March 4, 1947. A. J. IRISH ET AL 2,416,922

VOLTAGE REGULATING CIRCUIT

Filed Aug. 30, 1943

Fig. 1.

Prior Art

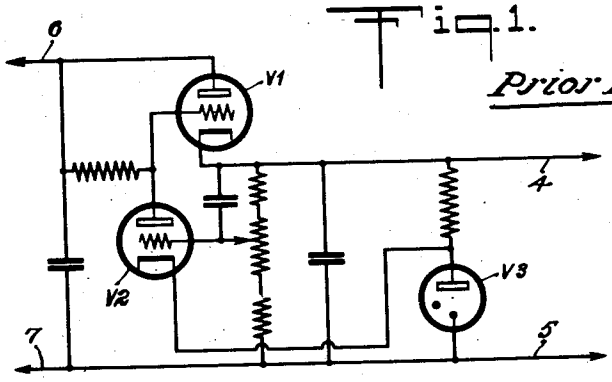


Fig. 2.

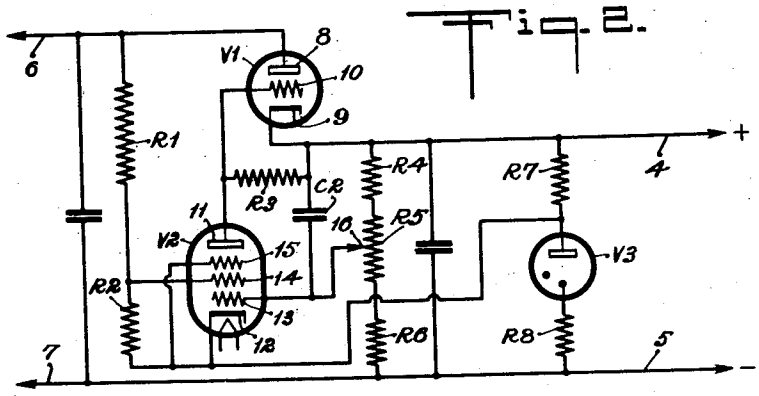
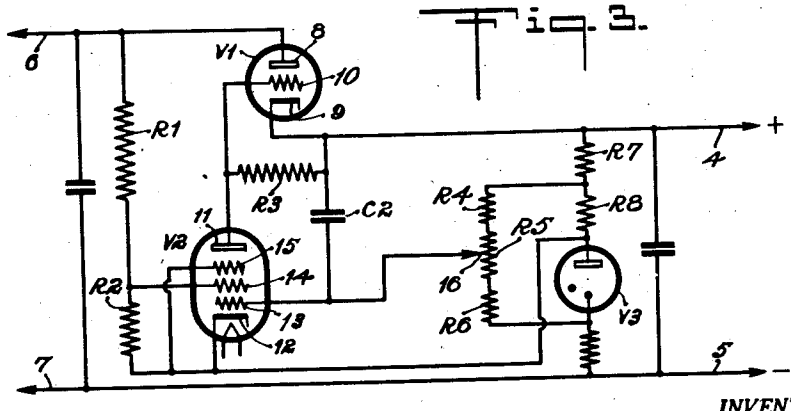


Fig. 3.



INVENTORS
Alfred J. Irish,
Donald G. Lindsay
H. S. Grover
ATTORNEY.

Patented Mar. 4, 1947 2,416,922

UNITED STATES PATENT OFFICE

2,416,922

VOLTAGE REGULATING CIRCUITS

Alfred John Irish and Donald Gordon Lindsay, Sydney, New South Wales, Australia, assignors to Amalgamated Wireless (Australasia) Limited, Sydney, New South Wales, Australia, a company of New South Wales

Application August 30, 1943, Serial No. 500,546
In Australia February 3, 1943

1 Claim. (Cl. 171—312)

1

This invention relates to voltage regulators and more particularly to voltage regulators employing thermionic valves which are utilized to regulate the voltage or current of a load circuit.

It is frequently desirable to control the voltage of a direct current circuit within very narrowly defined limits. For example, in many applications such as television, wireless and the like, it is important to maintain the voltage substantially constant within wide ranges of load current. Where a source of unidirectional voltage is obtained by means of a rectifier energized from an alternating current circuit, it is desirable to employ an electronic voltage regulator between the output circuit of the rectifier and the load circuit, to maintain the voltage of the load circuit substantially constant. It is well understood that, as the load current fluctuates, variations in voltage drop due to the impedance of the rectifiers and other portions of the circuit causes a substantial variation in the value of the voltage transmitted to the load circuit. Also, variations in the main supply may cause undesirable changes in the output.

