

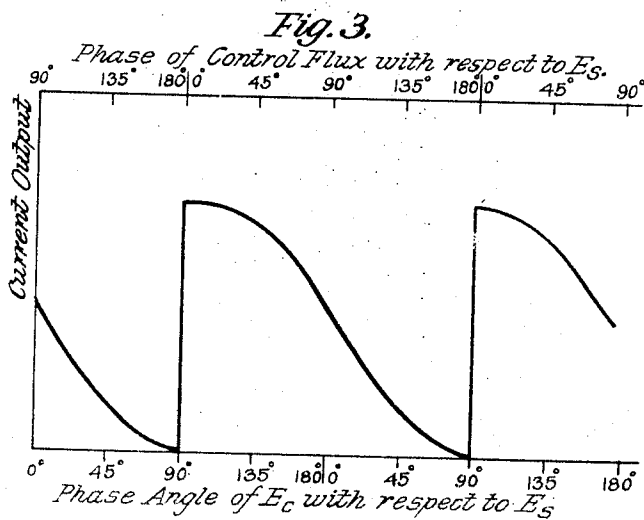
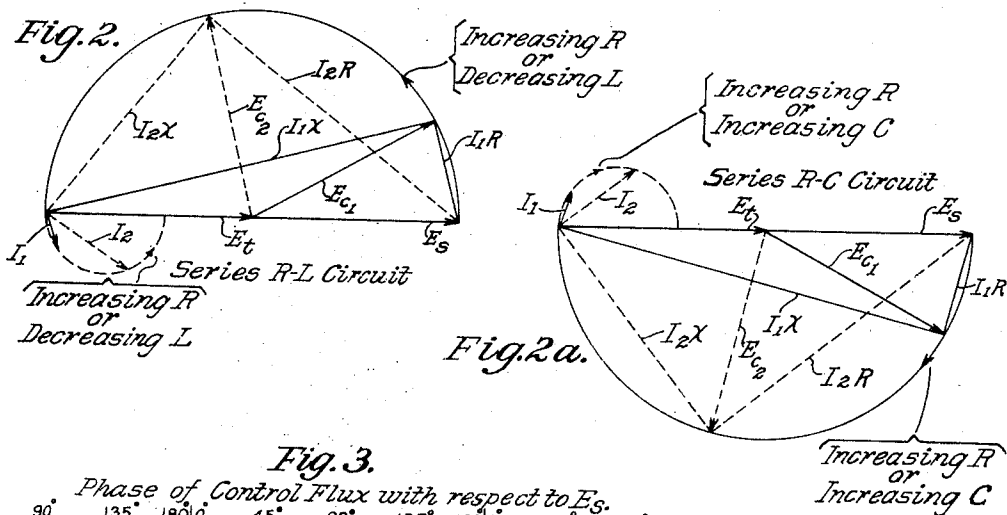
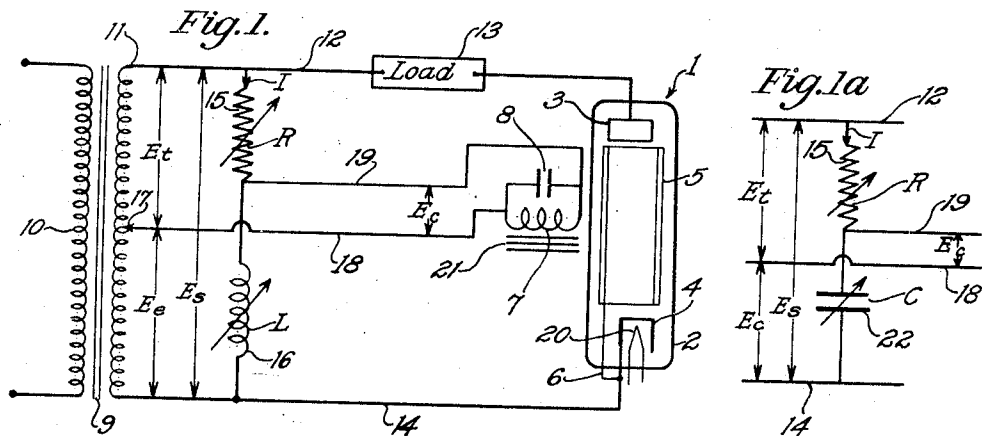
Aug. 11, 1942.

