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(54) Circuit arrangement for braking a direct-current motor drive

(57) A circuit for braking a direct current motor drive has means for dynamic rheostatic braking in an upper speed range, and means for effecting a combined dynamic braking and counter-current regenerative braking under a set control in a lower speed range extending from the end of the upper range until the drive is almost stopped. A resistor 3 is provided in the armature circuit, and a controllable thyristor bridge rectifier circuit 2 is in series with the resistor.

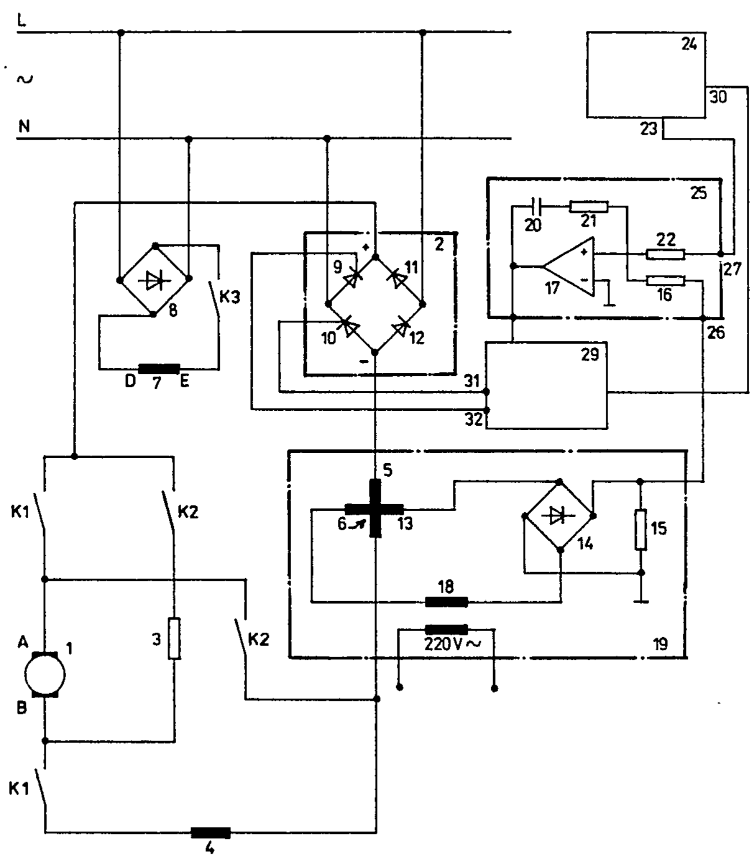

Fig. 1

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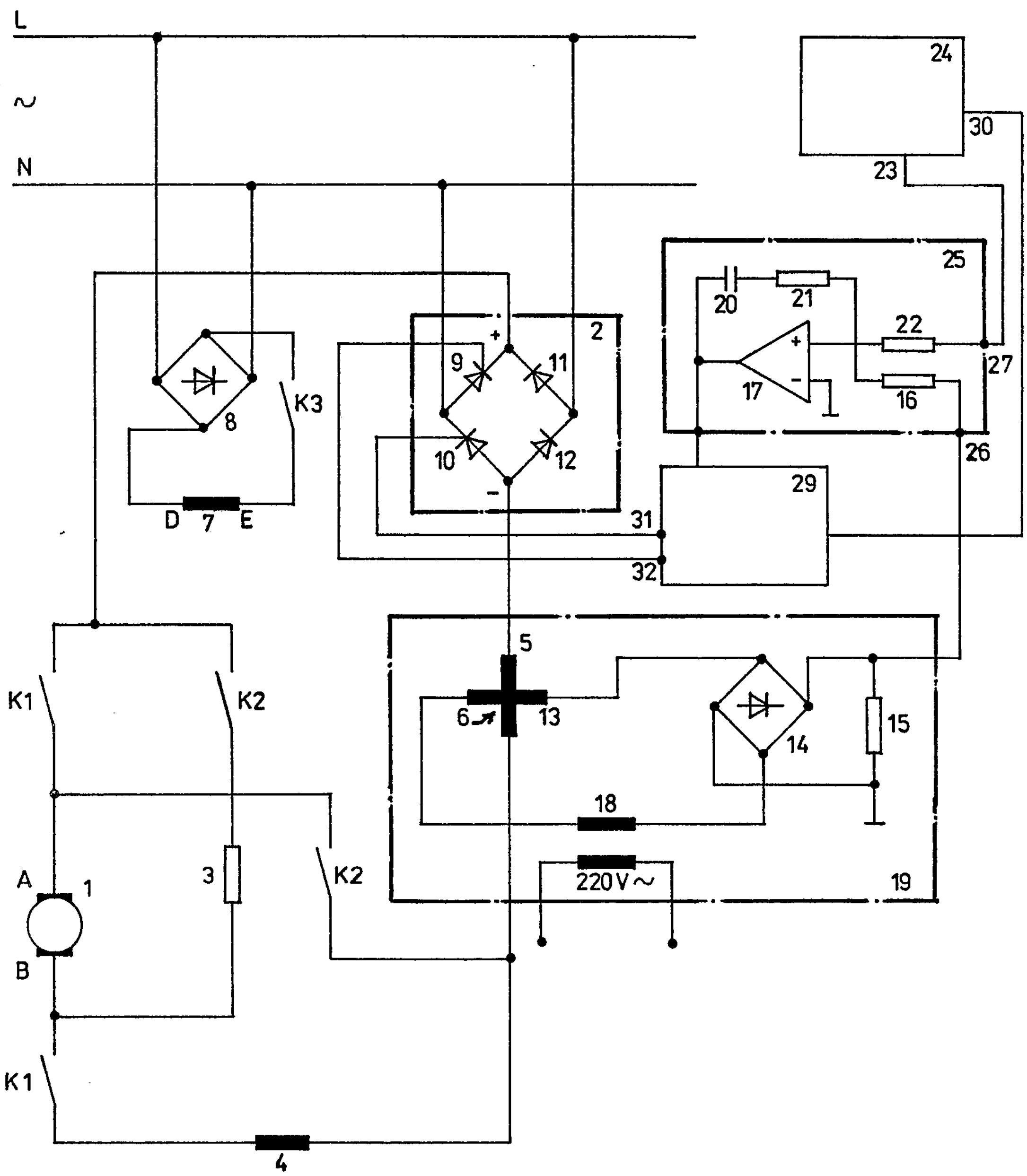