In systems of this character it has been proposed to derive, from a resistor connected in shunt to the load circuit, a regulating potential which is applied through a control channel to the control grid of a regulating device having its cathode-anode circuit connected in series with the load. This control channel usually includes an amplifier which functions to maintain, at the control grid of the regulating device, a potential which opposes variations in the load circuit voltage, thereby maintaining the load voltage variations within narrow limits, regardless of substantial variations in main voltage or load resistance.

A typical circuit arrangement for an electronic voltage regulator in accordance with the teachings of the prior art is shown in Figure 1 of the accompanying drawings.

It has been found that the control amplifier valve V_2 in the exemplary circuit of Figure 1 is required to have voltage ratings higher than the full output voltage of the system because at plate current cut-off the total input voltage would appear across the plate and cathode of the valve.

Where output voltages up to 400 or 500 volts are required, the easily obtainable receiving type valves having the necessary voltage ratings may

2

be satisfactorily employed in the control amplifier V_2, but where the regulator is employed in a circuit having a high voltage output, for example 1,000 or 2,000 volts, it is no longer possible to use receiving type valves and consequently transmitting valves with adequate voltage rating have to be employed in the control amplifier V_2.

It is obvious that the necessity for using transmitting type valves in the amplifier V_2, in order to comply with the voltage requirements of the circuit when used in high voltage applications, greatly increases the cost of the regulating equipment and thus imposes an undesirable restriction on its use in this direction.

The object of this invention is to provide an improved electronic voltage regulator circuit which enables receiving type valves, with low voltage ratings, to be used in the control amplifier when the regulator is employed in high voltage applications.

The principal reason why it has not been possible in the past to use receiving type valves in the control channel of a voltage regulator, when employed in high voltage application, is because it was previously thought necessary to maintain the cathode of the amplifier at a fixed potential with respect to the negative conductor of the system in order to obtain satisfactory regulation.

This requirement, and the limited range of stabilizing tubes available and which could be used for that purpose, restricted the potential to which the cathode could be raised above the negative conductor to a relatively low value.

It has now been found that, so long as it is possible to obtain sufficient amplification in the system to compensate for any variation in cathode potential, the value of such cathode potential may be raised to any value within the limits of such amplification.

The present invention is based on the above discovery and provides a new and improved electronic voltage regulator in which the voltage at the cathode of the amplifier V_2 is raised to such value that the difference of potential between the cathode of the valve V_2 and the positive terminal of the load is reduced to an extent that will permit receiving type valves having high amplification factor and low voltage rating being used in this part of the circuit.

Electronic high voltage regulators constructed

in accordance with this invention have the following advantages. If a receiving type valve, having sufficient amplification to maintain stable conditions regardless of variation of cathode potential, is employed in the control amplifier V_2, the output voltage may be stabilized to a high order of precision. As receiving type valves having very high amplification factors are available, their use in the control amplifier channel enables a better regulation characteristic to be obtained over that possible by the use of the more expensive transmitting valves because of the lower amplification factors obtainable in the latter types.

In some applications for voltage regulators it is desirable that the voltage remain substantially constant throughout the entire range of the load, and in other applications it is desirable that the load voltage rise or fall at a predetermined rate as the load is increased.

Various methods have been suggested in the past for obtaining this type of control, but these have mostly been related to regulators in low voltage applications. The use of a screen grid or pentode valve in the present invention and the amount and method of connecting the potential to the screen grid provides a ready and economical method of obtaining this control when the regulator is used in high voltage applications.

If the screen grid potential for the low voltage receiving type valve in the control amplifier is derived from a potential divider across the input to the regulator, it is possible to obtain the type of control outlined above by variations of the screen grid tapping on the potential divider. This method of deriving the screen grid potential not only permits variation of the output voltage control characteristic, but, because of the high amplification factor of the valve, provides more perfect regulation for both input voltage variation and output load variation. This follows since the screen and control grids are not independent and the screen works in the correct phase to aid the effect of the control grid, and this allows the stabilization ratio to be made infinite over a suitable output voltage range. This phase relationship between screen grid and control grid voltages permits a wider variation of cathode potential without affecting the resultant precision of operation of the system, and consequently facilitates the necessary raising of the cathode potential to the value required to permit the use of receiving type valves of low voltage rating in the control amplifiers of regulators employed in high voltage applications.

An additional advantage arising from the use of low voltage receiving type valves in the control amplifier of a high voltage regulator is the reduction in cost brought about by the ability to use a condenser of the low voltage rating between the grid of the control valve and the positive terminal of the load. This condenser is often desirable in order to keep ripple in the output at a minimum.

