July 22, 1952 O. B. RUDOLPH 2,604,612

CONTROL CIRCUIT

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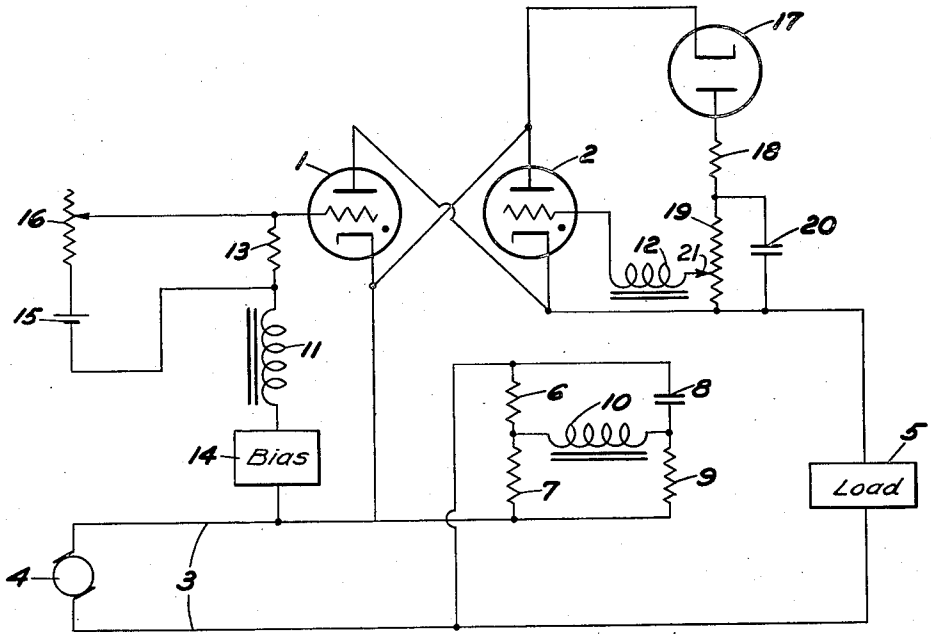


FIG. 1.

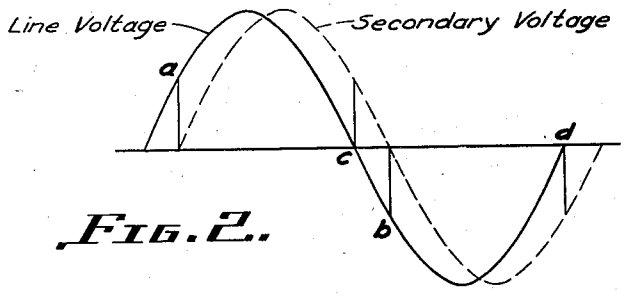


FIG. 2.

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CONTROL CIRCUIT

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My invention relates to alternating current control circuits, and more particularly to full wave alternating current control circuits for controlling the power supplied to a load and is especially applicable for controlling the speed of A. C. motors.

Thyratron and other electric discharge devices, having the characteristic that a certain potential upon the grid will cause them to become conducting, and thereafter conduct until the anode potential falls below a predetermined minimum, have been used for the control of current from an alternating current power source to a load. By controlling the time in the cycle at which the potentials upon the grids of the tubes become sufficient to render them conducting, the portions of the cycle in which the tubes will deliver current to a load is controlled, and, thus the average value of the current delivered to the load is regulated.

In order to take advantage of the power delivered by both halves of the cycle, it has been the practice to connect gas-filled tubes, such as thyratrons, in "back to back" relation. However, it is customary to individually control the thyratrons through use of auxiliary tubes which must in turn be controlled by other means.

Applicant with a knowledge of these problems in the prior art has for an object of his invention the provision of an electronic control circuit which permits full wave control and which responds to the control of only one of the tubes of the control circuit.

Applicant has as another object of his invention the provision of a thyratron control circuit providing full wave control of an alternating current line.

Applicant has as another object of his invention the provision of a full wave control circuit wherein the control tubes are connected in "back to back" relation and respond to the application of a control signal.

Applicant has as another object of his invention the provision of an alternating current voltage controlled circuit wherein gas tubes connected in "back to back" relation are controlled by the application of a control signal to one of the tubes.

Applicant has as another object of his invention the provision of a control element for one of a pair of tubes employed to control alternating current voltage in order to synchronize it with the other tube.

