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I. EACHUS, JR
ELECTRICAL CONTROL SYSTEM

2,637,831

Filed Sept. 9, 1949

3 Sheets-Sheet 2

FIG. 3A

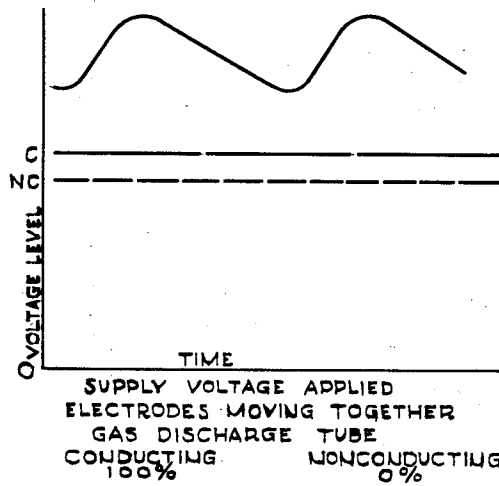


FIG. 3B

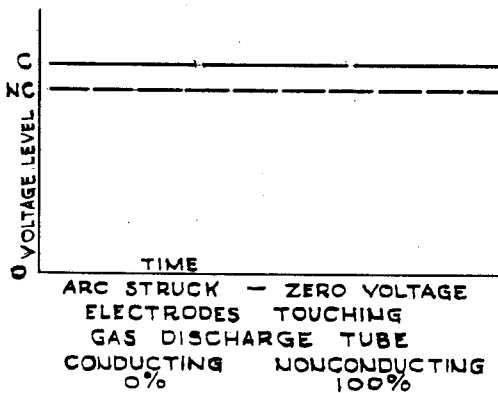


FIG. 3C

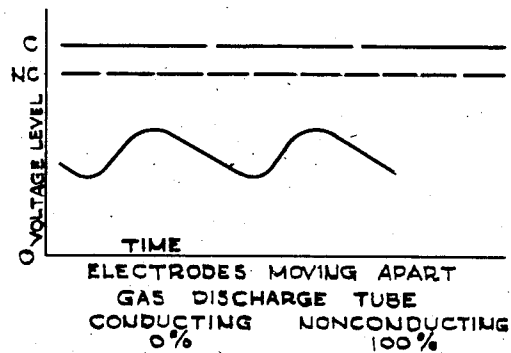
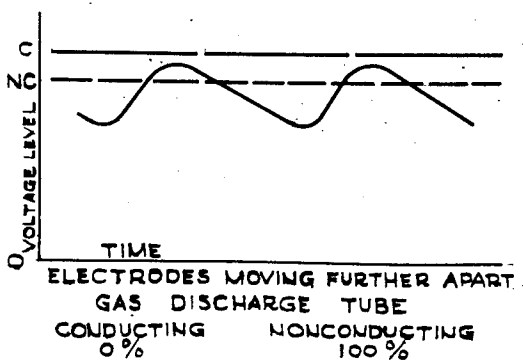


FIG. 3D



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FIG. 3E

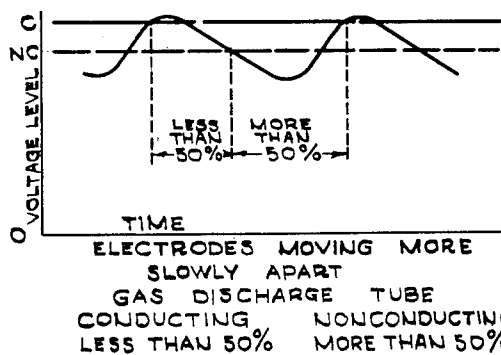
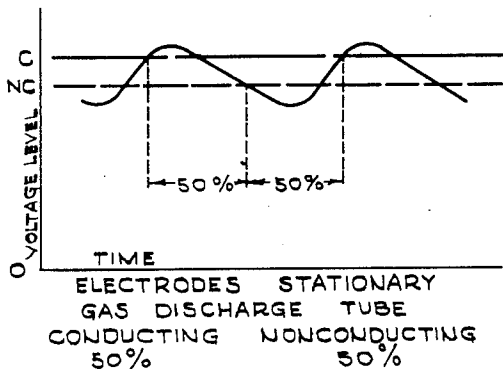


