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ELECTRONIC CONTROL SYSTEM

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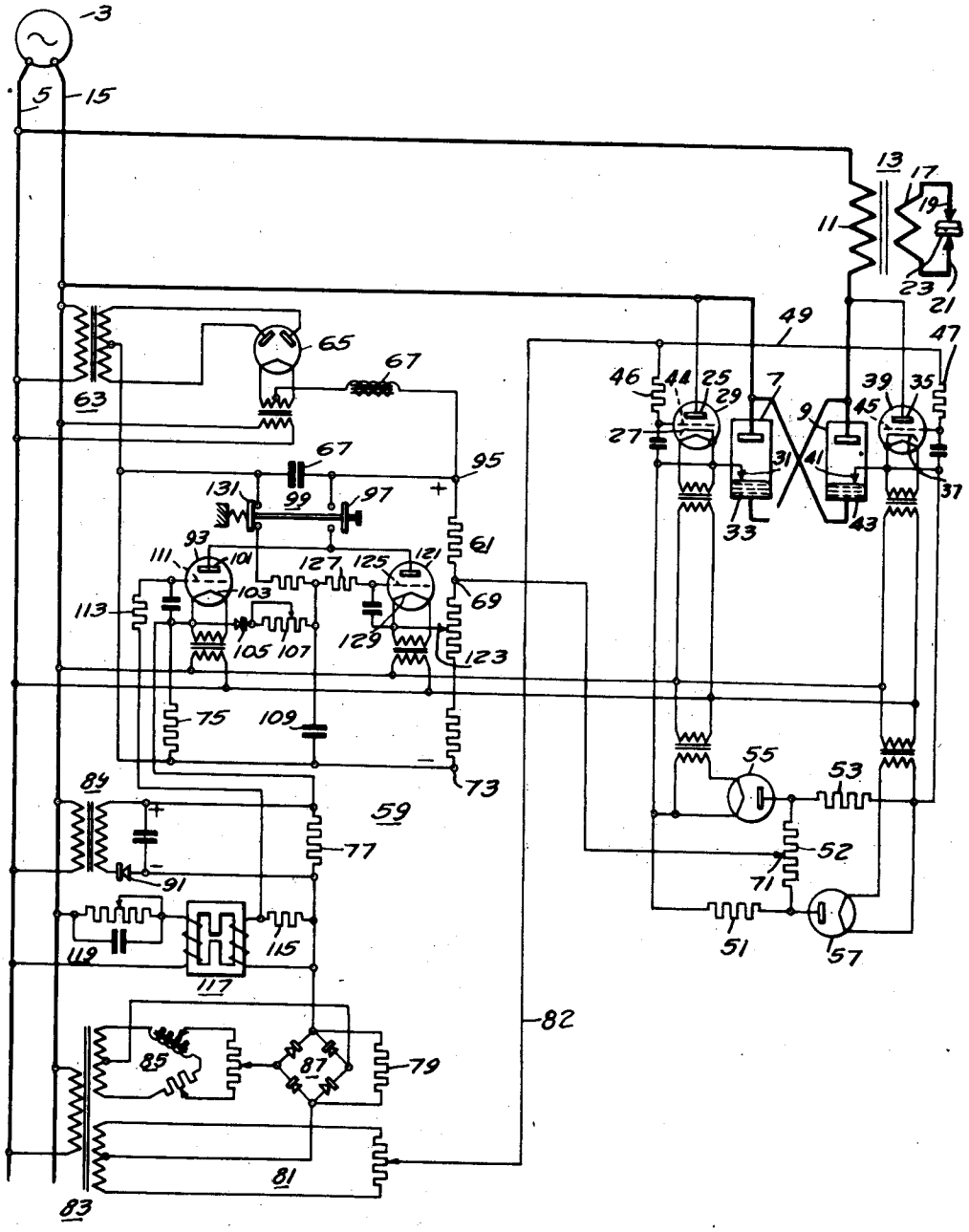

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ELECTRONIC CONTROL SYSTEM

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This invention relates to an electronic control system and has particular relation to a system in which power is supplied from an alternating potential source to a load through a pair of inversely connected electric discharge valves.

