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CONTROL APPARATUS

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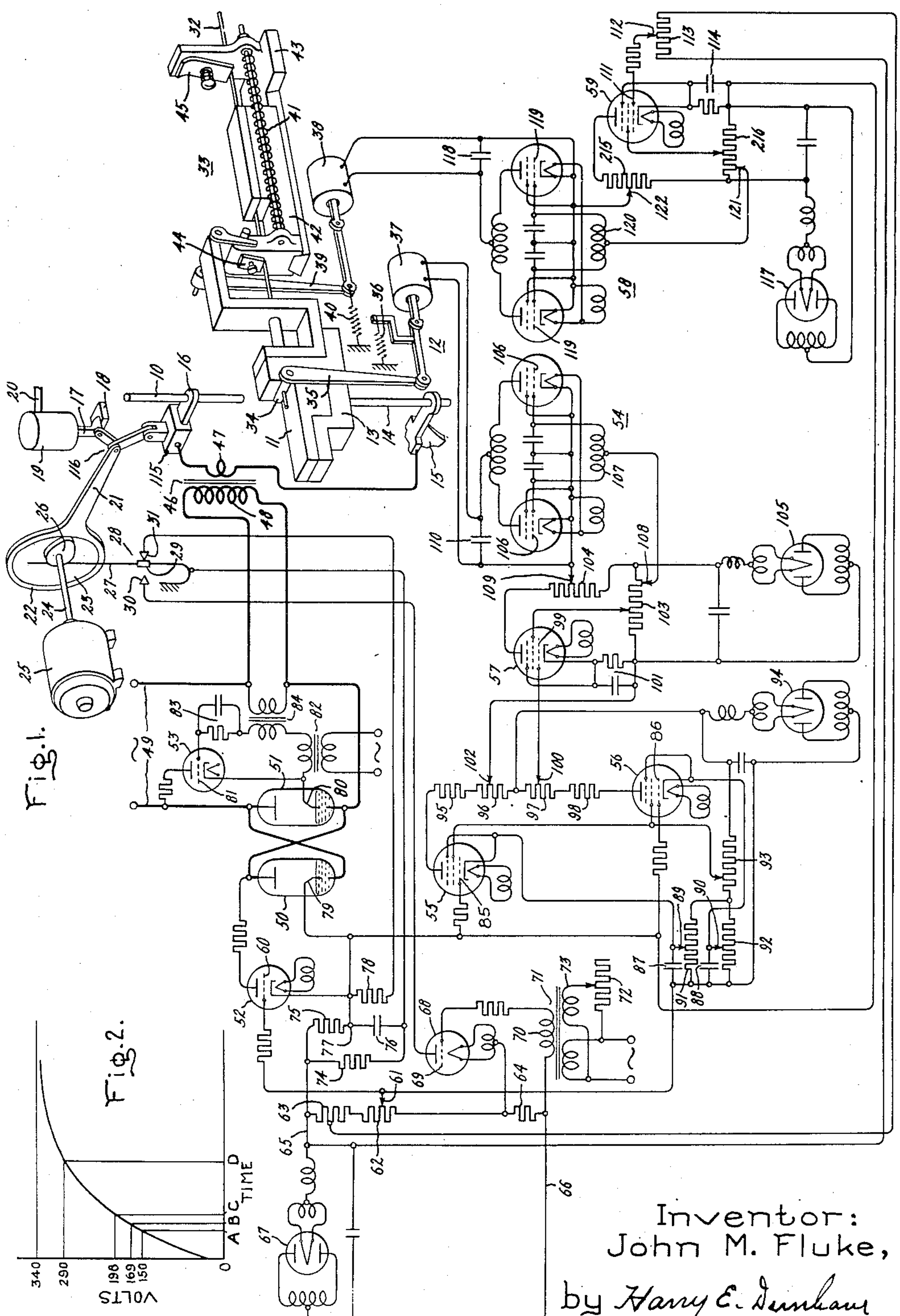

Fig. 1.

Fig. 2.

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CONTROL APPARATUS

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8 Claims. (Cl. 171—97)

My invention relates to control apparatus and particularly to electronic apparatus for timing and sequencing a plurality of operations.

