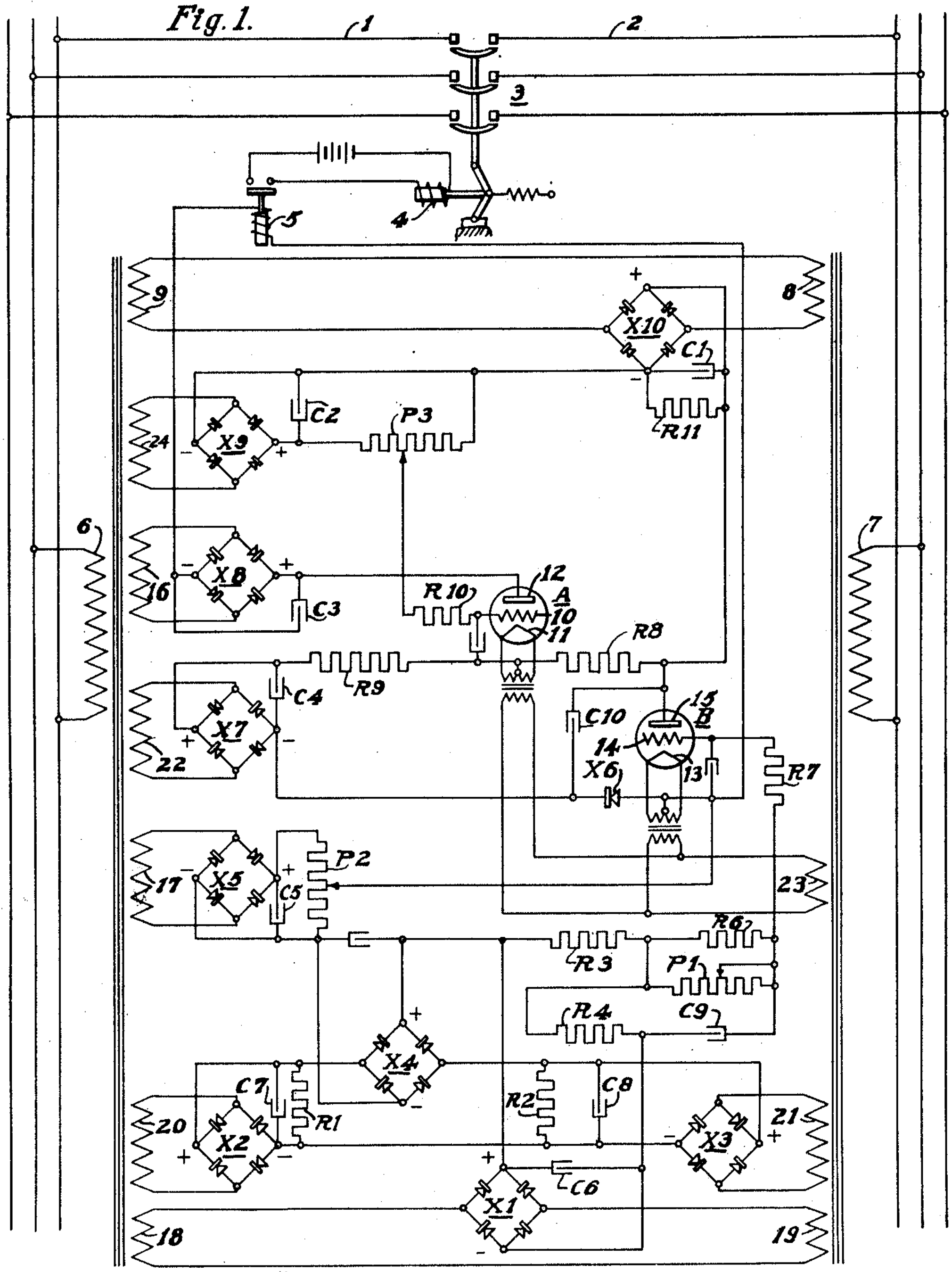
Feb. 11, 1941. F. H. GULLIKSEN 2,231,713

AUTOMATIC SYNCHRONIZER

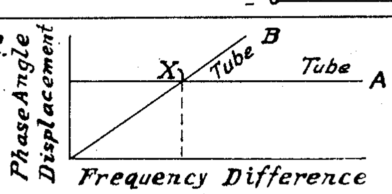
Filed Dec. 14, 1938

Fig. 1.



