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PHASE-SHIFT CIRCUITS
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FIG. 1.

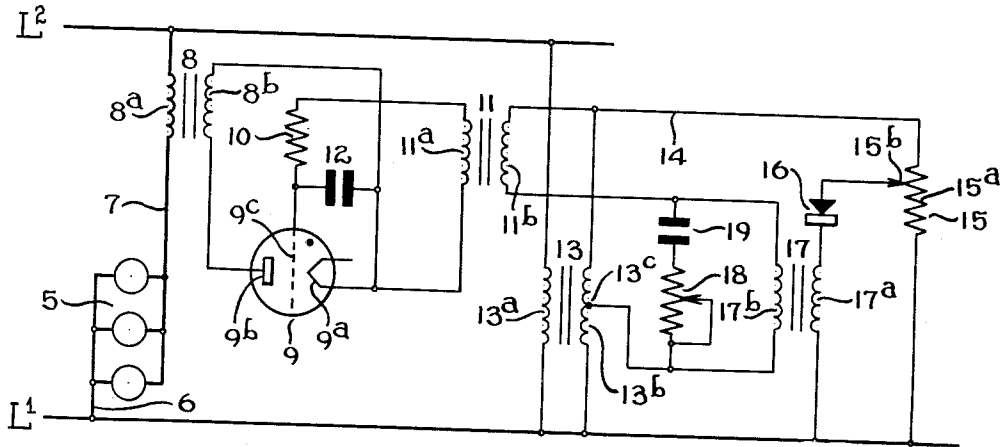
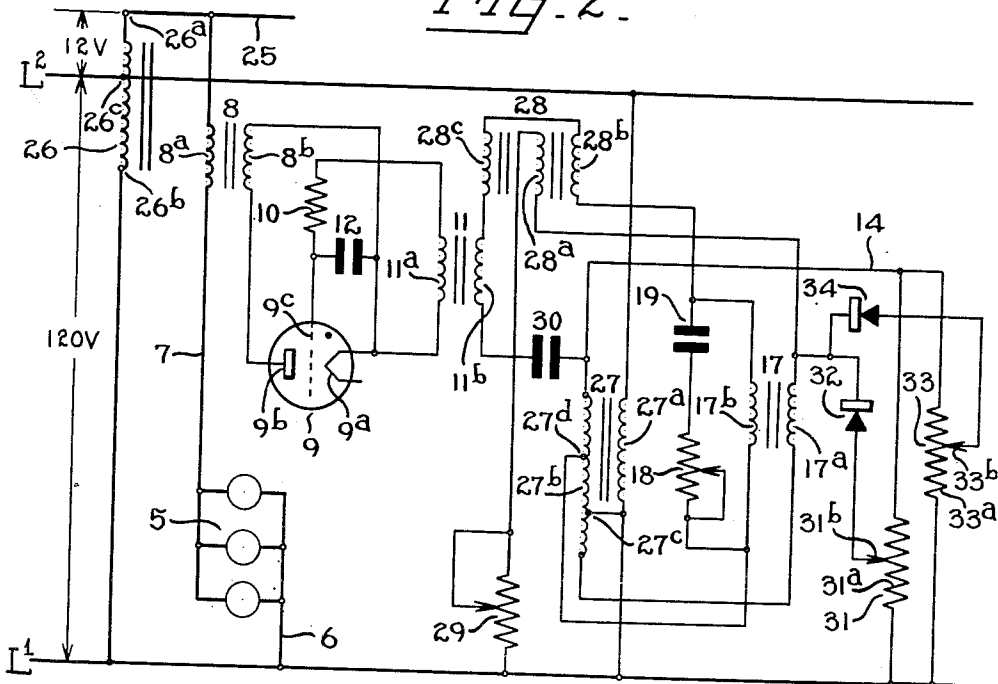


FIG. 2.



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PHASE-SHIFT CIRCUITS

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1

This invention relates to electrical control systems and more particularly to phase-shift circuits which while not limited thereto are particularly advantageous for controlling gaseous discharge tubes in lamp dimming circuits.

