) A SPEED CONTROLLER FOR A UNIVERSAL MOTOR

(71) We, ROBERT BOSCH GmbH, a German company of 50 Postfach, Stuttgart, Germany, 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 particularly described in and by the following statement:-

This invention relates to a speed controller for a universal motor suitable for use in electric tools. With the hitherto usual speed controllers, only one half wave of the AC mains voltage is used wherein first of all a speed control is effected with the aid of the phase shift control through an RC-device comprising a potentiometer, and simultaneously a certain additional regulation of the set speed results due to the back EMF at the armature of the universal motor. It is a disadvantage of the known speed controllers that their regulating effect is relatively small which leads to the fact that, with an increase in load, the speed of the universal motor drops to a greater extent than would be desirable. On the other hand, with other known speed regulation, the possibility is lacking of limiting the idling speed. This is especially critical with universal motors of an appreciable power for example of 450 watts since, without a speed limitation, these motors reach such a high idling speed that they produce inadmissible noise, a high bearing wear and a deformation of the commutator. For these reasons limitation of the idling speed is forced.

According to the invention there is provided a speed controller for a universal motor comprising a first controlled rectifier with a load circuit in series with the motor, a second controlled rectifier connected parallel to an in opposite polarity to the first controlled rectifier, a control circuit for the second controlled rectifier inductively coupled to the load circuit of the first controlled rectifier so that during the conductive period of the first controlled rectifier a capacitor in the control circuit of the second controlled rectifier is charged to a voltage which depends on the plate current value in the load circuit of the first controlled rectifier, and during the non-conductive period of the first controlled rectifier the second controlled rectifier becomes conductive after a time interval beginning at the start of the conductive period of the second controlled rectifier, the duration of the time interval depending on the voltage stored in the capacitor.

The term 'conductive period' is used herein to express the period during which the related rectifier may be in the conductive state, and non-conductive period implies that the related rectifier is not in its conductive period. The two inversely parallel connected controlled rectifiers, which may each comprise thyristors, with their separate control circuits form a first circuit for the speed control and speed limiting and a second circuit for the control of the speed to a set value. Thus, there is provided a non-symmetrical phase shift control. Setting of the speed in the control circuit of one of the thyristors may be effected by varying the phase shift through an RC-phase shifter whereby a continuous control of the speed up to a predetermined maximum idling speed may be possible in which one half wave of the AC mains voltage, for example the positive half wave, is shifted. Furthermore, for the control circuit which includes the second thyristor which may be effective during each second half wave of the AC mains voltage, thus for example during the negative half wave, an inductively coupled feedback signal is used which is dependent on the current in the load circuit of the first thyristor, that is to say on the motor current, wherein use is made of the fact that, with a suitable phase shift angle set in the speed control circuit, the motor current is only varied in accordance with the load on the motor.

In order that the present invention be more readily understood an embodiment thereof will now be described by way of example with reference to the accompanying drawings, in which:-

Fig. 1 is a circuit diagram showing the principle of the control circuit; and

Figs. 2a-f are diagrams of the voltage curves at two different points in the control circuit according to Fig. 1 for various operating conditions.

As Figure 1 of the drawing shows, the speed controller is connected to an AC voltage source 10, that is to say connected in the normal manner to the usual AC mains at a voltage of 220 volts and a frequency of 50 Hertz. A motor 12 which is designed as a universal motor in the form of a series commutator motor, is supplied from the AC source 10. The motor 12 is in series with a first tyristor 14 between the terminals of the AC source 10. A control circuit, which has a first branch comprising the series circuit of a Zener diode 16, a resistor 18 and a diode 20, is provided for controlling the first thyristor 14. When the diode 20 is poled in the forward direction thus, for example, during the positive half waves of the AC voltage, a current flows through the first branch 16, 18, 20 of the control circuit. Moreover, the Zener diode 16 limits the voltage at its point of connection A with the resistor 18 to a predetermined value. The point of connection A is connected to the other terminal of the Zener diode 16, or to the AC source 10, through a series circuit comprising a potentiometer 22, a resistor 23 and a capacitor 26. Furthermore, a further resistor 24 is provided parallel to the potentiometer 22. The parallel resistor 24 limits the total resistance of the parallel circuit 22, 24 to such a value that the phase shift angle in the control circuit for the first thyristor 14 cannot fall below a predetermined smallest phase shift angle. The control electrode of a threshold value switch, which in the embodiment is formed as a unijunction transistor 28, is connected to the connecting point B of the capacitor 26 to the resistor 23. Of the base contacts of the unijunction transistor 28, one is connected directly to the control electrode of the first thyristor 14 and, moreover, through a resistor 30 to the AC source. The other base contact of the unijunction transistor 28 is connected through a resistor 32 to the point of connection A. Moreover, by stabilising the input voltage to the unijunction transistor 28 with the aid of the Zener diode 16, complete independence of fluctuations in the supply voltage is achieved for the speed control.