In many systems in which the supply of current to a load is controlled by inversely connected electric discharge valves, it is highly desirable to employ a single source of control potential for both valves. In a resistance welding system, for example, the flow of welding current is supplied through a pair of inversely connected ignitrons. A firing circuit is provided for each ignitron and includes an electric discharge valve, preferably a thyration, connected between the anode and igniter of the corresponding ignitron, so that the firing valves themselves are inversely connected in circuit with the source. The firing valves are then controlled to render the ignitrons conductive alternately in successive half periods of the source. A control system is arranged to provide a pulsating control potential of suitable wave form for rendering the firing valves conductive at a selected instant in each half period for a predetermined interval of time. It is obviously desirable to employ a single control potential for both firing valves rather than provide a second control system. However, if a single source of control potential is to be connected in the control circuit of both firing valves, the grids of the valves must be connected together and the cathodes must be connected together. To avoid a short circuit across the firing valves, a large impedance must be inserted in the connection between the cathodes. As a result, an alternating potential appears across this impedance which interferes with the impressing of a control potential of suitable wave form between the grids and cathodes of firing valves.

Different arrangements have been employed in the past in an attempt to counteract or nullify the alternating potential appearing across the impedance which is connected between the cathodes of the firing valves. One way of accomplishing this result is to employ an inversely connected transformer to impress another alternating potential in the control circuit which is 180° out of phase with the source potential. However, in actual practice where current is conducted through the valves during only a portion of each half period, the alternating potential across the impedance between the cathodes is not a sine wave and consequently an alternating potential of sine wave form 180° out of phase with the source cannot effectively remove the undesired potential from the impedance.

Another method of counteracting the alternating potential appearing across the impedance which is connected between the cathodes of the firing valves employs a pair of gaseous discharge rectifier tubes connected back-to-back across the impedance. The junction point between the two rectifiers is then connected to a center tap on the impedance, the rectifiers being arranged to conduct current away from the center tap. The control potential of suitable wave form is then impressed between the grids of the firing valves and the center tap on the impedance. In a half-period of one polarity, one of the rectifiers short-circuits the one-half of the impedance in the control circuit of the firing valve which is in condition to become conductive. During the opposite half period, the other rectifier short-circuits the other half of the impedance which is in the control circuit of the other firing valve.

The prior art control arrangement just described operates satisfactorily on low voltage circuits. However, when a high voltage is employed, one rectifier becomes conductive just as the other has ceased to conduct current and the back potential appearing across the nonconducting rectifier causes it to backfire. As the conducting rectifier has extremely low resistance, a very large current passes through the backfiring rectifier and causes considerable damage thereto and disrupts the control of the firing valves.

It is, accordingly, an object of my invention to provide a new and improved system for supplying power from an alternating potential source to a load through a pair of inversely connected electric discharge valves in which a single control potential source is connected in circuit between the control electrode and cathode of both valves.

Another object of my invention is to provide a novel system for supplying power from an alternating potential source to a load through a pair of inversely connected electric discharge valves of the arc-like type in which a single source of periodically pulsating control potential is connected in circuit between the control electrode and cathode of both valves.

More specifically, it is an object of my invention to provide a new and improved system for supplying power from an alternating potential source to a load through a pair of inversely connected electric discharge valves controlled by a single source of control potential in which the alternating potential is effectively removed from

the control circuit without danger of breakdown because of high voltage.

In accordance with my invention, a first, second and third impedance means is connected in series in the order named between the cathodes of the firing valves. A first gaseous rectifier discharge tube is connected to effect short-circuiting of the first and second impedance means when the valve whose cathode is connected to the first impedance means has a positive anode potential. A second gaseous discharge rectifier tube is connected to short-circuit the second and third impedance means in the opposite half period of the source. The second impedance means may be short-circuited by either rectifier. The control potential is then impressed between the control electrode of the firing valves and a center tap on the second impedance means.