A primary object of this invention is to provide adjustable phase-shift circuits capable of producing relatively large changes in the phase angle of an output voltage while maintaining the magnitude of such voltage relatively constant.

Another object is to provide phase-shift circuits of the aforementioned character which are responsive to the magnitude of an A. C. signal voltage.

Another object is to provide a phase-shift circuit of the aforementioned character which is responsive only to the A. C. signal voltage of greatest magnitude where more than one such signal voltage is applied, and

A still further object is to provide a control system for lamp dimming wherein a phase-shift circuit of the aforementioned character is utilized for controlling a gaseous discharge tube in such a manner that lamp dimming characteristics of a preferred form are obtained.

Other objects and advantages of the invention will hereinafter be apparent.

The accompanying drawing illustrates preferred embodiments of the invention which will now be described in detail, it being understood that such embodiments are susceptible of various modifications without departing from the scope of the appended claims.

In the drawings:

Figure 1 is a diagrammatic showing of a control system for controlling the illumination intensity of incandescent lamps, and

Fig. 2 is a modified form of the system shown in Fig. 1.

Referring to Fig. 1, it shows a plurality of incandescent lamps 5 connected in parallel to buses 6 and 7.

Bus 6 is connected to supply line L¹ of a single phase alternating current source and bus 7 is connected to line L² of said source in series with the primary winding 8^a of a transformer 8 having a secondary or control winding 8^b. Winding 8^b of transformer 8 is connected at one end to the cathode 9^a of a gaseous electron discharge tube 9 and at its other to the anode 9^b of tube 9. Tube 9 is provided with a control grid 9^c which is connected to cathode 9^a in series with a resistor 10 and a secondary winding 11^a of a transformer 11 which has a primary winding 11^b. Control grid 9^c is also connected to cathode 9^a in series with a capacitor 12.

2

The part of the control system thus far described is of known form and it will be appreciated that the intensity of illumination of the lamps 5 is controllable by variation in the impedance of winding 8^a of transformer 8. The impedance of winding 8^a is controlled by variation in the current flowing in the winding 8^b of the transformer as a function of conduction of tube 9 during its conducting half cycles. The conduction of tube 9 is controlled by varying the phase angle of the potential to which primary winding 11^b of transformer 11 is subjected. The part of the control system now to be described comprises a phase-shift network for supplying and adjusting the phase angle of the voltage applied across winding 11^b of transformer 11.

A transformer 13 has a primary winding 13^a connected across lines L¹ and L² and a center-tapped secondary winding 13^b which is connected at its lower end terminal to line L¹ and at its upper end terminal to a bus 14. A voltage divider 15 has a resistance element 15^a which is connected at lower end to line L¹ and at its upper end to bus 14 and is provided with an adjustable tap 15^b. Tap 15^b is connected to line L¹ in series with a half-wave rectifier 16, primary winding 17^a of a transformer 17, which has a secondary winding 17^b. Winding 17^b is connected at one end to bus 14 and at its other end to center-tap terminal 13^c of winding 13^b of transformer 13 in series with secondary winding 17^b of transformer 17. An adjustable resistor 18 and a capacitor 19 are connected in parallel or shunt across secondary winding 17^b.

The behavior and operation of the phase-shift network will now be described.

Let it be assumed that rectifier 16 is omitted from the circuit and that winding 17^a is directly connected to tap 15^b of voltage divider 15. Further, let it be assumed that resistor 18 and capacitor 19 are omitted from the circuit. With this assumed circuit arrangement it will be apparent that when tap 15^b is positioned on resistance element 15^a at the lower end of the latter, winding 17^a will be unenergized and consequently no voltage will be induced in winding 17^b of transformer 17. Hence, the voltage across winding 17^b of transformer 17 will be approximately of the same magnitude and in phase with the voltage across the portion of winding 13^b from center-tap terminal 13^c to the upper end thereof.