The time interval, which is required after the start of a positive half wave in order to generate the necessary switching voltage for the unijunction transistor 28 at the point of connection B, is dependent on the setting of the potentiometer 22 with a predetermined Zener voltage through the Zener diode 16 and in accordance with the resistance values of the fixed resistors 23, 24. Thus, the phase shift angle for turning on the first thyristor 14 is adjustable by means of the said potentiometer 22 and with it the speed of the motor 12 is controllable. Furthermore, in the speed controller according to Figure 1, a transformer 34 is provided the primary winding 34.1 of which is inserted in the load circuit of the first thyristor 14. On the other hand, the secondary winding 34.2 of the transformer 34 is in the control circuit of a speed regulating circuit which is described in more detail in the following.

In particular, the speed regulating circuit of the speed regulator in accordance with the invention, has a second thyristor 36 which is connected inversely parallel with the first thyristor 14 which is also connected to the AC source 10 in series with the motor 12 but, however, with the opposite polarity to the first thyristor 14. Thus, when the first thyristor 14 is made conductive during one portion of each positive half wave, then the second thyristor 36 is made conductive during a portion of each negative half wave of the AC voltage from the AC source 10, whereby, the operation likewise proceeds once again in accordance with the phase shift control.

In particular, with the circuit referred to, there exists with a current through the primary winding 34.1 of the transformer 34, a corresponding voltage on the secondary side 34.2 of the said transformer through which a trigger capacitor 38 is charged to a voltage corresponding to the peak value of the motor current with the first thyristor 14 conducting, and which serves as a feedback voltage. Proceeding from the said feedback voltage, the trigger capacitor 38 is re-charged during the next negative half-wave until the ignition voltage of a trigger diode 42 in the control circuit of the second thyristor 36 is reached. Thus, the second thyristor 36 is turned on that much earlier during each negative half wave the higher was the motor current during the previous positive half wave, that is to say the higher is the load on the motor 12.

With the circuit under consideration, charging of the trigger capacitor 38 during the negative half wave is achieved through a diode 41 and a resistor 43 connected in series therewith. Furthermore, the secondary winding 34.2 of the transformer 34 is not connected directly to the capacitor 38 but through the series circuit of a resistor 44 and a diode 46. On the secondary side, the transformer is connected to a resistor 40. The capacitor 50 connected in parallel therewith, serves for smoothing and for suppressing interference pulses. Furthermore, on the side of the diode 46 remote from the capacitor 38 the series circuit of a diode 52 and a Zener diode 54 is provided in parallel with the capacitor 38 in order to prevent the ignition voltage for the trigger diode 42 being reached during the course of a positive half wave with a load which is greater than the nominal load.

So that, at the start of each half wave or each control procedure, the voltage at the trigger capacitor 38 is a definite output voltage, namely zero voltage, the speed regulator in accordance with the invention has a quenching circuit with an auxiliary thyristor 58 which is connected in series with a resistor 60. This series circuit is in parallel with the trigger capacitor 38. The control electrode of the auxiliary thyristor 58 is connected to the output from a threshold value switch in the form of a trigger diode 62. The input to the trigger diode 62 is from the point of connection between a resistor 64 and a diode 66 wherein these two components 64, 66 are in parallel with a further resistor 68 which is part of a series circuit comprising a capacitor 70 which is in parallel with the first thyristor 14. The quenching circuit comprising the described components operates as follows: when the first thyristor 14 in the control circuit turns on, then the voltage jump produced thereby is differentiated by the RC-member 68, 70 whereby the ignition voltage for the trigger diode 62 is reached and as a result the auxiliary thyristor 58 becomes conductive. The resistor 60 in series with the auxiliary thyristor 58 is of relatively low resistance so that whilst the auxiliary thyristor 58 is turned on the trigger capacitor 38 has built up sufficiently, the thyristor 58 turns off once again so that the renewed charging of the trigger capacitor 38 can then take place to a voltage which corresponds to the peak value of the current through the first thyristor 14 and therewith through the motor 12. Moreover, commutating peaks existing during interruption of the motor current are limited in the quenching circuit to values of, for example, approximately 8 volts, which do not lead to a turning on of the trigger diode 62 (trigger voltage about 32 volts), by suitable values for the resistor 68 and the capacitor 70 which, together, represent a so-called carrier-level-effect (CLE) wiring circuit. Also, the trigger diode 42 in the control circuit of the second thyristor 36 is protected against high frequency interference pulses and indeed by a capacitor 72 connected in parallel therewith. Finally, it should be stated that the control electrode of the auxiliary thyristor 58 is connected through a resistor 74 to the point of connection between the auxiliary thyristor 58 and the trigger capacitor 38.

