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(54) IMPROVEMENTS IN OR RELATING TO D.C. MOTOR CONTROL CIRCUITS

(71) We, STILL, G.m.b.H., a German Company, of Berzeliusstrasse, 10, 2000 Hamburg 74, German Federal Republic, 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:—

The invention relates to D.C. motor control circuits of the kind in which regenerative braking is provided in a control circuit incorporating a series resistance, for use in electric battery-powered vehicles in conjunction with electronic pulse control systems.

In order to slow down a vehicle movement with such a drive system and simultaneously return electrical energy to the vehicle's battery, special circuit arrangements are necessary. The motor which is to act as a generator during such braking must be initially energised by the battery via an impedance if it is to be able to work as a generator. The size of this impedance depends upon the speed of rotation of the motor at which self energisation is to commence, and a main thyristor may be connected in series with the machine to provide control. In addition a commutating arrangement is provided, containing a capacitor which is charged once the main thyristor has been turned off, the charging current flowing via that impedance through which the current serving for energisation flows when the braking state is introduced, and through a charging path including a second, extinguishing thyristor.

In known circuits of this kind the impedance connected in series with the motor, and through which the energising current flows, has a small impedance value, and is normally a pure resistance of low value. Consequently the capacitor of the commutating arrangement is rapidly charged up through this resistance and there are no problems regarding any delay in capacitor charging. On the other hand, the fact that this resistance has a very small value means that it conducts very large currents, and converts a great deal of energy into wasted heat. In addition, heat dissipation then poses a problem.

One object of the present invention is to provided a control circuit in which the value of the above-mentioned resistance can be increased to reduce the energy loss therein, whilst reducing problems that might otherwise arise through the capacitor charging up too slowly.

The invention consists in a D.C. motor control circuit in which means are provided to permit regenerative braking, and comprising a D.C. motor armature and field winding connected in series with a resistor that is bridged by a switch, a first thyristor connected between said motor and a supply battery terminal, a commutating arrangement which incorporates a capacitor and is connected in parallel with the first thyristor, the arrangement being such that, following extinguishing of the first thyristor, current for charging said capacitor flows through said resistor, and a voltage sensor arrangement provided in the commutating arrangement, to sense the potential of said capacitor at any instant and inhibit ignition of said thyristor when said capacitor holds a charge below a given value. The relatively large time constant of the R-C element formed by the named resistance and the capacitor when the resistance has a large resistance value is such that the capacitor of the commutating arrangement would normally be charged up too slowly to ensure trouble-free operation, but the proposed circuit makes it possible to employ a high resistance value with trouble-free operation.

The invention will now be described with reference to the drawing, which schematically illustrates the circuit of one exemplary embodiment for use in a heavy duty transporter or other such material-handling vehicle.

A driving motor has an armature 1 in series with a field winding 2, and is powered by a battery 3. The motor current is controlled by a pulse generator 4, via a control circuit which consists of a first, main thyristor 5 and a second turn-off thyristor 6, the gate connection of the second thyristor 6 being controlled from the pulse generator 4. A capacitor 7 serving as an extinguishing capacitor is connected between the anodes of the two thyristors 5 and 6. The cathode of each of the thyristors 5 and 6 is connected to a tapping of a current transformer winding 8, a winding section 8 (1) lying between the cathode of the first thyristor 5 and the battery 3, whilst a winding section 8 (2) lies between the cathode of the thyristor 6 and its anode, in series with a diode 10, the combination of this diode 10 and the winding section 8 (2) of the current transformer thus being in parallel with the thyristor 6 and also a shunt resistor 9. The circuit so far described is similar to other known control circuits for such vehicles.

In the known circuits there is a resistance 11 bridged by a switch 12 in series with the armature 1 and the field winding 2 of the motor, as is shown in the drawing. In the circuits known to date, this resistance has relatively low value, produces considerable heat, and therefore has a correspondingly large volume, for example a resistance with a value of 5 ohms, used with an operating voltage source of 80 volts will consume 1280 watts.

In contrast, in the illustrated embodiment of the invention, resistance 11 is a resistance of relatively high value, i.e. a resistance of 68 ohms which can be used with an operating voltage source of 80 volts to consume only 94 watts, so that the power loss in this resistance is only about 7% of the power loss that would occur in a 5 ohm resistance.

The relatively high resistance value of resistance 11 means that the capacitor 7 will only charge up slowly through this resistance when the switch 12 is open, since resistance 13, which serves for quite different purposes not relevant to the present discussion, is itself of a very high value, and consequently can only make a very small contribution towards the charging up of the capacitor 7. Some preliminary charging of the capacitor 7 takes place through this resistance 13 and the resistance 9, and as this charging follows an exponential function the time constant is much greater when the resistance in the feeding line is large. If the voltage at connection point 14 between the field winding 2 and thyristor 5 is too low, because the capacitor 7 has not charged up enough, if the thyristor 5 were to be ignited in this state, the tiny voltage at point 14 would cause only a tiny discharge current to pass through the thyristor 5, the current transformer 8 and the diode 10, so that too little energy is available for a subsequent extinguishing operation with the result that the thyristor 5 will not be extinguished. This further results in the function of the circuit being impaired, as if the driving pedal is operated in this state, the vehicle will not move away, but a fault signal will be emitted.