FIG. 3F

FIG. 3G

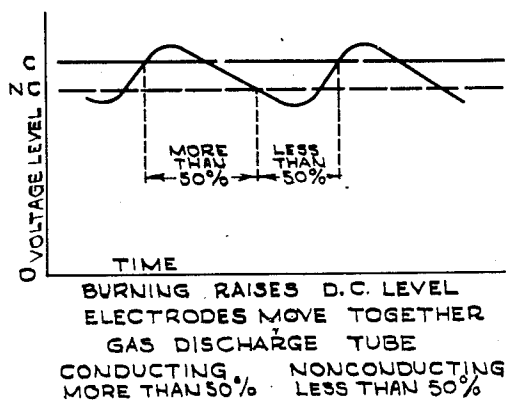
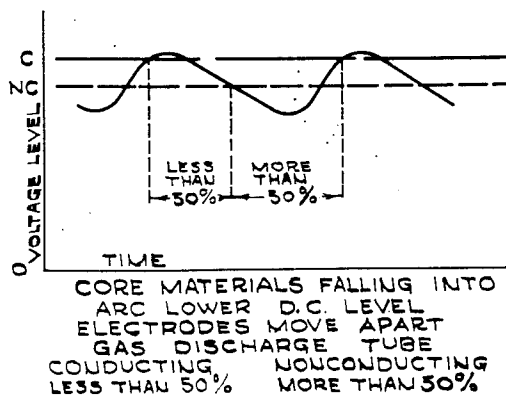


FIG. 3H



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UNITED STATES PATENT OFFICE

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ELECTRICAL CONTROL SYSTEM

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7 Claims. (Cl. 314-64)

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This invention relates to electrical control systems of the type embodying voltage-responsive control of an adjustable device. In its more limited aspect, the invention relates to control of arc lamps.

The principal object of the invention is to provide a highly efficient servo system of the voltage-responsive type.

A more specific object of the invention is to provide an improved system for the control of arc lamps.

While it is intended that the servo system provided by the present invention shall be utilized for control purposes wherever it may find useful application, the invention is especially adapted to arc lamp control and therefore it will be described with specific reference thereto.

The present invention evolved from an extensive study and investigation of arc lamp operation and control, and from extensive development work toward improved operation of arc lamps. In the past, arc lamps have not been entirely satisfactory, and careful investigation has shown that this has been due to the fact that the available control systems have been inadequate to provide the type of control action that is necessary to maintain steady light intensity. The two factors which determine the light intensity of an arc lamp are the voltage across the arc and the current flow. The voltage across the arc is proportional to the length of the arc gap which becomes greater as the electrodes burn away. It is therefore, necessary to adjust the length of the arc gap to maintain a substantially constant voltage thereacross, if the light intensity of the arc is to be maintained substantially constant. However, prior systems for automatically adjusting the length of the arc gap have not been entirely satisfactory.

By the present invention there is provided a rapid-action servo system of the voltage-responsive type which is capable of controlling an arc lamp in a highly efficient manner. As an additional feature, where A. C. operation of an arc lamp is desired, the invention provides for relatively slow action control of the arc current. This latter control is achieved by the use of a constant current transformer. The dual control, provided by using both the servo system and the constant current transformer, is highly desirable, although the servo system may be used alone where it is desired to supply D. C. to an arc lamp.

The invention may be fully understood by reference to the accompanying drawings in which:

Fig. 1 is a diagrammatic illustration of system

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embodying both types of control as above mentioned;

Fig. 2 is a similar illustration of a system embodying only the rapid servo control action; and

Figs. 3A to 3H are graphic illustrations which depict the operation of the servo system under different conditions.