It is an object of my invention to provide a control in which a voltage whose magnitude varies with the lapse of time sequentially operates a plurality of electric discharge devices according to a time pattern determined by different bias voltages which oppose the effect of said timing voltage on the control elements of said electric discharge devices.

It is also an object of my invention to provide electronic control apparatus in which the timing of one operation may be adjusted without materially altering the timing sequence of other operations or the timing of such other operations.

Further objects of my invention will become apparent from a consideration of the system diagrammatically represented in Fig. 1 of the accompanying drawing for operating a plurality of load devices. Fig. 2 of this drawing is a diagram which will be used in explaining the operation of this system.

In accordance with my invention a plurality of circuits, each of which includes an electric discharge device having a control element, is employed for controlling the energization of a plurality of load devices. The operations of these devices are timed to follow one another in a desired sequence. The timing and sequencing of these operations are determined by applying different bias voltages to the control elements of these electric discharge devices and simultaneously opposing these bias voltages with a voltage whose magnitude varies with the lapse of time. Means are also provided for simultaneously varying these bias voltages for determining the time during which one of said electric discharge devices functions without materially altering the timing sequence or timing operations determined by the other electric discharge devices.

In the system of Fig. 1 of the drawing, my control has been used to time the flow of welding current, then operate a cutting device, and finally operate a feeding mechanism in accordance with a preset time pattern.

The electrodes 10 and 11 and the cutting mechanism 12 of the resistance welding machine diagrammatically illustrated have been described and claimed in my United States Letters Patent 2,263,294, granted November 18, 1941, and assigned to the assignee of this invention. Electrode 11 is carried by a support member 13 mounted on a rod 14 which is clamped in the lower arm 15 of the welding machine. Electrode 10 is carried by the upper arm 16 of the welding machine. This arm projects from a slide 115 which is moved toward and away from arm 15 by a toggle 116, one end of which is connected to slide 115 and the other end of which is connected to a piston rod 17. This piston rod is held against a stop 18 by air pressure acting on its piston within a cylinder 19. Air at a predetermined pressure is supplied through a pipe 20 to the upper part of cylinder 19 and determines the welding pressure between electrods 10 and 11 when toggle 116 has been straightened sufficiently to move piston rod 17 from stop 18.

Toggle 116 is collapsed and straightened by an arm 21 which is connected to an eccentric strap 22. This eccentric strap rides on an eccentric 23 which is mounted on a shaft 24 and rotated therewith by a substantially constant speed motor 25. A switch cam 26 is also mounted on shaft 24 and is oriented relative to eccentric 23 so that when the eccentric is in a position to straighten toggle 116 sufficiently to apply welding pressure to electrodes 10 and 11, this switch cam moves a member 27 of a switch 28 to bring contacts 29 and 30 of this switch into engagement with one another. The arrangement is also such that when the welding pressure is released by the eccentric 23 acting to collapse toggle 116, switch member 27 moves to a position completing a circuit between contacts 29 and 31 of switch 28.

A measured length of material 32 used in making the welded assembly is fed by a hitch feed 33 through a passageway in the cutting cylinder 34 of the cutting mechanism 12. Hitch feed 33 and cutting mechanism 12 are mounted on support 13 for electrode 11. Cutting cylinder 34 is provided with an arm 35 which is biased by a spring 36 to a position permitting this feeding operation. It may be moved against the bias of spring 36 through the agency of electromagnet 37 to rotate cylinder 34 relative to electrode 11 and cut the measured length of material extending from cylinder 34.

The hitch feed is operated by an electromagnet 38. This electromagnet moves an arm 39 against the bias of springs 40 and 41 to move a slide 42 relative to its support 43. Slide 42 and its support 43 are provided with ratchets 44 and 45 which engage and cooperate in feeding material 32. The hitch feed is cocked by the energization of electromagnet 38 and when this electromagnet is deenergized spring 41 moves slide 42 forwardly carrying along material 32 due to the engagement of ratchet 44 therewith.

Welding current is supplied to electrodes 10 and 11 by a welding transformer 46. The terminals of the secondary 47 of this transformer are connected to electrodes 10 and 11 of the welding machine and the terminals of its primary 48 are connected to a source of alternating current 49 through reversely connected electric discharge devices 50 and 51.

