Oct. 13, 1936. C. E. HALLER 2,057,485

CONTROL APPARATUS

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Fig. 1.

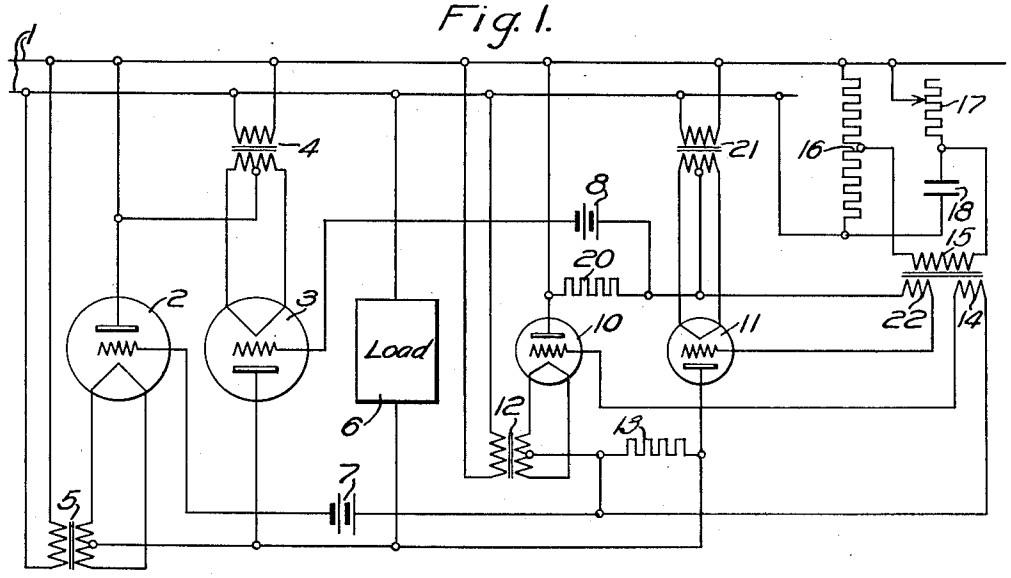
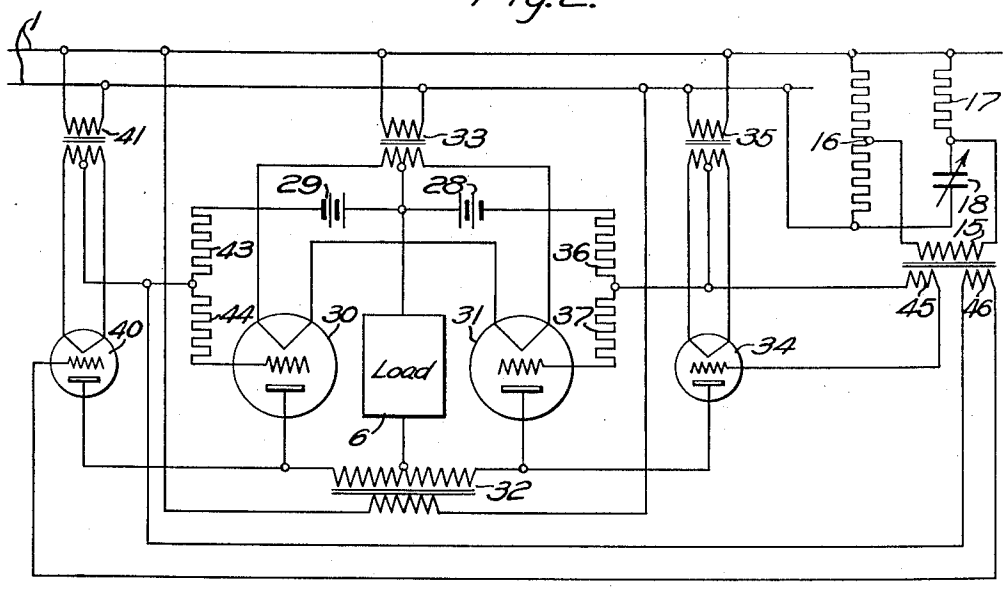



Fig. 2.