Referring first to Fig. 1 of the drawings, a pair of electrodes are represented at 1 and 2, which may be considered to be carbon electrodes of an arc lamp. These electrodes are connected across the secondary 3 of a constant current transformer 4 whose primary 5 is connected to a suitable A. C. source by means of supply conductors 6. The source of A. C. voltage may be a 220-volt, 60 cycle source. The constant current transformer 4 serves as the relatively slow-acting ballast control means hereinbefore mentioned, and it serves to regulate the current supplied to the arc lamp electrodes independently of the rapid-acting voltage-responsive control arrangement now to be described.

The positioning of the electrodes 1 and 2 is effected by means of a conventional two-phase reversible motor designated generally by reference character 7. The motor shaft may be connected to reducing gears 8, the dotted line 9 representing the mechanical connection. The positioning of the electrodes may be effected by means of gear racks 10 and 11 connected respectively to the electrodes 1 and 2, and having associated therewith a common pinion or driving gear 12 which is driven from the reduction gears 8 through the mechanical connection represented by the dotted line 13. It will be seen that rotation of gear 12 in one direction will cause the electrodes 1 and 2 to move toward one another, while rotation of said gear in the opposite direction will cause the electrodes to move away from each other.

The reversible motor 7 is controlled by a relay 14 having an energizing winding 15 and a movable contact 16 which is pivoted at 17 and is adapted to engage either of the stationary contacts 18 and 19. A biasing spring 20 urges the movable contact 16 toward contact 19, and when these contacts are engaged, the motor 7 is caused to operate in a direction to effect separation of the electrodes 1 and 2. The relay winding 15 acts against the spring 20, and when the relay is energized, the movable contact 16 is urged toward contact 18. Engagement of these two contacts causes the motor to operate in the direction to effect movement of the electrodes 1 and 2 toward one another.

The motor 7 may be energized from the same voltage source which supplies the electrodes. The motor may be a 110 volt motor and it may be supplied by means of conductors 21 and 22, conductor 21 being connected to a suitable tap on the primary winding 5, and conductor 22 being connected to one of the supply conductors 6. It will be seen that conductor 21 extends to the pivoted end of the movable relay contact 16, while conductor 22 is connected to the junction of the field windings of motor 7. Contacts 18 and 19 are connected via conductors 23 and 24 to the other ends of the motor field windings.

The voltage across electrodes 1 and 2 is supplied via conductors 25 and 26 to the primary winding 27 of a transformer 28. The secondary winding 29 of this transformer is connected to a control circuit which includes a rectifier 30, filter components which may comprise resistors 31, 32, 33, and condensers 34, 35, 36, a gas-discharge tube 37, and the relay winding 15. The filter components may be varied considerably and some of them may be omitted, depending upon the specific application.

The control circuit above described effects rapid action control of the positioning of electrodes 1 and 2 in response to the voltage across the electrodes. Thus, there is provided a rapid-action servo system which is responsive to variations of the voltage across the electrodes and which functions to maintain the voltage constant during operation of the arc lamp, independently of the current-controlling action of the constant current transformer 4.

The operation of the servo system will now be described in detail with reference to Figs. 3A to 3H. In these figures, the line C represents the starting voltage level of tube 37, i. e., the level which must be reached by the applied voltage to render the tube conductive. Line NC represents the non-conducting voltage level of the tube, i. e., the voltage level below which the tube becomes non-conductive. V represents the applied voltage.

