June 19, 1923. 1,459,427

P. I. WOLD

THERMIONIC REGULATOR

Filed July 29, 1918

Fig. 1.

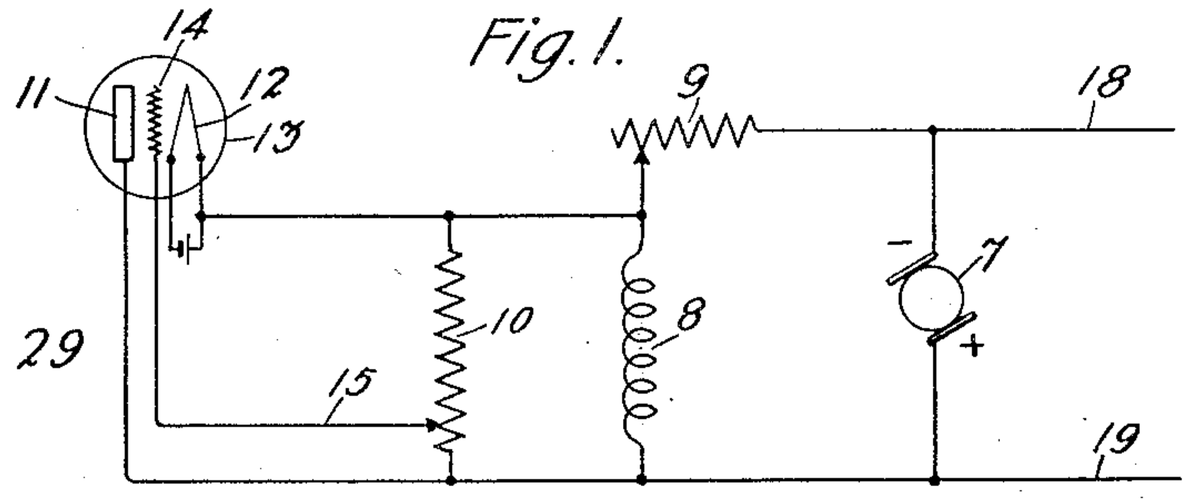


Fig. 2.