When one of the firing valves has a positive anode potential, one of the rectifiers becomes conductive to short-circuit the impedance in the control circuit of that valve. The rectifier does not, of course, have a zero arc drop potential. However, the rectifier arc drop potential is so low that the voltage thereacross is very small, of the order of 10 volts regardless of the magnitude of current thereto. Consequently a substantially constant residual potential of 10 volts appears across the two impedance means shorted by the rectifier but as the control potential is impressed between the control electrode of the firing valve and the center tap of the second impedance means, the residual potential remaining in the control circuit is of the order of 6 volts, which is negligible for all practical purposes.

At the end of the first half-period the first rectifier ceases to conduct and the other rectifier is rendered conductive to nullify the alternating potential in the control circuit of the second firing valve. It is to be noted that the second impedance means is connected between the two rectifiers. Then, if the first rectifier backfires, the current therethrough is limited to a low value because of the second impedance means in series therewith. Consequently, there is very little danger of permanent disruption of the control system by a backfiring of one of the rectifier tubes.

The novel features that I consider characteristic of my invention are set forth with particularity in the claims. The invention itself, however, both as to its organization and its method of operation, together with additional objects and advantages thereof, will best be understood from the following description of a specific embodiment when read in connection with the accompanying drawing, in which:

The single figure illustrates my invention as embodied in a resistance welding apparatus.

In the apparatus as shown in the drawing, current is supplied from an alternating potential source 3 in a circuit extending from one terminal 15 of the source through a pair of inversely connected ignitrons 7 and 9 and the primary 11 of a welding transformer 13 to the other terminal 5 of the source. The secondary 17 of the welding transformer 13 is connected across a pair of welding electrodes 19 and 21 in engagement with the material 23 to be welded. The firing circuit for one of the ignitrons 7 may be traced from the terminal 15 of the source 3, through the anode 25 and cathode 27 of an electric discharge firing valve 29, the igniter 31 and cathode 33 of the ignitron 7 and the primary 11 of the welding transformer 13 to the other terminal 5 of the source. The firing circuit for the other ignitron 9 may be traced from the terminal 5, through the primary 11, the anode 35 and cathode 37 of a second electric discharge firing valve 39, the igniter 41 and cathode 43 of the second ignitron 9 to the other terminal 15 of the source. It is thus apparent that the firing valves 29 and 39 are also connected inversely or in antiparallel in circuit with the source. The firing valves are of the arc-like type, preferably thyratrons, and their control electrodes 44 and 45 are interconnected through corresponding grid resistors 46 and 47 and a conductor 49. The cathodes 27 and 37 of the firing valves 29 and 39 are also interconnected through first, second and third resistors 51, 52 and 53. A gaseous discharge rectifier tube 55 is connected across the first and second resistors 51 and 52 and a second gaseous discharge rectifier tube 57 is connected across the second and third resistors 52 and 53. The rectifier tube 55 is arranged to conduct current away from the junction point of the first and second resistors 51 and 52, and rectifier tube 57 is arranged to conduct current away from the junction point of the second and third resistors 52 and 53.

A control system 59 is provided to supply a control potential for controlling the firing valves 27 and 37. The control system includes a voltage divider 61 energized from the source 3 through an auxiliary transformer 63, a full wave rectifier 65 and filtering elements 67. An intermediate tap 69 on the divider 61 is connected to a center tap 71 on the second resistor 52 interconnecting the cathodes of the firing valves 29 and 39. The negative terminal 73 of the divider 61 is connected to the control electrodes 44 and 45 of the firing valves. The circuit from the negative terminal 73 of the divider 61 may be traced through resistors 75, 77 and 79, a balancing potentiometer circuit 81, conductor 82, conductor 49 and resistor 46 to control electrode 44 or resistor 47 to control electrode 45. As will be explained hereinafter, the impressing of a control potential between the control electrodes 44 and 45 of the firing valves and the center tap 71 is the same as impressing the control potential directly between the control electrode and cathode of the firing valve whose anode is positive at the time.