In the inoperative state of the system, i. e., with the supply source disconnected, the spring 20 is effective to maintain contact 16 in engagement with contact 19. When the system is placed in operation by the connection of the supply source, the motor 7 is operated in a direction to effect the movement of the electrodes 1 and 2 away from each other. At the same time an A. C. potential is applied to the control circuit through transformer 28. The voltage appearing on the secondary winding 29 is rectified by rectifier 30 and is filtered by the filter comprising components 31 to 36. The rectified voltage, which appears across the gas discharge tube 37, is as shown at V in the illustrations of Figs. 3A to 3H, having D. C. and ripple components dependent upon the relative sizes of the filter components. This voltage varies with changes in the arc voltage, as may be seen from the illustrations. When the supply source is first connected, the voltage across the gas discharge tube 37 will be in excess of the amount necessary to cause it to conduct, as may be seen in Fig. 3A. Current will flow through relay winding 15, and movable contact 16 will be drawn to the stationary contact 18 so that the rotation of the motor 7 will move the electrodes 1 and 2 toward each other. Electrodes 1 and 2 will continue to move together until an arc is struck. At this time the voltage across the electrodes 1 and 2 and the control transformer 28 will have dropped to zero. Con-

sequently, the voltage across the gas discharge tube 37 will have dropped to zero so that it will be in a non-conducting state (see Fig. 3B). There will be no current through relay winding 15, and biasing spring 20 will return movable contact 16 to engage with stationary contact 19. Thus the voltage applied to motor 7 will cause it to rotate in a direction which will move electrodes 1 and 2 apart. A voltage will appear across the tube 37 but it will not be of sufficient amplitude to start the tube (see Fig. 3C).

As the electrodes 1 and 2 move apart the voltage across the arc, which also appears across the control transformer 28, increases. In turn, the voltage induced in the secondary 29 and the voltage across the gas discharge tube 37 will increase (see Fig. 3D). The rate at which this voltage increases will depend upon the relative sizes of the components in the filter circuit. The electrodes 1 and 2 will continue to move apart at a rapid rate until the voltage across the gas discharge tube 37 has increased to such a value that the peak of that voltage exceeds the level C necessary for conduction (see Fig. 3E). The gas discharge tube 37 will start to conduct and will continue to conduct until the value of the voltage across the tube drops below the level NC required to maintain conduction. The length of time that the tube will conduct will increase as the electrodes 1 and 2 move farther apart, until the gas discharge tube 37 is conducting 50% of the time (see Fig. 3F). When this is the situation, the movable contact 16 will dwell equally upon both stationary contacts 18 and 19 so that the motor 7 will be motionless.

As the lamp burns the electrode material is consumed, lengthening the arc gap and causing the arc voltage to rise. The increase of the voltage across the control transformer 28 will increase the voltage across the gas discharge tube 37 so that it will conduct for more than half the time (see Fig. 3G). Contact 16 will dwell on contact 18 for more than half the time and the rotation of the motor 7 will bring the electrodes 1 and 2 toward each other until the proper arc gap is obtained.

Similarly when core material falls into the arc, the distance between the electrodes 1 and 2 is reduced and the voltage across the arc decreases. This decrease in the voltage across the primary 27 of control transformer 28 will result in a lowered voltage across the gas discharge tube 37 so that it will conduct for less than half the time (see Fig. 3H). The movable contact 16 will dwell on contact 19 for more than half the time so that the net rotation of the motor 7 will be to move the electrodes 1 and 2 apart until the proper distance between the electrodes 1 and 2 has been restored and the electrodes become stationary.

From the foregoing description, it will be seen that the motor 7 is controlled according to the conductivity or non-conductivity of the electron tube 37, and the relative time percentages of conductivity and non-conductivity of said tube are varied according to the amplitude of a controlling voltage.

An important advantage of the system is that in controlling both fields of the motor 7, the restoring torque will vary approximately as the square of the deviation from the null position. This permits the use of a sensitive and smooth-operating feed mechanism without the use of additional mechanism or electrical damping elements. The apportionment of the three condensers and the three resistors in the filter cir-

unit permits the sensitivity and shape of the torque error curve to be varied in such a manner as to be most advantageous to the particular application involved.

