

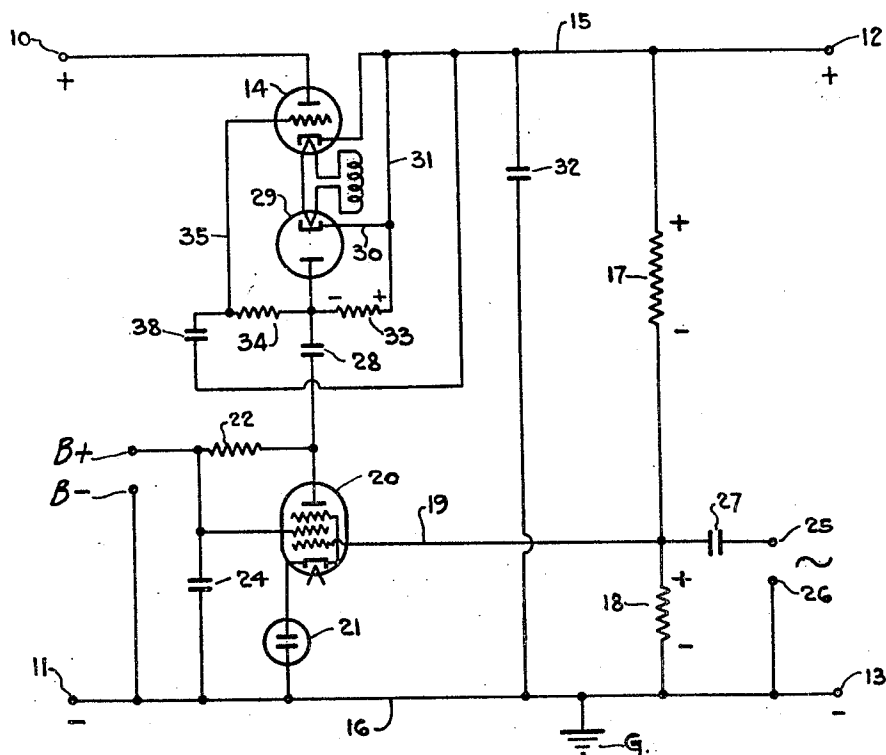
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S. C. SPIELMAN

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HIGH VOLTAGE REGULATOR CIRCUIT

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INVENTOR.

Sterling C. Spielman.

BY

Hawson + Hawson

Attorneys.

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HIGH-VOLTAGE REGULATOR CIRCUIT

Sterling C. Spielman, Huntingdon Valley, Pa., assignor, by mesne assignments, to Philco Corporation, Philadelphia, Pa., a corporation of Pennsylvania

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This invention relates to control devices for electrical systems, more particularly to the provision of a voltage regulating system, and has for an object the provision of a system utilizing low voltage devices for regulating in a desired manner a direct current voltage which may greatly exceed the normal voltage ratings of the devices included in the system.

The present invention relates to systems of the type disclosed in U. S. Patent 2,120,884, granted on June 14, 1938, to R. D. Brown, Jr. In accordance with the systems of that patent, an electric valve is connected in series with a load or output circuit and a second electric control valve is arranged to control the resistance of the series connected valve in a manner to maintain constant the voltage across the output or load circuit.

In carrying out the present invention in one form thereof, low voltage electric valves are utilized to regulate the voltage across a high voltage load or output circuit. This is accomplished even though the output voltage exceeds the voltage ratings of the individual valves. Instead of applying the output voltage directly between the control grid and the cathode of the control valve, a separate alternating source of supply is utilized to indicate the gain of the control valve in accordance with the condition to be regulated. The output from this valve after passage through an alternating current coupling means is rectified. The rectified output is then utilized to control the bias on a valve connected in series between the input circuit and the output or load circuit. In consequence, none of the individual valves is subjected to the high voltage of either the input or output circuits.

For a more detailed explanation of the invention, and for further objects and advantages thereof, reference is to be had to the following description, taken in conjunction with the accompanying drawing, in which the single figure is a diagrammatic illustration of a system embodying the invention.