Under the same assumed circuit arrangement and with tap 15^b positioned at the midpoint of resistance element 15^a, the voltage across winding 17^a will be equal to approximately half the value of the voltage between line L¹ and bus 14,

3
or equal to half the voltage across winding 13^b of transformer 13. Assuming further that the windings 17^a and 17^b of transformer 17 have approximately the same number of turns and that the connections to winding 17^b are so made that the voltage across winding 17^b is in opposition to that across winding 13^b, then the voltage across winding 17^b will effectively cancel that across the portion of winding 13^b from center-tap 13^c to bus 14 so that there will then be zero voltage across winding 11^b.

If tap 15^b is then moved to the upper end of resistance element 15^a, the voltage across winding 17^a will be equal to twice that from the center tap 13^c to bus 14, and being in opposition to the voltage across winding 13^b will apply a voltage across winding 11^b equal in magnitude to half that across winding 13^b and in phase opposition thereto. It will be seen with this assumed circuit arrangement that in moving tap 15^b from the lower end to the upper end of resistance element 15^a, it is possible to effect an approximately 180° phase shift of the voltage applied across winding 11^b. However, this assumed circuit arrangement has a defect in that the voltage applied across winding 11^b drops to unacceptably low magnitudes for control purposes as tap 15^b is positioned on resistance element 15^a in the mid-portions thereof.

It has been found that with the circuit of Fig. 1 as actually constituted with rectifier 16 included in circuit between tap 15^b and winding 17^a and with adjustable resistor 18 and capacitor 19 connected in shunt across winding 17^b, it is possible to effect shift in the phase of the voltage applied across winding 11^b through a wide angular range without attendant excessive drop in scalar magnitude of such voltage when tap 15^b of voltage divider 15 is moved from one end to the other of resistance element 15^a. With proper selection of the values for adjustable resistor 18 and capacitor 19, the voltages induced in winding 11^a of transformer 11 will be of such magnitude and phasal relationship as to provide a wide range of control for the tube 9.

Fig. 2 discloses a circuit which in certain respects is similar to that shown in Fig. 1 but has additional refinements, principally in its phase-shift network, which makes it particularly desirable for lamp dimming applications. The portions of the circuit of Fig. 2 which are the same as that of Fig. 1 bear the same reference numerals and only portions that are different will now be described in detail.

In the circuit of Fig. 2, the lamps 5 are connected in parallel to buses 6 and 7 and bus 6 is connected to line L¹ while bus 7 is connected to a bus 25, which is connected to the overhanging end terminal 26^a of an autotransformer 26 in series with winding 8^a of transformer 8. Autotransformer 26 is connected through its end terminal 26^b to line L¹ and through its intermediate terminal 26^c to line L². The autotransformer 26 is utilized as a booster transformer for raising the lamp supply voltage above that available between supply lines L¹ and L², a sufficient amount to compensate for the drop through winding 8^a of transformer 8 occasioned by the normal impedance drop and the effect of the voltage drop across tube 9.

In place of the transformer 13 of the circuit of Fig. 1 a transformer 27 is used. Transformer 27 is provided with a primary winding 27^a connected across lines L¹ and L² and with a secondary winding 27^b having two intermediate tap

terminals 27^c and 27^d. Winding 27^b is connected through its upper end terminal to bus 14 and through its lower end terminal to line L¹ in series with primary winding 17^a of transformer 17, control winding 28^a of a saturable reactor 28, and an adjustable resistor 29. Intermediate tap terminal 27^c of winding 27^b is connected to the lower end terminal of primary winding 27^a and intermediate tap terminal 27^d is connected to the point common to the connection between upper end terminal of winding 27^b and bus 14 in series with secondary winding 17^b of transformer 17, A. C. windings 28^b and 28^c of reactor 28, primary winding 11^b of transformer 11 and capacitor 30. Adjustable resistor 18 and capacitor 19 are connected in parallel or shunt with winding 17^b.

