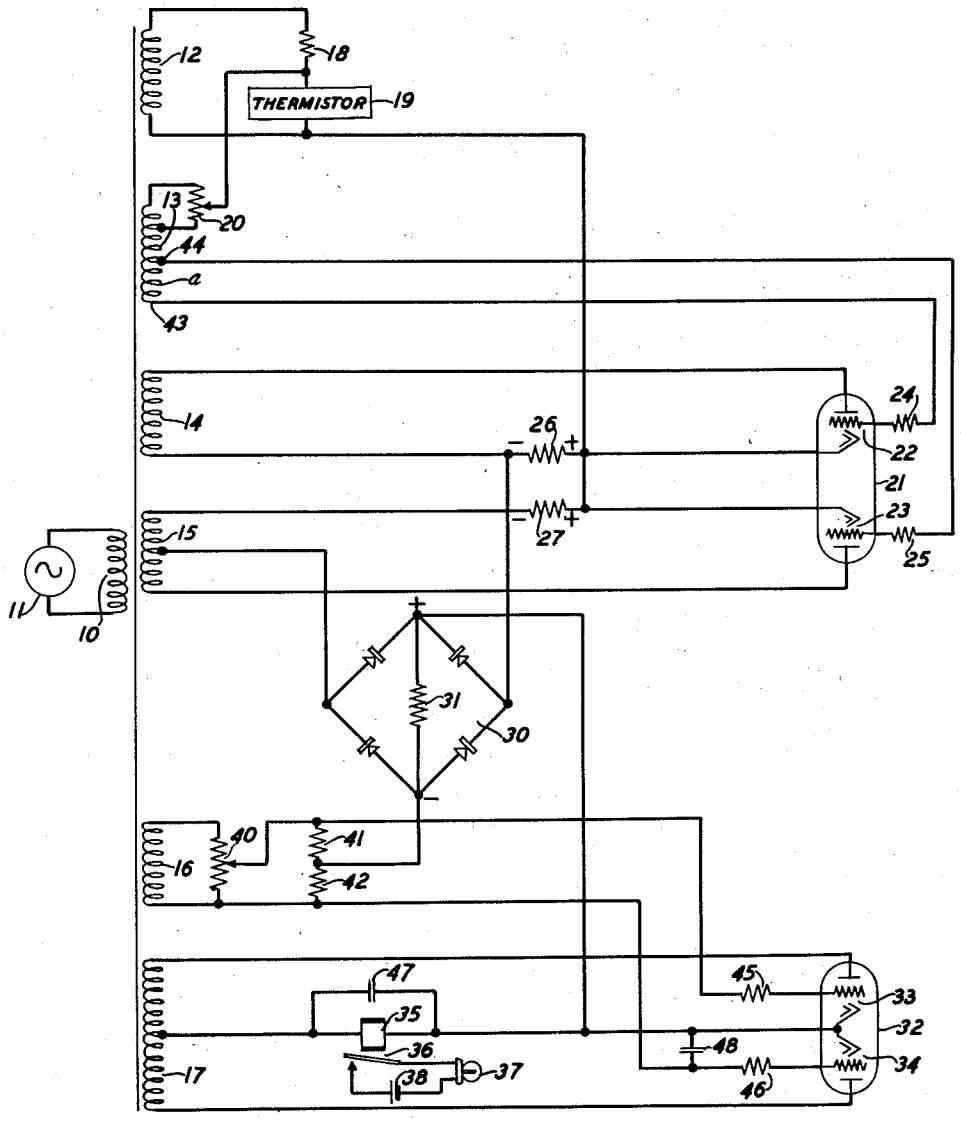
July 14, 1953 W. H. BIXBY 2,645,765

ABNORMAL VOLTAGE INDICATING DEVICE

Filed April 25, 1950 2 Sheets-Sheet 1

FIG. 1



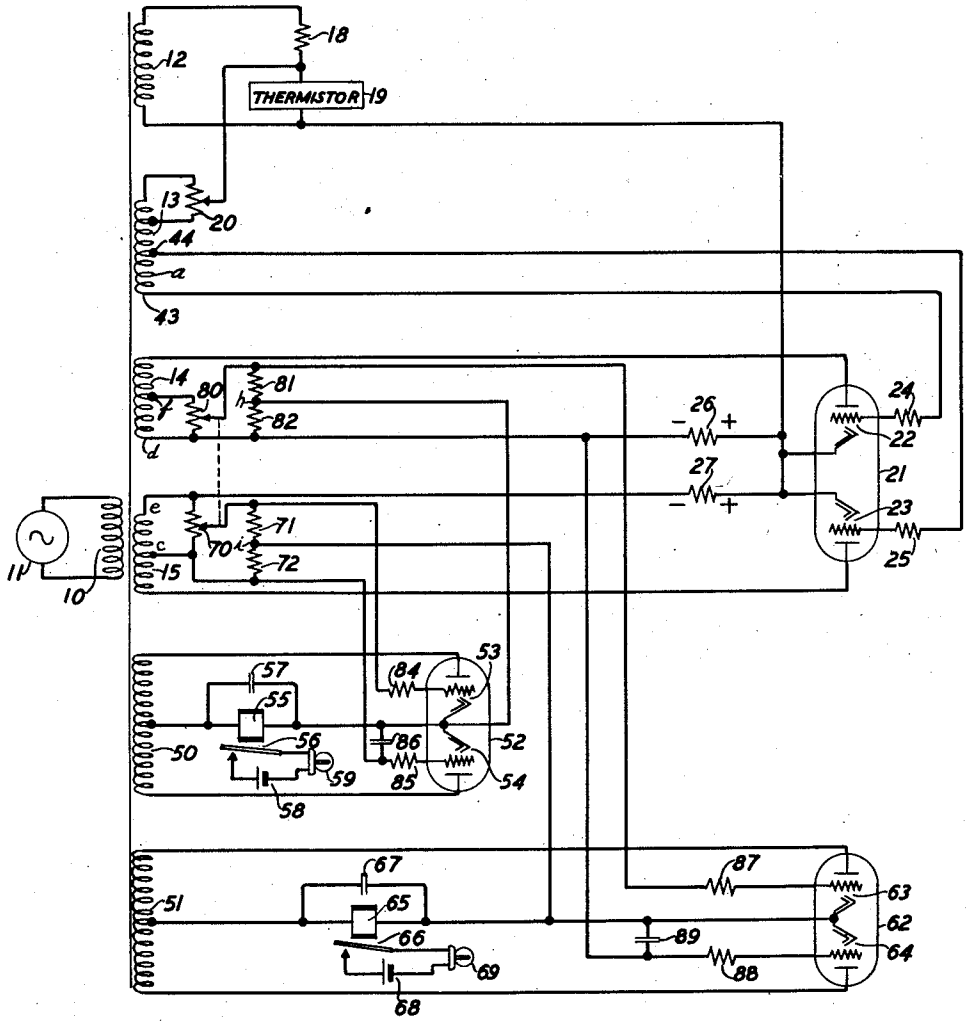
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ABNORMAL VOLTAGE INDICATING DEVICE

Filed April 25, 1950 2 Sheets-Sheet 2

FIG. 2



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Patented July 14, 1953

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UNITED STATES PATENT OFFICE

2,645,765

ABNORMAL VOLTAGE INDICATING DEVICE

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Application April 25, 1950, Serial No. 158,042

16 Claims. (Cl. 340—248)

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This invention relates to relay circuits and more particularly to circuits for controlling the operation of a relay in response to a predetermined change of an alternating supply voltage.

The invention may be used, for example, to control the energization of an electromagnetic relay for opening or closing an alarm circuit for indicating a change of voltage of a current supply source with respect to a predetermined normal voltage. Instead of controlling an alarm circuit, the electromagnetic relay may also be employed for protecting apparatus to which current is supplied directly or indirectly from the supply source to prevent damaging the apparatus due to an abnormally high or low voltage of the supply source.

An object of the invention is to provide an improved circuit for changing in a predetermined sense the current in a current path in response to an increase of voltage of a current supply source and also in response to a decrease of voltage of the supply source.

Another object of the invention is to provide a circuit arrangement for changing the current in one current path in a predetermined sense in response to a decrease of voltage of a current supply source below a minimum voltage of a desired voltage range and for changing the current in another current path in said predetermined sense in response to an increase of voltage of said current supply source above a maximum voltage of said voltage range.

