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ACCELERATION CONTROL SYSTEM

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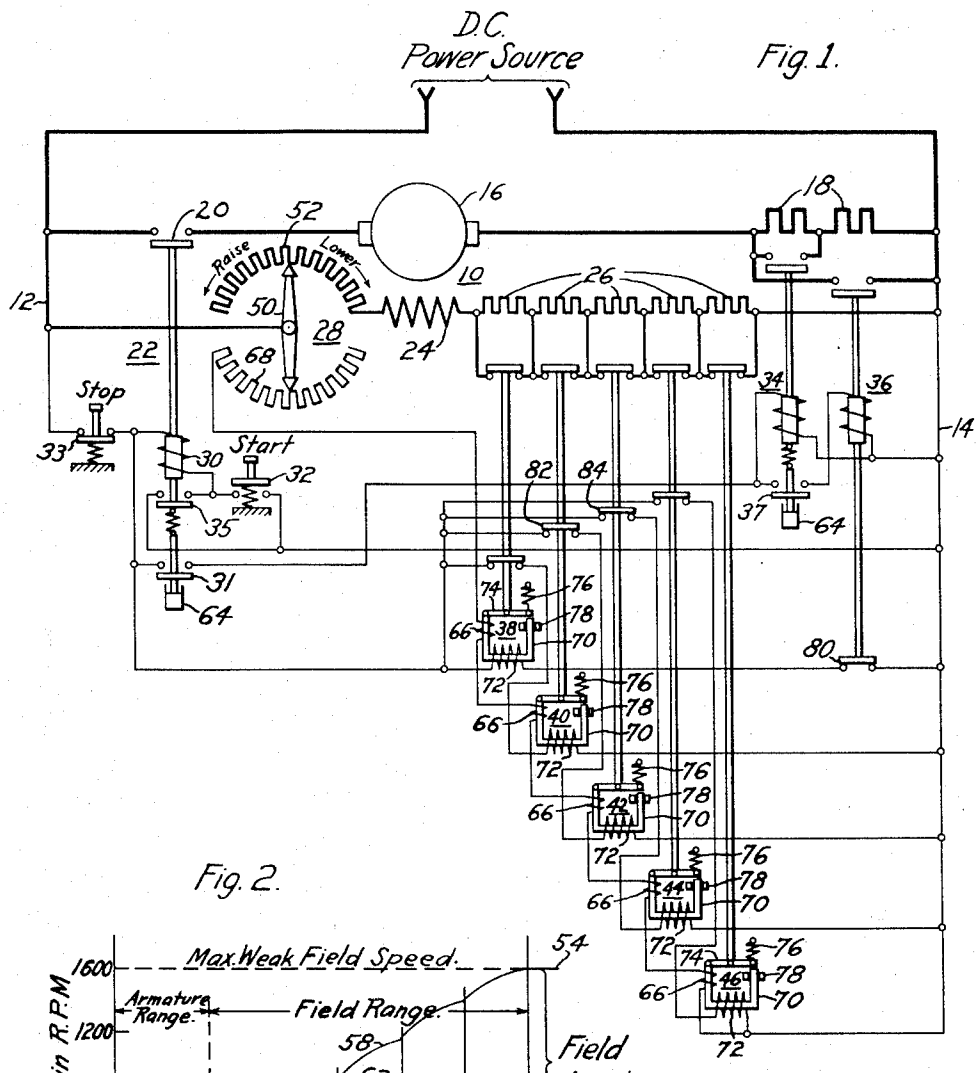


Fig. 1.

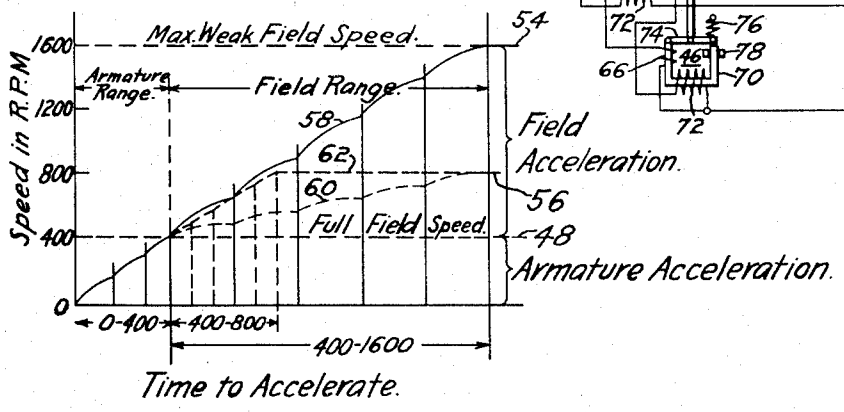


Fig. 2.