The conductivity of electric discharge devices 50 and 51 is controlled by electric discharge devices 52 and 53 associated therewith. The operation of electromagnet 37 for cutting mechanism 12 is determined by a full-wave controlled rectifier 54 which in turn is controlled by electric discharge devices 55 and 56 acting through the agency of an electric discharge device 57. The operation of electromagnet 38 for operating the hitch feed 33 is determined by a full-wave controlled rectifier 58 which in turn is controlled by an electric discharge device 59. The sequential operations of electric discharge devices 52, 55, 56 and 59 time the welding operation, thereafter sever an end portion of material 32, and then operate the feeding mechanism 33 to supply a measured length of material 32 for the next welding operation.

Electric discharge device 52 serves the dual purpose of timing as well as controlling electric discharge device 50. It connects through its anode-cathode circuit the anode of electric discharge device 50 to its control element 79.

Control element 60 of electric discharge device 52 is connected to a slider 61 on a resistor 62. This resistor is connected between resistors 63 and 64 across a source of direct current 65, 66. This source of direct current is obtained from an alternating current source through a rectifier 67 which is connected so that conductors 65 and 66 become respectively positive and negative conductors.

The cathode of an electric discharge device 68 is connected between resistor 62 and resistor 64 above referred to. The anode of this electric discharge device is connected through contacts 29 and 30 of switch 28 and loading resistor 74 which is in parallel with a charging resistor 75 and timing condenser 76, to the positive conductor 65 of the direct current source of supply 65, 66. A discharge resistor 78 is connected across condenser 76 through contacts 29 and 31 of switch 28.

Electric discharge device 68 causes the flow of welding current to start at the desired point on the voltage wave of source 49 after contacts 29 and 30 of switch 28 have closed. The control element 69 thereof is connected to the negative terminal of resistor 64 through the secondary 70 of a peaking transformer 71 which supplies a voltage overcoming the negative bias obtained from resistor 64. The point on the alternating current wave of the source of supply 49 for the welding transformer 46 at which this peaked voltage occurs is controlled by the variable resistor 72 connected in series with one of the primary windings 73 of transformer 71 which is energized from the alternating current source 49.

As previously stated, control element 60 of electric discharge device 52 is connected to slider 61 of resistance 62. Its cathode is connected at 77 between charging resistor 75 and condenser 76.

Electric discharge device 53 controls electric discharge device 51. It connects through its anode-cathode circuit the anode of electric discharge device 51 to its control element 80. A bias voltage 180° out of phase with the anode voltage of electric discharge device 53 is applied to its control element 81 through a transformer 82 which is energized from source 49. A self-rectified bias voltage is also applied to this control element by the parallel connected resistor and condenser 83. A control voltage for rendering electric discharge device 53 conductive is obtained from a feedback transformer 84 whose secondary is connected in circuit with control element 80 of electric discharge device 53 and whose primary is connected across the primary 48 of welding transformer 46.

Control elements 85 and 86 of electric discharge devices 55 and 56 are connected to point 77 between charging resistor 75 and timing condenser 76. The cathodes of these electric discharge devices are connected respectively through bias voltage condensers 87 and 88 to slider 61 on resistor 62. The voltage of condenser 88 is adjusted to be greater than the voltage of condenser 87. This is accomplished by an adjustment of sliders 89 and 90 on resistors 91 and 92. These resistors 91 and 92 are connected in parallel with one another and in series with resistor 93 across the output terminals of rectifier 94. These resistors serve as a source of direct current voltage for electric discharge devices 55 and 56. The anode of electric discharge device 55 is connected through resistors 95 and 96 to the positive terminal of resistor 93 and the cathode of electric discharge device 55 is connected to slider 89 on resistor 91. The anode of electric discharge device 56 is connected through resistors 97 and 98 to the positive terminal of resistor 93 and its cathode is connected to slider 90 on resistor 92.