In an embodiment of the invention herein shown and described for the purpose of illustration, there are provided a circuit comprising a thermistor or other resistance device the resistance of which changes in a consistent, non-linear manner with change of current through the device and a pair of space current devices for setting up, during half-cycle periods of one polarity of an alternating-current source, voltage pulses the amplitude of which decreases in response to a voltage increase of the source, and vice versa, and, during half-cycle periods of opposite polarity, voltage pulses the amplitude of which increases in response to a voltage increase of the source, and vice versa, the percentage change of the pulsating voltages being large with respect to the percentage change of the source voltage. Such an arrangement is disclosed in my United States Patent No. 2,486,250 granted October 25, 1949. Means are provided for adjusting the amplitudes of the pulsating voltages with respect to the amplitude of the supply voltage. The two pulsating voltages are combined with an

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alternating voltage derived from the source voltage so that the voltage pulses are opposed to successive half cycles, respectively, of the alternating voltage. The amplitudes of the pulsating voltages and the derived alternating voltage are such as to give a resultant voltage which is substantially zero amplitude when the voltage of the source has a predetermined amplitude and which increases in amplitude in response to an increase of the source voltage and also in response to a decrease of the source voltage. The reultant voltage has one polarity when the source voltage rises above the predetermined value and the opposite polarity when the source voltage falls below the predetermined value. This rsultant voltage is rectified and the rectified pulsating voltage is combined with an alternating voltage in the grid-cathode circuit of each of a second pair of space current devices so that the pulses of the rectified pulsating voltage are opposed to the half cycles of the alternating voltage in the control grid-cathode circuit of each space current device when the anode of the device is positive with respect to its cathode, the anode-cathode voltage of each space current tube also being supplied from the alternating-current source. The energization of an electromagnetic relay connected in the space current circuits of the second pair of space current devices will thus decrease in response to an increase and also in response to a decrease of the voltage of the alternating-current source to cause the armature of the relay to be released. The release of the relay armature may cause the completion of an energizing circuit for an indicating lamp or othr alarm device, for example.

