PATENT SPECIFICATION

(11) 1 599 375

(21) Application No. 24553/78 (22) Filed 30 May 1978

(31) Convention Application No. 7718874

(32) Filed 20 June 1977 in

(33) France (FR)

(44) Complete Specification published 30 Sept. 1981

(51) INT CL³ H02P 7/18

(52) Index at acceptance

H2J 2J3 2S3 2X D

(19)

1 599 375

(54) A SYSTEM FOR CONTROLLING A SEPARATELY EXCITED CONSTANT LOAD DC ELECTRIC MOTOR

(71) We, COMPAGNIE INTERNATIONALE POUR L'INFORMATIQUE CII-HONEYWELL BULL a French Body Corporate, of 94, avenue Gambetta 75020 Paris, 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 system for controlling a separately excited, constant load DC electric motor, in which compensation is made for the losses occurring in the motor as a function of a signal controlling the desired speed of the motor.

Separately excited DC electric motors are often used because their speed can be adjusted over a wide range by varying their supply voltage. In theory, for a given supply voltage and flux, the load characteristic of these motors in independent of the direct current which flows through them. However, it is observed in practice that their speed decreases linearly when the value of the energising current increases. This is due to the resistive losses which occur in the motor as a result of its internal resistance, which is the sum of, in particular, the resistances of the armature and the commutator windings. The formula which represents this phenomenon is: $E=U-RI$, in which E is the electromotive force of the motor, U its supply voltage, R its internal resistance and I its armature current. The product RI represents the internal resistive drop (also termed voltage drop) in the motor. In cases where the motor operates at a constant supply voltage, increases in the speed of rotation are regulated by varying the control current I, which has to be greater the shorter the time allowed to speed up or slow down. Consequently, if it is desired to adjust the speed quickly, the resistive drop is considerable and greatly upsets the adjustment process. This is why separately excited DC electric motors which are used under these conditions have associated with their control systems an arrangement for compensating for losses which enables the required speed to be reached in the required time.

In the prior art, a common system for controlling a separately excited DC electric motor comprises a generator for generating a signal to control the speed required from the motor, a power amplifier connected to the motor which receives the control signal in order to adjust the speed of the motor, and an arrangement for compensating, as a function of the control signal, for the losses which occur in the motor, this arrangement being formed by a feedback loop which feeds back to the input of the amplifier a value proportional to the value of the current flowing through the motor. To do this, a small resistor is placed in series with the armature of the motor and from it is derived a voltage proportional to the size of the current flowing through the armature.

However, a compensating arrangement of this nature proves ineffective when it is desired to adjust the speed of the motor within very short spaces of time, equivalent for example to the commutator of the motor turning by one or a few bars or strips. In such a case, the effect of the slots is to produce, in the feedback resistor which forms the compensating arrangement, a very irregular signal in the form of one or a few surges of current which, even when effectively filtered, cannot be used as a feedback signal. Thus, there is only an advantage in using this kind of compensating arrangement when the changes in speed required are equivalent to the commutator turning by a number of bars, so that a suitable feedback signal can be obtained. If the angle through which the commutator turns whilst the speed is adjusting is small, the compensating arrangement is ineffective.

The invention proposes a control system

which employs a compensating arrangement which has the advantage of being effective no matter what the angle of rotation of the commutator of the motor, whilst at the same time being of very simple construction and dispensing with a feedback resistor which necessarily adds to the internal resistance of the motor in conventional control systems.

Accordingly the present invention consists in a system for controlling a separately excited constant load D.C. electric motor of the kind comprising a generator for generating a signal to control the speed required from said motor, a power amplifier connected to the motor which receives said control signal in order to adjust the speed of said motor, and an arrangement for compensating for the internal voltage drop in the motor during periods when the speed of the motor is to be changed, the compensating arrangement comprising means connected between said generator and said power amplifier and which react to said control signal to generate a loss signal representing the expected losses occurring in the motor due to the resistance of the motor armature during the change in speed of the motor, and means to combine the loss signal with the control signal.

In order that the present invention may be more readily understood a prior art system and an embodiment of the invention will now be described by way of example and with reference to the accompanying drawings.