The voltage divider 15 and rectifier 16 combination of the circuit of Fig. 1 are replaced by two such voltage dividers-rectifier combinations in the circuit of Fig. 2. One voltage divider 31 has its resistance element 31^a connected between line L¹ and bus 14 and has its adjustable tap 31^b connected to the upper end terminal of winding 17^a of transformer 17 in series with a half-wave rectifier 32. The other voltage divider 33 has its resistance element 33^a connected across line L¹ and bus 14 and its adjustable tap 33^b connected to the upper end terminal of winding 17^a in series with a half-wave rectifier 34. When two or more such voltage dividers are connected as shown in Fig. 2, the effective signal applied to the phase-shift network is obtained from the voltage divider whose adjustable tap is positioned closest to the upper end of its associated resistance element, i. e., the highest A. C. signal dominates. Lower voltage signals from the other voltage dividers have no appreciable effect on lamp voltage.

Capacitor 30 improves the transient stability of the phase-shift network, while saturable reactor 28 widens the range of possible phase-shift for a given change in A. C. signal voltage. Adjustable resistor 29 permits adjustment of the effectiveness of saturable reactor 28 since its adjustment determines the degree of saturation of such reactor and hence its impedance for a given A. C. signal voltage.

With the phase-shift network of Fig. 2, phase-shift control of the gaseous discharge tube 9 may be obtained to provide adjustment of the intensity of illumination of lamps, such as the lamps 5, from blackout to full brilliance. The utilization of the transformer 27 with its overhanging section in its secondary winding 27^b between intermediate tap terminal 27^c and its lower end terminal provides that the change in lamp voltage will be substantially directly proportional to the change in magnitude of the A. C. signal voltage throughout the range of signal voltage adjustment.

I claim:

1. For supplying and effecting adjustment of the phase angle of a voltage applied to a control circuit, a network comprising a transformer having a primary winding to be supplied from an alternating current source and having a secondary winding with at least one intermediate tap, a saturable reactor, a second transformer having a primary winding in circuit with the secondary winding of the first mentioned transformer and the control winding of said reactor and having a secondary winding in circuit with one intermediate tap of the secondary winding of said first mentioned transformer and the alternating current windings of said reactor, a resistor connected in parallel with the secondary winding of

said second transformer, a plurality of half-wave rectifiers, and a corresponding number of adjustable voltage dividers each of which has a resistance element connected in parallel with the secondary winding of said first mentioned transformer and an adjusting element connected in series with an associated rectifier to the connection between the primary winding of said second transformer and the control winding of said reactor, said network being adjusted in accordance with the adjustment of the voltage divider whose adjusting element affords the highest signal voltage.

2. For supplying and effecting adjustment of the phase angle of a voltage applied to a control circuit, a network comprising a transformer having a primary winding to be supplied from an alternating current source and having a secondary winding with two intermediate taps and an overhanging section between one of such taps and one end terminal thereof, a saturable reactor, an adjustable resistor, a second transformer having a primary winding in circuit with said one end terminal of the secondary winding of the first mentioned transformer, the control winding of said reactor and said adjustable resistor and having a secondary winding in circuit with the other intermediate tap of the secondary winding of said first mentioned transformer and the alternating current windings of said reactor, a resistor and a capacitor connected in series and together in parallel with the secondary winding of said second transformer, a plurality of half-wave rectifiers, and a corresponding number of adjustable voltage dividers each of which has a resistance element connected in parallel with the secondary winding of said first mentioned transformer and an adjustable tap connected in series with an associated rectifier to the connection between the primary winding of said second transformer and the control winding of said reactor, said network being adjusted in accordance with the adjustment of the voltage divider whose tap affords the highest signal voltage.

3. In combination, a source of single phase alternating current, an output element, and an adjustable phase-shift network comprising a transformer having a primary winding connected to said source and having a secondary winding with at least one intermediate tap, an adjustable voltage divider having a resistance element connected in parallel with the secondary winding of said transformer, a half-wave rectifier, a second transformer having a primary winding connected to said source and to the adjusting element of said voltage divider through said rectifier and having a secondary winding in circuit with one intermediate tap of the secondary winding of the first mentioned transformer, said output element and said resistance element of said voltage divider and a resistor and a capacitor connected in series and together in parallel with the secondary winding of said second transformer.