Applicant has as a further object of his invention the provision of an alternating current voltage control circuit wherein out of phase voltages operate in conjunction with a controlled signal to control the power fed to a load.

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Other objects and advantages of my invention will appear from the following specification and accompanying drawings, and the novel features thereof will be particularly pointed out in the annexed claims.

In the drawings, Fig. 1 is a schematic of my improved full wave alternating current regulating circuit employing "back to back" connected thyratron gas tubes. Fig. 2 is a schematic of line and control voltages shown in graphical form.

Referring to the drawings in detail, 1 and 2 designate a pair of gas-filled tubes such as thyratrons or the like connected in "back to back" relation, that is, the cathode of tube 1 is connected to the anode of tube 2, and the anode of tube 1 is connected to the cathode of tube 2. This tube combination is connected in series with one side of the power line 3 so that the power is fed from the alternating current power source 4 through the line 3 and tubes 1 and 2 to the load 5.

Bridged across the line in parallel is a resistance combination and a resistance capacitance combination. The resistance combination includes a pair of resistances 6, 7 connected in series, while the resistance capacitance combination includes a condenser 8 and resistance 9 connected in series. Bridged across the junctures of the elements of the resistance combination 6, 7 and the resistance capacitance combination 8, 9 is the primary winding 10 of a transformer whose secondaries 11 and 12 form parts of the grid circuits of tubes 1, 2 as described more in detail hereinafter. The foregoing constitutes a phase shifting network for providing the transformer with a leading current and a lagging voltage.

The grid circuit of tube 1 includes a resistance 13 connected in series with transformer secondary 11 and a source of grid bias 14. This grid bias source 14 may be a battery or rectifier or any other suitable source of D. C. voltage. These elements make up the grid to cathode circuit of tube 1. Bridged across the resistance 13 is a signal or control source. It may take any suitable form such as a battery 15 and variable resistor 16. However, the signal source may take any other appropriate forms and is not to be considered as restricted to the embodiment shown in the drawings.

Connected across the plate to cathode of tube 2 is a rectifier 17 preferably of the hard tube type, in series with a resistance 18 and a parallel re-

sistance capacitance network combination 19, 20. The resistance 19 takes the form of a voltage divider having a moving contact 21 joined to one side of secondary 12 of the transformer while the other side thereof is connected to the grid of tube 2. It will be noted that the condenser 20 is bridged directly across the resistance 19 so that flow of current through resistance 19 when tube 17 is operating will store up energy in condenser 20 to provide a biasing voltage for tube 2 during the period that diode 17 is not operating.

In its operation, the application of power to line 3 from source 4 impresses a voltage across tubes 1 and 2. When no signal is impressed across the resistance 13, the tube is biased to cut off by source 14, and the tube 1 does not fire. This places the entire line voltage across tube 2 since the two tubes are connected in "back to back" relation. Line voltage is also impressed across rectifier 17 causing it to break down and current to flow through the circuit including resistances 18 and 19 during alternate half cycles. This creates a voltage drop across resistance 19 and stores up electrical energy in condenser 20. During the other half cycle when tube 17 is not operating, condenser 20 discharges through resistance 19, continuing the negative bias placed upon the grid of tube 2 by the flow of current through rectifier 17 during the other half cycle. The constants of the circuit may be made such that tube 2 will be biased to cut off during the whole of the half cycle when tube 17 is not in operation. In other words, the size of resistance 19 and the capacity of condenser 20 may be such that flow through resistance 19 from condenser 20 will continue during the half cycle while tube 17 is not in operation. In this way both tubes 1 and 2 may be rendered inoperative during both halves of the cycle by the application of grid bias to the grid of tube 1 from the source 14. This is accomplished by adjusting the moving contact of resistance 16 to increase or decrease the voltage drop across resistance 13. However, when a signal or positive potential is applied to the grid of tube 1 through the control circuit 15, 16 to overcome the negative bias of element 14, the tube 1 is caused to fire over all or a portion of the half cycle of alternating current fed to the load, depending upon the voltage lag in secondary winding 11 which is generally fixed at about 70° lag. Over this same half cycle the voltage impressed across high vacuum or gas rectifier tube 17 causes it to fire since the anodes and cathodes of tubes 1 and 17 are in parallel through impedances 18, 19 and 20. Flow of current through voltage divider 19 builds up a charge on the plates of the condenser 20 and at the same time places a bias on the grid of tube 2. Since tube 1 is firing during the half cycle, the voltage across tube 17 and the network 18, 19 and 20 is proportionately lower as the voltage across tube 1, during the period of firing, is reduced. Under these conditions the charge built up on condenser 20 is not nearly as great as that built up on the condenser when tube 1 is not firing. Thus, it is seen that the charge built up on condenser 20 is proportional to the voltage across tube 1. Accordingly, during the times when tube 1 is firing, the charge built up on condenser 20 will not be sufficient to prevent tube 2 from firing in the other half cycle. However, this may be adjusted somewhat by regulating the position of movable contact 21.