When electric discharge device 55 becomes conductive it causes electric discharge device 57 to become conductive and when electric discharge device 56 becomes conductive it causes electric discharge device 57 to become nonconductive. The control element 99 of electric discharge device 57 is connected to a slider 100 on resistor 97 and its cathode is connected through a stabilizer consisting of a parallel connected resistor and condenser 101, to slider 102 on resistor 96. The anode cathode circuit of electric discharge device 57 is connected across a resistor 103 through a resistor 104. Resistor 103 in turn is connected across the output teminals of a full-wave rectifier 105 so that it serves as a source of direct current voltage.

So long as electric discharge device 57 is conductive it causes the controlled full-wave rectifier 54 to become conductive and energize electromagnet 37 of the cutting mechanism. A source of negative bias voltage for control elements 106 of the electric discharge devices of rectifier 54 is obtained from the secondary 107 of a bias transformer and slider 108 on resistor 103. The control voltage for these electric discharge devices is obtained from resistor 104 through its slider 109. The output circuit of rectifier 54 is connected to the operating winding of electromagnet 37 which is provided with a smoothing condenser 110.

The electric discharge device 59 controls the operation of electromagnet 38. Its control element 111 is connected to a slider 112 on a resistor 113 which is connected across a portion of resistor 63. Its cathode is connected through a stabilizer consisting of a parallel connected resistor and condenser 114, to point 77 between charging resistor 75 and timing condenser 76.

Its anode cathode circuit is completed through a resistor 215 to the terminals of a resistor 216. This resistor is connected across the output circuit of a rectifier 117 and consequently serves as a source of direct current voltage for electric discharge device 59.

When electric discharge device 59 is conductive full-wave rectifier 58 also becomes conductive to energize electromagnet 38 of the hitch feed 33. The operating winding of electromagnet 38 is also provided with a smoothing condenser 118. A source of negative bias voltage for control elements 119 of the electric discharge devices of rectifier 58 is obtained from the secondary 120 of a bias transformer and terminal 121 of resistor 216. The control voltage for these electric discharge devices is obtained from resistor 215 through its slider 122.

Electric discharge devices 55, 56, 57, and 59 may be of the vacuum type in which the control elements above identified are control grids. These electric discharge devices are also provided as indicated with suppressors and screen grids. As usual, the suppressor grid of each electric discharge device has been connected to its cathode and its screen grid has been connected to a source of voltage that is positive relative to its cathode. Discharge devices 50, 51, 52, 53, and 68 and the electric discharge devices of full-wave rectifiers 54 and 58 are of the gaseous type. The output circuit of each of the rectifiers 67, 94, 105, and 117 is provided with a filter circuit including a series connected inductance and a parallel connected condenser.

In order to simplify the drawing only the secondaries of certain alternating current transformers have been illustrated in the drawing. It is to be understood, of course, that each of these secondaries is energized through a primary which is connected to a source of alternating current which may be the same source 49 to which the welding transformer 46 is connected.

The system has been shown in its deenergized condition. None of the controlled electric discharge devices is conducting. The alternating current source is applied to the anode-cathode circuits of the electric discharge devices connected thereto and to the input circuits of the rectifiers and their filaments as well as the cathode heaters of the electric discharge devices. By reason of the energization of the rectifiers, the several sources of direct current control voltage across the potentiometers or resistors connected thereto will be available.

The system is set in operation by starting motor 25. Rotation of this motor rotates eccentric 23 which through its strap 22 and arm 21 straightens toggle 116 to move electrode 10 toward electrode 11. As a result of this movement electrode 10 engages the assembly to be welded including the end of material 32 extending through cutting cylinder 34. The assembly may comprise a switch member to which a contact formed from material 32 is welded. The switch member will be located on electrode 11 between it and the end of material 32 extending through cutting cylinder 34. Thereafter further straightening of toggle 116 moves piston rod 17 upwardly against the air pressure in cylinder 19 to apply a welding pressure determined by the amount of this air pressure. About this time switch cam 26 moves switch member 27 to bring switch contacts 29 and 30 into engagement with one another.