W. P. OVERBECK

2,292,397

MAGNETIC PHASE CONTROL OF ELECTRICAL SPACE DISCHARGE DEVICES

Filed Jan. 12, 1938



Inventor
WILCOX P. OVERBECK
by Elmer J. Gorn
Attorney

UNITED STATES PATENT OFFICE

2,292,397

MAGNETIC PHASE CONTROL OF ELECTRICAL SPACE DISCHARGE DEVICES

Wilcox P. Overbeck, Waltham, Mass., assignor to Raytheon Manufacturing Company, Newton, Mass., a corporation of Delaware

Application January 12, 1938, Serial No. 184,617

3 Claims. (Cl. 175-363)

This invention relates to phase control of electrical space discharge devices, and more particularly to such control as applied to an electrical space discharge device in which the starting of the current is determined by means of an electromagnetically energized control element.

In electrical gaseous discharge tubes in which the current output is controlled by varying the phase angle at which the current starts to flow upon the application of an alternating voltage to such a tube, it is often desirable to control the current down to zero and up to its maximum value. It is also desirable to produce an arrangement so that at one point in the variation of the control element an abrupt change of the current from zero to its maximum value or from its maximum value to zero occurs. With previous arrangements using an electrostatically-controlled grid for determining the starting of current, it has been theoretically impossible to produce these results completely. Even where such results were approximated, it was necessary to resort to the use of movable contacts and complicated and massive arrangements. In order for a grid-controlled tube to produce the desired results, it is necessary to shift the phase of the control voltage through a value of zero degrees or 180 degrees. In a simple phase-shifting circuit using a resistance and a reactance, one of which is variable, it is necessary for the variable element to reach a limit of either zero or infinity in order to produce the desired results. A simple variable inductance or condenser cannot accomplish either of these results and still cover a sufficiently large variation to perform useful control, while with a variable resistance it is impossible to approach either zero or infinity uniformly, and the point of zero current cannot be passed through without an abrupt change from zero to infinite resistance which necessarily means the use of electrical contacts or some other complicated system.

One of the objects of my invention, therefore, is to produce a control for a gaseous discharge device so as to control the average current output through its zero value and its maximum value without the use of electrical contacts or complicated and massive equipment.

Another object is to provide means for controlling through zero the phase angle at which the control element of such a device causes conduction of current to start.

A still further object is to provide an arrangement in which by means of a small continuously-variable impedance, an abrupt change from zero to maximum current output may be obtained.

The foregoing and other objects of my invention will be best understood from the following description of exemplifications of my invention,

reference being had to the diagrammatic drawing, wherein:

Fig. 1 is a circuit diagram illustrating one embodiment of my invention;

Fig. 1a represents a variation of the arrangement shown in Fig. 1;

Fig. 2 is a vector diagram representing the operation of the circuit of Fig. 1;

Fig. 2a is a vector diagram representing the operation of the circuit of Fig. 1a; and

Fig. 3 is a curve showing the relationship between the output current of my device and the phase between the control factors and the anode voltage.