If ignitrons 7 and 9 are identical and firing valves 29 and 39 are identical, the balancing potentiometer circuit 81 does not supply a potential in the circuit. Therefore, function of the balancing potentiometer may be omitted from immediate consideration and will be explained hereinafter.

A potential is impressed across the resistor 79 in the circuit between the negative terminal 73 of the divider 61 and the control electrodes of the firing valves. This potential is derived from the source 3 through an auxiliary transformer 83 a phase shifting circuit 85 and a full wave rectifier 87, so that the potential takes the form of a rectified alternating potential, inverted with respect to the control electrodes and displaced in phase relative to the source.

A direct-current potential is impressed across the other resistor 77 in the circuit between the negative terminal 73 of the divider 61 and the control electrodes of the firing valves which is derived from the source 3 through an auxiliary transformer 89 and rectifier 91. The polarity of the potential across the resistor 77 is the same with respect to the control electrodes of the firing valves as the polarity of the potential across the

portion of the divider 61 between the intermediate tap 69 and the negative terminal 73. Because of the high negative direct-current potential supplied from the divider 61 and the resistor 77, the resultant potential impressed between the control electrodes of the firing valves 29 and 39 and the center tap of the second resistor 52 remains below the critical control electrode-cathode potential necessary to render the firing valves conductive.

Another electric discharge valve 93 of the arc-like type, preferably a thyratron hereinafter designated as the start valve, is connected across the voltage divider 61 in a circuit extending from the positive terminal 95 through a contactor 97 of a push-button switch 99, the anode 101 and cathode 103 of the start valve 93 and parallel circuits comprising the resistor 75 on one side and a rectifier 105, potentiometer 107 and capacitor 109 on the other side to the negative terminal 73 of the divider 61. The control circuit of the start valve 93 may be traced from its control electrode 111, through a grid resistor 113, a resistor 115, and resistor 77 to the cathode 103. As previously set forth, a direct-current potential is impressed across the resistor 77, and this potential is of such polarity as to tend to maintain the start valve 93 nonconductive. Potential impulses are impressed across the other resistor 115 in the control circuit of the start valve through a peaking transformer 117 and a phase shifting circuit 119 energized from the source. The phase shifting circuit 119 is arranged to be adjusted according to the power factor of the load so that an impulse across the resistor 115 occurs at the beginning of each half-period of alternating current. The polarity and magnitude of the impulse across the resistor 115 at the beginning of a positive half-period of the source current is such that the impulse overcomes the biasing potential across the resistor 77 and renders the start valve 93 conductive if the push-button contactor 97 is closed.

When the start valve 93 becomes conductive, the upper end of the resistor 75 in series therewith is effectively connected to the positive terminal 95 of the divider 61. Consequently, the direct-current potential supplied from the divider to the circuit between the control electrodes of the firing valves and the center tap 71 of the second resistor 52 becomes considerably less negative. As a result, the peaks of the inverse rectified potential in the circuit rise above the critical control electrode-cathode potential necessary to render the firing valves conductive. This inverse rectified alternating potential is employed to determine the instant at which the firing valves 29 and 39 and, therefore, the ignitrons 7 and 9 become conductive in a half-period of the source. The particular instant is selected by adjustment of the phase shifting circuit 85 to shift the position of the peaks and is effective to determine the amount of current supplied to the weld in a half-period, which, in turn, determines the character of the weld.