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Fig. 1

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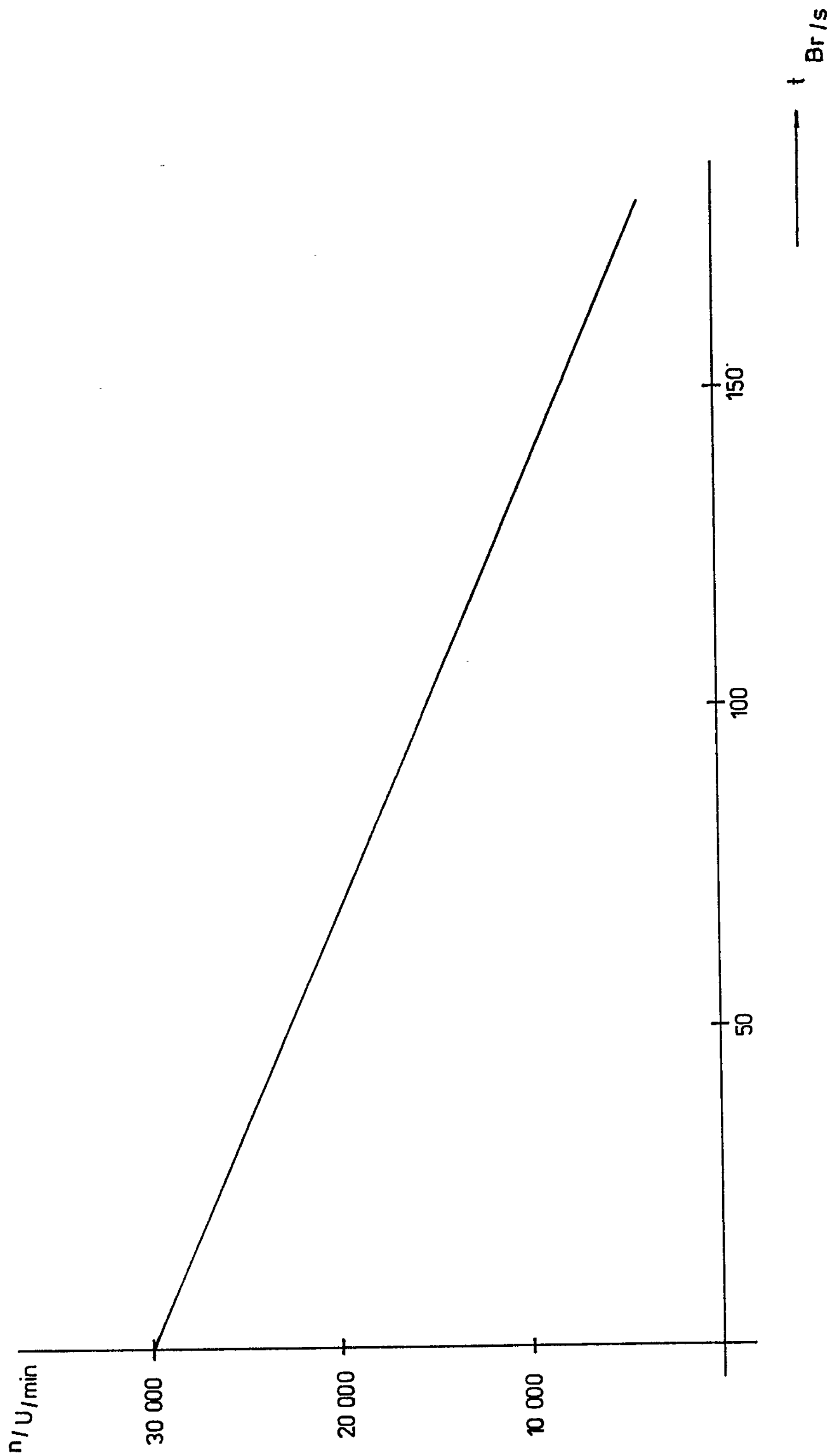

Fig. 2

SPECIFICATION

Circuit arrangement for braking a direct-current drive

The invention relates to a circuit arrangement for braking direct-current drives having relatively great mass moments of inertia as is the case with centrifuges for example. It is also an advantage where short braking times are necessary.

In the course of development, three methods have emerged for braking direct-current motors: rheostatic or dynamic braking, counter-current braking and braking by means of a four-quadrant regulating device. In order to carry out these methods, a large number of brake circuits have been proposed, all of which are adapted to more or less special reguirements.

Dynamic braking using a constant braking resistance allows little or no variation in braking intensity. Dynamic braking using a braking resistance which is variable in stages needs a large number of switching stages dependent on speed of rotation and corresponding power switching means in order to achieve a substantially constant braking torque over a wide range.

Braking by means of a four-quadrant regulating device is used predominantly in dynamically high-quality, direct-current, actuating drives. A drive with a four-quadrant actuator requires a fully controlled bridge circuit with corresponding control. This expense is, however, unjustifiable for low quality drives.

Pure counter-current braking is relatively rarely used because of the high thermal and electrical stress on the motor. Variable braking action is expensive.