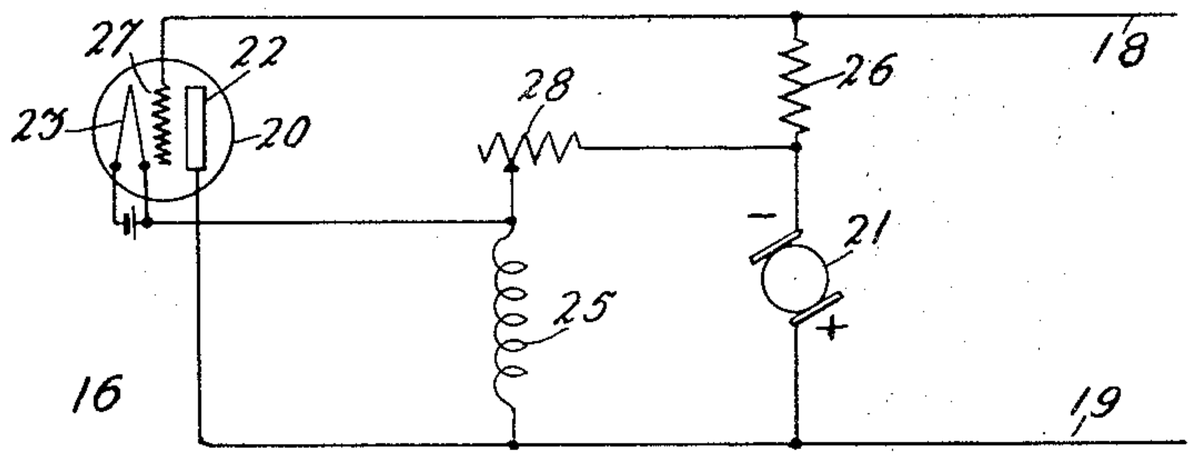
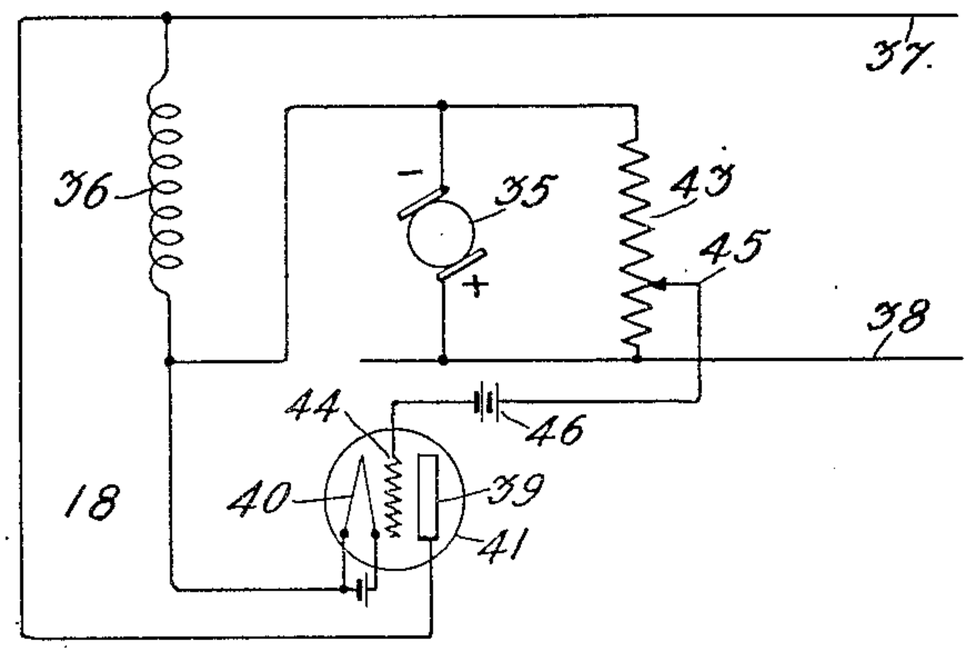


Fig. 3.



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UNITED STATES PATENT OFFICE.

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THERMIONIC REGULATOR.

Application filed July 29, 1918. Serial No. 247,275.

To all whom it may concern:

Be it known that I, PETER IRVING WOLD, a citizen of the United States, residing at East Orange, in the county of Essex and State of New Jersey, have invented certain new and useful Improvements in Thermionic Regulators, of which the following is a full, clear, concise, and exact description.

This invention relates to a novel type of regulator which is applicable in general for the regulation of electric currents and is particularly adapted to be employed for regulating the electrical output such as the voltage or current of a generator, or for controlling the electrical energy applied to a motor in order that its speed may be regulated.

An object of this invention is to produce a regulator for electric generators which will maintain a constant voltage or a constant current output. Another object is to produce such a regulator as will be continuously acting and in which there will be no moving parts such as are present in relays and the like. Still another object is to provide a regulator that is light in weight and which may be readily employed as a regulator for an electric machine without the necessity of altering the construction of the machine.

The regulator provided according to the present invention is of the thermionic type such as an audion comprising a vacuum tube containing electrodes. The manner in which such a vacuum tube is employed as a regulator is this: The vacuum tube comprises a cathode which serves as a source of electrons that travel to the anode or plate electrode. The amount of this electron stream or space current depends upon several factors, primarily upon (*a*) the voltage applied between these electrodes; (*b*) the temperature of the cathode, an increase in temperature producing a stronger space current; and (*c*) the potential of the grid electrode with respect to the filament, the more positive the potential of the grid within certain limits, the greater will be the space current.