On the next half cycle neither tube 1 nor diode rectifier 17 fire, and, if the constants of the circuit are so chosen, the flow of current from condenser 20 through resistance 19, during this time, will not be sufficient to prevent operation of tube 2. This tube will then fire over as much of the half cycle as is permitted by the lagging voltage provided by the secondary of the transformer, and the bias provided by the condenser 20 and resistance 19.

From the foregoing it will be seen that the period of operation over any half cycle of tubes 1 and 2 is determined by the lag of the voltage in the secondary windings 11 and 12 of the transformer and the grid bias provided by the source 14 as affected by the positive signal and the drop across resistance 13. The greater the lag of the voltage in secondary windings 11 and 12, the shorter the period of fire during any half cycle. It will thus be seen from the graph of Fig. 2 that where a line extending perpendicular from the base line at the point of intersection therewith of the lagging secondary voltage curve, intersects the line voltage curve, as at *a* and *b*, the respective tubes commence to fire and continue to fire until the line voltage curve crosses the base line, as at *c*, *d*. By changing the lag in voltage, it is seen that the tubes 1, 2 may be made to conduct over a greater or lesser portion of the cycle.

The positive signal applied to tube 1 controls its operation, and this in turn controls the operation of tube 2 since the voltage drop across tube 1 determines the charge built up on condenser 20, and this in turn, determines the length of time during each half cycle when the tube 2 is permitted to operate. When the circuit is properly adjusted, the second thyratron tube 2 will follow the first thyratron tube 1 providing identical cutoff points, except for polarity, for both halves of a cycle. This in turn will determine and control the power fed to the load 5 so that accurate voltage control and regulation may be secured with a simple adjustment.

Having thus described my invention, I claim:

1. A full wave electrical control circuit of the character described comprising an electrical discharge device, a second electric discharge device coupled to said first electric discharge device so that said discharge devices operate only on opposite half cycles, means for applying an out of phase voltage to said discharge devices to control the periods of their operation in each cycle, and means responsive to line voltage for building up a negative charge on the control grid of the second discharge device for blocking its operation, and means responsive to the operation of the first electric discharge device for removing said charge and permitting said second electric discharge device to operate.

2. A full wave alternating current control circuit of the character described comprising a pair of electric discharge devices connected in back to back relation, and means responsive to the operation of one of said discharge devices for controlling the operation of the other of said discharge devices, said means including a diode and a parallel resistance-capacitance network for normally building up a negative charge to be applied to the other of said discharge devices, said diode and said network being bridged across the output circuit of the first of said discharge devices, whereby operation of said first discharge device reduces the charge built up by said network and controls the operation of said second electric discharge device.

3. A full wave alternating current control circuit of the character described comprising an

electric discharge device, a second electric discharge device coupled to said first electric discharge device, a gas diode and a parallel resistance capacitance network bridged across the output of said first electric discharge device and coupled to the input of said second discharge device for normally applying a negative bias to said second discharge device and means for applying a sginal to said first discharge device to render it operative and limit the charge of said network thru said diode whereby to control the operation of said second electric discharge device.

4. A full wave alternating current control circuit of the character described comprising an electric discharge device, a second electric discharge device connected to said first electric discharge device in back to back relation, means for applying an out of phase biasing voltage to said discharge devices to render them operative over portions of the cycle, a gas diode and a parallel resistance capitance network connected in series and bridged across the output of said first discharge device and to the input of said second discharge device for normally applying a negative bias to said second electric discharge device, and means for applying a biasing signal to said first discharge device to render it operative for controlling the charging up of said network through said gas filled tube, whereby to control the operation of said second discharge device.

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