Protection for the trigger diode 42 against noise voltages during the period of the positive half wave, can also be achieved by connecting a transistor and a discharging resistor in series with the trigger diode 42 wherein the transistor (not shown) is only triggered during the negative half wave through its base so that ignition pulses for the second thyristor 36 likewise fall during the positive half wave of the AC voltage.

The function of the speed controller in accordance with the invention described above with the aid of Figure 1, will become particularly clear from Figure 2, the partial figures 2a, 2b and 2c of which show the voltage at the motor 12 present during three different types of operation and the partial figures 2d - 2f of which show the voltage curves across the trigger capacitor 38 during these types of operation.

In particular, Figures 2a and 2d apply to the idling of the motor, Figures 2b and 2e to normal operation in which the speed is controlled at a previously set value, and Figures 2c and 2f give the case in which the motor operates under nominal load. From Figure 2 it will be clear that, to this end, under all three operating conditions the current flowing during the positive half wave proceeds so that the voltage across the trigger capacitor 38 - this voltage is referenced U_c - first of all rises to a predetermined level and then remains at this level up to the end of the positive half wave. The level of the voltage U_c reached at the end of the positive half wave is then different during idling, partial load (Figures 2b, e) and nominal load and reaches the highest value during nominal load whilst during idling the lowest value is produced. Proceeding from the level reached during the course of the positive half wave, the voltage U_c increases across the trigger capacitor 38 then, during the subsequent negative half wave, and in so doing approaches the ignition voltage U_z for the trigger diode 42. As Figure 2 shows, this ignition voltage U_z is not even reached during idling since in this instance the motor current is small during the positive half wave and subsequently the voltage across the trigger capacitor 38 reaches only a relatively low level. This has the result that during idling of the motor 12 the second thyristor 36 remains turned off during the whole negative half wave. On the other hand, with a partial load, a relatively high level of the voltage U_c across the trigger capacitor 38 is already achieved during the positive half wave so that, during a portion of the following negative half wave, the thyristor 36 is made conductive after reaching the ignition voltage U_z for the trigger diode 42. With the third condition of operation referred to, that is to say during a nominal load, the level of the voltage U_c across the trigger capacitor 38 reached during the positive half wave is so high that, to reach the ignition voltage U_z, only a small additional recharging of the trigger capacitor 38 is necessary during the negative half wave so that the thyristor 36 is made conductive shortly after the start of the negative half wave. It will be clear from Figure 2 that the speed controller in accordance with the invention, with a predetermined conductive angle α in the speed control circuit, controls the average current levels through the motor 12 in accordance with load within wide limits. The conductive angle α itself, is introduced into the speed control circuit by a corresponding setting of the potentiometer 22. Moreover, the resistor combination 22, 23, 24 is so designed that on setting the potentiometer 22 to the zero speed a certain minimum conductive angle α for the thyristor 14 of the speed control circuit is always guaranteed. In this manner, the quenching circuit causes a discharge of the trigger capacitor 38 at the end of each positive half wave. On the other hand, the minimum conductive angle α is maintained so small that the motor 12 does not start. This can be achieved, for example, with conductive angles of approximately 40°.

Finally, it should be stated that the trigger diodes 42 and 62 are prefereably formed as diacs and that a diac can also be introduced with advantage instead of the unijunction transistor 28.