The control is preferably utilized in a magnetically-controlled tube shown at 1 in Fig. 1. This tube is of the type which is fully described and claimed in the copending application of Percy L. Spencer, Serial No. 612,235, filed May 19, 1932, for an improvement in Electrical gaseous discharge devices. The tube 1 consists of an envelope 2 containing an anode 3 and an indirectly-heated cathode 4 which may be raised to temperature of thermionic emission by means of a heating filament 20. Surrounding the discharge space between the cathode 4 and the anode 3 is an auxiliary electrode 5 which may consist of a metal cylinder, either perforate or imperforate. Instead of completely surrounding the discharge space, the auxiliary electrode 5 may partially surround it. The envelope 2 is filled with a suitable ionizing gas or vapor, preferably with argon at a pressure of the order of one millimeter or less. The auxiliary electrode 5 is connected to the cathode 4 by means of the conductor 6. In order to control the starting of the current between the cathode 4 and the anode 3, a control winding 7 wound upon a magnetic core 21 is provided. The magnetic core 21 has pole pieces which impress a transverse magnetic field across the discharge path within the auxiliary electrode 5. In parallel with the winding 7 is connected a condenser 8. The condenser 8 is preferably selected of such a size as to make the parallel circuit resonant at the frequency of the voltage applied thereto. A magnetically-controlled tube of the type described above operates so that when a positive voltage is impressed upon the anode, starting of current between the cathode and anode will be delayed until the magnetic field created by the control magnet falls to a predetermined minimum value. In many instances this value may be substantially zero.

In order to supply the device with power, transformer 9 is provided. The transformer 9 has a primary 10 which may be connected to a suitable source of alternating current and a secondary 11. One end of the secondary 11 is connected by means of a conductor 12 through a load 13 to the anode 3. The other end of the sec-

ondary winding 11 is connected by means of a conductor 14 to the cathode 4.

In order to supply the control winding 7 with current, a phase-shifting circuit consisting of a resistance in series with an inductance 16 is connected between the conductors 12 and 14. Either the resistance 15 or the inductance 16, or both, may be adjustable. The secondary winding is provided with a tap 17 intermediate its ends. Preferably this tap is located at the central point on the winding 11. A conductor 18 extends from the tap 17 to one end of the control coil 7, while a conductor 19 extends from the point intermediate the resistance 15 and inductance 16 to the other end of said control coil. When the transformer 9 is energized and either the resistance 15 or inductance 16, or both, are varied, the time at which the current starts between the cathode 4 and the anode 3 in each alternating current cycle is delayed to a predetermined extent, and in this way the amount of current or power delivered to the load 13 is controlled.

In order to analyze the operation of the circuit as illustrated in Fig. 1, the resistance 15 is represented by the symbol R , the inductance 16 is represented by the symbol L , the voltage between the upper end of the secondary winding 11 and the tap 17 is represented by E_t , the voltage between the lower end of the secondary winding 11 and the tap 17 is represented by E_s , the total voltage across the secondary winding 11 is represented by E_s , and the voltage across the control coil 7 is represented by E_c . The current which flows through the resistance 15 and inductance 16 is represented by I . The vector diagram shown in Fig. 2 utilizes the various quantities so designated, and illustrates the operation of the arrangement as shown in Fig. 1.

As will be noted in Fig. 2, the long horizontal vector is E_s , while E_t being in phase with E_s is represented by a horizontal vector of half the length of E_s . If R and L are adjusted so that L predominates, a current I_1 which lags the voltage E_s may flow through the series RL circuit. The current I_1 will produce through the resistance, a voltage drop of I_1R in phase with the current. This current will also produce a voltage drop I_1X through the inductance. This latter voltage drop will be at right angles to the current I_1 . As illustrated in Fig. 2, the sum of I_1R and I_1X must equal the voltage E_s . The voltage which appears across the control winding 7 may then be determined by the vector E_{c1} extending from the end of the vector E_t to the intersection of the two vectors I_1R and I_1X . If the resistance R is increased or the inductance L is decreased so as to bring the current I more nearly into phase with the voltage E_s , a current I_2 may flow through the series RL circuit. This current will produce the voltage drops I_2R and I_2X in the relationship as shown, whereupon the control voltage E_{c2} will appear across the control winding 7. The large solid semi-circle in Fig. 2 represents the locus of the end of the vector E_c as the current I is varied from 90 degrees out of phase with the vector E_s into a condition in which it is in phase with said voltage. The arrow on said solid semi-circle represents the direction in which the vector E_c is shifted as R is increased or as L is decreased. Changing the direction of variation of these quantities will change the direction in which the vector E_c is shifted. The dotted circle and the arrow thereon represent similarly the direction in which the end of the vector I is shifted as the quantities R and L are varied.