A second electric discharge valve 121 of the arc-like type, preferably a thyratron, which is hereinafter designated as a stop valve, is connected between the positive terminal 95 of the divider 61 and another intermediate tap 123 on the divider. The control circuit of the stop valve 121 may be traced from the control electrode 125 thereof through a grid resistor 127 and the capacitor 109 to the negative terminal 73 of the divider 61 and from the intermediate tap 123 to the cathode 129 of the stop valve. The potential between the negative terminal 73 and intermediate tap 123 of the divider normally biases the stop valve to maintain it nonconductive. However, when the start valve 93 is conductive the capacitor 109 in series therewith is charged at a rate determined by the setting of the potentiometer 107. After a predetermined interval of time, the potential across the capacitor 109 rises to a sufficient magnitude to counteract the biasing potential in the control circuit of the stop valve 121 and render the stop valve conductive. When the stop valve 121 becomes conductive, the intermediate tap 123 is effectively connected to the positive terminal 95 of the divider so that the upper end of resistor 75 is again highly negative with respect to intermediate tap 69. A back contactor 131 on the push-button switch 99 is arranged to complete a discharge circuit for the capacitor 109 when the push-button switch is released.

From the foregoing description it is apparent that the potential between the control electrodes of the firing valves 29 and 39 and the center tap 71 of the second resistor 52 between the cathodes 27 and 37 originally comprises an inverse rectified alternating potential superimposed on a highly negative direct-current potential of such value that the ignitrons are not rendered conductive. When the push-button contactor 97 is closed, the direct-current potential becomes less negative while the inverse rectified alternating potential remains the same and the ignitrons are rendered conductive alternately at a selected instant in successive half-periods. After a preselected interval of time determined by the setting of the potentiometer 107, the direct-current potential again becomes highly negative and the flow of current through the ignitrons is halted.

A careful consideration of the control circuits for the firing valves reveals that the impressing of a control potential between the control electrodes 44 and 45 and the center tap 71 is the same as impressing the potential between the control electrode and cathode of the valve whose anode is positive at the time.

The three resistors 51, 52 and 53 interconnecting the cathodes 27 and 37 of the firing valves 29 and 39 are also connected across the source 3 through the igniters 31 and 41 and cathodes 33 and 43 of the ignitrons 7 and 9. Consequently, an alternating potential in phase with the source appears across these resistors. When the potential across the resistors 51, 52 and 53 is of such polarity that the cathode connected end of the first resistor 51 is negative, the first rectifier 55 becomes conductive to short-circuit the first and second resistors 51 and 52. It follows that the control potential impressed between the control electrodes 44 and 45 of the firing valves 29 and 39 and the center tap 71 of the second resistor 52 is then effectively impressed directly between the control electrode 44 and cathode 27 of the first firing valve 29. Similarly, when the cathode connected end of the third resistor 53 is negative, the second rectifier 57 becomes conductive to short-circuit the second and third resistors 52 and 53 and the control potential is effectively impressed between the control electrode 45 and cathode 37 of the second firing valve 39. Interference with the shape of the wave form of the control potential by the alternating potential across the three resistors is thus avoided. As a result, the control potential may be adjusted to rise above the critical value of the firing valves at any selected instant in a half-period and the

ignitrons are rendered conductive at that selected instant.

Should the igniting characteristic of the two ignitrons be slightly different, the balance potentiometer 81 may be adjusted to add an alternating potential component to the control potential to raise alternate peaks of the inverse rectified alternating potential. As a result, the two ignitrons may be conductive for the same percentage of a half-period.

In a system connected as illustrated and tested, the ignitrons 7 and 9 were Westinghouse WL–656 tubes, and the firing valves 29 and 39 were Westinghouse WL–632 thyratrons. Each of the three resistors 51, 52 and 53 had a resistance of 15,000 ohms and the gaseous discharge rectifiers 55 and 57 were Westinghouse WL–866A–866 tubes.

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

I claim as my invention:

1. For use in supplying power from a source of alternating potential to a load, the combination comprising a pair of electric discharge valves, each having an anode and cathode connected between said source and load and a control electrode, said valves being connected in anti-parallel, a first, second and third impedance means connected in series in the order named between the cathodes of said valves whereby an alternating potential in phase with said source appears across said three impedance means, means responsive to a potential across said three impedance means of such polarity that the cathode connected end of said first impedance means is negative for short circuiting said first and second impedance means, means responsive to a potential across said three impedance means of opposite polarity for short circuiting said second and third impedance means, and means for impressing a control potential between said control electrodes and an intermediate tap on said second impedance means.

