Oct. 19, 1948. E. F. KUBLER 2,451,834

PHASE SHIFTING CIRCUIT

Filed Sept. 26, 1947

2 Sheets-Sheet 1

Fig. 1.

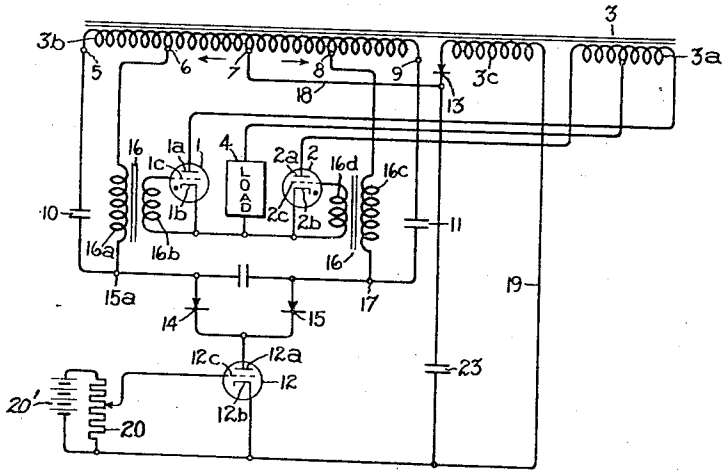
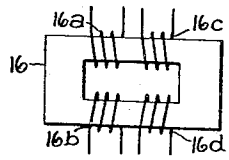


Fig. 4.



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2 Sheets-Sheet 2

Fig. 2.

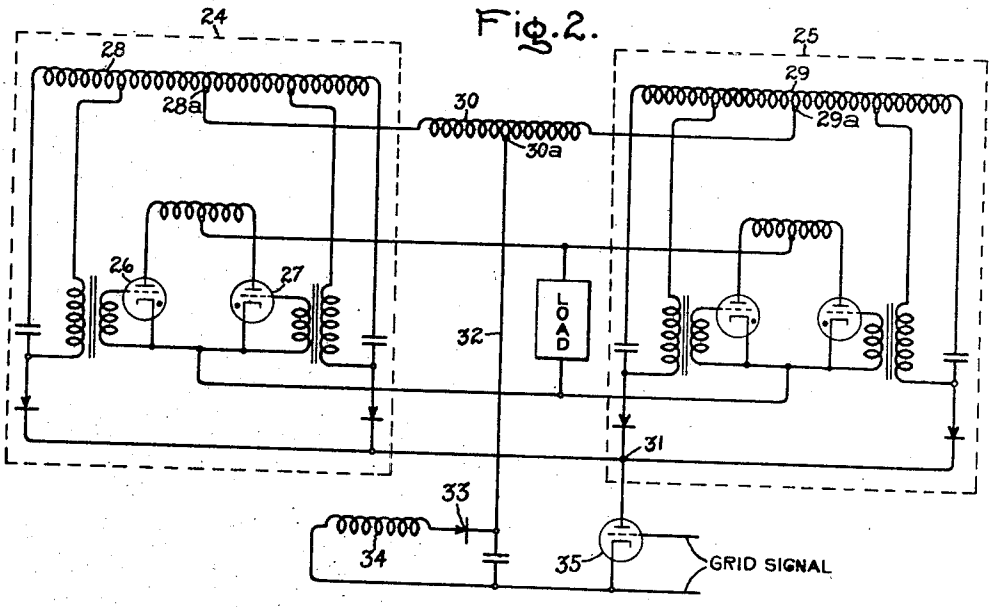
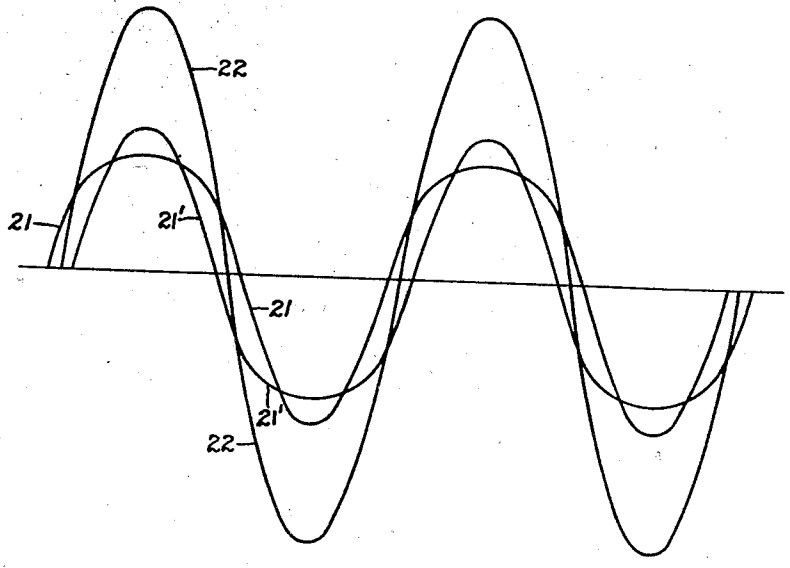