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ACCELERATION CONTROL SYSTEM

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7 Claims. (Cl. 172—288)

My invention relates to control systems for adjustable-speed electric motors, and it has particular relation to systems incorporating automatic accelerating means which, during the starting cycle, progressively increase the speed of the motor in a plurality of time-spaced steps.

Generally stated, the object of my invention is to improve the starting performance of adjustable-speed electric motors, particularly those intended for use in cloth finishing and other applications where closely controlled acceleration is important.

A more specific object is to maintain the rate of starting acceleration substantially uniform for differing settings of the field rheostat or other device which selects the motor operating speed.

My invention itself, together with additional objects and advantages, will best be understood through the following description of a specific embodiment thereof when taken in conjunction with the accompanying drawing in which:

Figure 1 is a diagrammatic view of apparatus and circuits representing one preferred form of my invention applied to an automatic accelerating system for a direct-current motor, and

Fig. 2 is a diagram of curves illustrating the performance of the complete system of Fig. 1 for two different settings of the speed-selecting rheostat.

In Fig. 1 of the drawing, the motor to be controlled is represented at 10 as being of a well-known direct-current type adapted to derive energizing current from a power circuit 12—14. The circuit through which the armature winding 16 is energized includes one or more starting resistor sections 18 and the contact member 20 of a main control contactor 22. The energizing circuit for the field winding 24 includes a plurality of accelerating resistor sections 26 and a speed-setting rheostat 28.

Contactor 22 controls the operation of motor 10 by completing its armature energizing circuit. It is actuated by a winding 30 energized through a push button 32 and deenergized by a second push button 33. Once actuated, contactor 22 locks itself in through an auxiliary member 35 thereby maintaining the armature circuit closed until this actuating circuit is interrupted at push button 33.

Resistors 18 limit the initial starting current to a safe value. A short time after the armature is energized a relay 34 is actuated through a circuit which includes a delayed closing member 31 of contactor 22. This bypasses one of the sections of resistor 18. The resulting increase in current further raises the motor speed. After a further short delay, a second relay 36 is similarly actuated by action of an auxiliary contact member 37 of relay 34. This bypasses the remaining resistor section 18, thereby impressing the full power circuit voltage upon the motor armature.

In the system disclosed, field circuit resistors 26 are then progressively bypassed by the associated accelerating relay devices 38, 40, 42, 44 and 46 which are arranged automatically to actuate one after the other in time-spaced succession. The range of this automatic field acceleration control begins at what may be designated as full field speed. This is indicated at 48 in Fig. 2. It ends at the value of motor operating speed which the setting of rheostat 28 determines.

When the arm 50 of this rheostat is rotated counter-clockwise to insert all of the resistor 52 into the field winding circuit, this operating speed of the motor will be maximum. Such a value is indicated at 54 in Fig. 2 and may be designated as a maximum weak field speed. When, as represented in Fig. 1, the rheostat arm occupies an intermediate position in its range of adjustment, this final operating speed will be of some lower value such as indicated at 56, in Fig. 2.

Systems of the general type thus far described are well known, and have for some time been extensively utilized with adjustable-speed direct-current motors. Such motors are excellently suited for use in driving cloth finishing machines and in other applications, where a large range of adjustment in driving speed is essential. A range of adjustment of 3 to 1 or 4 to 1 by field control is readily attained.

All such prior art control systems with which I am familiar are, however, subject to a serious disadvantage. In the past the accelerating relays (devices 38, 40, 42, 44 and 46 of Fig. 1) have been designed to introduce the same time delay between successive actuations under all conditions of motor operation. This uniform time spacing of successive decreases in the motor excitation means that the total time required to accelerate the motor from its full-field speed 48 to its final operating speed is always the same.