When contacts 29 and 30 of control switch 28 engage one another a charging circuit for condenser 76 is completed from conductor 65 through resistor 75 and electric discharge device 68 to conductor 66. Electric discharge device 68 is normally held nonconductive by the negative bias applied to its control element 69 and consequently the engagement of contacts 29 and 30 does not initiate the flow of charging current to condenser 76. At some point in the positive half cycle of the alternating current source determined by the adjustment of variable resistor 72, peaking transformer 71 applies a voltage to control element 69 of electric discharge device 68 which overcomes this negative bias and renders electric discharge device 68 conducting. Since the voltage on the anode of this electric discharge device is direct current this tube will remain conducting until its anode circuit is opened by the separation of contacts 29 and 30 of control switch 28.

When contacts 29 and 30 of control switch 28 are closed and electric discharge device 68 becomes conductive point 77 between charging resistor 75 and timing condenser 76 is brought to the potential of conductor 66 except for the voltage drop in resistor 64 and about 15 volts drop in electric discharge device 68. It is to be noted that point 77 is connected to the cathode of electric discharge device 52 whose control element 60 is connected to a more positive source of potential determined by the connection of slider 61 with resistor 62 of potentiometer 63, 62, 64. Electric discharge device 52 will consequently become conductive and in turn causes electric discharge device 50 to become conducting. The welding transformer 46 will consequently become energized from the source of supply 49.

The half cycle energization of the welding transformer through electric discharge device 50 will energize the control or feedback transformer 84 which will overcome the alternating bias voltage of transformer 82 and the self-rectified bias voltage of 83 to render electric discharge device 53 conductive which in turn renders electric discharge device 51 conducting during the next half cycle. Electric discharge device 50 will continue to conduct until the current passes through zero, at which time, due to the inductive nature of the welding transformer load, there will be considerable voltage across electric discharge devices 51 and 53 for the above described operation.

At the same time electric discharge device 52 became conducting electric discharge device 59 also became conducting energizing through controlled rectifier 58 the electromagnet 33 of hitch feed 33. The energization of electromagnet 38 cocks the hitch feed against the bias of its spring 41 so that upon deenergization of electromagnet 38 the hitch feed will supply a new length of material 32 for the next welded assembly.

Electric discharge device 59 becomes conductive by reason of the positive bias voltage applied to its control element 111 through potentiometer 113. The cathode of electric discharge device 59 is connected through stabilizer 114 to point 77 which is negative relative to the bias voltage applied to its control element 111. When electric discharge device 59 becomes conducting current flows from the plus terminal of resistor 216 through resistance 215 and stabilizer 114 to the negative terminal of 216. The voltage drop across the lower portion of resistor 215 overcomes the bias voltage obtained between the positive terminal and slider 121 of resistor 216 and the alternating bias of transformer secondary 120, thereby rendering the electric discharge devices of control rectifier 58 conductive to supply operating current to electromagnet 38.

As condenser 76 charges up, the voltage of point 77 gradually approaches that of conductor 65 until it is fully charged when it will be at the same potential as conductor 65. Loading resistor 74 connected across charging resistor 75 and condenser 76 will draw sufficient current to keep electric discharge device 68 ionized after condenser 76 has been fully charged.

At a time determined by the setting of slider 61 on resistor 62 a negative voltage will be applied to control element 60 of electric discharge device 52, thereby rendering it nonconductive after its anode voltage reverses and the current therethrough falls to zero. Consequently electric discharge devices 50, 53, and 51 also become non-conductive and interrupt the flow of welding current.

At some later time determined by the bias voltage of condenser 87 electric discharge device 55 will become conductive. It will be noted that the control element 85 of this electric discharge device is connected to point 77 which is growing positive due to the charging of condenser 76 and that its cathode is connected through the bias voltage of condenser 87 to slider 61 of resistor 62.

At a still later time electric discharge device 56 will become conducting. It is to be noted that its control element 86 is also connected to point 77 which is growing positive as condenser 76 is being charged and that its cathode is connected through the bias voltage of condenser 88, which is greater than the bias voltage of condenser 87, to slider 61 of resistor 62.

When electric discharge device 55 becomes conducting it connects resistors 96 and 95 across resistor 93 and a portion of resistor 91. A voltage drop consequently appears across resistor 96 which makes control element 99 of electric discharge device 57 positive relative to its cathode. This device consequently becomes conducting and in like manner previously described for electric discharge device 59 and renders controlled rectifier 54 conducting to energize the electromagnet 37 of the cutting mechanism and sever strip 32 from the welded assembly.

