

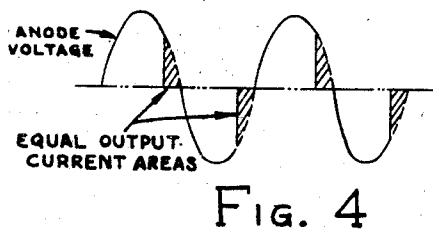
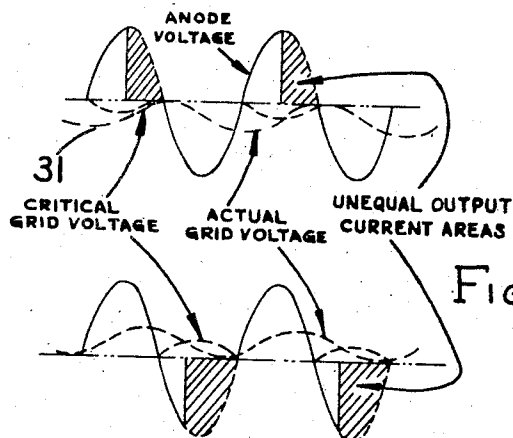
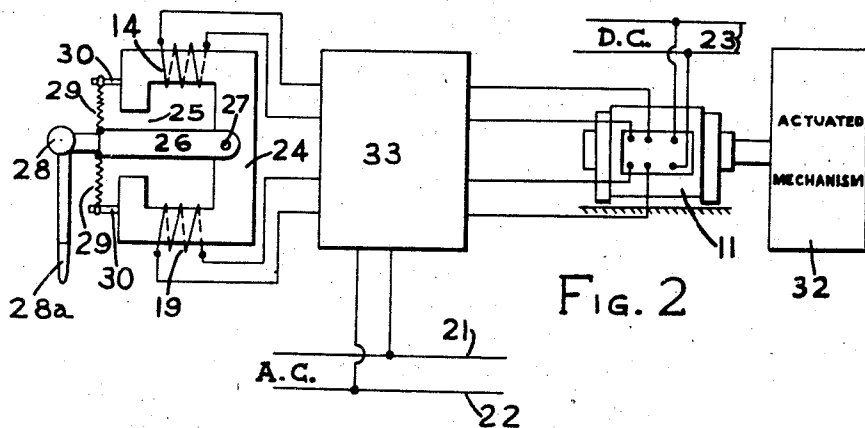
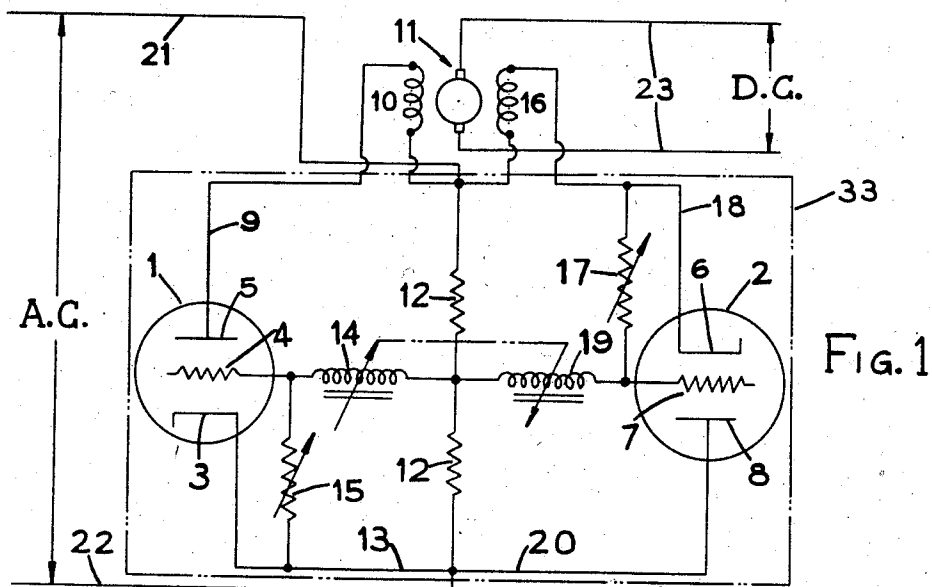
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ELECTRONIC CONTROL CIRCUIT

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ELECTRONIC CONTROL CIRCUIT

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2 Claims. (Cl. 318-297)

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The present invention relates to the control of mechanical operation, particularly by the use of electronic devices as applied to direct current loads such as motors, relays, etc.