A high voltage direct current source of supply is indicated at 10 and 11 and is herein designated the input circuit. By means of the present invention the voltage across the output or load circuit indicated at 12 and 13, or another electrical condition thereof, is regulated in a predetermined manner. The manner in which the system functions to maintain constant the voltage across the output circuit or terminals 12 and 13 will now be described.

Load current flows from the positive terminal

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10 through the electric valve 14, by way of conductor 15 to the load circuit connected to the terminals 12 and 13, and by the conductor 16 to the negative terminal 11. The valve 14 may be a triode having the usual anode, control grid, and cathode. Although it may be of any suitable type it is preferably a power tube characterized by high current-carrying ability. In a manner later to be explained the control electrode or grid is normally biased for the operation of the valve 14 on the linear portion of its characteristic curve, and preferably about midway thereof.

The D. C. voltage across the load circuit 12 and 13 divides across the resistors 17 and 18, which are connected in series across conductors 15 and 16. Preferably the resistor 17 has a resistance materially higher than that of the resistor 18 the ratio being established by required operating conditions as described later. The reduced D. C. voltage appearing across the resistor 18 is applied through conductors 16 and 19 to the control grid circuit of an electric valve 20, which is shown as a pentode. As compared with the valve 14, the tube or valve 20 preferably has high gain, and a sharp grid voltage-plate current cut off characteristic, and high current carrying capacity is not necessary. To provide a constant cathode potential a battery, a fixed source of D. C. potential, a glow tube or a cold-cathode gaseous tube 21 may be connected in series circuit relation with the cathode. As is well understood by those skilled in the art, the glow tube 21 possesses the characteristic of a substantially constant voltage drop over a wide range of current flow. As applied to the valve 20, this means that a substantially constant component of grid bias is applied to the control grid of the valve 20 by the glow tube 21.

The magnitude of the overall D. C. grid bias applied to the tube 20 is the difference between the cathode bias (or potential across the glow tube 21) and the bias or potential across the resistor 18. Therefore, the difference between these two potentials determines the operating point of the tube or valve 20 and the gain thereof.

The source of anode supply for the valve 20 is indicated at B+ and B-, the circuit from the terminal B+ including an anode load resistor 22. The screen grid may be connected directly to the B+ terminal, with a capacitor 24 leading from the screen grid circuit to the cathode by way of conductor 16. The capacitor 24 forms a part of a filter circuit to eliminate alternating current from the source of anode and screen potential.

The suppressor grid of the valve 20 is illustrated as directly connected to the cathode.

There is applied to the control grid of the valve 20 the voltage from an alternating current source indicated at 25 and 26. This voltage, preferably of a relatively low order, is applied through a direct current blocking capacitor 27 and by way of conductors 19 and 16 to the grid-cathode circuit. Normally, i. e., when there appears across the load terminals 12 and 13 the desired voltage, the tube 20 is preferably biased in such a manner that positive peaks of plate current occur near the middle portions of the tube's characteristic curve. Then a part of the positive portions of the alternating current voltage applied to the control grid from the source 25—26 are reproduced in the output circuit of the tube 20, and with the amplitude thereof increased to an extent depending upon the gain of the tube 20. The output circuit may be traced from the anode through a coupling and blocking capacitor 28, resistor 33, a rectifying device shown as a diode 29, the conductors 30, 31 and 15, the return circuit being by way of a capacitor 32.

The diode 29 produces a rectified output current which circulates through a local circuit including the resistor 33. The voltage across this resistor applies a negative bias on the control grid of the valve 14 through the filter comprising resistor 34 and condenser 38. Normal operating conditions have now been described.