In the drawings:—

Figure 1 is a block diagram of a common, known system for controlling a separately excited, constant load DC electric motor,

Figure 2 shows an embodiment of compensating arrangement as generally used in a control system such as is shown in Figure 1,

Figure 3 is a block diagram of a system according to the invention for controlling a separately excited, constant load DC electric motor,

Figure 4 is a general diagram of an embodiment of a compensating arrangement according to the invention,

Figure 5 shows, in schematic form, an actual embodiment of a compensating arrangement according to the invention which is based on the general diagram of Figure 4 and,

Figure 6 illustrates waveforms derived at various points of the control systems shown in Figures 1 to 5.

In Figure 1, a system 10 for controlling a separately excited DC electric motor 12 includes an instructing member 14 such as a press button key board, a generator 16 which reacts to the instruction given to member 14, in order to emit a control signal for the motor, by determining the speed corresponding to the instruction received and the time allowed to reach this speed, a power amplifier 18 connected to the armature of the motor 12 which processes the control signal supplied by the generator 16 in order to energise the motor 12 accordingly, and an arrangement 20 for compensating for the internal drop in the motor. A compensating arrangement of the conventional kind servo-controls the motor by means of a feedback loop which consists of a differential amplifier 22 and a feed back unit 24. In accordance with the familiar principles of servo-control, the differential amplifier 22 receives at one input the control signal supplied by generator 16 and at its other input it receives the signal produced at the output of the feedback unit 24. This unit is generally formed by the components shown in Figure 2. These components consist of a resistor 26 of very low impedance which has one end connected to earth and its other end forming the input terminal 24*a* of the unit. This resistor 26 is connected in series with the armature of the motor 12. Connected in parallel with resistor 26 is a fixed, high impedance resistor formed by a potentiometer 28 whose moving contact forms the output 24*b* of the feedback unit 24. In certain cases the feedback unit 24 includes a filtering network (not shown) for the reasons given above.

The operation of the control system 10 which has just been described will now be explained with reference to the waveforms shown in Figure 6.

In the present example, it will be assumed that waveforms A and B represent the instruction signals produced by instructing member 14. Waveform A, for example, will order the motor 12 to run in the forward direction during the periods t1—t2 and t4—t5, whilst signal B will order the motor to run in reverse during the interval t3—t4.

Waveform C is an illustration of a control signal which the generator 16 may produce and of the pattern of the change in required speed. Thus, starting in the forward direction will have to take place in the period t1—t'1 and stopping in the forward direction in the period t2—t'2. It is assumed that the circumstances are as normally occur where the starting and stopping periods are different. An instruction will then be given to start in the reverse direction from time t3 to time t'3 and to stop in the reverse direction from time t4 to time t'4. Since time t'4 lies in the interval t4—t5 in which the instruction for running in the forward direction is situated, the generator 16 determines the predetermined period of forward starting, which will extend from time t'4 to time t"4. At the time t5 which corresponds to the instruction to stop forward running, the generator 16 orders a stop in the predetermined stop period t5—t'5.

Since the predetermined starting periods are shorter than the predetermined stopping periods, the current which flows through the motor 12 will need to be greater during starting than during stopping. This is shown by waveform E in Figure 6. These differing currents cause different resistive drops in the armature and at the terminals of the resistor 26 in the feedback unit 24. The differential amplifier receives the control signal C emitted by the generator 16 at one input and at its other input the output signal from terminal 24*b* of feedback unit 24.

As was seen above, the resistance of the feedback unit 24 adds to the internal resistance of the motor and the unit is distributed by interference signals which are introduced into the feedback signal at the edges of the bars of the commutator, which signals cannot effectively be filtered if there are only a few of them during the desired acceleration.

Figure 3 is a block diagram of an embodiment of a system 30 according to the invention for controlling a separately excited, constant load DC electric motor 32. Like the prior art system 10, the control system 30 comprises an instructing member 34, a generator 36 for generating a control signal similar to the control signals supplied by generator 16, and a power amplifier 38 which is intended to energise the motor 32 in such a way that the speed of the motor corresponds to the desired speed indicated by the control signal produced by generator 36. However, unlike the prior art control system 10, the control system 30 according to the invention employs a compensating arrangement 40 which is connected between the generator 36 and the power amplifier 38, whilst the motor 32 is connected directly to earth.