In a modified embodiment of the invention, two electromagnetic relays are provided, one for changing the energization of an indicating or protective device in response to an increase of the supply source voltage above a maximum voltage of a selected normal voltage range and the other for changing the energization of an indicating or protective device in response to a decrease of the supply source voltage below a minimum value of the normal voltage range. Pulsating voltages are produced as described in the preceding paragraph and the pulsating voltages are combined with an unsymmetrical alternating voltage derived from the source and in opposed phase with respect thereto in the control electrode-cathode circuit of each of four space current devices. The relationship of the unsymmetrical alternating voltage and the pulsating voltages in the grid-cathode circuits of one pair of these space current devices is such that the

space currents of the devices decreases in responce to a decreae of voltage of the source to cause the release of the electromagnetic relay which is energized by said space currents. The relationship of the unsymmetrical alternating voltage and the pulsating voltages in the grid-cathode circuits of the remaining pair of space current devices is such that the space currents of the devices decrease in response to an increase of voltage of the source to cause the release of the remaining electromagnetic relay. Preferably each of the unsymmetrical alternating voltages is formed by adding to half cycles of one polarity of a first symmetrical alternating voltage of a certain amplitude, half cycles of a second symmetrical alternating voltage of a smaller amplitude to thereby increase the amplitude of alternate half cycles of the unsymmetrical voltage and by subtracting from half cycles of opposite polarity of the first symmetrical alternating voltage half cycles of the second symmetrical voltage to thereby reduce the amplitude of the remaining half cycles of the unsymmetrical voltage. The amplitude of the smaller amplitude alternating voltage may be varied to control the voltage range of the alternating-current source for which both electromagnetic relays are actuated so that one relay releases its armature to produce an indication when the source voltage rises above the maximum value of said range and so that the other relay releases its armature to produce an indication when the source voltage decreases below the minimum value of said range.

Fig. 1 of the accompanying drawing is a schematic view of an alarm circuit embodying the invention; and

Fig. 2 is a schematic view of a modification of the alarm circuit of Fig. 1.

Referring to Fig. 1 of the drawing, there is provided a transformer having a primary winding 10 connected to an alternating-current supply source 11 and a plurality of secondary windings 12, 13, 14, 15, 16 and 17. Across transformer winding 12 are connected in series a resistor 18 and a thermistor 19 having the operating characteristic that is resistance decreases in response to an increase of alternating current flowing therethrough at such a rate that the voltage across the thermistor decreases. Thermistors are described, for example, in "Bell Laboratories Record," December 1940, page 106 et seq. A potentiometer 20 is connected across a portion of transformer winding 13, the variable tap of the potentiometer being connected to the common terminal of resistor 18 and thermistor 19.

There is provided a twin-triode space current tube 21 comprising space current triodes 22 and 23 each having an anode, a cathode and a control electrode. The control electrodes of triodes 22 and 23 are respectively connected through resistors 24 and 25 to terminals 43 and 44 of transformer winding 13. Space current is supplied to triode 22 from transformer winding 14 through a circuit comprising a resistor 26 and space current is supplied to triode 23 from transformer winding 15 through a circuit comprising a resistor 27. A common terminal of resistors 26 and 27 and the cathodes of triodes 22 and 23 is conductively connected to a common terminal of thermistor 19 and transformer winding 12 to complete the control grid-cathode circuits of triodes 22 and 23. The transformer taps 43 and 44 are chosen to provide the proper operating biases for triodes 22 and 23 when the anodes of the respective triodes are positive with respect to the cathodes. The voltage measured from the tap of potentiometer 20 to the point a which is electrically mid-way between the terminals 43 and 44 is substantially equal to the voltage across thermistor 19 when the voltage of source 11 is at its normal value so that the voltage measured from the tap of potentiometer 20 to terminal 44 is less than the voltage across thermistor 19 and the voltage measured from the tap of potentiometer 20 to terminal 43 is greater than the voltage across thermistor 19. The grid of each triode will thus be negative with respect to its cathode when its anode is positive with respect to the cathode.