In Fig. 2, there is illustrated a modified form of the system in which a D. C. voltage is applied to the electrodes. In this instance, the constant current transformer 4 of Fig. 1 is eliminated, and an interrupter 38 is provided as shown so as to supply a simulated A. C. voltage to the control transformer 28. The interrupter may be in the form of a relay having a winding 39, a movable contact 40, and stationary contacts 41 and 42. Both the motor 7 and the relay 38 may be energized from a common A. C. supply over conductors 43. Aside from the above-mentioned modifications the system is identical with that of Fig. 1 and elements are designated by the same reference numerals. The operation of the system of Fig. 2 is the same as the operation of the system of Fig. 1 as described above.

The present invention has gone into commercial use and has proved to be highly successful. In one physical embodiment according to Fig. 1, the gas discharge tube 37 is a miniature type OB2; relay 14 is a Western Electric Relay Type 275B; rectifier 30 is of the selenium type; and the filter components have values as follows:

Resistor 31	(none required this arrangement)
Resistor 32	1000 ohms
Resistor 33	4000 ohms
Condenser 34	2 microfarads
Condenser 35	2 microfarads
Condenser 36	0 microfarad

The transformer 28 has a step down ratio of 5.55 for an arc voltage of 28 volts.

While certain embodiments of the invention have been illustrated and described, the invention is not limited thereto but is capable of other forms of physical expression.

Moreover, the servo system provided by the invention is not limited to arc lamp control. By way of example of other uses, this system has been applied to the maintenance of constant speed in magnetic sound-recording devices. Obviously, this system may be utilized wherever it is desired to maintain some condition and it is convenient to provide an A. C. voltage which varies with that condition.

I claim:

1. In a servo system for control of an adjustable device; means including a reversible motor for adjusting said device; a single controlling relay having a winding, a pair of spaced stationary contacts, and a movable contact biased toward one of the stationary contacts and movable toward the other stationary contact upon energization of said winding; reversing connections for said motor connected to the relay contacts for control of said motor by said relay; a single gas-discharge tube in circuit with the winding of said relay to control the same, said tube becoming conductive at a certain voltage level and becoming non-conductive at a certain lower voltage level; and means for applying to said tube a cyclically fluctuating unidirectional voltage whose amplitude varies in relation to said voltage levels according to the adjustment of said device, whereby the relative time percentages of conductivity and non-conductivity of said tube are varied according to the adjustment of said device, and said motor is controlled accordingly through the operation of said relay under control of said tube.

2. In a servo system for control of an adjust-

able device; means including a reversible motor for adjusting said device; a single controlling relay having a winding, a pair of spaced stationary contacts, and a movable contact biased toward one of the stationary contacts and movable toward the other stationary contact upon energization of said winding; reversing connections for said motor connected to the relay contacts for control of said motor by said relay; a control circuit for supplying current to the winding of said relay; a single gas-discharge tube in said circuit to control said relay, said tube becoming conductive at a certain voltage level and becoming non-conductive at a certain lower voltage level; and means for producing in said circuit across said tube a cyclically fluctuating unidirectional voltage whose amplitude varies in relation to said voltage levels according to the adjustment of said device, whereby the relative time percentages of conductivity and non-conductivity of said tube are varied according to the adjustment of said device; and said motor is controlled accordingly through the operation of said relay under control of said tube.

3. In a servo system for control of an adjustable device; means including a reversible motor for adjusting said device; a single controlling relay having a winding, a pair of spaced stationary contacts, and a movable contact biased toward one of the stationary contacts and movable toward the other stationary contact upon energization of said winding; reversing connections for said motor connected to the relay contacts for control of said motor by said relay; a control circuit for supplying current to the winding of said relay; a single gas-discharge tube in said circuit to control said relay, said tube becoming conductive at a certain voltage level and becoming non-conductive at a certain lower voltage level; means for supplying to said circuit an alternating voltage whose amplitude varies according to the adjustment of said device; and means in said circuit for converting said alternating voltage to a cyclically fluctuating unidirectional voltage whose amplitude varies in relation to said voltage levels according to the adjustment of said device, whereby the relative time percentages of conductivity and non-conductivity of said tube are varied according to the adjustment of said device; and said motor is controlled accordingly through the operation of said relay under control of said tube.