2. For use in supplying power from a source of alternating potential to a load, the combination comprising a pair of electric discharge valves, each having an anode and cathode connected between said source and load and a control electrode, said valves being connected in anti-parallel, impedance means connected between the cathodes of said valves whereby an alternating potential in phase with said source appears across said impedance means, means responsive to a potential of one polarity across said impedance means for short circuiting a first section of said impedance means, means responsive to a potential of opposite polarity across said impedance means for short circuiting a second section of said impedance means, said first and second sections having a common portion with each section including part of said impedance means between said common portion and the cathode which is negative when the corresponding section is short circuited, and means for impressing a control potential between said control electrodes and an intermediate tap on said common portion.

3. For use in supplying power from a source of alternating potential to a load, the combination comprising a pair of electric discharge valves, each having an anode and cathode connected between said source and load and a control electrode, said valves being connected in anti-parallel, a first, second and third impedance means connected in series in the order named between the cathodes of said valves, first rectifying means connected across said first and second impedance means in a manner to conduct current away from the junction of said second and third impedance means, second rectifying means connected across said second and third impedance means in a manner to conduct current away from the junction of said first and second impedance means, and means for impressing a control potential between said control electrodes and an intermediate tap on said second impedance means.

4. For use in supplying power from a source of alternating potential to a load, the combination comprising a pair of electric discharge valves, each having an anode and cathode connected between said source and load and a control electrode, said valves being connected in anti-parallel, a first, second and third impedance means connected in series in the order named between the cathodes of said valves, first rectifying means of the gaseous discharge type connected across said first and second impedance means in a manner to conduct current away from the junction of said second and third impedance means, second rectifying means of the gaseous discharge type connected across said second and third impedance means in a manner to conduct current away from the junction of said first and second impedance means, and means for impressing a control potential between said control electrodes and an intermediate tap on said second impedance means.

5. For use in supplying power from a source of alternating potential to a load, the combination comprising a pair of electric discharge valves of the arc-like type, each having an anode and cathode connected between said source and load and a control electrode, said valves being connected in anti-parallel, a first, second and third impedance means connected in series in the order named between the cathodes of said valves, first rectifying means connected across said first and second impedance means in a manner to conduct current away from the junction of said second and third impedance means, second rectifying means connected across said second and third impedance means in a manner to conduct current away from the junction of said first and second impedance means, and means for impressing a periodically pulsating control potential having a selected phase relation to said source between said control electrodes and an intermediate tap on said second impedance means.

6. For use in supplying power from a source of alternating potential to a load, the combination comprising a pair of electric discharge valves of the arc-like type, each having an anode and cathode connected between said source and load and a control electrode, said valves being connected in anti-parallel, impedance means connected between the cathodes of said valves whereby an alternating potential in phase with said source appears across said impedance means, means responsive to a potential of one polarity across said impedance means for short circuiting a first section of said impedance means, means responsive to a potential of opposite polarity across said impedance means for short circuiting a second section of said impedance means, said first and second sections having a common portion with each section including part of said impedance means between said common portion and the cathode which is negative when the corresponding section is short circuited, and means

for impressing a periodically pulsating control potential having a selected phase relation to said source between said control electrodes and an intermediate tap on said common portion.

7. For use in supplying power from a source of alternating potential to a load, the combination comprising a pair of electric discharge valves of the arc-like type, each having an anode and cathode connected between said source and load and a control electrode, said valves being connected in anti-parallel, a first, second and third resistance means connected in series in the order named between the cathodes of said valves, first rectifying means of the gaseous discharge type connected across said first and second resistance means in a manner to conduct current away from the junction of said second and third resistance means, second rectifying means of the gaseous discharge type connected across said second and third resistance means in a manner to conduct current away from the junction of said first and second resistance means, and means for impressing a periodically pulsating control potential having a selected phase relation to said source between said control electrodes and an intermediate tap on said second resistance means.

DONALD P. FAULK.