In prior art high voltage regulating circuits of the general type shown in Figure 1, this condenser has had to withstand the full voltage across the load and consequently has had to be of high voltage rating.

For a more complete understanding of the invention and the manner in which it is to be carried out, attention is now directed to the following description in connection with the accompanying drawings in which Figure 1, as previously stated, is a voltage regulator circuit

exemplifying the teachings of the prior art, while Figure 2 is the circuit arrangement of an improved electronic voltage regulator constructed in accordance with this invention, and Figure 3 is a modification of Figure 2.

Referring now to Figure 2, the invention is there illustrated as applied to an electronic regulator for controlling an electrical condition such as the voltage of a D. C. (direct current) load or output circuit comprising a positive conductor **4** and a negative conductor **5**. The regulator may be energized from a suitable source of D. C. comprising a positive conductor **6** and a negative conductor **7**. The supply circuit may, in turn, be energized via a rectifier from an A. C. supply circuit (not shown).

Between the positive conductors **4** and **5** of the output circuit and the supply circuit, there is provided a variable impedance electronic discharge device V_1 of the high vacuum type, comprising an anode **8**, a cathode **9** and a control means such as a control grid **10**. If desired the device V_1 may be provided with a screen grid (not shown), which is connected to the anode **8**, or, more advantageously to a source which maintains screen potential constant with respect to cathode **9**.

In order to control the conductivity of the electronic discharge device V_1 and to control an electrical condition such as the voltage of the output circuit, there is provided in series relation across the output circuit an impedance element such as resistance R_3, a control electronic discharge device V_2, a glow discharge device V_3 and an additional impedance such as the resistance R_8. The control voltage device V_2 is of the high vacuum type and is in accordance with this invention, a high mu low voltage receiving type valve having an anode, a cathode and one or more intermediate grids. In the present example the valve V_2 is a receiving type pentode having an anode **11**, a cathode **12**, a control grid **13**, a screen grid **14** and a suppressor grid **15**. The suppressor grid **15** is conductively connected to the cathode **12**, either within or outside the envelope.

The glow discharge device V_3 and the resistance R_8 together with a further resistance R_7, provide an additional potential divider across the supply. The cathode **12** of valve V_2 is connected to the divider at the junction point between the anode of V_3 and the resistor R_7, the relationship between the resistance values of the resistor R_7 and the combined series resistance of the glow discharge device V_3 and resistor R_8 governing the operating potential of the cathode **12**. In accordance with this invention the relationship between these resistances is made such that the operating potential applied to the cathode **12** does not differ from the full output potential of the system by an amount greater than the voltage rating of the valve V_2.

Generally speaking the voltage on the cathode **12** is raised to such a value, by adjusting of the voltage divider R_7—V_3—R_8, that the difference in potential between cathode **12** and the positive conductor **4** is between 200 and 400 volts.

The anode **11** of the control valve V_2 is connected to the grid **10** of the discharge device V_1. The control valve V_2 transmits variable amounts of unidirectional current through the resistance R_3, and hence controls the potential of the grid **10** of valve V_1.

As an agency for controlling the conductivity of the control valve V_2 in response to the mag-

nitude of the voltage of the output circuit, there is employed a potential divider comprising the serially connected resistors R_4—R_5—R_6 and the control grid 13 is connected through an adjustable contact 16 to the resistor R_5. The contact 16 serves as a means for adjusting the magnitude of the output voltage which is maintained by the regulator.

Filtering means such as capacitor C_2 may be connected between the positive conductor 4 of the output circuit and control grid 13.

Operating potential for the screen grid 14 is derived from a high resistance potential divider comprising the resistors R_1—R_2 serially connected between the positive conductor 6 on the input side of the variable impedance V_1 and the cathode 12 of the control valve V_2. The ratio between the resistors R_1—R_2 governs the output control characteristic of the regulator. This ratio may be made such that the regulator will function to maintain the output voltage constant or it may be proportioned so that the output voltage is caused to have either a rising or falling characteristic. If the screen grid 14 is connected by means of an adjustable tapping to the potential divider R_1—R_2, the output voltage characteristic may be controlled as required.