An important feature of this invention is that such a vacuum tube as above described is an amplifier, that is, the application of a given voltage on the grid is more effective in controlling the impedance of the tube as measured between the cathode and anode electrodes than the application of the same voltage applied between the two last mentioned electrodes. On account of its amplifying properties a vacuum tube of the three-electrode type is therefore well adapted to regulate the current or voltage of a circuit with great sensitiveness.

If it is desired to regulate the output of the generator in accordance with this invention, the field winding thereof may be connected in circuit with the cathode and plate electrodes. The output of the generator depends of course upon the field current which, within limits, is controlled by the current flowing between the cathode and plate electrodes and which may be varied in intensity by varying the potential applied to the grid. The increase in the voltage or current of the generator serves to vary the potential of the grid, thereby modifying the space current so that the desired regulation is obtained. Specifically, the vacuum tube is connected in shunt to the field winding of the machine, and the field current is variably diverted through the vacuum tube in accordance with the potential of the grid electrode which is responsive to the voltage or current to be regulated.

As the thermionic device may be associated with an electric machine in a variety of ways, several forms that this invention may possess are hereinafter described in detail in connection with the drawings, in which Fig. 1 represents an embodiment of this invention in connection with a shunt-wound direct current generator for voltage regulation, while Fig. 2 shows the invention adapted to regulate for constant current. Fig. 3 illustrates a thermionic regulator in connection with the series-wound generator.

Referring more particularly to Fig. 1, 7 is a direct current generator having a field winding 8. In series with the field winding is an adjustable resistance 9. In shunt with this winding is a high resistance 10 and also the anode 11 and cathode 12 of a vacuum tube amplifier 13. The grid 14 of the tube is connected to an intermediate point of the resistance 10 by tap 15. The grid 14 is therefore positive with respect to the cathode 12 by the I R drop across that part of resistance 10 which is included between tap 15 and the cathode. With such an arrangement the vacuum tube 13 serves as a shunt

path across the terminals of field winding 8, and since the potential of the grid determines the value of the impedance of the tube, it follows that the potential of the grid determines the value of the field winding current. If, now, the voltage of the generator 7 should tend to increase, due, for example, to a change in the speed of the generator or a change in its load, the I R drop across resistance 10 would become larger, thereby making the grid more positive with respect to the filament, increasing the current through the vacuum tube and making it a more complete shunt for the field winding 8. The current through the field winding would therefore decrease, thereby reducing the voltage of the generator and substantially annulling the change in its output voltage across the leads 18, 19 of the generator. In a similar manner, if the voltage of the generator would tend to decrease below the desired value, the grid would become less positive, thereby decreasing the current flowing in the tube and consequently increasing the current flowing through the field winding so that voltage of the generator would be held substantially constant.

Fig. 2 shows how a thermionic regulator 20 may be employed to regulate a direct current generator 21 for constant current output. As in Fig. 1, the anode 22 and cathode 23 of the thermionic regulator 20 are shunted across the terminals of the field winding 25. The anode and cathode are so connected in the circuit of the generator that the anode is made positive with respect to the cathode. Included between the negative terminal of the generator and the line 18 is a resistance 26 which is so connected in circuit with the cathode 23 and grid 27 that the I R drop across its terminals tends to make the grid positive with respect to the cathode. Since the resistance 28, which is in series with the field winding 25, is also connected between the cathode and grid of the tube, it follows that the resultant potential of the grid is determined by the algebraic sum of the I R drop in resistance 28 and the I R drop in resistance 26. It is preferable, however, that the values of these resistances should be so adjusted that the resultant potential of the grid 27 is positive with respect to the potential of the cathode 23. If desired, the resistance 28 may be connected between the other end of coil 25 and the positive terminal of the generator 21, in which case it will still be effective in adjusting the field current, but will not be a part of the grid circuit, and in this case the potential of grid 27 will depend on the I R drop through 26 only. Since resistance 26 is in series with lead 18 with respect to the generator 21, the potential of the grid is dependent upon the current supplied to the line 18 and will vary as the current varies. The thermionic regulator will therefore regulate for constant current, for if the current of the generator would tend to increase, due for example, to an increase in the speed of the generator or a decrease in its load, the I R drop in resistance 26 would become greater, thereby making the grid more positive, decreasing the impedance of the tube 20 and causing a corresponding decrease in the field winding current. This change in the field winding current would consequently tend to reduce to a low value the change in the output current of the generator. In a similar manner, if the current output of the generator would tend to decrease, thereby making the grid less positive, the impedance of the tube would increase and the field winding current would increase so that the desired regulation would be obtained.