There is provided a bridge-type full wave rectifier 30 having a resistor 31 connected across its output terminals. The input circuit of rectifier 30 comprises in series resistors 26 and 27 and a portion of secondary transformer winding 15. A twin-triode space current tube 32 comprising triodes 33 and 34 is connected as a full wave rectifier for rectifying current supplied from transformer winding 17 and for supplying the rectified current to the winding of an electromagnetic relay 35 having an armature 36, the end terminals of winding 17 being connected to the anodes of triodes 33 and 34, respectively, and a mid-tap of winding 17 being connected through relay 35 to the cathode of triodes 33 and 34. A circuit completed in response to the release of the armature 36 of relay 35 comprises an indicating device such as lamp 37 and a source of energizing current for the lamp such as battery 38.

A potentiometer 40 is connected across secondary transformer winding 16. Resistors 41 and 42 in series are provided in a current path connecting the variable tap of potentiometer 40 and a common terminal of winding 16 and potentiometer 40. The control electrode-cathode circuit of triode 33 comprises resistors 45, 41 and 31 in series and the control electrode-cathode circuit of triode 34 comprises resistors 46, 42 and 31 in series. Where it is desired to delay the response of relay 35 to sudden fluctuations in voltage, a capacitor 47 may be connected in a path across the relay winding. To avoid high frequency oscillations in the circuit, a capacitor 48 of very small capacitance is provided in a path connecting the cathode of triode 34 and the common terminal of resistors 42 and 46.

An increase of the voltage of source 11 results in a decrease of voltage across thermistor 19 in addition to a voltage increase across the portion of the transformer winding 13 which is in the control electrode-cathode circuits of triodes 22 and 23. Therefore, during half-cycle periods of the alternating-current source 11 when triode 22 is conducting space current, an increase of the voltage of source 11, for example, results in the control grid of triode 22 becoming relatively more negative with respect to its cathode to cause the current flowing through resistor 26 to decrease. During half cycles of opposite polarity, an increase of voltage of source 11 results in the control electrode of triode 23 becoming relatively more positive with respect to its cathode to cause the space current flowing through resistor 27 to increase.

The pulsating voltages across resistors 26 and 27 are opposed in phase with respect to and have predetermined amplitudes with respect to the alternating voltage from winding 15 in the input circuit of rectifier 30. The opposed pulsating and alternating voltages may have substantially equal amplitudes when the voltage of source 11

has a certain normal value so that the output voltage of rectifier 30 is equal to zero. Then, if it is desired to bring the output voltage of rectifier 30 to this same value, zero, for a higher voltage of source 11, it is merely required to adjust potentiometer 20 to increase the voltage between its variable tap and point *a* of winding 13. The voltage impressed across the input terminals of rectifier 30 and the voltage across resistor 31 connected to the rectifier output terminals are then each substantially zero. The voltages across resistors 41 and 42 thus make the control grids of triodes 33 and 34 positive with respect to the cathodes to cause sufficient current flow through relay winding 35 to cause the relay to open the energizing circuit for lamp 37.

When the voltage of source 11 rises above the predetermined amplitude, the pulsating voltage across resistor 26 decreases to a value less than the amplitude of the concurrent half-cycle pulses across the portion of winding 15 which is in the input circuit of rectifier 30 and the pulsating voltage across resistor 27 increases to a value greater than the amplitude of the concurrent half-cycle pulses across the portion of winding 15. A pulsating voltage is thus impressed upon the input circuit of rectifier 30. When the voltage of source 11 decreases, the pulsating voltage across resistor 26 increases to an amplitude greater than the voltage across the portion of winding 15 and the pulsating voltage across resistor 27 decreases to an amplitude less than the voltage across the portion of winding 15. A pulsating voltage of opposite polarity with respect to the pulsating voltage produced when the source voltage rises is thus impressed upon the input of rectifier 30. The rectified output voltage across resistor 31 has a polarity such as to make the control electrodes of triodes 33 and 34 relatively more negative with respect to the cathodes to cause the current in relay 35 to decrease. The increase or decrease of the voltage of source 11 from the predetermined normal value which is required to cause the armature of relay 36 to release may be varied by adjusting the potentiometer 40 to change the voltages across resistors 41 and 42. An increase of the voltage across resistors 41 and 42, for example, will effect a change in operation of the circuit such that a larger increase or decrease of the voltage of source 11 will be required to effect the release of the armature of relay 36 to thereby cause the energization of the lamp 37. The armature 36 of relay 35 thus releases to cause the energization of lamp 37 when the line voltage increases above the maximum voltage of a certain desired voltage range and also when the line voltage decreases below the minimum voltage of the voltage range.