Fig. 3.



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UNITED STATES PATENT OFFICE

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PHASE SHIFTING CIRCUIT

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4 Claims. (Cl. 323—119)

1

This invention relates to control systems; more particularly to systems for controlling the operation of electric valves, and it has for one object the provision of a simple, reliable and improved control system of this character.

More specifically the invention relates to systems for controlling the operation of gas filled electric valves, and a more specific object of the invention is the provision of improved means for shifting the phase of the grid voltage with respect to the anode voltage to vary the conductivity of the valve.

In carrying the invention into effect in one form thereof, a gas-filled electric valve having an anode, a cathode and a control grid is connected to have an alternating voltage supplied to its anode-cathode circuit. For supplying an alternating voltage to the grid catrode or input circuit a phase shifting network is provided. It comprises two bridge circuits. Each of these bridge circuits has an individual reactance arm and they have a variable resistance arm which is common to both. In this common arm there is connected a control electric valve and a source of direct voltage from which it is supplied. The direct voltage supplied to this control valve is modulated by alternating voltages which are supplied to both bridge circuits from the secondary winding of a transformer. Two portions of this winding are connected to constitute arms of one of the bridges and two other portions constitute arms of the other bridge. Across the output terminals of the two bridges are connected two primary windings of a grid transformer of which the secondary winding is connected between the cathode and grid of the gas filled valve. The control valve in the common arm acts as a variable resistor. Consequently, variation of the grid voltage of the control valve varies the phase of the modulated voltage supplied to the grid of the gas filled valve relative to its anode voltage and thus varies its conductivity. In a modification, one gas filled valve is supplied from one phase of a quarter phase source and a second gas filled valve is supplied from the other phase. The phase shifting network for the grid voltage comprises four bridge circuits, i. e. a double bridge circuit for each valve. A resistance arm common to all four bridge circuits includes a source of direct voltage and a control valve supplied therefrom. Variation of this grid voltage of the control valve in the common arm produces simultaneous phase shift of the modulated voltages supplied to the grids of both gas filled valves.

For a better and more complete understanding

2

of the invention, reference should now be had to the following specification and to the accompanying drawing of which Fig. 1 is a simple, schematic diagram of an embodiment of the invention; Fig. 2 is a simple, schematic diagram of a modification; Fig. 3 is a chart of characteristic curves which serve to illustrate the invention; and Fig. 4 is detail.