When electric discharge device 56 becomes conducting, it connects resistors 97 and 98 across resistor 93 and a portion of resistor 92. A voltage drop consequently appears across resistor 97 which makes control element 99 of electric discharge device 57 negative relative to its cathode. Electric discharge device 57 consequently becomes nonconducting, causing controlled rectifier 54 to be nonconducting and thereby deenergizing electromagnet 37. Upon the deenergization of electromagnet 37 the cutting mechanism is returned to the position illustrated so that a new length of material 32 may be fed through and between electrodes 10 and 11.

During the cutting operation electrodes 10 and 11 engage and hold the welded assembly. Thereafter motor 25 begins to raise electrode 10 from the welded assembly but before switch cam 26 separates contacts 29 and 30 of switch 28 sufficient time elapses for point 77 to become sufficiently positive to deenergize electric discharge device 59 and consequently electromagnet 38. The hitch feed which has been previously cocked now moves a new length of material 32 into position over electrode 11 for the next welding operation. Shortly thereafter contacts 29 and 31 of switch 28 are closed discharging condenser 76 through resistor 78 and thereby conditioning the timing circuit for the next sequence of operations which will be a repetition of those above described. These operations continue until motor 25 is stopped.

The above operation may be summarized by referring to Fig. 2 which diagrammatically represents the increase in voltage of point 77 with the lapse of time, an adjustment of slider 61 for applying a bias voltage of 150 volts in the control circuit of electric discharge device 52, an adjustment of slider 89 for increasing this bias voltage by 19 volts in the control circuit of electric discharge device 55, an adjustment of slider 90 for increasing this first mentioned bias voltage by 48 volts in the control circuit of electric discharge device 56, and an adjustment of slider 112 of potentiometer 113 for applying a bias voltage of 290 volts in the control circuit of electric discharge device 59. Welding current flows from 0 time when contacts 29 and 30 of switch 28 close and electric discharge device 68 becomes conductive until time A when the voltage of point 77 equals the voltage of slider 61. At time B when the additional 19 volts of condenser 87 are attained by point 77 electric discharge device 55 becomes conductive to energize electromagnet 37 which energizes the cutting mechanism. At time C when the additional 48 volts of condenser 88 are attained by point 77, electric discharge device 56 becomes conducting to deenergize electromagnet 37. It will be noted that the energization and deenergization of electromagnet 37 occurs in a time sequence determined by the bias voltages across condensers 87 and 88 which are always greater by a predetermined amount than the adjustable bias voltage obtained by adjusting slider 61 on variable resistor 62. By individually adjusting the bias voltages of condensers 87 and 88 through the agency of sliders 89 and 90 it is possible to time the energization and deenergization of electromagnet 37 relative to the time welding current ceases flowing. Electric discharge device 59 causes electromagnet 38 to be energized at zero time and to be deenergized at time D when the voltage of point 77 equals 290 volts which is subsequent to the operation of the cutting mechanism under the control of electromagnet 37.

It is of course apparent that my control system may be variously modified without departing from my invention. In place of condenser 76, other energy storage devices may be employed for obtaining a timing voltage. Furthermore, some of the electric discharge devices may be set to have initially a slight conduction, rather than zero conduction as stated above. Thus, for example, electric discharge devices 57 and 59 may be set for a slight conduction before the system is set in operation by the closure of contacts 29 and 30 of switch 28. Types of electric discharge devices different from those above described, yet functionally the equivalent thereof, may be used. Furthermore, in order to simplify the description of the system illustrated it has been assumed that the various electric discharge devices become conducting when their control elements are positive relative to their cathodes. It is of course apparent that this is not always the case and that allowance must be made therefor when electric discharge devices having different characteristics are employed.