In any series circuit, such as is represented in Fig. 1, it is substantially impossible to obtain a current exactly in phase or entirely out of phase with the voltage impressed across the ends of such a circuit. However, a phase shift of the order of magnitude as illustrated in Fig. 2 can very easily be secured. It will be seen that such a phase shift varies the vector E_c through a considerable range, and further that this vector is shifted through a phase angle of 90 degrees with respect to the horizontal voltages.

In Fig. 3 is represented the manner in which the current output from the tube 1 varies as the variations described in connection with Fig. 2 are produced. Along the horizontal axis at the top of Fig. 3 is plotted the phase angle of the flux which is set up by the control winding 7 with respect to the voltage E_s impressed between the cathode 4 and the anode 3. When the flux is in phase with the voltage E_s , its value is substantially zero at the time the anode voltage passes through zero, and therefore conduction of current will occur substantially throughout the entire period that the anode remains positive. Under these conditions the maximum amount of current will flow through the output circuit. Since the operation of the magnetic field upon the discharge is independent of the direction of that field, the in-phase condition of the flux may be represented either as a value of zero degrees or as 180 degrees. However, as the flux is shifted more and more out of phase with the applied voltage, the starting of the current is delayed to a greater and greater extent until the point is reached at which the flux is displaced 180 degrees with respect to the applied voltage when starting of the tube is prevented entirely. Under these conditions, zero current flows in the load. From the foregoing it will be seen that at the value of 180 degrees or zero degrees, the current through the load is either zero or a maximum. This means that in a practical device as the phase angle of the flux with respect to the applied voltage approaches 180 degrees, the current output approaches zero, and as the flux passes through a value of 180 degrees, the current jumps suddenly from zero to the maximum value. The flux of the control magnet 21 is in phase with the current which flows through the coil 7, and this current lags the voltage E_c applied to said winding 7 by substantially 90 degrees. Thus the phase angle of E_c with respect to E_s is plotted along the horizontal axis at the bottom of Fig. 3 on which the phase angles are displaced 90 degrees with respect to those along the upper horizontal axis. Under these conditions the curve represents accurately the manner in which the current through the load will vary as the phase angle of E_c varies with respect to E_s , as illustrated in the vector diagram of Fig. 2. As pointed out above in connection with Fig. 2, it is a comparatively simply matter to shift the vector E_c through a value of 90 degrees with respect to the voltage E_s . Therefore, it is a comparatively easy matter to obtain the type of control as represented in the vicinity of 90 degrees on the lower horizontal axis. It will be seen at this point that a continuous and smooth control of the current output can be secured down to a zero value, the same type of control can be secured up to a maximum value, and a sudden transition from zero to maximum current output can be produced by shifting the control voltage E_c through the value of 90 degrees.

In the foregoing analysis the ideal conditions

were assumed, including the fact that the parallel circuit consisting of the coil 7 and the condenser 8 should draw no current. Since this parallel circuit is resonant to the applied voltage, this is theoretically true. Moreover, I have found that if the impedance of the parallel circuit is three times the value of the resistance R or more, there is no appreciable deviation from the analysis as given above. Furthermore, an arrangement as represented in Fig. 1 actually performs without any substantial variation in the manner as analyzed in Figs. 2 and 3.

Instead of using an inductance in series with the resistance 15, a condenser could be used as illustrated in Fig. 1a. In Fig. 1a the reference numerals correspond to identical parts in Fig. 1. The condenser is represented at 22. In Fig. 1a either the resistance R or the condenser C, or both, may be varied.