Referring now to the drawing, and particularly to Fig. 1, a pair of gas filled electric valves 1 and 2, such as thyratrons, are connected as a biphase, half wave rectifier. The valves have anodes 1*a* and 2*a*, cathodes 1*b* and 2*b* and control grids 1*c* and 2*c* respectively. Within their envelopes is contained a small quantity of mercury vapor or inert gas such as argon. They are supplied from a suitable source of alternating voltage which is illustrated as a secondary winding 3*a* of a power supply transformer 3. As shown, the anodes 1*a* and 2*a* are connected to opposite terminals of the secondary winding 3*a*. A load 4 which may be any electrical translating device is connected between the cathodes and the center tap of secondary winding 3*a*.

For the purpose of varying the conductivity of the valves 1 and 2, means are provided for supplying periodically varying voltages to the grids 1*c* and 2*c* and for varying the phase relationships of these grid voltages relative to the anode voltages. This means comprises two alternating voltage bridge circuits having their output terminals connected through a grid transformer to the input circuit of the valves. These bridge circuits comprise a secondary winding 3*b* of the transformer 3. It has five taps 5, 6, 7, 8 and 9 equally spaced apart. The two portions 5—8 and 8—7 of the secondary winding constitute two arms of one of the bridge circuits. A reactance device such as the capacitor 10 constitutes the third arm of this bridge. Similarly the portions 7—8 and 8—9 of the secondary winding constitute two arms of the second bridge circuit and the capacitor 11 constitutes the third arm. An electric valve 12 is included in a connection which is common to both bridges and constitutes the fourth arm of each bridge. This connection is traced from the tap 7 through a rectifier 13 and a secondary winding 3*c* and through vacuum valve 12 and rectifiers 14 and 15 in parallel to the lower terminals of capacitors 10 and 11.

Between the output terminals 6 and 15*a* of the first bridge is connected the primary winding 16*a* of a transformer 16 of which the secondary winding 16*b* is connected between the grid and cathode of thyratron valve 1. Similarly, between the

output terminals 8 and 17 of the second bridge is connected another primary winding 16c of the transformer 16, and another secondary winding 16d of the transformer is connected between the cathode 2b and grid 2c of thyratron valve 2. The arrangement of the primary windings 16a and 16c and secondary windings 16b and 16d on the core of the grid transformer is indicated in Fig. 4.

The electric valve 12 is provided with an anode 12a, a cathode 12b and a control grid 12c. A direct voltage is supplied to the anode-cathode circuit of the valve 12 by means of the transformer secondary winding 3c and the rectifier 13 which are connected in the arm which is common to both bridges. The current flow is traced from the lefthand terminal of secondary winding 3c through rectifier 13, conductor 18, to the midtap 7. At this point the circuit divides and current flows in the arm 7—6, primary winding 16a of the grid transformer 16, and rectifier 14. In the parallel branch current flows through bridge arm 7—8, primary winding 16c of the grid transformer 16 and the rectifier 15. At this point the parallel branches unite and current flows through the anode-cathode circuit of valve 12 and conductor 18 to the right-hand terminal of secondary winding 3c.

A suitable direct voltage is supplied between the grid and cathode of valve 12 by means of a potentiometer 20 connected across a source of direct voltage such as the battery 20'.

The operation is as follows: The direct voltage which is supplied to the anode-cathode circuit of valve 12 is modulated by the alternating voltage between the center tap and output terminal 15a and also by the alternating voltage between the center tap 7 and the output terminal 17. These two alternating voltages are 180° out of phase with each other. Alternating voltages displaced 180° from each other appear across the primary winding 16a and 16c of the grid transformer.

Varying the conductivity of the valve 12 by varying its gird voltage produces the same effect that would be produced by varying the ohmic resistance of the common arm. In other words, the valve 12 behaves like a resistance. Consequently, the phase of the modulated voltage across the valve 12 and the phase of the modulated voltages across the primary windings 16a and 16c are varied when the grid voltage of valve 12 is varied. Since the anode voltage of the valve varies with the amount of modulation and since the resistance of the valve varies with its anode voltage, the alternating voltages across the primary windings 16a and 16c are distorted considerably from the desired pure sine wave form. This distortion is illustrated in the curve chart of Fig. 3 in which curve 21 represents the voltage across primary winding 16a during a positive half cycle of the voltage. The positive half cycles of this voltage embrace more than 180 electrical degrees and the negative half cycles embrace less than 180 degrees. Furthermore, the amplitude of the negative half cycle is greater than the amplitude of the positive half cycle.