Figure 6 clearly shows the principle employed by the invention is compensating for losses by resistive drop in the armature. It was seen above that this resistive drop corresponds to the product of the internal resistance of the motor multiplied by the value of the current flowing through it. Since the internal resistance of the motor is a relatively fixed characteristic known to the user, as also is the value of current, which is a function of the said motor, of inertia and of acceleration, the resistive drop causes a linear reduction in the electromotive force of the motor in comformity with the equation

$$E=U-RI$$

given at the beginning of the text. To cancel out the effects of the resistive drop, the invention consists in generating, by simulating the supply current and the internal resistance of the motor, a loss signal which represents the internal drop in the motor as a function of the control signal supplied by the generator 36, and in combining the loss signal with the control signal in such a way that the supply voltage to the motor causes the motor to reach the required speed rapidly. In other words, the invention consists in simulating the product RI to form a loss signal S_p, which is added to the control signal U so that the electro motive force

$$E=U+S_p-RI=U.$$

Assuming that member 34 is operated in the same way as member 14 in Figure 1 and that the generator 36 emits a control signal C such as that shown in Figure 6 (like generator 16), the compensating arrangement 40 will supply to the amplifier 38 a signal D which is the sum of the signal C and a component proportional to the current I which is represented by waveform E in Figure 6, which latter occurs during the starting and stopping periods of the motor.

In other words, a compensating arrangement being described herein is characterised in that it comprises means which are connected between the generator 36 for generating the control signal for the motor and the power amplifier 38, and which react to the said control signal to generate a loss signal representing the losses occurring in the motor, and means to combine the loss signal with the control signal in such a way that the speed of the motor is quickly brought into correspondance with the desired speed. Figure 4 is a general diagram of the combination formed by the instructing member 34, the generator 36 and the compensating arrangement 40. This general diagram will show how easily the invention may be put into practice.

In Figure 4, the instructing member 34 is designed to cause the motor 32 to run in the forward and reverse directions by means of two switches 42, 42', which are connected in series between the two sources B+ and B− of voltage of opposite polarities via respective ones of two resistors 44 and 44'. The embodiment of generator 36 and the compensating arrangement 40 illustrated in Figure 4 has the advantage of combining the two, as will be seen below.

The conductor which connects the two switches 42 and 42' is connected firstly to a terminal 46 via a resistor 48. It is also connected to the direct input (+) of a differential amplifier 50 which has its inverting input (–) earthed. The output of the differential amplifier 50 is connected by a resistor 52 to the inverting input (–) of a differential amplifier 54 which has its direct input (+) earthed. The inverting input of differential amplifier 54 is also connected to the output of amplifier 54 via a capacitor 56 and a resistor 58. The dot 60 represents the output of the differential amplifier 54, which is connected to a terminal 64 which forms the output of the compensating arrangement 40, from which can be extracted a signal intended for the power amplifier 38, such as the signal D in Figure 6. A point 57, which is common to capacitor 56 and resistor 58, is connected to the direct input (+) of another differential amplifier 62, whose inverting input (–) is directly connected to its output which is in turn connected to resistor 48.