This is a divisional application of the original application Serial Number 506,983, filed October 20, 1943, which became Patent Number 2,437,140 on March 2, 1948.

Various schemes have been advanced to control the speed of direct current motors from a remote position, and in general, most of them depend on the use of a variable resistor connected either in the field or in the armature circuit. Rheostats of this general character entail considerable losses when dealing with large power since they operate on the energy dissipative principle and, in addition, their effectiveness of control is affected by a number of variables such as changes in room temperature, humidity and the presence of dust, etc. There is also present the danger from electric shock when operating the rheostat because the adjustable arm on the resistor is directly associated with the line and electrical leakage due to poor insulation of the parts may be involved.

Many forms of mechanical operation require a sudden reversal of rotation of the motor as well as changes in speed, in which case, a reversing device such as a switch is usually provided in addition to the variable resistor to effect reversal and speed control in the opposite direction. The difficulty of arcing and resulting burned contacts may be encountered at the switch, particularly when large currents are being carried.

There is, therefore, a specific need in the art of electrical control systems for an improved structure and/or system by which the current supplied to a direct current load may be accurately controlled as to magnitude and direction without the breaking of contacts and without the necessity for auxiliary switches or other devices which are connected directly to the energy supply mains.

The primary object of the invention is to provide an efficient control system for an electric load and in which the current passing through the load may be limited to a predetermined amount and to a predetermined direction without having any direct connection between the control element and the current supply for the load.

Another object is to provide a combined control and supply system for a direct current load of the character set forth which would have the advantage of being self-rectifying so that the load may be energized from an alternating current source.

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Still another object is to provide a direction control for motors in which the control element or elements are not electrically connected to the high voltage lines so as to eliminate all danger of shock.

A still further object is to provide a highly sensitive but stable speed and direction control of direct current motors in which the exercised control is so sensitive that individual movements of the control element produce accurately proportional movements of the motor.

Another object is to provide an efficient and a sensitive control for direct current motors which permits reversal of the motor at the control element without the breaking of current carrying circuits and offers the same degree of sensitivity of speed control in either direction of rotation.

A more general object is to provide a control for a direct current load such as a motor or relay which is so sensitive that only an infinitesimally small movement of the control element is necessary to find adequate response in the operation of the motor or relay and a correspondingly small movement of the control element is necessary to reverse the operation of the motor or relay and to control the speed of operation in the reverse direction.

These objects are attained in brief by employing a plurality of electron discharge devices of the gaseous type and controlling the sequence of firing of the devices with respect to one another by means of a magnetic element having a control member which is completely disconnected from the electric system, but the movement of which is so related to the control element of the electric circuits as to change the electrical conditions within the electron discharge devices sufficient to control the currents passing there-through. These devices are preferably connected in opposition in the case of a reversible motor but may be connected in the same direction in case separate loads are employed with the individual devices.

The invention will be better understood when reference is made to the following description and the accompanying drawings in which:

Figure 1 is an elementary diagram of an improved electrical circuit and structure incorporating the features of this invention.

Figure 2 is a diagram particularly showing the control apparatus for the electric control circuit.

Figures 3 and 4 are diagrams indicating the voltage and current conditions within the improved circuit and associated structure.

Referring more particularly to Figure 1, a pair

of gaseous discharge devices 1 and 2, either of the glow discharge or arc discharge type, depending on the current requirements of the load, may be employed. The device 1 includes a cathode 3 which may be directly or indirectly heated, an electrostatic control element or grid 4 and an anode 5, while the device 2 includes a cathode 6, a grid element 7 and an anode 8. The anode 5 may be connected through a conductor 9 to a field winding 10 of a direct current motor 11, the circuit being completed through a pair of fixed resistors 12 and a conductor 13 back to the cathode 3.

The input circuit of the device 1 includes a variable reactor 14 connected between the grid 4 and a position between the resistors 12. A variable resistor 15 may also be connected between the grid element and the conductor 13.

The device 2 has corresponding elements and functions as those described in connection with device 1 except that it is connected to the field winding load circuit 16 in the reverse manner from the other device. A variable resistor 17 is connected between the grid element 7 and the conductor 18 which passes to the cathode 6 and there is a variable reactor 19 connected to the lower connection of the lower resistor 12 through conductor 20. While I have shown the field coils 10 and 16 of the motor 11 as constituting separate elements, it will be understood that if desired a single field winding may be provided for the motor as long as the tap is taken from the midpoint of the winding through the upper bridge resistor 12 to the inner terminals of the reactors 14, 19.