WITNESSES:

Fig. 2.



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UNITED STATES PATENT OFFICE

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AUTOMATIC SYNCHRONIZER

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20 Claims. (Cl. 171—118)

My invention relates, in general, to synchronizers and more particularly to automatic synchronizers of the electronic tube type utilizing electrical discharge or gaseous conduction tubes.

Many automatic synchronizers of the mechanical type have been designed and introduced into the electrical industry to improve methods of paralleling alternating current systems, however, these mechanical type synchronizers are found to have many undesirable features. Because of friction and inertia of the moving parts of a mechanical type synchronizer, a heavy volt ampere burden is often placed on the instrument transformers utilized with the device. This power demand often exceeds the maximum power output of the instrument transformer necessitating that it be replaced with another of greater power capacity before the synchronizing device can be used. This undesirable feature of heavy volt ampere requirement makes the mechanical synchronizer impractical for operation from standard condenser bushing potential devices which have a very low volt ampere capacity.

Automatic synchronizers of the thermionic tube type have been developed as an improvement over the mechanical type synchronizer, one of which is disclosed in my United States Patent No. 1,977,384, issued October 16, 1934. The automatic synchronizer of this type was a decided improvement over the mechanical type in that moving parts were reduced in number and the volt ampere requirement was also reduced.

However, it was found in practice that this thermionic tube synchronizer also had disadvantages which seemed desirable to eliminate. While the power requirements for its operation was of a low value, the device embodied a number of interlocking mechanical relays which operated in a certain predetermined sequence. It is well known that all mechanical relays have certain operating time constants for the reason that there is a time lag between the time current as applied to the operating winding of the relay and the time it takes for the relay to complete its mechanical movement. By means of variable adjustments which were provided in the thermionic tube synchronizer, the time constants of the relays could be compensated for. However, it was found that, because of inherent characteristics of the relay, among which were close clearances between contact members and delicate structure of relay parts, this time constant did not remain at a fixed value, therefore making it difficult to maintain the correct adjustment of the synchronizer at all times to compensate for the time constant of the relays.

It will be readily understood that much damage may be done to electrical systems and equipment should such systems be paralleled at a time when either or both the phase angle displacement and the frequency difference between the two systems exceed certain predetermined safe limitations. In connection with such limitations, increments of time in the range of 3 or 4 thousandths of a second are of paramount importance in the successful and satisfactory operation of automatic synchronizers and it will be appreciated that the elimination of as many relays as possible would be a decided improvement. My invention, as will be described in detail hereinafter, serves to eliminate all of the mechanical relays found in the thermionic tube type synchronizer, with the exception of a single relay for controlling the energization of the closing coil of the circuit breaker, which results in more satisfactory and more efficient operation of devices of this type, and minimizes the possibility of paralleling two alternating-current systems at an improper time.

The object of my invention, generally stated, is to provide an automatic synchronizer of the electrical discharge tube type which will be of simple and economical construction and which will be efficient and reliable in operation.

A more specific object of my invention is to provide for initiating the closing of a circuit breaker or switch for connecting together in parallel two alternating current sources at a point in advance of phase coincidence within predetermined maximum limits of instantaneous frequency difference between the two current sources so that the current sources will actually be connected at substantially zero phase angle displacement.

A further object of my invention is to provide for interlocking the electric discharge tubes of my device in such a manner that a closing of the switch for paralleling the two current sources is prevented should the instantaneous frequency difference between the two current sources exceed a predetermined value.