When the field rheostat 28 is set for maximum operating speed, the rate of acceleration will be determined by the slope of curve 58 of Fig. 2. When, however, the setting is for a lower speed 56, the rate of acceleration will be decreased to the much lower value represented by the slope of curve 60. The average rate of acceleration cannot therefore be the same for two different settings of the speed determining device 28.

For many applications this variation is highly objectionable. In cloth finshing machines for example, the operating speed of the driving motor must be adjusted in accordance with the cloth being processed. A fine open material such as surgical gauze usually runs at a speed approximately four times as fast as a heavy shirting material. Particularly when a comparatively weak material is to be run at high speed, the driving motor must be accelerated with caution. In order that the material may not be injured during the starting cycle, it is necessary that the acceleration be uniform from standstill up to the full operating speed.

In accordance with my invention, I so arrange the automatic accelerating apparatus that the rate of acceleration of the motor speed will be maintained substantially uniform regardless of the setting of the field rheostat 28 or other speed determining device. I attain this desirable result through the provision of means which vary the length of time delay between successive actuations of the speed raising relays 38 to 46 in accordance with the speed setting of rheostat 28.

This permits me to maintain the rate of acceleration substantially uniform under all conditions of motor operation. For example, when the system of Fig. 1 is arranged in accordance with my invention, the motor 10 will be accelerated to intermediate speed 56 in accordance with curve 62, the rising portion of which substantially coincides with the curve 58 according to which the motor accelerates to the high speed 54. As examination of these curves will reveal, the total accelerating time is much less for the slower final speed 56 than for the high operating speed 54. The time for each individual step of acceleration, determined by the spacing between successive actions of devices 38 to 46, is correspondingly reduced for the slower speed.

The curves of Fig. 2 apply to the control system of Fig. 1 which provides three steps of armature control and five steps of field control. The curve 58 represents how the motor 10 accelerates to a maximum speed of 1600 R. P. M. while the curve 62 applies to the same motor accelerating to 800 R. P. M. Up to the full-field speed of 400 R. P. M. the two curves exactly coincide. From this point on, however, or within the range of field acceleration, the increment per step is three times as great for curve 58 as for curve 62.

In the embodiment of my invention represented in Fig. 1, the timing between the successive steps of armature acceleration may be determined by any suitable form of delaying device associated with control devices 22 and 34 and represented in the form of dash pots 64. The proper timing for these steps of acceleration will in general remain constant for a given application and when once determined may remain fixed thereafter.

As previously explained, the timing relays 38 to 46 which control the field acceleration are of a type capable of adjustment in response to the setting of motor field rheostat 28. In the system of Fig. 1, the relays chosen for this purpose are of the inductive type, the time of operation of which is readily adjusted by varying the current flow through a demagnetizing or timing winding 66. The magnitude of this current, in turn, is adjusted by means of an auxiliary element 68 of the speed-setting rheostat 28. This element is included in the circuit through which the several relay timing windings 66 are energized.

In addition to the timing windings, each of the field accelerating relays comprises a U-shaped or other equivalent core 70 which, when magnetized by a main winding 72, biases a pivoted armature 74 into the downwardly illustrated position against the upward pull of a spring 76. The core also carries a heavy damping conductor 78 which prevents rapid changes in flux. The main winding 72 produces a stronger magnetizing force than the opposing one of the magnetizing winding 66.

As long as the main winding 72 is energized, the relay will occupy the position illustrated in which the associated contact members complete the circuits of which they form a part. Deenergization of the main winding allows neutralizing winding 66 slowly to reduce the core flux. After a time delay, this reduction is carried to a point where spring 76 biases the armature 74 upwardly, thereby opening the relay contact members.

The operation of these field accelerating relays in the system represented is as follows:

Upon closure of armature accelerating relay 36, which impresses full line voltage upon the motor armature winding 16, an auxiliary contact 80 deenergizes the main winding of field accelerating relay 38. After a time delay this relay biases its contact members upwardly, inserting the first resistor section 26 into the motor field winding circuit.

In so actuating, an auxiliary contact member 82 of the relay interrupts the energizing circuit for the main winding of field accelerating relay 40. After a time delay it similarly inserted a second resistor section 26 into the field winding circuit and by an auxiliary contact 84, places relay 42 in a condition for actuation. In delayedly actuating this relay introduces a third resistor section 26 and places relay 44 in condition for actuation. This, in turn, causes relay 46 to insert the last resistor section 26 into the field winding circuit.