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## CONTROL APPARATUS

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2 Claims. (Cl. 250—27)

This invention relates to controlling systems and particularly to systems in which the current through the load is controlled by means of space-current devices.

Grid-glow tubes and other space-current devices, having the property that a certain potential upon the grid will cause them to become conducting and thereafter they will continue to conduct until the anode potential falls below a characteristic minimum, have been used for the control of current from an alternating power source to a load. By controlling the time in the positive half-cycle at which the potential upon the grid becomes sufficient to render the tube conducting, the portion of the cycle during which the tube will deliver current to the load is controlled and, in this way, the average value of the current delivered to the load is controlled.

Heretofore, a very substantial amount of power has been required for impressing the necessary potential upon the grids of the controlling tubes. A considerable portion of the power supplied to the grids is expended without any corresponding useful result, because, once the grid has rendered the tube conducting, a change in the potential of the grid will not stop the tube from conducting.

Moreover for the control of large-power tubes, say tubes intended to conduct over fifteen amperes, apparatus for controlling directly the phase of the potential supplied to the grids would be of impractical size.

It is an object of my invention to supply power to the grids of the control tubes during only the time necessary to render the tube conductive. I thereby minimize the power needed for the control of the grids.

It is a further object of my invention to control the main control tubes by auxiliary tubes and to limit the currents through the auxiliary tubes to momentary currents.

It is a further object of my invention to impress the controlling potential upon the grids of the main control tubes by means of the drop through a resistor, the current in which is controlled by the auxiliary tube.

It is a further object of my invention to control the anode potential upon the auxiliary tubes by the drop through the main control tubes, whereby the anode potential of the auxiliary tubes may become too small to maintain a discharge through them immediately after the main control tubes begin to conduct.

Other objects of my invention and a detailed knowledge of the circuits and apparatus employed may be obtained from the following description and the accompanying drawing, in which

Figure 1 shows one application of my invention, and

Fig. 2 shows another application thereof.

The source of power is represented by the power line 1 which, in Fig. 1, supplies two main control tubes 2 and 3. The anode of the tube 2 is connected to one side of the line 1. The same side of the line is connected to the middle point of the secondary of a transformer 4 which energizes the cathode of the tube 3. The cathode of the tube 2 is energized by a similar transformer 5 and the middle point of this transformer is connected to the anode of the tube 3. The cathode of the tube 2 and the anode of the tube 3 are connected to one terminal of the load 6 and the other terminal of the load 6 being connected to the other side of the line 1 from the anode of the tube 2.

A pair of smaller tubes 10 and 11 serve to control the grids of the tubes 2 and 3. The anode of the tube 10 is connected directly to the same side of the line 1 as the anode of the tube 2. The anodes of tubes 2 and 10 are thus connected together and so maintained at the same potential. Similarly, the anode of the tube 11 is connected to the anode of the tube 3 and to that side of the load 6 which is remote from the line.

The cathode of the tube 10 is energized through a transformer 12 and the center point of the secondary of this transformer is connected through a resistor 13 to the anode of the tube 11 and also to the terminal of the load 6 remote from the line. The anode of the tube 11, one terminal of the load 6, the anode of the tube 3 and the cathode of the tube 2 are thus connected together and through the resistor 13 to the cathode of the tube 10.

The grid of the tube 2 is connected to a point between the cathode of the tube 10 and resistor 13. The connection may, if desired, include a means for impressing potential on the grid of tube 2 independent of the condition of tube 10. Such a source of potential has been illustrated as a battery 7 with its negative pole toward the grid, but a source of alternating potential may be used. A separate transformer might be used for the purpose if it is so connected that it impresses a negative potential on the grid of tube 2 during the half-cycle in which the anode thereof is positive. Both battery and transformer may be used together if desired.

The battery 7 provides a potential between the grid and the cathode of the tube 2 by reason of which the tube 2 is maintained in deenergized condition until the other elements of the system are actuated. In the tubes utilized in the preferred practice of my invention the battery 7 is of such polarity that the potential of the grid is normally maintained negative relative to the cathode.