A still further object of my invention is to provide for interlocking the tube circuits of my device in such a manner that the current flow in the tube circuit which serves to energize the control apparatus, for initiating the closure of the paralleling switch, is permitted only when both of the tubes in the device are simultaneously conductive.

Another object of my invention is to provide a novel interlock for a control system by which current is permitted to flow in the control system only when the tubes become conductive in a certain predetermined sequence.

These and other objects of my invention will become more apparent to those skilled in the art from the following detailed description when considered in connection with the drawing, in which:

Figure 1 is a diagrammatic view of an automatic synchronizer embodying the principal features of my invention, and the circuits controlled thereby; and

Fig. 2 is a graphic representation of the operating characteristics of the synchronizer showing the limits within which the synchronizer will operate.

Referring to Fig. 1, two separate sources of alternating current are represented by conductors **1** and **2** which may be connected together by the circuit breaker **3**. The circuit breaker **3** may be of any well known type having a closing coil **4**, the energizing current for which may be supplied from any suitable source, such as the battery shown, and controlled by the relay **5**.

Generally speaking, my automatic synchronizer comprises a circuit arrangement in which two tubes of the electrical discharge type are utilized in an interlocking tube circuit arrangement which is described in detail hereinafter, so that the current through the control circuit to initiate the closing of the circuit breaker **3**, flows only when certain predetermined values of phase angle difference and frequency difference between the alternating current sources are present. This current which flows in the synchronizer circuit energizes the control relay **5** which, in turn, closes the circuit to the closing coil **4** of the circuit breaker **3**.

As shown, the synchronizer is connected to the two alternating current sources by means of transformers **6** and **7**, each having a primary winding and a plurality of secondary windings.

In order to more clearly disclose the principal features and operation of the synchronizer, the operation of each of the two tubes and their associated control circuits will be described, followed by a description of the operation of the synchronizer.

Control circuit tube A

As shown, the secondary windings **8** and **9** of transformers **6** and **7** are connected in series to the alternating current terminals of the full wave rectifier X**10** which may be of the well known copper oxide type, so that the voltages induced in these windings are directly opposed when the phase angle displacement between the two alternating current sources **1** and **2** is zero. Accordingly, it will be apparent that the direct-current output of the rectifier X**10** is essentially a pulsating voltage which varies from a minimum of zero when the phase angle difference or displacement between the two systems is zero, to a maximum when the phase angle displacement between the two systems is at a maximum of 180°. To smooth out the alternating current components of the rectified voltage, a condenser C**1** may be connected across the direct-current output terminals of the rectifier. This direct-current output from rectifier X**10** is impressed across a resistor R**11** and accordingly will produce a voltage drop which, as has been explained, will vary from zero to a maximum depending upon the phase angle displacement between the two systems. This voltage drop across R**11** forms a part of the grid bias for tube A. The rectifier output connections are so arranged that this voltage drop with respect to cathode **11** and the grid **10** of the tube A represents a negative grid bias.

Another component of grid bias for tube A is obtained from another rectifier X**9** connected to the secondary winding **24** of transformer **6**. The direct-current output of this rectifier is impressed across a potentiometer P**3**, and produces a voltage drop which may be varied by changes in the potentiometer setting. The polarity of this voltage drop is so arranged that with respect to cathode and grid of tube A, it represents a positive grid bias. A smoothing condenser C**2** may be also connected across the output terminals of this rectifier to function in the same manner and for the same purpose as condenser C**1**. It will be evident that since the alternating-current terminals of rectifier X**9** are connected only to the source **1**, the direct-current voltage appearing across the potentiometer P**3** is independent of any phase angle displacement between the two systems, and accordingly may be adjusted to any value by means of the variation in setting of the potentiometer P**3**.

A grid leak resistor R**10** may also be utilized in the grid circuit of tube A as shown. The power supply for inducing a current flow in the discharge circuit of tube A when tube A becomes conductive, is produced by another rectifier X**8** which may be connected to the secondary winding **16** of transformer **6**. A smoothing condenser C**3** may be connected across the output terminals of this rectifier.