The portions of the circuit shown in Fig. 2 which are similar to corresponding portions of Fig. 1 are identified by the same designations. There is provided a twin-triode space current tube 52 having triodes 53 and 54 the anodes of which are connected to the end terminals, respectively, of a secondary transformer winding 50. The mid-tap of transformer winding 50 is connected through the winding of an electromagnetic relay 55 to the cathodes of triodes 53 and 54, a condenser 57 being connected in a shunt path across the relay winding. The release of the armature 56 of relay 55 completes an energizing circuit from battery 58 to an indicator lamp 59. There is provided a twin-triode tube 62 having triodes 63 and 64 the anodes of which are similarly connected to the end terminals of a secondary transformer winding 51. The mid-tap of transformer winding 51 is connected through the winding of an electromagnetic relay 65 to the cathodes of triodes 63 and 64, a condenser 67 being connected across relay winding. The release of the armature 66 of relay 65 completes an energizing circuit from battery 68 to an indicating lamp 69.

A potentiometer 70 is connected across a portion *e*—*c* of transformer winding 15. Similar resistors 71 and 72 are connected in series across a variable portion of potentiometer 70 between the variable tap of the potentiometer and the terminal connected to terminal *c* of the transformer winding. The common terminal of resistors 71 and 72 is connected to the cathodes of triodes 63 and 64. The remaining terminal of resistor 71 is connected through a resistor 84 to the control electrode of triode 53 and the remaining terminal of resistor 72 is connected through a resistor 85 to the control electrode of triode 54. A condenser 86 is provided in a path connecting the cathode of triode 54 and a common terminal of resistor 72 and 85.

A potentiometer 80, similar to potentiometer 70, is connected across a portion *f*—*d* of transformer winding 14. Similar resistors 81 and 82 in series are connected across a variable portion of potentiometer 80 between the variable tap of the potentiometer and the terminal connected to terminal *d* of transformer winding 14. The variable taps of potentiometers 70 and 80 are mechanically connected so that, preferably, the voltage across resistors 71 and 72 is at all times equal to the voltage across resistors 81 and 82. The common terminal of resistors 81 and 82 is connected to the cathode of triodes 53 and 54. The other terminal of resistor 81 is connected through a resistor 87 to the control grid of triode 63 and the other terminal of resistor 82 is connected through a resistor 88 to the control grid of triode 64. A condenser 89 is provided in a path connecting the cathode of triode 64 and a common terminal of resistors 82 and 88.

For the purpose of explaining the operation of the circuit, let it be assumed that potentiometers 70 and 80 are set so that the variable taps are at the potentials of points *c* and *d*, respectively. There will then be zero voltage across resistors 71 and 72 and across resistors 81 and 82. Let it further be assumed that the setting of potentiometer 20 and the voltage of source 11 are such that the voltage between the movable tap of the potentiometer 20 and point *a* of transformer winding 13 is equal to the voltage across thermistor 19. Under these conditions, during half-cycle periods when the anode of triode 53 is positive with respect to its cathode, there will be impressed upon the grid-cathode circuit of triode 53 half cycles of the voltage across the portion *e*—*c* of transformer winding 15 and, in opposition thereto, the voltage pulses of equal amplitude across resistor 26, the voltage across resistor 27 being zero during these half-cycle periods. Similarly, during half-cycle periods when the anode of triode 54 is positive with respect to its cathode, there will be impressed upon the grid-cathode circuit of triode 54 half cycles of the voltage *e*—*c* and, in opposition thereto, the voltage pulses of equal amplitude across resistor 27. The control grids of triodes 53 and 54 will then be at the same potential as the cathodes and sufficient space current will flow through the winding of relay 55 to maintain the relay in the operated condition. A slight increase of voltage

of the source 11 above the assumed "normal" value will cause the voltage pulses across resistor 26 to decrease in amplitude and the voltage pulses across resistor 27 to increase in amplitude, thereby making the control grids of triodes 53 and 54 sufficiently negative with respect to the cathodes to cause the current in the winding of relay 55 to be reduced and to cause the relay armature 56 to be released. The resulting energization of lamp 59 produces an indication of the high line voltage condition.

For the conditions stated in the preceding paragraph, when the anode of triode 63 is positive with respect to its cathode, there will be impressed upon the grid-cathode circuit of triode 63 half cycles of the voltage *e*—*c* and, in opposition thereto, the voltage pulses of equal amplitude across resistor 26. When the anode of triode 64 is positive with respect to its cathode, there will be impressed upon the grid-cathode circuit of triode 64 half cycles of the voltage *e*—*c* and, in opposition thereto, the voltage pulses of equal amplitude across resistor 27. The polarities of the component voltages in the grid-cathode circuits of triodes 63 and 64, however, are reversed with respect to the polarities of the corresponding voltages in the grid-cathode circuits of triodes 53 and 54. A slight decrease of the voltage of the source 11 below the assumed normal value will cause the voltage pulses across resistor 26 to increase in amplitude and the voltage pulses across resistor 27 to decrease in amplitude, thereby making the grids of triodes 63 and 64 sufficiently negative with respect to the cathodes to cause the armature of relay 66 to be released. Lamp 69 is thus energized to produce an indication of the low voltage condition.