The cathode of the tube 10 is also connected to one terminal and the grid thereof to the other terminal of a secondary 14 of a transformer, the primary 15 of which is connected across a phase-determining device. The phase-determining device consists of a resistor 16 connected across the line 1 and the combination of a resistor 17 and a condenser 18 connected in series, the combination of the two being in parallel to the resistor 16. The primary 15 is connected between the middle point of the resistor 16 and the junction point uniting resistor 17 and condenser 18.

One of the elements in parallel to the resistor 16 is adjustable. As shown in Fig. 1, the adjustment is provided for the resistor 17 but, if desired, the condenser 18 may be made adjustable instead.

A resistor 20 connects the anode of the tube 10 with the midpoint of the secondary of a transformer 21 which energizes the cathode of the tube 11. The grid of the tube 3 is connected to that terminal of the resistor 20 which is remote from the anode of the tube 10. A source of potential 8, which may be direct, alternating or a combination of the two, may be inserted in this connection if desired.

The source of potential 8 functions in the same manner as the source 7.

An additional secondary 22 associated with the primary 15 is connected between the cathode and the grid of the tube 11. The cathode of the tube 11 is thus connected through the resistor 20 to the common connection uniting the anode of the tube 10, the anode of the tube 2, the cathode of the tube 3 and one side of the line 1.

In Fig. 2, the tubes 30 and 31, like the tubes 2 and 3 of Fig. 1, are adapted to carry the heavy current supplying the load 6, but the tubes 30 and 31 are arranged to constitute a rectifier supplying the load 6 with direct current from the source of alternating current represented by the line 1. This is accomplished by means of connections including the transformer 32, the primary of which is connected across the line 1. The midpoint of the secondary of the transformer 32 is connected to one terminal of the load, the other terminal of the load is connected to the midpoint of the secondary of a transformer 33 which energizes the two cathodes of the tubes 30 and 31. The anode of the tube 31 is connected to one terminal of the secondary 32 and the anode of the tube 30 is connected to the opposite terminal of the secondary.

A small tube 34 has a cathode energized by a transformer 35 and an anode connected to the anode of tube 31 and one terminal of the secondary of transformer 32. A resistor 36 is connected between the midpoint of the secondary of transformer 35 and the midpoint of the secondary of transformer 33. The connection may, if desired, include a source of alternating potential, of direct potential or both. This is indicated by the battery 28. The connection of resistor 36 to the midpoint of the secondary of transformer 35 is connected to the grid of the tube 31 through a resistor 37.

Similarly, a small tube 40 has its cathode energized from a transformer 41 and its anode connected to the anode of the tube 30 and thus to one terminal of the secondary of transformer 32. The midpoint of the secondary of the transformer 41 is connected through a resistor 43 to the midpoint of the secondary of transformer 33. The connection may include a potential source 29 of the same character. The terminal of resistor 43, which is connected to the midpoint of the secondary of the transformer 41, is connected through a resistor 44 to the grid of the tube 30.

The sources of potential 28 and 29 function in the same manner as the sources 7 and 8 of the system shown in Fig. 1.

A phase-determining device comprising a resistor 16, a resistor 17 and a condenser 18, connected as explained in connection with Fig. 1, delivers power to the primary 15 of a transformer having two secondaries. One secondary 45 is connected between the grid and the cathode of the tube 34, the other secondary 46 is connected between the grid and the cathode of the tube 40, the connection to the cathode being in each instance by means of a connection to the midpoint of the secondary of the filament-heating transformer.

In the operation of the device as illustrated in Fig. 1, alternating current from the line 1 delivers power to the load 6, first through the tube 2 and then through the tube 3. Current to the load through the tube 2 does not occur during the whole of the half-cycle throughout which the anode of the tube 2 is positive, but only during that part of this half-cycle which remains after the grid of the tube 2 has rendered the tube conductive; similarly concerning the current through the tube 3 during the other half-cycle.