The characteristics of the electric discharge tubes are such that with a highly negative voltage impressed between the grid **10** and the cathode **11** of tube A, the tube remains non-conductive and thus no current can flow in the circuit of the tube. However, when this negative voltage is reduced to a sufficiently low value, which low value depends upon the inherent characteristics of the tube itself, the tube will become conductive and current will flow through the tube between cathode **11** and anode **12** and hence in the circuit of tube A.

Thus it will be evident that with the combination of the positive voltage drop across the potentiometer P**3** the amount of which may be selectively controlled by variations in the setting of the potentiometer, and the negative voltage drop across resistor R**11** which is proportional to the phase angle displacement between the two alternating-current sources, the grid bias between cathode **11** and grid **10** of tube A may be varied so that the tube A can be made to become conductive in advance of synchronism at any selected phase angle displacement which will be independent of any difference in frequency existing between the two alternating-current sources.

Accordingly, when tube A becomes conductive, current will flow through the discharge circuit thereof which extends from the positive terminal of rectifier X**8**, through anode **12** and cathode **11** of tube A, resistor R**8**, anode **15** and cathode **13** of tube B (provided tube B is also conductive simultaneously with tube A) the winding of relay **5** and back to the negative terminal of rectifier X**8**.

Control circuit tube B

A rectifier X**5** having its alternating-current terminals connected to the secondary winding **17** of the transformer **6** furnishes one component of grid bias for tube B. The direct current output of this rectifier is impressed across a potentiometer P2, the setting of which may be varied to produce a variable voltage drop across the potentiometer. The connections are such that the polarity of this voltage drop with respect to the grid 14 and cathode 13 of tube B represents a negative grid bias. A condenser C5 may be connected across the direct current output terminals of rectifier X5 to smooth out the alternating-current components of the rectified voltage. It will be understood that since the alternating-current terminals of rectifier X5 are connected only to the source 1, the direct-current voltage thus obtained will be independent of any phase angle displacement existing between the two alternating-current sources.

Another negative component of grid bias of tube B is supplied by the direct-current output of rectifier X1. The alternating-current terminals of rectifier X1 are connected to the secondary windings 18 and 19 of transformers 6 and 7, respectively, in the same manner in which the alternating-current connections were made with respect to rectifier X10 hereinbefore described, thus producing across the direct-current output terminals of rectifier X1 a pulsating voltage of zero value when the phase angle displacement of the two sources is zero, and of maximum value when the phase angle displacement is 180°. This pulsating direct-current output is impressed across resistor R3, thus producing a variable voltage drop which will accordingly vary between values of zero and maximum depending upon the phase angle displacement of the two systems. This resistor R3 is so connected in the grid circuit of tube B that the polarity of the voltage drop obtained across this resistor is such that with respect to grid 14 and cathode 13 of tube B, it represents a negative grid bias. A smoothing condenser C6 may be connected across the output terminals of rectifier X1.

In order to compensate for any voltage difference between the two sources which may appear across the alternating-current terminals of rectifier X1 when the two sources are at a zero phase angle displacement, rectifiers X2 and X3 are connected to secondary windings 20 and 21 of transformers 6 and 7, respectively. Smoothing condensers C7 and C8 may be connected in the output circuits of rectifiers X2 and X3. It will be seen that the direct-current outputs of rectifiers X2 and X3 are impressed across resistors R1 and R2, respectively, and are further connected to rectifier X4. The direct-current output terminals of rectifier X4 are connected in the grid circuit of tube B and thus furnish a positive component of grid bias for tube B which will be proportional to any voltage difference existing between the two systems at zero phase angle displacement. Without such a voltage compensator, the negative grid bias of tube B might not be lowered sufficiently to allow tube B to become conductive even though other prerequisites of phase angle displacement and frequency difference between the two systems had been met.

Still another component of grid bias for tube B is the voltage drop across the combination of resistor R6 and the variable potentiometer P1. This component of grid bias as will now be explained is a function of the frequency difference between the two sources to be paralleled and hence renders tube B conductive at a time when the frequency difference is below a predetermined value.