In view of the above described application of my invention modifications, variations and other applications thereof will occur to those skilled in the art. I consequently intend in the appended claims to cover all such modifications, variations, and applications as fall within the true spirit and scope of my invention as defined in the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. Control apparatus comprising an electrical energy storage device, means for charging and discharging said energy storage device and thereby producing a timing voltage which varies in magnitude with the lapse of time, a plurality of electric discharge devices each of which has a control element, a plurality of circuits each of which includes one of said electric discharge devices, means for applying a different bias voltage to the control element of each of said electric discharge devices, means for simultaneously adjusting all of said bias voltages by the same amount and thereby adjusting the time during which one of said biased voltages is effective against said timing voltage without materially altering the time required for said timing voltage to pass from one value of bias voltage to another, and means for simultaneously applying said timing voltage to each of said control elements of said electric discharge devices in opposition to said bias voltages and thereby controlling the conductivities of said electric discharge devices and the timing operation of one of said circuits without materially altering the timing sequence in which said circuits operate.

2. Control apparatus comprising a plurality of electric discharge devices each of which has a control element, a plurality of circuits each of which includes one of said electric discharge devices, a condenser, means for charging and discharging said condenser and for producing a timing voltage which varies in magnitude with the lapse of time, means for simultaneously applying said timing voltage to each of said control elements of said electric discharge devices, means for timing the sequential operation of said electric discharge devices by applying to said control elements of said electric discharge devices in opposition to said timing voltage a bias voltage which is different for each of said electric discharge devices by an amount equal to the variation in said timing voltage for a desired time interval in said sequential operation of said electric discharge devices, and means for simultaneously adjusting said bias voltages by the same amount and thereby adjusting the operating time of that one of said electric discharge device having the low value of bias voltage applied thereto while maintaining said desired sequential operation of said electric discharge devices according to the time pattern determined by the diffrences in their said bias voltages.

3. Control apparatus comprising a source of direct current, a condenser, a resistance, a switch which in one position connects said condenser and said resistance in series with one another across said source of direct current to charge said condenser and in another position interrupts said charging circuit and completes a discharge circuit for said condenser, means including an electric discharge device for controlling the operation of a load device, means including another electric discharge device for controlling the operation of another load device, each of said electric discharge devices having a control element, a control circuit for each of said electric discharge devices, each of said control circuits having a common portion including an adjustable bias voltage which is opposed to and acts conjointly with a voltage which varies in accordance with the charge on said condenser for adjusting the time interval before one of said electric discharge devices exerts a control on its said load device and each of said control circuits having a portion which is individual to each of said control circuits, and means in the portions of said control circuits individual to each of said electric discharge devices for providing a predetermined difference in the bias voltages applied to the control elements of said electric discharge devices and thereby controlling the time interval between the control of one of said load devices by one of said electric discharge devices and the control of the other of said load devices by the other of said electric discharge devices.

4. Control apparatus comprising a source of direct current, a condenser, a resistance, a switch which in one position connects said condenser and said resistance in series with one another across said source of direct current to charge said condenser and in another position interrupts said charging circuit and completes a discharge circuit for said condenser, a source of alternating current, means for initiating the flow of direct current to said condenser at a predetermined point on the voltage wave of said source of alternating current, means including an electric discharge device for energizing a load device from said source of alternating current so long as said electric discharge device is rendered conductive, means including another electric discharge device for controlling the operation of another load device, each of said electric discharge devices having a control element, a control circuit for each of said electric discharge devices, each of said control circuits having a common portion including an adjustable bias voltage which is opposed to and acts conjointly with a voltage which varies in accordance with the charge on said condenser for adjusting the time interval before one of said electric discharge devices exerts a control on its said load device and each of said control circuits having a portion which is individual to each of said control circuits, and means in the portions of said control circuits individual to each of said electric discharge devices for producing a predetermined difference in the bias voltages applied to the control elements of said electric discharge devices and thereby controlling the time interval between the control of one of said load devices by one of said electric discharge devices and the control of the other of said load devices by the other of said electric discharge devices.

5. Control apparatus comprising a source of direct current, a condenser, a resistance, a switch which in one position connects said condenser and said resistance in series with one another across said source of direct current to charge said condenser and in another position interrupts said charging circuit and completes a discharge circuit for said condenser, a control circuit including an electric discharge device having an anode, cathode, and control element, a second control circuit including a second electric discharge device having an anode, a cathode, and control element, means for connecting a source of bias voltage between the cathode of said second electric discharge device and the control element of said first electric discharge device, means for directly connecting the control element of said second electric discharge device to the cathode of said first mentioned electric discharge device and both

said cathode of said first electric discharge device and said control element of said second electric discharge device to a voltage that varies in accordance with the charge and voltage of said condenser, and means for adjustably connecting the control element of said first electric discharge device and the cathode of said second electric discharge device in circuit with said source of bias voltage to a second source of bias voltage which is in circuit with said voltage that varies in accordance with the voltage of said condenser.