The operation of the embodiment of the invention shown in Figure 2 will be explained by considering the system when it is operating to maintain the voltage impressed on the load circuit at a substantially constant value. The discharge device V_1 operates as a variable impedance to maintain the voltage of the load circuit constant. If it be assumed that the voltage of the output circuit tends to rise above a predetermined value, due to variations of the input voltage or load, the conductivity of the control valve V_2 is increased by the increase in the voltage across the divider R_4—R_5, which raises the positive potential on the grid 14. The incident increase of current through the resistor R_3 drives the grid 10 of the valve V_1 increasingly negative with respect to its cathode 9, thus causing its impedance to increase and tend to restore the output voltage to the desired value. Conversely, if the output voltage tends to decrease the voltage applied to the grid 14 of valve V_2, the tapping point 16 on the voltage divider 4—5—6 becomes less positive or, in other words, more negative. This causes a decrease in the conductivity of the valve V_2 thereby reducing the current through the resistor R_3 and producing a resultant variation of potential in the positive direction on the grid 10 of valve V_1. This increase in positive potential on the grid 10 of the valve V_1 reduces its impedance and consequently raises the voltage impressed on the load.

If a screen grid or pentode valve is employed as the control amplifier valve V_2, the regulation of the system is greatly improved. This improved regulation is brought about by reason of the fact that the screen grid 14 works in the correct phase to aid the effect of the control grid 13. As the control grid 13 is made more positive, due to an increase in output potential, the conductivity of valve V_2 is increased thus causing an increase in the current flow through the valve. This increase in current is further magnified by the increase in positive potential on the screen grid. The relationship between the potential on the screen grid and the potential on the control grid, and hence the extent to which the screen grid potential aids the control grid potential in controlling the current flow

through V_2, is governed by the ratio of R_1 to R_2 and the initial regulation of the input source. If this ratio is made variable by varying the point at which the screen grid 14 is connected to the divider R_1—R_2, or by varying the values or ratio of R_1—R_2, the variable effect on the output characteristic previously outlined may be obtained.

When the input or output voltage falls, the reduction of current through the valve V_1 brought about by the increasing negative potential applied to control grid 13 as a result of this contion is further reduced by a corresponding fall in positive potential on the screen grid 14.

This variation in current through V_2 brought about by an increase or decrease in the input or output voltages is applied to the grid 10 of the valve V_1 to control its impedance in the direction necessary to restore the output voltage to the desired value.

Because the potential applied to the screen grid 14 is in the correct phase to aid the effect of the control grid 13, a wider range of variation in cathode potential is permissible without producing any undesirable effects on the operation of the system. Because of this the potential of the cathode may be raised to the value required in the invention with only a slight degree of stabilization. This stabilization may be brought about by the use of the stabilizing valve V_3. The extent of the stabilization required for stable operation of the system is inversely proportional to the effective amplification factor of V_2, and the remainder of the control circuit.

The circuit in Figure 3 is essentially the same as that of Figure 2, except that the circuit of the control grid 13 of the amplifier valve V_2 is connected across a small portion of the output load resistor and not across the full output as in Figure 2.

The circuit of Figure 3 is preferable because it arrives at the desired output immediately the high voltage is applied whereas a unit of the type illustrated in Figure 2 takes several minutes, unless precautions are taken when selecting R_7 and R_8 to use resistors with ratings many times the minimum wattage rating or of small temperature coefficient of resistance so that their relative resistance values will not alter appreciably with change in temperature.

What we claim is:

In a system of the type comprising a pair of current leads of a relatively high potential difference, a regulator tube having at least a cathode, control grid and plate, the plate to cathode impedance of the regulator tube being connected in series in the high potential lead; the improvement comprising a control tube provided with at least a cathode, control grid, screen grid and plate, a first voltage divider connected across said leads, means connecting said control tube cathode to a point on the divider which is highly positive relative to the low potential lead, a second voltage divider connected from the plate of the regulator tube to said control tube cathode, means connecting said screen grid to a predetermined intermediate point on the second divider, a third voltage divider connected in parallel with at least a portion of the first divider, means connecting the control grid of the control tube to a predetermined intermediate point on the third divider, and a resistive element, disposed in the space current path of the control tube, connected between the control grid and cathode of the regulator tube, a stabilizing tube

of the gas-filled type having its plate to cathode path in series between two resistive sections of the first divider, said third divider being connected in shunt with said last-mentioned path, and said control grid connection to said third divider being adjustable and being free of electron discharge devices.

ALFRED JOHN IRISH.
DONALD GORDON LINDSAY.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,219,195	Norgaard	Oct. 22, 1940
2,301,343	Tarr	Nov. 10, 1942
2,316,577	Ford	Apr. 13, 1943
2,318,644	Tubbs	May 11, 1943
2,299,942	Trevor	Oct. 27, 1942
2,210,393	Braden	Aug. 6, 1940