The constant voltage, after the motor has started, is determined by the value of the supply voltages B+, B– and the values of resistors 44 and 44′ and resistor 48. The time taken by the motor to start up and stop is set by the circuit in parallel with resistor 48. In this circuit, differential amplifier 50 acts as a buffer, whilst differential amplifier 54 acts as an integrator by virtue of capacitor 56 and resistor 52. Consequently, the gradient of signals C and D in the starting and stopping periods is determined by the values of resistor 52 and capacitor 56. In the general case where the starting and stopping periods are different, the integration constant set by resistor 52 and capacitor 56 must be altered accordingly. In the example illustrated where the starting up period needs to the shorter than the stopping period, it may be arranged that the resistor 52 and capacitor 56 form the stopping time constant and, by placing an additional resistor 52′ in parallel with resistor 52, to set a starting-up time constant which is shorter by virtue of the fact that the overall resistance of resistors 52 and 52′ connected in parallel is lower than that of resistor 52 on its own. Consequently, if point 57 were connected directly to terminal 60, the differential amplifier 62 would transmit to terminal 46 the required control signal for the motor, such as signal C in Figure 6, given that the voltage of the control signal after starting up is determined in particular by resistor 48, as was seen above. The compensating arrangement 40 of Figure 3 is produced quite simply by adding a resistor 58 between point 57 and point 60. Given that the internal voltage drop in the motor is proportional to the current flowing through it, and that the current is in turn inversely proportional to the starting up and stopping times demanded and thus to the integration constants of differential amplifier 54, and in view of the fact that the current in resistor 52 (which determines the stopping time-constant) or in resistors 52 and 52′ (which determine the starting time-constant) is the same as that flowing through resistor 58, then between point 57 and point 60 there is thus a voltage proportional to the current which will flow through the motor. By adjusting the value of this resistor to ensure that the voltage between point 57 and point 60 is equal to the internal drop RI in the motor, this internal drop in thus simulated. It can also be seen in Figure 4 that the voltage between points 57 and 60, which represents the internal drop in the motor, adds to the integrated voltage which represents the gradient of signal C during the starting and stopping periods, so that there is present at terminal 64 during operation a voltage such as is illustrated by waveform D in Figure 6.

Figure 5 shows an actual circuit based on the general circuit diagram shown in Figure 4. Thus, components which are the same as those in Figure 4 are shown in Figure 5 with the same references. The two chief differences are firstly that a decoupling capacitor 56′ is inserted in parallel with the resistor 58 for simulating the internal drop, and secondly that there is a switching arrangement 66 which is intended to connect or disconnect resistor 52′ depending upon whether the period corresponds to the starting or stopping of the motor. This switching arrangement is produced in a simple manner. The output signal from terminal 46 is applied to the direct input of a differential amplifier 68, whose inverting input (–) is on the one hand earthed via a resistor 70 and on the other hand is connected to the output of the amplifier via a resistor 72. The output of the amplifier is connected to two circuits which are provided respectively to bias two field-effect transistors 74 and 76 of opposite types. The two biasing circuits comprise respectively two diodes 78, 80 connected in series with respective ones of two earthed resistors 82, 84, in the manner shown in Figure 5. The gates of transistors 74 and 76 are respectively connected to the points common to diodes 78 and 80 and resistors 82 and 84. The transistors have their sources connected to the inverting input (–) of differential amplifier 54 and their respective drains connected to one end of resistor 52′ via two diodes 86 and 88 which are biased to conduct current in the same direction as their corresponding transistor.

The circuit in Figure 5 is intended to receive instruction signals (such as signals A and B in Figure 6) at its two input terminals 90 and 92 respectively, these signals corresponding to the motor running forward and in reverse. These signals are processed by an input circuit 94 which contains two field effect transistors 96 and 98 of the same type, whose gates are connected to input terminals 90 and 92 respectively. The drains of these transistors are respectively connected by two resistors 100 and 102 to two sources B+ and B– of supply voltage, whilst their sources are combined at a common point 104. This point is connected to resistor 48. Two diodes 106 and 108 are connected in opposite directions between point 104 and earth. Point 104 is also connected to the direct input of a differential input amplifier 110 whose output is connected to a resistor 112. The output of this amplifier is also connected by a resistor 114 to its inverting input and by a resistor 116 to earth. Finally, two diodes 118 and 120 respectively connect the drains of transistors 96 and 98 to earth and two diodes 122 and 124 limit the maximum voltage applied to the resistors 52 and 52′ to which these diodes are connected.

Thus, if for example the voltage applied to terminal 92 exceeds a value of zero so as to order forward running, for example; the voltage at terminal 64 changes as a function of the supply voltage B′ and of resistors 100 and 48. By this instruction, point 104 is raised to a negative potential which is restricted by the value of the junction voltage of diode 106. In this way, the switching arrangement 66 places transistor 76 in circuit during starting. The conduction of differential amplifier 54 changes as a function of the integration constant set by capacitor 56 and the parallel resistors 52 and 52′. When the output level is reached the potential at point 104 becomes zero again.