4. In combination, a source of single phase alternating current, an output element, and an adjustable phase-shift network comprising a transformer supplied from said source and having a secondary winding with at least one intermediate tap connected to one side of said source, a half-wave rectifier, an adjustable voltage divider having a resistance element connected to said one side of said source in parallel with said secondary winding of said transformer, a second

transformer having a primary winding connected to said one side of said source and to the adjusting element of said voltage divider through said rectifier and having a secondary winding connected at one end to one intermediate tap of the secondary winding of said first mentioned transformer and at its other end to the connection between the resistance element of said voltage divider and said secondary winding of said first mentioned transformer in series with said output device and a resistor and a capacitor connected in series and together in parallel with the secondary winding of said second transformer.

5. In combination, a source of single phase alternating current, an output device, and an adjustable phase-shift network comprising a transformer having a primary winding connected to said source and having a secondary winding with at least one intermediate tap, a saturable reactor, a second transformer having a primary winding in circuit with the secondary winding of the first mentioned transformer and the control winding of said reactor and having a secondary winding in circuit with one intermediate tap of the secondary winding of said first mentioned transformer, the alternating current windings of said reactor and said output device, a resistor and a capacitor connected in series and together in parallel with the secondary winding of said second transformer, a plurality of half-wave rectifiers and a corresponding number of voltage dividers each of which has a resistance element connected in parallel with the secondary winding of said second transformer and an adjusting element connected in series with an associated rectifier to the connection between the secondary winding of said second transformer and the control winding of said reactor, said network being adjusted in accordance with the adjustment of the voltage divider whose adjusting element affords the highest signal voltage.

6. In combination, a source of single phase alternating current, an output device, and an adjustable phase-shift network comprising a transformer having a primary winding connected to said source and having a secondary winding with two intermediate taps and an overhanging section between one of such taps and one end terminal thereof, a saturable reactor, an adjustable resistor, a capacitor, a second transformer having a primary winding in circuit with said one end terminal of the secondary winding of the first mentioned transformer, the control winding of said reactor and said adjustable resistor and having a secondary winding in circuit with the other intermediate tap of the secondary winding of said first mentioned transformer, the alternating current windings of said reactor, said output device and said capacitor, an adjustable resistor and a capacitor connected in series and together in parallel with the secondary winding of said second transformer, a plurality of half-wave rectifiers and a corresponding number of adjustable voltage dividers each of which has a resistance element connected in parallel with the secondary winding of said first mentioned transformer and an adjusting element connected in series with an associated rectifier to the connection between the primary winding of said second transformer and the control winding of said reactor, said network being adjustable in accordance with the adjustment of the volt-

7

age divider whose adjusting element affords the highest signal voltage.

7. For supplying and effecting adjustment of the phase angle of a voltage applied to a control circuit, a network comprising a transformer having a primary winding to be supplied from an alternating current source and having a secondary winding having at least one intermediate tap, an adjustable voltage divider having its impedance element connected in parallel with the secondary winding of said transformer, a pair of impedance devices having different impedance characteristics with respect to each other connected in series and together in parallel with a portion of said secondary winding of said transformer, half wave rectifying means, a second transformer having a primary winding in series circuit with said rectifying means between the adjusting element of said voltage divider and the secondary winding of said first mentioned transformer, said second transformer having a secondary winding connected in parallel with one of said impedance devices.

8. The combination of claim 7 in which said impedance device in parallel with the secondary

8

winding of said second transformer includes resistive impedance and the other of said impedance devices includes inductive impedance.

9. The combination of claim 8 in which said other of said impedance devices comprises a control element of a control circuit.

10. The combination of claim 8 in which said other of said impedance devices comprises a control element of a control circuit and a saturable reactor.

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