Since the secondary windings 18 and 19 of transformers 6 and 7, respectively, are connected to the alternating current terminals of rectifier X1 in such manner that the voltages of the two systems are directly opposed when the phase angle displacement between the two systems is zero, it is evident that a beat voltage proportional to the frequency difference between the two systems will be applied to the rectifier. The direct current voltage output of rectifier X1, therefore, will be substantially a pulsating voltage varying from zero to a maximum once per second for each cycle per second frequency difference between the two systems. Since resistor R4 is connected in series with resistor R3 across the direct current output terminals of rectifier X1, the voltage drop across R4 will also vary from zero to a maximum once per second for each cycle per second difference in frequency between the two systems to be paralleled.

A condenser C9 is connected across resistor R4 to be charged with the beat voltage and will attain a maximum value proportional to the voltage drop across R4 when such drop is also at maximum value. As this beat voltage is decreasing towards its zero value, the voltage drop across R4 is also decreasing. The potential applied to condenser C9 now being higher than that across R4, condenser C9 will discharge through the combination of resistor R6 and variable potentiometer P1. Such a discharge produces a voltage drop across potentiometer P1 and resistor R6 which is connected in the grid circuit of tube B. The current from condenser C9 flows through R6 and P1 in such a direction as to produce a component of positive grid bias. A grid leak resistor R7 may be used in the grid circuit of tube B.

The electrical discharge device B is similar to discharge device A, and as heretofore explained in reference to operation of the device A, will not become conductive while a high negative voltage exists between cathode 13 and grid 14. When this grid voltage is reduced to a sufficiently low value, device B will become conductive and current will flow between cathode 13 and anode 15 and hence in the discharge circuit of device B.

The power supply for energizing the discharge circuit of device B consists of another rectifier X7 which has its alternating-current terminals connected to the secondary winding 22 of transformer 6. Condenser C4 may be connected across this rectifier to smooth out alternating current components of rectified voltage.

As heretofore explained, the component of grid bias consisting of the voltage drop across resistor R6 and potentiometer P1 will vary between values of zero and maximum at a rate equal to the beat frequency of the two systems to be paralleled. It is evident then that with this component of grid bias in combination with those grid biases obtained from the voltage drop across potentiometer P2, resistor R3 and rectifier X4, the total grid bias of device B can be so varied as to make device B conductive at a point in advance of synchronism within predetermined limits of frequency difference between the systems.

Electrical discharge device B becoming conductive, current supplied from rectifier X7 will pass from the positive terminal of rectifier X7 through resistors R9 and R8, anode 15 and cathode 13 of device B, rectifier X6 and back to the negative terminal of the rectifier. When device B becomes conductive, the discharge circuit of device A is completed, and, providing that device A is also conductive, current will flow in the winding of the relay **5** to energize the closing coil **4** of the circuit breaker **3**.

In the preferred embodiment of my invention. I employ electric discharge tubes, the cathodes of which are heated. To furnish such heating, I have shown the heating elements connected to the secondary winding **23** of transformer **7**. While I prefer to use this heated cathode, I do not wish to be so limited as it is evident that other types of electrical discharge devices having similar operating characteristics may be used without departing from the spirit and scope of my invention.

Likewise, it is evident that with respect to those rectifiers which I have shown as being connected to only one of the two alternating current systems, the same results could be obtained by connecting any or all of them to the other system shown, or by connecting them to still another alternating-current source. Therefore, I do not wish to be limited to the arrangement of secondaries as shown.

Operation

An automatic synchronizer should not operate to energize the closing coil of a paralleling switch or breaker unless the instantaneous frequency difference between the two systems to be paralleled is less than a predetermined lock-out value. This will prevent paralleling alternating-current generators which are running at too great a speed differential. Also, it will be evident to those skilled in the art that in order for the two systems to be parallel at substantially the exact instant of zero phase angle displacement between the voltages of the two systems, allowance will have to be made for the time constants inherent in the closing mechanisms employed to parallel the alternating-current sources. This means that such closing mechanisms should be energized at a point in advance of phase coincidence and within predetermined safe limits of instantaneous frequency difference between the two systems. It will be evident that from the following description, my invention meets both of these requirements.