4. In a servo system for control of an adjustable device; means including a reversible motor for adjusting said device; a single controlling relay having a winding, a pair of spaced stationary contacts, and a movable contact biased toward one of the stationary contacts and movable toward the other stationary contact upon energization of said winding; reversing connections for said motor connected to the relay contacts for control of said motor by said relay; a gas diode which becomes conductive at a certain voltage level and becomes non-conductive at a certain lower voltage level; a control circuit including said diode and the winding of said relay in series; a transformer connected to supply current to said control circuit; means for supplying to said transformer an alternating voltage whose amplitude varies according to the adjustment of said device; and rectifying and filtering means in said control circuit for converting the voltage from said transformer to a cyclically fluctuating unidirectional voltage whose amplitude varies in relation to said voltage levels according to the

adjustment of said device, whereby the relative time percentages of conductivity and non-conductivity of said diode are varied according to the adjustment of said device, and said motor is controlled accordingly through the operation of said relay under control of said diode.

5. In a servo system for control of an arc lamp; means including a reversible motor for adjusting the lamp electrodes; a single controlling relay having a winding, a pair of spaced stationary contacts, and a movable contact biased toward one of the stationary contacts and movable toward the other stationary contact upon energization of said winding; reversing connections for said motor connected to the relay contacts for control of said motor by said relay; a single gas-discharge tube in circuit with the winding of said relay to control the same, said tube becoming conductive at a certain voltage level and becoming non-conductive at a certain lower voltage level; and means responsive to the voltage across said electrodes for applying to said tube a cyclically fluctuating unidirectional voltage whose amplitude varies in relation to said voltage levels according to the voltage across said electrodes, whereby the relative time percentages of conductivity and non-conductivity of said tube are varied according to the voltage across said electrodes, and said motor is controlled accordingly through the operation of said relay under control of said tube.

6. In a servo system for control of an arc lamp; a constant current transformer for supplying operating current to the arc lamp; means including a reversible motor for adjusting the lamp electrodes; a single controlling relay having a winding, a pair of spaced stationary contacts, and a movable contact biased toward one of the stationary contacts and movable toward the other stationary contact upon energization of said winding; reversing connections for said motor connected to the relay contacts for control of said motor by said relay; a single gas-discharge tube in circuit with the winding of said relay to control the same, said tube becoming conductive at a certain voltage level and becoming non-conductive at a certain lower voltage level; and means responsive to the voltage across said electrodes for applying to said tube a cyclically fluctuating unidirectional voltage whose amplitude varies in relation to said voltage levels according to the voltage across said electrodes, whereby the relative time percentages of conductivity and non-conductivity of said tube are varied according to the voltage across said electrodes, and said motor is controlled accordingly through the operation of said relay under control of said tube.

tuating unidirectional voltage whose amplitude varies in relation to said voltage levels according to the voltage across said electrodes, whereby the relative time percentages of conductivity and non-conductivity of said tube are varied according to the voltage across said electrodes, and said motor is controlled accordingly through the operation of said relay under control of said tube.

7. In a servo system for control of an arc lamp; means for supplying unidirectional current to the arc lamp; means including a reversible motor for adjusting the lamp electrodes; a single controlling relay having a winding, a pair of spaced stationary contacts, and a movable contact biased toward one of the stationary contacts and movable toward the other stationary contact upon energization of said winding; reversing connections for said motor connected to the relay contacts for control of said motor by said relay; a single gas-discharge tube in circuit with the winding of said relay to control the same, said tube becoming conductive at a certain voltage level and becoming non-conductive at a certain lower voltage level; means for deriving a simulated alternating voltage from the voltage across the lamp electrodes; and means responsive to the derived voltage for applying to said tube a cyclically fluctuating unidirectional voltage whose amplitude varies in relation to said voltage levels according to the voltage across said electrodes, whereby the relative time percentages of conductivity and non-conductivity of said tube are varied according to the voltage across said electrodes, and said motor is controlled accordingly through the operation of said relay under control of said tube.

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