A supply of alternating current is taken to the devices 1, 2 through mains 21, 22, one of which is connected to the mid-tap between the fields 10 and 16 and the other is connected to conductors 13 and 20. The armature circuit of the motor 11 may be energized with direct current through a supply circuit 23.

It will be noted in the drawing that the arrows drawn across the reactors 14 and 19 point in opposite directions and are connected together. This is to signify that the reactances of these reactors are adjustable in a differential manner. Thus, as one of the reactances is increased in value the other reactance is decreased proportionately or in the same degree.

Any suitable structure may be provided in order to obtain this differential change in the reactors 14, 19 and one such structure has been illustrated in connection with Figure 2. The coils of the reactors 14, 19 are wound on a common magnetic core 24 having a C shape, i. e., one of the legs includes an air gap 25. A magnetic armature 26 is pivoted at 27 to the other leg of the core, this armature terminating in a knob 28 adapted to be operated by a stylus or lever 28a.

A pair of oppositely disposed springs 29 maintain the armature in an approximate midway position between a pair of supports 30, the arrangement being such that when the knob is moved upwardly, the lower spring 29 is placed under tension and the upper spring is relieved partly of its tension so that when the hand is removed from the knob the armature will assume a midway position within the air gap 25. It will be understood that this air gap would in practice be of considerably less length than that illustrated in Figure 2 in order that the permeability of the core as a whole will be sufficiently large to provide the proper reactance effects at the coils. It is apparent that as the armature 26 is moved upwardly the effective air gap in the upper

portion of the core 24 is decreased, thus increasing the reactance of the coil 14 while the effective air gap of the lower portion of the core is increased to decrease the reactance of the coil 19. By thus simply swinging the armature 26 upwardly, the reactance of coil 14 is increased and the reactance of coil 19 is decreased in a corresponding manner.

Referring now to Figure 1, it is apparent that alternating voltage is applied both to the output circuit which comprises the cathode 3 and the anode 5 and also to the input circuit which includes the electrodes 3 and 4. The phase relationship between the grid voltage and the anode voltage can obviously be changed by varying the reactance 14 and the same thing applies to the voltage relationships in the tube 2 when the reactance 19 is correspondingly varied. The net result is that by varying the reactance 14 in one direction and the reactance 19 in the opposite direction, the phase relationships of the voltages applied to the electrostatic control elements 4 and 7 are shifted with regard to the anode voltages applied to the respective tubes 1 and 2. This can be readily seen by examination of the diagrams shown in Figure 3 if it is assumed that the tubes 1 and 2 are of the arc or glow type and each have a critical negative grid voltage characteristic as shown in the figure which prevents the device from starting unless this critical voltage is exceeded. Assume that the adjustment made on the reactor 14 is such that the actual voltage applied to the grid 4 intercepts the critical grid voltage at point 31 (Figure 3), the tube will fire and the resulting glow or arc discharge will pass through the tube throughout the remainder of the positive half cycle of the anode voltage. The firing period of the tube is indicated by the shaded area in each half cycle of the anode voltage.

Now let us assume that the reactance 14 is increased, for example by raising the armature 26 (Figure 2) upwardly. The effective voltage applied to the grid will shift phase-wise so that the actual grid voltage curve will cut the critical grid voltage curve at a later period and the aggregate amount of current passing through the tube 1 will decrease. It is apparent that by varying the reactance 14 over a sufficiently wide range the tube 1 can be triggered at any point in the positive half cycle of the anode voltage and thereby change the average amount of current flowing over a predetermined period of time through the field winding load 10.

The tube 2 operates in the same manner as tube 1 except that it is reversely connected and when the reactance 19 is decreased in an amount corresponding with the increase of reactance 14, the alternating voltage applied to the grid 7 is shifted phase-wise, but in the opposite direction to trigger the tube 2 earlier in each half cycle of the anode voltage as shown in the lower portion of Figure 3. Under these circumstances the current flowing through the field winding load 16 is increased. It will be understood that rectified current flowing through field winding 10 tends to move the armature 11 in one direction and rectified current of opposite direction and flowing through the field winding 16 tends to cause the motor to rotate in the reverse direction. Thus, by differentially altering the reactances 14, 19 by means of a swingable armature 26 (Figure 2) or in any other suitable manner the motor 11 can be caused to rotate in one or the other direction

depending on the relative magnitudes of the reactances 14, 19.