If the voltage across the output or load circuit terminals 12 and 13 increases, the voltage across the resistor 18 will also rise. The resultant effect is a decrease in the negative bias applied to the grid-cathode circuit of valve 20. This in turn causes the A. C. voltage to vary over a greater part of the grid characteristic curve of valve 20 and produce a correspondingly greater alternating voltage in the output circuit. It follows that the rectified output from the diode 29 also rises, and this in turn increases the negative bias on the control grid of the valve 14. The result of the higher negative bias is to increase the resistance to current flow through the valve 14, and in this manner the voltage drop across valve 14 will be increased and the rise in voltage across terminals 12 and 13 will be opposed. Stated differently, if the voltage across the terminals 12 and 13 should tend to change, either because of supply voltage variations or load current variations a change in resistance occurs in tube 14 which counteracts the voltage change across terminals 12 and 13 and maintains the voltage at that point nearly constant.

Similarly, if the voltage across the load circuit terminals 12 and 13 tends to decrease, less voltage appears across the resistor 18. The resultant effect is an increase in the negative bias applied to the control grid of the valve 20. The alternating current in the output circuit is then of correspondingly less amplitude and the rectified output from the diode 29 is also correspondingly less. It follows that the negative bias applied to the valve 14 is decreased and a greater amount of current tends to flow through the valve 14. This overcomes or corrects the tendency of the voltage across terminals 12 and 13 to decrease.

Now that the principles of the invention have been explained, it will be understood that many modifications thereof may be made. For example, the bias applied to the control grid of the valve 20 may be made to vary as a function of

the load current, or any other desired electrical condition of the output or load circuit may be regulated in a similar manner. It will also be noted that operation of the circuit depends upon maintaining the proper balance of biasing voltages on valve 20 and therefore the circuit responds to changes in the regulated parameter, regardless of whether they be caused by load conditions, or supply conditions.

By utilizing the low-voltage pilot signal, the alternating current source 25—26, it is possible electrically to separate the control valve 20 from the diode 29-triode 14 combination insofar as the direct current potentials are concerned, and at the same time control or regulate any desired electrical condition of the load circuit. Of course it will be understood the capacitors 28 and 32 will be subjected to substantially full direct current potential but this merely requires a capacitor having suitable voltage characteristics and of a size which offers a relatively low impedance to the alternating current pilot signal. Similarly, while both the diode 29 and the triode 14 are at a high voltage with reference to ground, yet the output direct current voltage is not applied between the electrodes of these tubes. Hence they may be low voltage devices.

In a typical embodiment of the invention, an unregulated high voltage source of supply of 2400 volts was connected between the terminals 10 and 11. By means of the invention the voltage across the load circuit, represented by terminals 12 and 13, was maintained at a constant value of 2,000 volts. The resistors 17 and 18 respectively had values of 2,000,000 and 160,000 ohms. For a pilot signal at the terminals 25 and 26 of 6.3 volts and a frequency of from 400 to 2400 cycles per second, the capacitors 27 and 32 each had a value of 0.01 microfarad, and the coupling and blocking capacitor 28 had a value of 0.005 microfarad. The resistors 33 and 34 were each one megohm. The capacitor 38 of 0.005 microfarad with resistor 34 forms a filter circuit to remove from the grid circuit of the valve 14 any of the alternating current which might otherwise tend to appear therein. The circuit constants will of course be selected in accordance with the requirements of particular applications of the invention, the foregoing being illustrative and not by way of limitation. Tubes of any suitable type may be used. For the foregoing embodiment of the invention, a type 6SN7 was used for the valves 14 and 29 and a 6AG5 for the valve 20.

It will be understood there may be a slight alternating current ripple present in the rectified output voltage applied across the input terminals 10 and 11. If such a ripple or hum should be present, and if the pilot signal is derived from the same source which supplies the rectified power, the pilot signal voltage may be applied so that its polarity or phase as appearing at the tube 14 will be in opposition to that present in the input circuit. The preferred phase relation may be readily determined by reversing the leads to the alternating current source 25, 26, and noting the connection which gives the better operating characteristics.

Where the bias and pilot signal are applied to the control grid a triode may be satisfactory for the tube or valve 20. In other applications it may be desirable to apply the grid bias to the control grid while the pilot signal is applied between another grid and the cathode of the tube. These possibilities are suggestive of further variations of the invention and the manner in which

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different types of tubes may be utilized therewith.