The alternating voltage which appears across the primary 16c is represented by the curve 21'. Since the direct current flows in opposite directions through the arms 6—7 and 7—8 with respect to the alternating voltage, the distortion in the alternating voltage across primary winding 16c is opposite to the distortion of the voltage across primary winding 16a. This opposite distortion is indicated by the curve 21'.

During its positive half cycles it embraces less than 180 electrical degrees and conversely during its negative half cycles it embraces more than 180 degrees. Its amplitude during positive half cycles is greater than its amplitude during negative half cycles.

Since both windings 16a and 16b are wound cumulatively on the same core, the resultant flux has the shape of the curve 22 which is a symmetrical wave, i. e. its positive and negative amplitudes are symmetrical with respect to the axes and positive and negative half cycles each embrace 180 electrical degrees. In other words, the distortion of one of the voltages is counteracted by the opposite distortion of the other so that the positive and negative half cycle are symmetrical.

Alternating voltages having substantially pure sine wave form are induced in the secondary windings 16b and 16d and are supplied to the grid-cathode or input circuits of the valves 1 and 2. Since the anode voltages of valves 1 and 2 are 180° out of phase, the connections of the grid transformer secondary windings are poled so that the voltages supplied to the grids 1c and 2c are 180° out of phase with each other.

To vary the phase relationship of the grid voltage of valves 1 and 2 relative to their anode voltages, the grid voltage of valve 12 in the common arm of the two bridges is varied. Since the valve 12 behaves as a variable resistor when its grid voltage is varied, and since the reactance of the capacitors 10 and 11 in the capacitance arms remain unchanged, the phase of the bridge output voltages supplied to the primary windings 16a and 16c are varied. Consequently, the voltages supplied to the grids 1c and 2c and current conducted by the thyratrons 1 and 2 are correspondingly varied.

The rectifiers 14 and 15 serve as blocking rectifiers to isolate the two resistance reactance bridges, i. e. to prevent their interference with each other.

A capacitor 23 is connected in parallel with the rectifier 13 and secondary winding 3c. This capacitor extends the range of phase shift of the thyratron grid voltages and makes it possible to phase the thyratrons to cut-off.

In the modification disclosed in Fig. 2, the invention is embodied in a phase control system for a quarter phase rectifier.

It comprises two rectifiers 24 and 25 each of which is substantially identical with the rectifier of the modification of Fig. 1. For example, the thyratron valves 26 and 27 correspond to the valves 1 and 2 of Fig. 1, and the supply transformer secondary winding 28 corresponds to the secondary winding 3b. The remaining elements of rectifier 24 are readily identifiable with their corresponding elements in the rectifier of Fig. 1. Similarly, the elements of rectifier 25 are readily identifiable with the corresponding elements of the rectifier of Fig. 1.

The windings 28 and 29 are secondary windings of a quarter phase transformer and consequently the alternating voltages induced in these windings are 90 degrees out of phase with each other. An interphase transformer winding 30 is connected between the center taps 28a and 29a.

An arm which is common to all four bridge circuits is connected from the center tap 30a of the interphase transformer to the common output terminal 31 of the bridges and includes the conductor 32, the rectifier 33, transformer secondary winding 34 and electric valve 35.

By varying the grid voltage of the valve 35, the phase of the voltages on the grids of all four thyratrons are simultaneously varied with respect to their anode voltages, and the currents conducted by both rectifiers are correspondingly varied.