Should the armature 26 remain in a position midway of the ends of the air gaps 25 so in effect to provide two air gaps of equal length within the upper and lower portions of the core 24, the phase relationships between the grid and anode voltages of the two tubes may be such as to permit as much current to flow through field coil 10 in one direction as flows through the field coil 16 in the opposite direction so that the motor does not rotate. This condition is shown in Figure 4 in which the output current areas of the upper and lower half cycles are exactly equal. Notwithstanding the fact that the motor does not rotate in either direction and is therefore stationary, it remains in a sensitive condition ready instantly to rotate in either direction upon the slightest change being made in the magnitudes of the reactances 14, 19. This highly sensitive but motionless condition of the motor is useful when an instantaneous response of the motor in either direction is required.

The resistances 15, 17 are provided to adjust the sensitivity of the circuit and it is apparent that due to the high state of balance that is possible in the bridge form of circuit shown in Figure 1 extreme orders of sensitivity can be obtained so that even the slightest change in the reactors 14, 19 is sufficient to bring instant response in the operation of the motor 11, either by way of change in speed or change in direction of rotation or both. Any speed of the motor may be obtained in this manner from the highest practical speed down to the slowest speed because any degree of voltage phase shift in the tubes 1 and 2 may be obtained and the instantaneous speed of the motor is directly proportional to the instantaneous changes in the voltage phase shifts.

In Figure 2 is shown a practical application of the control system of Figure 1 for regulating a D. C. motor 11 connected to a mechanism to be actuated indicated at 32. The vacuum tubes 1 and 2 and associated resistors and circuit wiring may be contained in a suitable cabinet 33 from which issue leads to the direct current motor field windings 11.

From the foregoing, it is evident that I have disclosed a highly sensitive and efficient control system, making use of gaseous discharge devices, both of the controllable and uncontrollable type, and the differential or the cumulative current through the devices may be advantageously employed to operate a direct current load which in turn may constitute a control element of a mechanical, electrical, or hydraulic system. The differential or cumulative currents passing through the system are sensitively and efficiently controlled by means of one or more reactors which may be operated simultaneously and either differentially or cumulatively to vary the reactances within the circuits and thus control the currents in the load.

While I have disclosed my invention in connection with the employment of variable reactors of the inductance type, it is obvious that I may utilize reactances of the capacitive type or even impedances (including resistance) in which the respective values of the impedances in the tube circuits are differentially or cumulatively con-

trolled in order to provide a phase shift between the grid and the anode voltages. It will also be apparent to those skilled in the art that instead of employing arc discharge devices for translating and controlling currents within the circuits I may if desired, and depending on the character of the load, utilize glow discharge devices.

It will be understood that I desire to comprehend within my invention such modifications as come within the scope of the claims and the invention.

Having thus fully described my invention, what I claim as new and desire to secure by Letters Patent is:

1. In combination in an electrical control circuit for varying the rate and direction of rotation of a direct current motor having an armature, a direct current source for exciting said armature, and first and second field windings associated with said armature, the combination of a first and second triode each having a cathode, an anode, and a grid, an alternating current supply including first and second leads, means connecting said first lead to one end of each of said field windings, means connecting said second lead to the cathode of said first triode and to the anode of said second triode, means connecting the other end of said first field winding to the anode of said first triode, means connecting the other end of said second field winding to the cathode of said second triode, a variable resistor connected between the cathode and grid of each of said triodes, a pair of fixed resistors connected in series across said first and second leads, a first variable reactor connected between an intermediate point between said fixed resistors and the grid of said first triode, and a second variable reactor connected between said intermediate point and the grid of said second triode, and mechanically operated means for simultaneously differentially adjusting said reactors.

2. In combination in an electrical control circuit for varying the rate and direction of rotation of a direct current motor having an armature, a direct current source for exciting said armature, and first and second field windings associated with said armature, the combination of a first and second triode each having a cathode, an anode, and a grid, an alternating current supply including first and second leads, means connecting said first lead to one end of each of said field windings, means connecting said second lead to the cathode of said first triode and to the anode of said second triode, means connecting the other end of said first field winding to the anode of said first triode, means connecting the other end of said second field winding to the cathode of said second triode, a variable resistor connected between the cathode and grid of each of said triodes, a pair of fixed resistors connected in series across said first and second leads, a first variable reactor connected between an intermediate point between said fixed resistors and the grid of said first triode, and a second variable reactor connected between said intermediate point and the grid of said second triode, mechanically operated means for simultaneously differentially adjusting said reactors, and means for normally positioning said last mentioned means to maintain said reactors at equal balanced values of reactance.

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