There will not be a discharge through the tube 10 throughout the whole of the half-cycle during which the anode of the tube 10 is positive. At some point in this half cycle, the potential of the grid of the tube 10 will be rendered sufficiently positive by the secondary 14 to cause the tube 10 to become conductive. The moment at which this occurs is determined by the setting of the adjustment of the resistor 17. When the tube 10 becomes conductive, current flows from one side of the line 1 through the tube 10 and the resistor 13 to the load 6 and through it to the other side of the line 1. This current provides a potential drop across the resistor 13 by which the grid of tube 2 becomes positive relative to the cathode of tube 2.

Thereupon, the tube 2 becomes conductive and a current much larger than that which flowed through the tube 10 flows from one side of the line through the tube 2 to one terminal of the load and through the load to the other side of the line. Since this current is large compared to that which flowed through the load from the tube 10, the drop across the load is much greater than before. The potential difference across the tube 10 is the potential on the line 1 minus the drop over the load 6. As the drop over the load 6 is now large, this remainder is now small. When the tube 2 is conducting current there will be a current from the grid thereof, through the resistor 13 to the cathode. This produces a drop across the resistor 13 which still further reduces the potential between anode and cathode of tube 10.

The potential impressed across the tube 10 has, therefore, become small. A certain difference of potential must be exerted across the tube 10 to

maintain the discharge through this tube. The action just described results in too small a potential across the tube 10 to maintain the discharge through it and the tube 10, therefore, ceases to conduct substantial current.

The cathode of tube 10, as illustrated, is hot. It therefore delivers some electrons which would produce a small current through this tube even at the diminished anode potential. This current is too small to produce any significant effect upon the grid potential of tube 2. By proper choice of potentials, a cold cathode tube can be used for tube 10 if preferred.

It is possible to utilize the thermionic electron emission for the current in tube 10 either in a gas-filled tube or in a vacuum tube by adding a direct-current bias of proper amount to the grid thereof, either in addition to the potential of controlled phase or as a substitute therefor.

It will be observed that the time during which the tube 10 was conductive began when the potential of the grid of the tube 10 first became sufficiently positive and continued until current was established through the tube 2. This time would ordinarily be only about a hundred micro-seconds. The current in the tube 10 can, therefore, properly be called momentary. The supply of energy to the filament by the transformer 21 continues through all of each half-cycle but the power required by it is small.

The current through the tube 2 endures from the instant at which the momentary current in the tube 10 occurred until the end of the half-cycle. At the end of the half-cycle, the potential impressed across the tube 2 by the line 1 is too small to maintain the discharge through the tube and the tube 2, therefore, ceases to conduct any substantial current.

During the other half-cycle, that is, while the anode of the tube 3 is positive, a potential upon the grid of the tube 11 sufficient to render the tube 11 conductive is impressed by the secondary 22 at a time fixed by the setting of the adjustment of resistor 17. Tube 11 then becomes conductive. Current then flows from the line through the load 6 to the anode of tube 11, through tube 11 to the resistor 20 and through this resistor to the other side of the line.

This current produces a drop over the resistor 20 by which the grid of the tube 3 is made positive relative to the cathode of the tube 3. The tube 3 then becomes conducting, the current through it greatly increases the drop through the load 6 and thus diminishes the potential across the tube 11 sufficiently to cause the tube 11 to cease to conduct. The tube 11, therefore, conducted momentarily only, but the current through tube 3 continues from this moment until the end of the half-cycle.

It is thus apparent that the load 6 receives, during each half-cycle, a current through one of the two power-controlling tubes which current endures throughout a portion only of said half-cycle and that the ratio of said portion to the whole half-cycle is determined by the adjustment of the phase-controlling device.

When one of the power controlling devices is conducting current, there is a space current between the grid and the cathode. In the case of tube 2, this space current is limited by the resistor 13 and, in the case of tube 3, a similar limitation upon the grid current is effected by the resistor 20. The magnitudes of resistors 13 and 20 must be so chosen that the grid currents are of convenient strength. The magnitude of resistors 13 and 20 must be such that the currents through the tubes 10 and 11 produce sufficient drop to establish proper control of the grid potentials of tubes 2 and 3. These two considerations can be met by approximately the same magnitudes of the resistors. The magnitudes actually used meet either consideration satisfactorily.