WHAT WE CLAIM IS:

1. A speed controller for a universal motor comprising a first controlled rectifier with a load circuit in series with the motor, a second controlled rectifier connected parallel to and in opposite polarity to the first controlled rectifier, a control circuit for the second controlled rectifier inductively coupled to the load circuit of the first controlled rectifier so that during the conductive period of the first controlled rectifier a capacitor in the control circuit of the second controlled rectifier is charged to a voltage which depends on the peak current value in the load circuit of the first controlled rectifier, and during the non-conductive period of the first controlled rectifier the second controlled rectifier becomes conductive after a time interval beginning at the start of the conductive period of the second controlled rectifier, the duration of the time interval depending on the voltage stored in the capacitor.

2. A speed controller according to claim 1 in which during the non-conductive cycle of the first controlled rectifier the partially charged capacitor is further charged at a predetermined rate until a threshold voltage is reached at which the second controlled rectifier is rendered conductive.

3. A speed controller according to claim 1 or claim 2 in which the control circuit of the second controlled rectifier includes a trigger switch which renders the second controlled rectifier conductive when the capacitor is charged to the required ignition voltage for the trigger switch.

4. A speed controller according to any preceding claim in which a quenching circuit is provided with the aid of which the capacitor can be charged to a definite voltage at the beginning of each working cycle.

5. A speed controller according to any preceding claim in which the controlled rectifiers comprise thyristors.

6. A speed controller according to claim 4 in which the quenching circuit comprises an auxiliary thyristor the switching path of which is parallel with the capacitor.

7. A speed controller according to claim 4 or 6 in which the quenching circuit comprises a differentiating element for generating quenching pulses with each turning on of the first controlled rectifier.

8. A speed controller according to any preceding claim in which the inductive coupling of the load circuit of the first controlled rectifier to the control circuit of the second controlled rectifier comprises a transformer from the secondary winding of which a voltage can be tapped off matching the ignition voltage of the trigger switch.

9. A speed controller according to any preceding claim in which the control circuit of the first controlled rectifier includes a Zener diode for stabilising the input voltage to the trigger switch with respect to fluctuations in the mains voltage.

10. A speed controller for a universal motor substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

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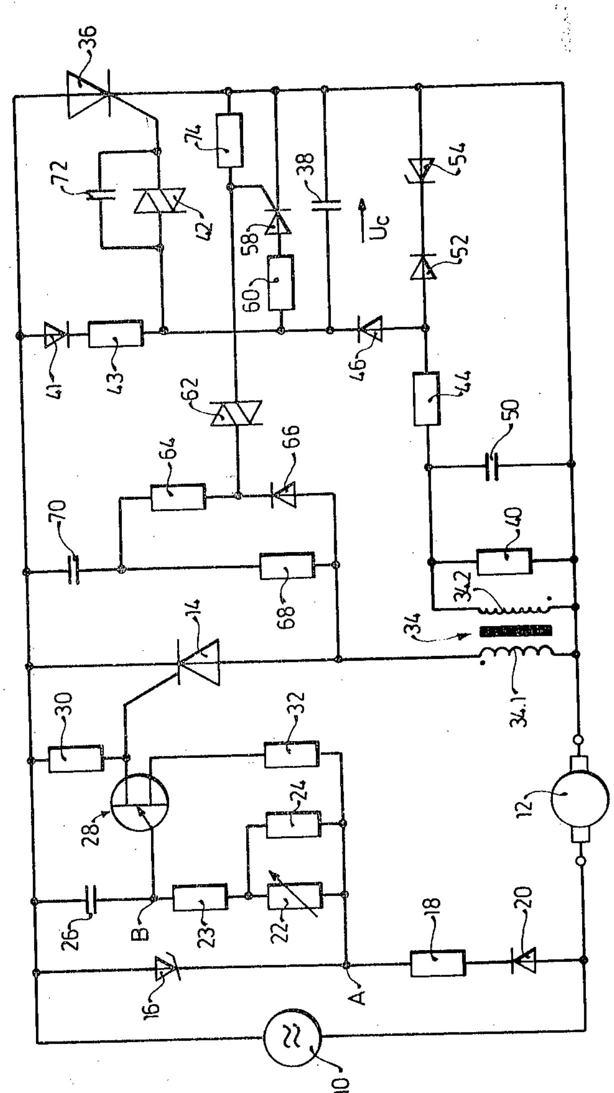
Sheet 1

Fig. 1



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Sheet 2

Fig. 2