My automatic synchronizer operates as follows. Assuming that it is desired to parallel the two alternating-current systems, the apparatus is connected to both systems in a circuit arrangement as shown. As has been already explained tube A will become conductive at a time in advance of synchronism which is proportional to the phase angle displacement between the two systems, and tube B will become conductive at a time in advance of synchronism which is proportional to the frequency difference between the two systems. When tubes A and B are simultaneously conductive, the control relay **5** will be energized and will operate to effect the closure of the circuit breaker **3**.

This may be illustrated by Fig. 2 in which I have shown in graphic form tube A becoming conductive at a point in advance of synchronism which is proportional to the phase angle displacement and independent of frequency difference and tube B becoming conductive at a phase angle in advance of synchronism which is proportional to the frequency difference. The point X which is the intersection of the two lines represents the maximum phase angle displacement and maximum frequency difference which have been selected in which to allow the two systems to be synchronized.

In this connection, it will be noted that in order for the synchronizer to function properly, tubes A and B must be simultaneously conducting current and must have been rendered conductive in a certain sequence.

At any instant of time in one cycle of beat voltage between the two systems, let us assume that the phase angle displacement between the two systems is not greater than that selected for paralleling, but the frequency difference does exceed the selected maximum limit. Tube **0** will become conductive and ready to pass current, however, since the frequency difference exceeds the limit and tube B is not conductive, no current from the source **X8** can flow through tube B which is a part of the path of the discharge circuit of tube A to energize the control relay **5**.

Current from source **X8** is also prevented from shunting tube B when it is not conductive and passing through resistor **R9** and rectifier **X7** to energize control relay **5** by the blocking action of rectifier **X6** which is so connected that it will not pass current in this direction.

When the frequency difference and the phase angle displacement both exceed the maximum limit selected, tube B will become conductive and pass current through its discharge circuit, but as previously explained tube A is prevented from becoming conductive. This results from the fact that when the current is flowing through resistor **R8** in the discharge circuit of tube B, a voltage drop will be produced which, as can be seen, forms a part of the total grid bias of tube A. This voltage drop increases the negative bias of this tube, thus preventing the grid of this tube from reaching a sufficiently low negative value to allow it to become conductive.

It is well known in the art that once tubes of the electrical discharge type begin to pass or conduct current, they will continue to do so regardless of changes in grid bias, so long as enough voltage is available to maintain the arc drop of the tube. Should conditions be such that tube B breaks down ahead of tube A, a condenser **C10**, which is connected to tube B as shown, and which has been charged to a potential existing between anode **15** and the negative lead of rectifier **X7**, will discharge through the cathode **13** and anode **15** of tube B. Resistors **R8** and **R9** are of such a value that the rate of discharge of condenser **C10** will be much greater than the rate of its charge from source **X7**. This difference in charging and discharging rates produces a constantly decreasing voltage across the condenser **C10** and also across the anode **15** and negative lead of rectifier **X7**, and functions to lower the voltage between these two points to a value below the arc drop of the tube, thereby making this tube non-conductive again and ready for further control by the grid bias which is proportional to the frequency difference.

At any instant of time, should tube A be conductive and the frequency difference be less than the predetermined maximum, thereby making tube B conductive, tubes A and B will both pass current through their respective discharge circuits and control relay **5** will be energized. The circuit thus completed for energizing the control relay extends from the negative terminal of rectifier **X8**, through the coil of relay **5**, cathode **13** and anode **15** of tube B, resistor **R8** and cathode **11** and anode **12** of tube A to the positive terminal of rectifier **X8**.