It will be noted that as the taps of potentiometers 80 and 70 are moved by equal amounts toward positions *f* and *e*, respectively, for any positions of the taps, the voltage between the common terminal of resistors 81 and 82 and the common terminal of resistors 71 and 72 will be equal to the difference of the voltage *e*—*c* and the voltage across resistor 26 during half-cycle periods when the anodes of triodes 22, 53 and 63 are positive with respect to their cathodes and said voltage will be equal to the difference of the voltage *e*—*c* and the voltage across resistor 27 when the anodes of triodes 23, 54 and 64 are positive with respect to their cathodes. The grid-cathode voltages of each of triodes 53, 54, 63 and 64 is the voltage between the common terminal of resistors 81 and 82 and the common terminal of resistors 71 and 72 plus a bias voltage across one of the resistors 71, 72, 81, 82, the bias voltage having a polarity such as to make the grid relatively more positive with respect to the cathode when the anode is positive with respect to the cathode. The voltages across resistors 71, 72, 81 and 82 are the added biasing voltages for triodes 53, 63, 54 and 64, respectively, these biasing voltages being equal and adjustable by moving the taps of potentiometers 70 and 80. An increase of these biasing voltages makes necessary a relatively larger decrease of voltage across resistor 26 and a relatively larger increase of voltage across resistor 27 to effect the release of relay 55. An increase of these biasing voltages also makes necessary a relatively larger increase of voltage across resistor 26 and a relatively larger decrease of voltage across resistor 27 to effect the release of relay 65. In other words, moving the potentiometer taps from *d* toward *f* and from *c* toward *e* increases the normal voltage range for which relays 55 and 65 remain operated, the relays, respectively being released only when the source voltage goes above and below the maximum and minimum values, respectively, of the normal voltage range.

If for one setting of potentiometers 70, 80 relay 65 should release when the voltage of source 11 is 98 per cent of a certain predetermined voltage and the release of relay 55 should occur when the voltage of source 11 is 102 percent of the predetermined voltage, for example, increasing the bias voltages by readjusting potentiometers 70, 80 could cause the relay 65 to release at 96 per cent of the predetermined voltage and the relay 55 to release at 104 per cent of the predetermined voltage. Thus the setting of potentiometers 70, 80 determines the range between the low voltage indication produced by lamp 69 and the high voltage indication produced by lamp 59 while the setting of potentiometer 20 determines the voltage level of the center point of this range, the two adjustments being almost independent of one another as far as their effects are concerned.

What is claimed is:

1. The combination with a source of alternating voltage the amplitude of which may change, of means for deriving from said source a symmetrical alternating voltage substantially proportional to the voltage of said source, means for deriving from said source during periods of one polarity thereof a first pulsating voltage the amplitude of which decreases by a larger amount than the amplitude increase of said derived alternating voltage in response to an increase of voltage of said source, means for deriving from said source during periods of opposite polarity thereof a second pulsating voltage the amplitude of which increases by a larger amount than the amplitude increase of said derived alternating voltage in response to an increase of voltage of said source, and means for combining said derived alternating and pulsating voltages with each of said pulsating voltages in phase opposition to said derived alternating voltage to produce a resultant voltage the amplitude of which changes in a predetermined direction when the voltage of said source either increases or decreases.

2. In combination, a space current device having an anode, a cathode and a control electrode, a first circuit connecting said anode and said cathode, means for causing current to flow in said first circuit, an alternating-current supply source the voltage of which may vary, a second circuit connecting the control electrode and cathode of said device, and means for deriving from said supply source and impressing upon said second circuit a voltage for causing the current in said first circuit to change in a predetermined sense in response to a voltage increase of said supply source to a certain relatively high voltage and for causing the current in said first circuit to change in said predetermined sense in response to a voltage decrease of said supply source to a certain relatively low voltage.

3. In combination, a space current device having an anode, a cathode and a control electrode, an alternating-current supply source the voltage of which may vary, a space current circuit for said device comprising a first source of alternating voltage derived from said supply source, means for deriving from said source a second voltage the amplitude of which increases in response to an increase of said supply voltage above a predetermined voltage and the amplitude of which

increases in response to a decrease of said supply voltage below said predetermined voltage and means for impressing said second derived voltage upon a circuit connecting said control electrode and said cathode for controlling the amplitude of said space current.

4. In combination, a space current device having an anode, a cathode and a control electrode, an alternating-current supply source the voltage of which may vary, means for supplying current from said source to a space current circuit connecting said anode and said cathode, means for deriving from said source a voltage the amplitude of which increases in response to an increase of said supply voltage above a predetermined voltage and the amplitude of which increases in response to a decrease of said supply voltage below said predetermined voltage, means for selecting a desired predetermined voltage above and below which said derived voltage increases, and means for impressing said derived voltage upon a circuit connecting said control electrode and said cathode for controlling the amplitude of said space current.