In the DE-OS 2824045, a device for the controlled braking of a centrifuge is described which works in the upper speed ranges at a constant braking torque which is achieved by reversing the polarity of the field winding. In the lower speed ranges, it provides a dynamic brake which, on the one hand is controlled by the actual value of the EMF and on the other hand can be varied by a variable excitation voltage. The current is fixed in the upper speed range, while in the lower speed range the exciting current can be set but only to one value, which, in the event of heating, can lead to different braking times with the same preselection of the value. The range having variable braking intensity is relatively small.

The object of the invention to allow variability of the braking torque within wide limits, and to shorten the braking times in drives having great mass moments of inertia.

Accordingly, the invention provides a circuit for braking a direct current drive comprising means for dynamic braking in an upper speed range, and means for effecting a combined dynamic braking and counter-current braking under a set control in a lower speed range extendinG from the end of the upper range until the drive is almost stopped.

Preferably, the circuit includes a circuit as claimed in claim 1 which includes a resistor switchable into the armature circuit (A, B) for dynamic braking in the upper speed range and a bridge rectifier circuit in series with the resistor which includes control thyristors subject to control by an actuator for braking in the lower speed range, the actuator being inhibited in the upper speed range.

In order that the invention shall be clearly understood, an exemplary embodiment thereof will now be described with reference to the accompanying drawings, in which:

Figure 1 shows the block circuit diagram of a circuit arrangement according to the invention; and

Figure 2 shows the braking characteristic thereof.

Armature terminals A; B of a direct-current motor 1 are in communication with the diagonals of a partially controlled thyristor bridge 2, in the operating state through contactor contacts K1 and in the braking state through contactor contacts K2, and they are connected in a transposed manner in these two operating states of the motor 1. In the transposing lines necessary for this are contactor contacts K2 and additionally, in one of these two lines, a braking resistor 3. A smoothing choke 4 is included in one of the two portions of line containing only the contactor contacts K1. One of the two common portions of line includes a control winding 5 of a transductor amplifier 6.

An exciting winding 7 of the motor 1 is connected through a contactor contact K3, to a rectifier bridge 8 which in turn is connected to a power supply N; L.

In one arm, the thyristor bridge 2 contains thyristors 9, 10 and in the parallel arm diodes 11, 12, connected in series. The diagonal points of these arms are connected to the supply main N, L. The diodes 11, 12 are arranged in the forward conducting direction for the braking current.

An operating winding 13 of the transductor amplifier 6 is connected across one diagonal of a rectifier bridge 14, the other diagonal of which receives a load resistor 15.

One diagonal point is connected to earth while the other diagonal point is taken through a resistor 16 to one input of an operational amplifier 17. The operating circuit of the transductor amplifier 6 contains the secondary winding of a mains transformer 18. The transductor amplifier 6, the rectifier bridge 14, the load resistor 15 and the mains transformer 18 together form a pick-up 19 for the actual value of the current.

The second input of the operational amplifier 17 is connected to earth. Its feedback path is a series connection of a capacitor 20 and a resistor 21. The first input is in communication, through a resistor 22, with the desired-value output 23 of a control unit 24. The operational amplifier 17 thus connected has the function of a proportional-integral (PI) controller 25 with an actual-value input 26, a desired-value input 27 and an output 28 for connection to an actuating circuit 29. This also has a second input which is connected to an inhibit pulse output 30 of the control unit 24. Its two outputs 31, 32 lead to the control electrodes of the thyristors 9, 10. The actuating circuit 29 has a conventional construction.

The contactors, their control circuit and the control unit 24 do not directly form part of the braking circuit described but they precede it functionally and are therefore of importance for an understanding of the mode of operation.

The circuit arrangement according to the invention operates as follows:

After a braking instruction has been given, the actuating circuit 29 receives an inhibit pulse and the contactor control circuit opens the contactor contacts K3. As a result, the contactor contacts K1 and K2 can be switched without current. After 3 seconds, the contacts K1 are opened and the contacts K2 closed. After another 7 seconds, the inhibit pulse dies out. At the same time, the field excitation of the motor 1 is switched on again by closing of the contact K3.