6. Control apparatus comprising a load device, means for controlling the electrical energization of said load device, said means including an electric discharge device having a control element, a second load device, means for electrically energizing said second load device, said means including a second electric discharge device having a control element, means for electrically deenergizing said second load device, said means including a third electric discharge device having a control element, means for applying a different bias voltage to the control element of each of said electric discharge devices to predetermine the sequential operation of said electric discharge devices, the bias voltage applied to said second electric discharge device being greater than that applied to said first electric discharge device and the bias voltage applied to said third electric discharge device being greater than the bias voltage applied to said second electric discharge device, a condenser, means for charging and discharging said condenser and producing a timing voltage which varies in magnitude with the passage of time, means for simultaneously applying said timing voltage to each of said control elements of said electric discharge devices in opposition to said bias voltages for rendering said first electric discharge device conductive for a predetermined time interval and thereafter rendering said second and third electric discharge devices conductive in a predetermined sequence after predetermined time intervals determined by the differences in the bias voltages applied to said control elements of said electric discharge devices, and means for simultaneously adjusting all of said bias voltages by the same amount for adjusting the time during which said first electric discharge device is conductive while maintaining said timed sequential operation of said electric discharge devices in accordance with said predetermined differences in their bias voltages.

7. Control apparatus comprising means including an electric discharge device for controlling the electrical energization of a load device so long as said electric discharge device is rendered conductive, means including a second electric discharge device for electrically energizing a second load device when said second electric discharge device is rendered conductive, means including a third electric discharge device for electrically deenergizing said second load device when said third electric discharge device is rendered conductive, each of said electric discharge devices being provided with a control element and a control circuit therefor, a condenser, means for charging and discharging said condenser and thereby producing a timing voltage which varies in magnitude with the lapse of time, means for initiating said timing voltage and simultaneously connecting it in each of said control circuits, means in each of said control circuits for applying to said control elements of said electric discharge devices bias voltages which are of increasingly greater magnitude for said second and third electric discharge devices in the order named from that applied to said control element of said first electric discharge device and which render said first electric discharge device conductive and said second and third electric discharge devices nonconductive at the time said control circuits for said electric discharge devices are completed by the connection of said timing voltage in said control circuits, and means for simultaneously adjusting said bias voltages of said first, second, and third electric discharge devices by the same amount for adjusting the conductivity period of said first electric discharge device and for rendering said second and third electric discharge devices sequentially conductive at predetermined times after said first electric discharge device becomes nonconducting.

8. Control apparatus comprising means including an electric discharge device for controlling the electrical energization of a load device so long as said electric discharge device is rendered conductive, means including a second electric discharge device for electrically energizing a second load device when said second electric discharge device is rendered conductive, means including a third electric discharge device for electrically deenergizing said second load device when said third electric discharge device is rendered conductive, means including a fourth electric discharge device for controlling the electrical energization of a third load device so long as said fourth electric discharge device is rendered conductive, each of said electric discharge devices being provided with a control element and a control circuit therefor, a condenser, means for charging and discharging said condenser and for producing a timing voltage which varies in magnitude with the lapse of time, means for initiating said timing voltage and simultaneously connecting it in each of said control circuits, means in each of said control circuits for applying to said control elements of said electric discharge devices bias voltages which are of increasingly greater magnitude for said second, third, and fourth electric discharge devices from that applied to said control element of said first electric discharge device and which render said first and fourth electric discharge devices conductive and said second and third electric discharge devices nonconductive at the time said control circuits for said electric discharge devices are completed by the connection of said timing voltage in said control circuits, and means for simultaneously adjusting said bias voltages of said first, second and third electric discharge devices by the same amount for adjusting the conductivity period of said first electric discharge device and for rendering said second and third electric discharge devices sequentially conductive at predetermined times after said first electric discharge device becomes nonconducting and before said fourth electric discharge device becomes nonconducting.

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