5. In combination, a space current device having an anode, a cathode and a control electrode, means for supplying current from an alternating-current supply source to a space current circuit connecting said anode and said cathode, means for deriving from said supply source a voltage the amplitude of which increases in response to an increase of said supply voltage from a first voltage to a second voltage and the amplitude of which increases in response to a decrease of said supply voltage from said first voltage to a third voltage, means for adjusting said second and third voltages relative to said first voltage to determine the voltage range of said supply source above and below which said derived voltage increases, and means for impressing said derived voltage upon a circuit connecting said control electrode and said cathode for controlling the amplitude of said space current.

6. A combination in accordance with claim 5 in which is provided means for adjusting said first voltage.

7. In combination, a first and a second space current device each having an anode, a cathode and a control electrode, means for supplying currents from an alternating-current supply source to space current circuits connecting the anode and cathode of said devices, respectively, means for deriving from said supply source a voltage the amplitude of which increases in one sense in response to an increase of said supply voltage from a first voltage to a second voltage and the amplitude of which increases in the opposite sense in response to a decrease of said supply voltage from said first voltage to a third voltage, means to impress said derived voltage upon a circuit connecting the control electrode and cathode of said first device with a polarity to cause the space current of said first device to decrease when said supply voltage increases from said first voltage to said second voltage, and means to impress said derived voltage upon a circuit connecting the control electrode and cathode of said second device with an opposite polarity to cause the space current of said second device to decrease when said supply voltage decreases from said first voltage to said third voltage.

8. A combination in accordance with claim 7 in which there are provided a first means connected in the space current path of said first device for producing an indication when said supply voltage increases to said second voltage, and a second means connected in the space current path of said second device for producing an indication when said supply voltage decreases to said third voltage.

9. In combination, a first and a second current responsive means, means comprising a first and a second space current device for supplying current from an alternating-current supply source to said first and second current responsive means respectively, each of said space current devices having an anode, a cathode and a control electrode, means for impressing upon the control electrode and cathode of said first device a voltage derived from said source for causing the current supplied to said first current responsive means to be reduced to a predetermined value in response to an increase of said supply voltage to a voltage above a certain normal range, and means for impressing upon the control electrode and cathode of said second device a voltage derived from said source for causing the current supplied to said second current responsive means to be reduced to a predetermined value in response to a decrease of said supply voltage to a voltage below said normal range.

10. The combination with an alternating-current supply source the voltage of which may change, of means for deriving from said supply source during periods of one polarity thereof a first pulsating voltage the amplitude of which decreases in response to a voltage increase of said source but at a higher rate, and vice versa, means for deriving from said supply source during periods of opposite polarity thereof a second pulsating voltage the amplitude of which increases in response to a voltage increase of said source but at a higher rate, and vice versa, a first full wave rectifier, means for combining said pulsating voltages with an alternating voltage derived from said source in the input circuit of said full wave rectifier, said pulsating voltages being in opposition to half cycles of said derived alternating voltage, resistance means having two end terminals and a mid-terminal, means for impressing across said resistance means an alternating voltage of variable amplitude and fixed phase derived from said source, a second full wave rectifier comprising two space current devices each having an anode, a cathode and a control electrode for rectifying current from said alternating-current source, means for connecting the mid-terminal of said resistors to the negative output terminal of said first full wave rectifier, means for connecting the cathodes of said space current devices to the positive output terminal of said first full wave rectifier, and means for connecting the end terminals of said resistance means to the control electrodes of said space current devices, respectively, thereby controlling the output current of said second full wave rectifier.

11. A combination in accordance with claim 10 in which there are provided an indicating device for producing an indication in response to abnormally high and abnormally low voltages of said supply source and an electromagnetic relay energized by the rectified output current of said second full wave rectifier for controlling the energization of said indicating device.

12. The combination with an alternating-current supply source, of a transformer having a primary winding connected to said source and a plurality of secondary windings, a full wave rectifier comprising a first and a second space cur-

rent device for rectifying current from said source supplied through a first of said secondary windings, each of said space current devices having an anode, a cathode and a control electrode, a first resistor having a terminal connected to a terminal of a second secondary winding, a first potentiometer connected across said second secondary winding and having a variable tap, means for connecting said variable tap to the control electrode of said first device, means for connecting a terminal of said second secondary winding to the control electrode of said second device, a second resistor having a terminal connected to a second terminal of said first resistor, a third secondary winding having a first terminal connected to a second terminal of said second resistor, a second potentiometer connected across said third secondary winding and having a variable tap, means for mechanically connecting the variable taps of said potentiometers, resistance means connecting the second terminal of said third secondary winding and the variable tap of said second potentiometer, said resistance means having a mid-tap, means for connecting said mid-tap to the cathodes of said devices, means for supplying current from said supply source to said first resistor to set up across said resistor during half-cycle periods of one polarity of said source a pulsating voltage the amplitude of which decreases in response to a voltage increase of said source and vice versa, and means for supplying current from said supply source to said second resistor during half-cycle periods of opposite polarity of said source a pulsating voltage the amplitude of which increases in response to a voltage increase of said source and vice versa, each of said pulsating voltages being in opposition to the voltage supplied by said second and third secondary windings in the control electrode-cathode circuits of said space current devices.