The definition of the invention which was given above shows that it may be put into practice by circuits different from those which have been described and illustrated with reference to Figures 4 and 5.

Generally speaking, the invention is in no way restricted to the embodiments shown and described and in fact covers all the means described and illustrated, as well as combinations thereof if these are made within the scope of the invention and are employed in the context of the following claims.

WHAT WE CLAIM IS:—

1. A system for controlling a separately excited constant load D.C. electric motor of the kind comprising a generator for generating a signal to control the speed required from said motor, a power amplifier connected to the motor which receives said control signal in order to adjust the speed of said motor, and an arrangement for compensating for the internal voltage drop in the motor during periods when the speed of the motor is to be changed, the compensating arrangement comprising means connected between said generator and said power amplifier and which react to said control signal to generate a loss signal representing the expected losses occurring in the motor due to the resistance of the motor armature during the change in speed of the motor, and means to combine the loss signal with the control signal.

2. A control system according to claim 1, characterised in that the said control signal includes a component for controlling the speed when running in a forward direction which contains an interval for controlling the starting-up speed, and interval for controlling the steady speed, and an interval for controlling the stopping speed.

3. A system according to claim 1 or 2, characterised in that the control signal includes a component for controlling the speed when running in reverse which contains an interval for controlling the starting up speed, and an interval for controlling the steady speed, and an interval for controlling the stopping speed.

4. A system according to any one of claims 1 to 3, characterised in that the said generator comprises an integrating means.

5. A system according to claim 4, characterised in that the integrating means is connected in parallel with a first resistor and includes a differential amplifier which has in its feedback loop a capacitor of which one terminal is connected to one end of the said first resistor, the said means for generating the said loss signal comprise a second resistor connected in the said feedback loop, and in that the aforesaid combining means are formed by connecting the second resistor between the output of the said differential amplifier and the said capacitor terminal which is connected to the said end of the said first resistor.

6. A system according to claim 4 or 5, characterised in that the integrating means provides at least two selectable time constants.

7. A system according to claim 6, characterised in that the integrating means includes third and fourth resistors, which are connected selectively to the said capacitor of the integrating means to give the two aforesaid time constants which correspond respectively to the said intervals when the motor is starting up and stopping.

8. A system according to claim 7, characterised in that one of the said third and fourth resistors is associated with a switching arrangement intended to connect it in parallel with the other resistor, or not to so connect it, in order to give the

aforementioned two time constants, the said switching arrangement including at least one device whose current conduction is controlled by a signal derived from the said control signal.

9. A system for controlling a separately excited D.C. motor substantially as hereinbefore described with reference to the accompanying drawings.

BARON & WARREN,
16 Kensington Square,
London, W.8.
Chartered Patent Agents.

Printed for Her Majesty's Stationery Office, by the Courier Press, Leamington Spa, 1981
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

1599375 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

Fig. 1.

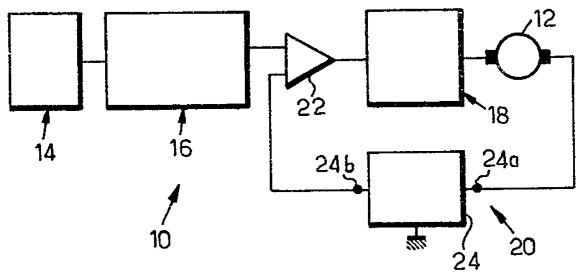


Fig. 2.

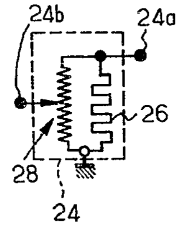


Fig. 3.

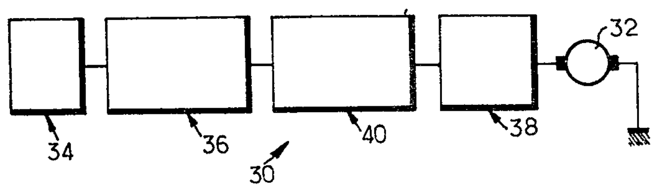


Fig. 4.