In this manner the motor speed is increased from the full-field value 48 to the final operating value in a plurality of time spaced steps. The spacing of these steps varies with the position of speed setting rheostat 28. When the arm 50 is rotated counter-clockwise to a high speed position, the portion of auxiliary resistor 68 in active circuit with the relay timing winding 66 is maximum. The comparatively weak current supplied to these windings causes the delay in the relay actuation to be prolonged, as is required to produce an acceleration of the type shown by curve 58.

When, however, the rheostat arm 50 is rotated clockwise to a low speed position, only a small portion of auxiliary element 68 is in the relay timing circuit and the current traversing windings 66 is correspondingly larger. In consequence the delay in the actuation of the field accelerating relays is correspondingly reduced to the smaller value required to produce an acceleration curve of the type shown at 62 in Fig. 2.

It will thus be seen that I have provided a very simple and effective method for maintaining the rate of acceleration uniform regardless of the setting of the speed determining rheostat associated with the controlled motor. My invention is not restricted to the particular arrangement illustrated, but is capable of broad application to all situations in which operation of the type above discussed is desired.

In representing it as applied to the field controlled direct current motor of Fig. 1, I have included only those portions of a conventional control circuit which are essential to a proper

explanation of my invention. No attempt, for example, has been made to show the system of dynamic braking which is commonly applied to motors of this type, nor have I represented various other control refinements such as under voltage protection, means for stopping the accelerating cycle at full-field speed, means for applying maximum exciting current to the field winding during the initial starting, and the like.

Although I have shown and described a certain specific embodiment of my invention, I am fully aware that many modifications thereof are possible. My invention, therefore, is not to be restricted except insofar as is necessitated by the prior art and by the scope of the appended claims.

I claim as my invention:

1. In a system comprising an electric motor, a device for adjusting the operating speed thereof, and starting means including apparatus adapted progressively to increase the speed of the motor in a plurality of time-spaced steps, the combination of means for maintaining the rate of motor-speed acceleration substantially uniform for differing speed settings of said device.

2. In a system comprising an electric motor, a device for adjusting the operating speed thereof, and starting means including apparatus adapted progressively to increase the speed of the motor in a plurality of time-spaced steps, the combination of means for varying the time-spacing of said steps in accordance with the speed setting of said device.

3. In a system comprising an electric motor, a device for adjusting the operating speed thereof, and starting means including apparatus adapted progressively to increase the speed of the motor in a plurality of time-spaced steps, the combination of means for causing the time-spacing of said steps so to vary with the speed setting of said device that the rate of motor-speed acceleration is maintained substantially uniform regardless of the magnitude of said setting.

4. In a system comprising an electric motor having a speed-determining winding, a speed-adjusting rheostat associated therewith and motor starting means including a plurality of speed-raising relays adapted to actuate in delayed time-spaced succession, the combination of means for varying the length of said time spacings in accordance with the speed-setting of said rheostat.

5. In a system comprising an electric motor having a speed-determining winding, a speed-adjusting rheostat associated therewith and motor starting means including a plurality of speed-raising relays adapted to actuate in delayed time-spaced succession, the combination of means for causing the length of said time spacings so to vary with the speed setting of said rheostat that the rate of motor-speed acceleration is maintained substantially uniform regardless of the magnitude of said setting.

6. In a system comprising a direct-current motor having a speed-determining field winding, a speed-adjusting rheostat connected in circuit therewith and motor-starting means including a plurality of speed-raising relays adapted to actuate in delayed or time-spaced succession and each of which is provided with a timing-adjusting winding, the combination of means actuated by said rheostat for adjusting the energization of said delay-adjusting windings whereby to vary the length of time spacings in accordance with the speed setting of the rheostat.

7. In a system comprising a direct-current motor having a speed-determining field winding, a speed-adjusting rheostat connected in circuit therewith and motor-starting means including a plurality of speed-raising relays adapted to actuate in delayed or time-spaced succession and each of which is provided with a timing-adjusting winding, the combination of an energizing circuit for said timing-adjusting windings and an auxiliary section of said rheostat included in said circuit to cause the relay timings to vary with the speed setting of the rheostat.

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