13. In combination, a transformer having a primary winding connected to an alternating-current supply source and a plurality of secondary windings, a thermistor and a first resistor connected in series to a first of said secondary windings, a first potentiometer connected across a portion of a second of said secondary windings, means for connecting the variable tap of said potentiometer to a common terminal of said thermistor and said first resistor, a first and a second space current device each having an anode, a cathode and a control electrode, a second and a third resistor, means for connecting a terminal of each of said second and third resistors to said cathodes and to a common terminal of said thermistor and said first secondary winding, means for connecting said control electrodes to said second secondary winding, a space current circuit for said first space current device comprising a third of said secondary windings and said second resistor, a space current circuit for said second space current device comprising a fourth of said secondary windings and said third resistor, a full wave rectifier, having input and output terminals, means for connecting one of said input terminals to a common terminal of said second resistor and said third secondary winding, means for connecting the other of said input terminals to said fourth secondary winding, a fourth resistor connected to the output terminals of said rectifier, a third and a fourth space current device each having an anode, a cathode and a control electrode, a second potentiometer connected across a fifth of said secondary windings, a fifth and a sixth resistor having a common terminal connected to a first terminal of said fourth resistor, means for connecting the other terminal of said fifth resistor to the variable tap of said second potentiometer, means for connecting the other terminal of said sixth resistor to a common terminal of said second potentiometer and said fifth secondary winding, means for connecting the terminals of said fifth and sixth resistors other than said common terminal to the control electrodes of said third and fourth space current devices, respectively, means for connecting the cathodes of said third and fourth space current devices to the second terminal of said fourth resistor, means for connecting the anodes of said third and fourth devices to the end terminals, respectively, of a sixth of said secondary windings, current responsive means, and means for connecting said current responsive means in a path connecting the cathodes of said third and fourth devices and a mid-terminal of said sixth winding.

14. In combination, a transformer having a primary winding connected to an alternating-current supply source and a plurality of secondary windings, a thermistor and a first resistor connected in series to a first of said secondary windings, a first potentiometer connected across a portion of a second of said secondary windings, means for connecting the variable tap of said potentiometer to the common terminal of said thermistor and said first resistor, six space current devices each having an anode, a cathode and a control electrode, a second and a third resistor having a common terminal connected to the cathodes of a first and a second of said space current devices and to a common terminal of said thermistor and said first secondary winding, means for connecting the control electrodes of said first and second devices to said second secondary winding, a space current circuit for said first device comprising a third of said secondary windings and said second resistor, a space current circuit for said second device comprising a fourth of said secondary windings and said third resistor, a second potentiometer connected to a common terminal of said third secondary winding and said second resistor and to another terminal of said third secondary winding, a third potentiometer connected to a common terminal of said fourth secondary winding and said third resistor and to another terminal of said fourth secondary winding, means for mechanically connecting the variable taps of said second and third potentiometers, a fourth and a fifth resistor having a common terminal connected to the cathodes of a third and a fourth of said space current devices, means for connecting the other terminal of said fourth resistor to the variable tap of said second potentiometer, means for connecting the other terminal of said fifth resistor to the common terminal of said third secondary winding and said second resistor, a sixth and a seventh resistor having a common terminal connected to the cathodes of a fifth and a sixth of said space current devices, means for connecting the other terminal of said sixth resistor to the variable tap of said third potentiometer, means for connecting the other terminal of said seventh resistor to said other terminal of said fourth secondary winding, means for connecting the terminals of said fourth and fifth resistors other than their common terminal to the control electrodes of said fifth and sixth space current devices, respectively, means for connecting the terminals of said sixth

and seventh resistors other than their common terminal to the control electrodes of said third and fourth space current devices, respectively, a first electromagnetic relay having a winding in a current path connecting the cathodes of said third and fourth space current devices and a mid-terminal of a fifth of said secondary windings, means for connecting the end terminals of said fifth winding to the anodes, respectively, of said third and fourth devices, means for connecting the end terminals of a sixth of said transformer windings to the anodes, respectively, of said fifth and sixth space current devices, and a second electromagnetic relay in a current path connecting the cathodes of said fifth and sixth devices and a mid-terminal of said sixth secondary winding.

15. In combination, a current responsive means, means for supplying current from an alternating-current supply source to said current responsive means, and means for decreasing by a predetermined amount the current supplied to said current responsive means in response to a predetermined voltage increase of said supply source above a certain normal voltage and also in response to a predetermined voltage decrease of said supply source below said normal voltage.

16. A combination in accordance with claim 15 in which means are provided for changing said predetermined voltage increase and said predeterined voltage decrease required for decreasing the current supplied to said current responsive means by said predetermined amount.

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