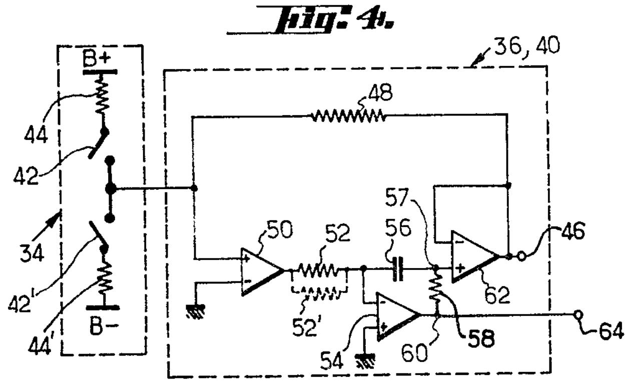


Fig. 5.

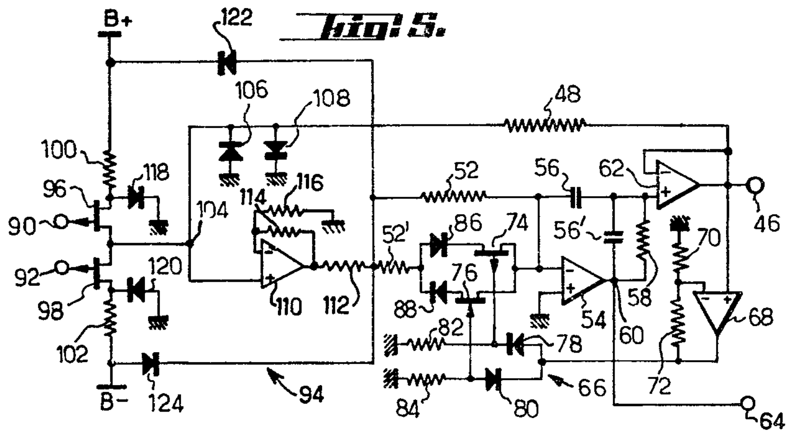
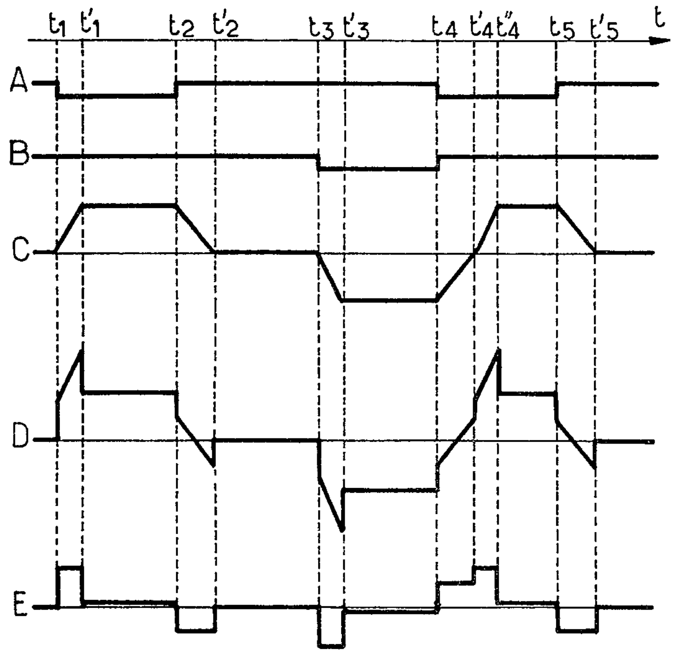

B+
122
106
108
48
100
118
96
90
114
116
104
52
56
62
46
52'
86
74
56'
70
92
120
76
88
82
110
112
54
58
60
68
98
102
78
72
B-
124
94
84
80
66
64

Fig. 6.


t1 t'1 t2 t'2 t3 t'3 t4 t'4 t''4 t5 t'5 t
A
B
C
D
E