Alternatively to the mode of operation described above, wherein a sharp cut-off valve is used, the valve 20 may be of the variable- μ or remote cut-off type. In this mode of operation the magnitude of the alternating current output of valve 20 is a function of the amplification factor of the said valve, the said amplification factor being a function of grid bias, i. e., of the voltage appearing at the junction of resistors 17 and 18.

I claim:

1. An electrical system comprising a high voltage circuit of unidirectional potential, an electric valve having a control electrode for regulating an electrical condition of said circuit, means including a rectifying device for applying a variable bias to said control electrode, a second electric valve having an output circuit and an input circuit, said output circuit including said rectifying device and means capable of transferring alternating current to and blocking said unidirectional potential from said second valve, said input circuit including a control electrode and a source of alternating current, and means for applying to said control electrode a bias whose magnitude is a function of said electrical condition, whereby upon variation of said condition said bias changes in a direction to produce a resultant corrective action by said first named valve.

2. An electrical system comprising a high voltage circuit of unidirectional potential, an electric valve having a control electrode for regulating an electrical condition of said circuit, means including a rectifying device for applying a variable bias to said control electrode, an electric control valve having an output circuit and an input circuit, said output circuit including a coupling capacitor and said rectifying device in series circuit relation, said coupling capacitor effectively blocking said unidirectional potential from said control valve, said input circuit including a control electrode of said valve, means for applying to last named electrode an alternating current pilot signal, and means varying in accordance with a condition to be controlled for varying the effective gain of said control valve to change the bias on said first-named valve in a direction to produce a resultant corrective action as regards said changed condition.

3. In an electrical system having an unregulated high voltage direct current source of potential, a load circuit across which the voltage is to be regulated, an electric valve having a control electrode for regulating the voltage across said circuit, and means including a rectifying device for applying a variable bias to said control electrode, the combination of an electric control valve having an output circuit and an input circuit, said output circuit including said rectifying de-

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vice and a coupling capacitor for blocking said direct current potential from said control valve, said input circuit including a control electrode and a source of alternating current, and means for applying to said last-named control electrode a bias whose magnitude varies with change in voltage of said source, thereby to increase and decrease the effective gain of said control valve, whereby upon variation of said voltage, said bias on said first-named valve is changed in a direction to produce a corrective action and to maintain the voltage across said load circuit at a predetermined value.

4. In combination, a high voltage direct current supply circuit, an electron tube serially included in one side of said circuit and having a control element for regulating an electrical condition of said circuit, a control tube having at least an anode, a cathode and a control electrode, an input circuit for said control tube connected between said cathode and said control electrode, means for supplying a low alternating voltage to said input circuit, means for applying to said control electrode a bias potential whose magnitude is a function of said electrical condition and is substantially less than the voltage of said supply circuit, means for supplying a unidirectional operating voltage to said anode, an alternating current output circuit for said control tube connected between said anode and said cathode, rectifying means included in said output circuit for deriving a bias voltage whose magnitude is proportional to the magnitude of alternating current flowing in said output circuit, and means for applying said bias voltage to the control element of said first-mentioned tube.

5. In combination, a high voltage direct current supply circuit, an electron tube serially included in one side of said circuit and having a control element for regulating the output voltage of said circuit, a control tube having at least an anode, a cathode and a control electrode, an input circuit for said control tube connected between said cathode and said control electrode, means for supplying a low alternating voltage to said input circuit, means for applying to said control electrode a portion of said output voltage so as to vary the conductivity of said control tube in accordance with variations of said output voltage, means for supplying a unidirectional operating voltage to said anode, an alternating current output circuit for said control tube connected between said anode and said cathode, rectifying means included in said output circuit for deriving a bias voltage whose magnitude is proportional to the magnitude of alternating current flowing in said output circuit, and means for applying said bias voltage to the control element of said first-mentioned tube.

STERLING C. SPIELMAN.