Although in accordance with the provisions of the patent statutes this invention is described as embodied in concrete form and the principle thereof has been explained together with the best mode in which it is now contemplated applying that principle, it will be understood that the elements shown and described are merely illustrative and that the invention is not limited thereto since alterations and modifications will readily suggest themselves to persons skilled in the art without departing from the true spirit of this invention or from the scope of the annexed claims.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A control system for an electric valve provided with an anode, a cathode and a control grid comprising means for supplying to the anode cathode circuit a periodically varying voltage, means for supplying to the grid and cathode a periodically varying voltage of adjustable phase with respect to the anode voltage comprising a pair of bridge circuits having a common arm, a source of direct voltage connected in said common arm, means for supplying to the input terminals of said bridges a periodically varying voltage of the same periodicity as said anode voltage to modulate the direct voltages at the output terminals, a transformer having a primary winding connected across the output terminals of one of said bridges, a second primary winding connected across the output terminals of the other of said bridges and a secondary winding connected between said grid and cathode, and a control electric valve connected in said common arm.

2. A control system for an electric valve provided with an anode, a cathode and a control grid, means for supplying to the anode cathode circuit of said valve a periodically varying voltage, means for supplying to the grid and cathode a periodically varying voltage comprising a pair of bridge circuits having individual reactance arms and a common resistance arm including a source of direct voltage and a control electric valve, means for supplying to the input terminals of said bridges periodically varying voltages of the same periodicity as said anode voltage to modulate the direct voltages at the output terminals, transformer means comprising a core structure provided with a first primary winding connected across the output terminals of one of said bridges, a second primary winding connected across the output terminals of the other of said bridges and a secondary winding connected between said grid and cathode, and means for varying the conductivity of said control valve thereby to shift the phase of the voltages of said grid relative to the voltages of said anodes.

3. A control system for an electric valve provided with an anode, a cathode and a control grid, connections from the anode cathode circuit

to a source of periodically varying voltage, a pair of bridge circuits having individual reactance arms and a common resistance arm, a transformer having a rectifier included in its secondary circuit for supplying a direct voltage in said common arm, a transformer having primary connections to said source and a secondary winding having a portion constituting two arms of one of said bridges and a second portion constituting two arms of the other of said bridges for modulating said direct voltage at the output terminals of said bridge circuit with a periodically varying voltage of the same periodicity as the voltage of said source, a pair of blocking rectifiers connected between corresponding output terminals of said bridge circuits and a terminal of said common arm, transformer means comprising a core structure provided with a first primary winding connected across the output terminals of one of said bridges and a second primary winding connected across the output terminals of the other of said bridges and having a secondary winding connected between said grid and cathode, for supplying thereto a periodically varying voltage, and a control electric valve in said common arm, and means for varying the conductivity of said control valve to vary the phase relationship of the grid and anode voltages of said first mentioned valve.

4. A control system comprising first and second electric valves each provided with an anode, a cathode and a control grid, a source of quarter phase alternating voltages for supplying quarter phase voltages to the anode cathode circuits of said valves, means for supplying quarter phase voltages to the grid cathode circuits of said valves comprising a pair of phase shifting networks, one for each valve and each comprising two bridge circuits, each bridge circuit having an individual reactance arm and all said bridge circuits having a common resistance arm, a source of direct voltage included in said common arm, a quarter phase transformer supplied from said source, one secondary phase winding constituting bridge arms for the both bridge circuits of one of said networks and the other phase winding constituting arms for the bridge circuits of the other of said networks for supplying quarter phase alternating voltages to modulate the direct voltages at the output terminals of said bridges, a first grid transformer having two primary windings connected across the output terminals of the two bridges respectively of one of said networks and having a secondary winding connected to the grid and cathode of one of said valves, a second grid transformer having two primary windings connected across the output terminals of the two bridges respectively of the other of said networks and having a secondary winding connected to the grid and cathode of the other of said valves, and a variable control valve connected in said common arm.

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No references cited.