The analysis of the variation of Fig. 1, as illustrated in Fig. 1a, is given by the vector diagram of Fig. 2a. In this figure the various vectors are marked exactly in the same manner in connection with Fig. 2. It will be noted that the only difference is the fact that in Fig. 2a the current vectors lead the voltages E_t and E_s , and therefore the voltage drops are of opposite phase with respect to those shown in Fig. 2. In Fig. 2a the control voltage E_c likewise is of opposite phase with respect to the voltage E_c of Fig. 2. The curve of Fig. 3, however, applies directly to the operation of Fig. 1a inasmuch, as has been previously pointed out, as the control of the discharge through the tube is independent of the control flux and is dependent only on the magnitude phase of said flux.

In any two-element phase shift circuit, such as illustrated in Fig. 1 or Fig. 1a, the maximum rate of change of phase angle with respect to change in impedance occurs at the point where both impedances are equal in magnitude. This condition represents a phase shift of E_c with respect to E_s of 90 degrees. It is in the region of this value of phase shift that many of the objects of my invention are accomplished. In any practical system it is easy to construct impedances which are equal, and therefore by my arrangement the control is made easiest at the point where the desired results are to be produced.

Of course it is understood that this invention is not limited to the particular details as described above inasmuch as many equivalents will suggest themselves to those skilled in the art. For example, instead of using the particular magnetic control tube described, any tube in which the starting of current is controlled by a magnetic field could be constructed to utilize the principles of my invention. Furthermore, it will be seen that one of the fundamental features of my invention is the production of a phase shift between the control voltage and the current which flows through the control circuit. Therefore, any tube in which the starting of that tube is made responsive to the flow of current through a control circuit likewise could be made to utilize the principles of my invention. Since the electrical circuit of the control coil 7 is separate from that of the tube 1, the voltage impressed across said tube may be any proportion of the secondary 11 or may be supplied to said tube by a separate transformer or transformer winding. If desired the condenser 8 may be omitted and the analysis given holds good provided the impedance

of 7 remains more than three times the impedance of 15. It is accordingly desired that the appended claims be given a broad interpretation commensurate with the scope of the invention within the art.

What is claimed:

1. In combination, a source of alternating current voltage including a transformer having a transformer winding, a tap on said transformer winding intermediate the ends thereof, a gas or vapor-filled space discharge device provided with electrodes, means for impressing across said electrodes an alternating current voltage in phase with the voltage across said transformer winding, electromagnetically-energized control means for controlling the starting of current flow between said electrodes, a phase-shifting circuit comprising a resistance and a reactance connected in series between the ends of said secondary winding, one of said impedances being variable, and means for impressing on said control means for energizing the same the voltage appearing between said intermediate tap and the point intermediate said resistance and impedance.

2. In combination, a source of alternating current voltage including a transformer having a transformer winding, a tap on said transformer winding intermediate the ends thereof, a gas or vapor-filled space discharge device provided with electrodes, means for impressing across said electrodes an alternating current voltage in phase with the voltage across said transformer winding, control means for controlling the starting of current flow between said electrodes, a control circuit associated with said control means, said control means being responsive to current flowing through said control circuit, a phase-shifting circuit comprising a resistance and a reactance connected in series between the ends of said secondary winding, one of said impedances being variable, means for impressing on said control circuit the voltage appearing between said intermediate tap and the point intermediate said resistance and impedance, and means in said control circuit for producing a substantial phase displacement between said last-named voltage and the current flowing in said control circuit.

3. In combination, a source of alternating current voltage including a transformer having a transformer winding, a tap on said transformer winding intermediate the ends thereof, a gas or vapor-filled space discharge device provided with electrodes, means for impressing across said electrodes an alternating current voltage in phase with the voltage across said transformer winding, electromagnetic control means for controlling the starting of current flow between said electrodes, a control circuit associated with said control means, said control means being responsive to current flowing through said control circuit, a phase-shifting circuit comprising a resistance and a reactance connected in series between the ends of said secondary winding, one of said impedances being variable, means for impressing on said control circuit the voltage appearing between said intermediate tap and the point intermediate said resistance and impedance, and means in said control circuit for producing a substantial phase displacement between said last-named voltage and the current flowing in said control circuit.

WILCOX P. OVERBECK.