Although 26 is shown as a resistance its important function is to give a source of potential connected to the grid which shall be responsive or proportional to the current flowing through the load. As such it may be the resistance in the series coil of a compound wound machine, in which case it will serve the purpose of doubly correcting for fluctuations first by its ampere turns on the field itself and second by controlling the impedance of the vacuum tube.

Fig. 3 shows this invention adapted to regulate a series-wound generator for constant voltage output. 35 is a generator having a series winding 36 and leads 37 and 38. Shunted across the field winding 36 are the electrodes 39 and 40 of the vacuum tube 41 in such a manner that the electrode 39 is positive with respect to the electrode 40. Shunted across the terminals of the machine is a high resistance 43 to an intermediate point of which the grid 44 is connected by tap 45. In the grid lead is also included a source of voltage 46 which may be poled in either direction, although it is shown as having its negative end connected to the grid. The resultant potential of the grid is the algebraic sum of the potential of source 46 and the I R drop in that part of the resistance 43 which is included between tap 45 and cathode 40. Since the potential of the grid is determined in part by the potential drop in resistance 43, it follows that any variation in the voltage output of the generator will vary the grid potential and consequently the effective impedance between the anode and cathode of the tube, so that the generator may be regulated for constant voltage. Thus if the voltage of the generator would tend to increase, the grid would become more positive, thereby increasing the space current of the tube and decreasing the field winding current. This change in the field winding current would tend to annul the change in the output voltage across the leads 37 and 38.

Although the use of a battery for determining in part the potential of the grid of an amplifier is shown only in Fig. 3, it is apparent that the use of such a battery is applicable to any of the other modifications. It is obvious that this invention is not limited in its applications and forms to those above described, but various modifications may be made therein as will occur to anyone skilled in the art without departing in any wise from the spirit of this invention, as defined by the appended claims.

What is claimed is:

1. An electric generator having a field winding, and means for holding substantially constant a characteristic of said generator, said means comprising a vacuum tube having an anode, a cathode and a control electrode, a by-path around said field winding comprising said anode and said cathode, said anode being connected to the positive terminal of said winding, said cathode being connected to the negative terminal of said winding whereby a portion of the current supplied to said winding is shunted through said tube varying in amount with variations in the effective impedance of the space current path between said anode and said cathode, and a resistance in circuit with said generator, and traversed with current from said generator varying with variations in a characteristic of said generator, at least a portion of said resistance being directly included between said cathode and said control electrode whereby the potential drop in said resistance controls the potential of said control electrode to produce amplified variations in the effective impedance between said anode and said cathode.

2. An electric machine having a field winding, current supply leads therefor, and means for holding substantially constant a characteristic of said machine, said means comprising a vacuum tube having an anode, a cathode and a control electrode, a bypath around said winding comprising said anode and said cathode, said anode being connected to the positive side of said winding, said cathode being connected to the negative side of said winding whereby a portion of the current supplied to said winding is shunted through said tube varying in amount with variations in the effective impedance of the space current path between said anode and said cathode, a resistance in circuit with said means and traversed by a current varying when variations occur in a characteristic of said machine, at least a portion of said resistance being directly included between said control electrode and said cathode whereby the potential drop in said resistance controls the potential of said control electrode to vary the effective impedance between said anode and said cathode.

In witness whereof, I hereunto subscribe my name this 27th day of July A. D., 1918.

PETER IRVING WOLD.