In one embodiment of the device illustrated in Fig. 1, in which 220 volts was the potential on the line 1, I have found it convenient to use, for tubes 2 and 3, two tubes which require 10 to 15 volts to maintain a discharge through them and which are capable of carrying from 50 to 75 amperes. For tubes 10 and 11, in the same embodiment of my invention, I have used tubes which require 10 to 15 volts to maintain a discharge across them and can carry only a few milliamperes, and for the resistors 13 and 20, I have used 2000 ohms each. The tubes 10 and 11, under these conditions, are capable of conducting only about 10 milliamperes.

In the operation of the device illustrated in Fig. 2, when the voltage delivered by the secondary of the transformer 32 is in the sense to make the anode of the tube 31 positive, the anode of the tube 34 will also be positive. At some time during this half-cycle, the secondary 45 will impress upon the grid of the tube 34 a potential which will render said tube conductive.

Current will then flow from one terminal of the secondary of transformer 32 through the tube 34 over the resistor 36 and through the load 6 to the center of the secondary of transformer 32. This produces a drop over the resistor 36 in consequence of which the grid of the tube 31 will be positive relative to the cathode. The tube 31 thereupon becomes conductive and a large current flows through the tube 31 and the load 6. The drop across the load 6 thus becomes large and, consequently, the voltage delivered to the tube 34 becomes small. The grid current from tube 31 produces a drop in resistor 36 which further reduces the anode potential on tube 34. This tube thereupon ceases to conduct any substantial amount of current, but the tube 31 continues to conduct current until the end of the half-cycle. The grid current in tube 31 is limited by the combined effect of resistors 36 and 37.

During the next half-cycle, the anodes of tubes 30 and 40 are positive. The tube 40 becomes conductive at a time fixed by the setting of the condenser 18, because of the potential impressed upon it by the secondary 46. When the tube 40 becomes conductive, current flows from one terminal of the secondary of transformer 32 through tube 40, resistor 43 and the load 6 to the center of the secondary. This produces a drop over resistor 43 which renders the grid of tube 30 positive relative to the cathode thereof.

The tube 30 thereupon conducts and produces a large drop across the load 6 which results in a small difference of potential across the tube 40. There is a further reduction because of the grid current from tube 30 which makes it even more certain that the anode potential will be too small to maintain the discharge through tube 40, which thereupon ceases. The current through tube 40 is thus momentary, but the current through tube 30 continues from this moment until the end of the half-cycle.

The load 6 thus receives current always in the same direction, first from one-half of the secondary of transformer 32 and then from the other half thereof, but this current is not continuous. It endures only for a portion of each half-

cycle and the ratio between said portion and the whole half-cycle is determined by the setting of the adjustable condenser **18**.

Obviously, in Fig. 2, the adjustment may be provided by the resistor **17** instead of by the condenser **18**.

In an embodiment of the system illustrated by Fig. 2, I have employed voltages and tubes of the same sizes as those described in connection with Fig. 1 and have found that, for resistors **36** and **43**, 6,000 ohms each is a suitable value, while resistors **37** and **44** were each 2,500 ohms.

Although I have illustrated and described in detail only two embodiments of my invention, I do not desire to be limited thereto, since many other applications of the invention and many variations in detail will occur to those skilled in the art. No limitation is intended except what is required by the prior art or indicated in the accompanying claims.

I claim as my invention:

1. In combination, a load, a source of power, a grid-controlled space-current device controlling the supply of power from said source to said load, phase-responsive means for changing the potential of the grid to a potential which will make said space-current device conductive at a predetermined moment in each cycle and means for limiting the delivery of energy from said phase-responsive means to said grid to the moments of said potential change.

2. In combination, a load, a source of power, a space-current device controlling the supply of power from said source to said load, said space-current device having a grid and a plurality of principal electrodes, phase-responsive means for changing the potential of the grid to a potential which will make said space-current device conductive at a predetermined moment in each cycle, said phase responsive means including a discharge device coupled between said control electrode and one of said principal electrodes, and means for limiting the delivery of energy from said phase responsive means to said grid to the moments of said potential change, said limiting means including conductive connections between said discharge device and said principal electrodes.

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