The braking current produced in the motor armature by its own movement flows from the terminal A through the first contact K2, the control winding 5 of the transductor amplifier 6, the diodes 11, 12, the second contact K2 and the braking resistor 3 back to the terminal B. It influences the alternating current flowing in the operating circuit of the transductor amplifier 6, which current is rectified in the rectifier bridge 14.

The voltage drop across the load resistor 15 is applied, through the resistor 16, at the input of the operational amplifier 17, which is operated as a phase-inverter amplifier. The voltage from the desired-value output 23 is likewise applied to this amplifier input through the resistor 22. Since the two voltages are connected in opposition to one another, a deviation or difference between the two is amplified in the operational amplifier 17. So long as the actual value of the current is above the desired value of the current, a voltage of a polarity which causes a blocking of the actuating circuit 29 is applied to the amplifier output 28. Since the generative braking current drops below the desired value of the current as a result of the braking, the polarity of the voltage changes at the amplifier output 28 as a result of which the actuating circuit 29 is released. The wiring in the feedback path of the operational amplifier 17 gives it a proportional-plus-integral behaviour. Through its outputs 31, 32, the actuating circuit 29 supplies control voltages for the opening of the thyristors 9, 10. The opening angle increases in proportion to the decrease in the generatively produced braking current. The difference current between the desired value of the current and the braking current produced generatively in the motor armature flows through the thyristors 9, 10. As a result, the braking current passing through the armature of the motor 1 is constant from the moment the regulation begins, that is to say from when the generative braking current drops below the desired vaLue of the current. The consequence is a constant braking torque and hence a constant braking action over by far the greatest part of the speed range. The braking time is very short. The speed (n)—braking-time (T_{Br}) curve (Figure 2) is a descending straight line in contrast to the corresponding curve of pure dynamic braking. At a preset minimum speed, for example a sixtieth of the maximum speed of rotation, the actuating circuit 29 receives an inhibit pulse as a result of which the thyristors 9, 10 are blocked and the braking current regulation is put out of operation.

Summing up, the operating mode can be described as a dynamic braking in the upper speed range and as controlled, combined dynamic braking and counter-current braking in the following speed range down to the lowest speeds of rotation.

CLAIMS

1. A circuit for braking a direct current drive comprising means for dynamic braking in an upper speed range, and means for effecting a combined dynamic braking and counter-current braking under a set control in a lower speed range extending from the end of the upper range until the drive is almost stopped.

2. A circuit as claimed in claim 1 which includes a resistor (3) switchable into the armature circuit (A, B) for dynamic braking in the upper speed range and a bridge rectifier circuit (2) in series with the resistor (3) which includes control thyristors (9, 10) subject to control by an actuator (29) for braking in the lower speed range, the actuator being inhibited in the upper speed range.

3. A circuit arrangement as claimed in claim 2 wherein the armature winding (A, B) is connected to the diagonals of the partially controlled thyristor bridge rectifier circuit (2), the diodes (11, 12) of which are arranged for the braking current in the forward conducting direction, the control electrodes of the thyristors (9, 10) are connected to the actuator (29), a pick-up (19) for the actual value of the braking current, the output of which is connected to the first input (26) of a PI-controller (25), is included in the armature circuit, the PI-controller (25) has a second input (27) for the desired value of the braking current and an output (28) for the connection to the actuator (29), and the actuator (29) is provided with a

further input for an inhibiting pulse.

4. A circuit arrangement as claimed in claim 3, wherein the pick-up (19) for the actual value of the current is composed of a transductor amplifier (6), a rectifier bridge (14), a load resistor (15) and a mains transformer (18).

5. A circuit arrangement as claimed in claim 3 or 4 wherein the PI-controller (25) is an operational amplifier (17) having a capacitor (20) and a resistor (21) in the feedback path and two parallel resistors (16, 22) in front of the input which is not earthed.

6. A circuit for braking a direct current drive substantially as described herewith with reference to the drawings.

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