To avoid this, a voltage divider formed by resistors 15 and 16 is connected between the connection point 14 and connecting line 17. The voltage at the tapping between the resistances 15 and 16 of this voltage divider is fed via a line 18 to a comparator 19, in which it is compared with a reference voltage fed from a voltage stabiliser 21 via a line 20. The output of the comparator 19 is connected to a gate circuit 22 which acts on the output of the pulse generator 4 via a line 23 so that this gate circuit switches ignition pulses through to the main thyristor 5 only when a voltage of adequate value is present at the connection point 14, this being indicated when the voltage at line 18 is higher than the reference voltage provided along line 20. This gating avoids any possibility of the thyristor 5 being switched conductive when the capacitor 7 is not sufficiently charged. As the voltage builds up rapidly, the driver will not normally notice any significant delay and be misled into thinking there may be a fault present.

A dropping resistance 24 is provided for the voltage stabiliser 21. A protective diode 25 offers protection against negative voltage peaks.

Thus, although the resistance 11 has a relatively high resistance value, the circuit components 15 to 23 serve to prevent the thyristor 5 being switched conductive when the capacitor charge voltage is too low.

Any braking current flows back into the battery 3. However, this circuit does not preclude the use of counter-current braking, i.e. of braking rapidly by switching the motor to turn in the opposite direction. However, it is improbable that a driver would select counter-current braking when the more convenient and more agreeable braking action is available, whose nature is dependent upon speed. The circuit can be constituted such that a reversing contactor is switched on when the brake pedal is operated, independently of the driving direction switch. In this case regenerative braking is only possible when the vehicle is moving forwards. The motor works in a self-energisation mode, the energising process being started by current through the resistance 11. When the first thyristor 5 is turned off, the energy stored in the motor is reduced through the free-running diode 26 and the braking diode 27. If the armature EMF is more than the voltage of the battery 3 when the armature 1 is turning at high speed, the diode 28 becomes conductive so that braking energy is fed to the battery 3.

Expediently the brake pedal (not shown) is connected both with this circuit and with a mechanical brake, such that some lost motion is provided in the mechanical brake control operation and the switch 12 is opened while the pedal is passing through this lost motion range. The vehicle is decelerated to a greater or lesser extent according to the brake transmission setting. For a given setting the braking effect increases as the speed rises. The vehicle can be driven downhill at virtually any desired speed with infinite adjustment. The motor is not subjected to greater loads than with rheostatic braking.

WHAT WE CLAIM IS:—

1. A D.C. motor control circuit in which means are provided to permit regenerative braking, and comprising a D.C. motor armature and field winding connected in series with a resistor that is bridged by a switch, a first thyristor connected between said motor and a supply battery terminal, a commutating arrangement which incorporates a capacitor and is connected in parallel with the first thyristor, the arrangement being such that, following extinguishing of the first thyristor, current for charging said capacitor flows through said resistor, and a voltage sensor arrangement provided in the commutating arrangement, to sense the potential of said capacitor at any instant and inhibit ignition of said thyristor when said capacitor holds a charge below a given value.

2. A circuit as claimed in Claim 1, in which the commutating arrangement contains a second thyristor whose anode is connected via the capacitor to the anode of the first thyristor, and whose cathode is connected to the cathode of the first thyristor, respective winding sections of a current transformer being connected to each of the two thyristors, and a gate circuit, controlled, in use, by the output of said voltage sensor arrangement, being provided to relay the control of the first thyristor.

3. A circuit as claimed in Claim 2, in which a diode is connected in series with the second thyristor and the current transformer winding section, the anode and cathode of the second thyristor being connected together via said diode.

4. A circuit as claimed in Claim 2, or Claim 3, in which a further resistor is connected in parallel with the second thyristor and a third resistor is connected in parallel with the motor.

5. A circuit as claimed in Claim 2, in which said voltage sensor comprises a voltage divider connected between the junction of the motor with the first thyristor and a line linking the cathodes of the two thyristors, any voltage at the tapping of said voltage divider being compared with a set reference voltage in a comparator whose output is fed to the gate circuit which influences a control pulse generator.

6. A circuit as claimed in Claim 5, in which the gate of the first thyristor is controlled by said gate circuit.

7. A D.C. motor control circuit substantially as described with reference to the drawing.

8. A material handling or a transport vehicle having a control circuit as claimed in any preceding claim.

For the Applicants:
G. F. REDFERN & CO.,
Marlborough Lodge,
14 Farncombe Road,
Worthing BN11 2BT.

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1575135 COMPLETE SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*