By means of the interlocking arrangement of the tubes A and B of my device which has just been explained, it is evident that there is no possibility of the two systems being paralleled unless the phase angle displacement and frequency difference between the two systems are within predetermined limits and bear such a relation to one another that the prerequisite of proper phase angle displacement must precede that of frequency difference before the synchronizer operates.

It will be evident from the aforesaid that I have provided an automatic synchronizer which will effect the operation of the paralleling switch or breaker to connect two alternating current systems in parallel at substantially the instant of zero phase displacement between the two systems provided the phase angle displacement and frequency difference between the two systems to be paralleled are less than predetermined values.

It is also evident that my invention constitutes a substantial advance in the art in that by means of the novel interlocking tube circuits, the synchronizer has been improved to give a better and more efficient performance and its construction has been simplified by the elimination of mechanical relays found in prior devices.

In conclusion, it will be understood that while I have shown and described one embodiment of my invention, it will be evident that various changes and modifications may be made therein without departing from the spirit and scope thereof.

I claim as my invention:

1. In a system of electrical control, the combination of a pair of electrical discharge devices, the anode cathode terminals of said devices being connected in series, interconnected discharge circuits for said devices, electro-responsive means disposed in one of said discharge circuits, a source of current for said discharge circuits to energize said electro-responsive means, and a grid control system for each of said devices including means for producing grid bias to render said devices conductive, a part of said grid system of one of said devices including an impedance connected in the discharge circuit of the other device whereby said current flows only when said devices become conductive in a predetermined sequence.

2. In a system for paralleling alternating current sources, the combination of a paralleling switch and means for initiating the closing of said paralleling switch at a phase displacement in advance of phase coincidence proportional to the frequency difference between the said current sources comprising an electrical discharge device responsive to control potentials proportional to the phase angle displacement between the voltages of the said sources, and an electrical discharge device responsive to control potentials proportional to the frequency difference between the said sources, said discharge devices being so electrically interconnected as to prevent closing of said paralleling switch while either of said discharge devices remains non-conductive.

3. In a system for paralleling alternating current sources, the combination of a paralleling switch and means for initiating the closing of said paralleling switch at a phase displacement in advance of phase coincidence proportional to the frequency difference between the said current sources comprising an electrical discharge device responsive to control potentials proportional to the phase angle displacement between the voltages of the said sources, an electrical discharge device responsive to control potentials proportional to the frequency difference between the said sources, a discharge circuit for each of said discharge devices, and a source of current for said discharge circuits, said discharge circuits being so interlocked as to permit the flow of said current only when said discharge devices become conductive in a predetermined sequence.

4. In a system for paralleling alternating current sources, the combination of a paralleling switch and means for initiating the closing of said paralleling switch at a phase displacement in advance of phase coincidence proportional to the frequency difference between the said current sources comprising an electrical discharge device responsive to control potentials proportional to the phase angle displacement between the voltages of the said sources, an electrical discharge device responsive to control potentials proportional to the frequency difference between the said sources, a discharge circuit for each of said discharge devices, and electro-responsive means disposed in one of said discharge circuits for controlling the operation of the paralleling switch, said electro-responsive means being energized only when both of said discharge devices are simultaneously conducting current.

5. In a system for paralleling alternating current sources at substantially the incidence of phase coincidence, the combination of a paralleling switch, an electrical discharge device responsive to control potentials proportional to the phase angle displacement between the voltages of the sources, an electrical discharge device responsive to control potentials proportional to the frequency difference between said sources, a discharge circuit for each of said discharge devices, and relay means disposed in one of said discharge circuits operable to close said paralleling switch only when both of said discharge devices are simultaneously conducting current.

6. In a system for paralleling alternating current sources, the combination of a paralleling switch and means for initiating the closing of said paralleling switch at a phase displacement in advance of phase coincidence proportional to the frequency difference between the said current sources comprising an electrical discharge device responsive to control potentials proportional to the phase angle displacement between the voltages of the said sources, an electrical discharge device responsive to control potentials proportional to the frequency difference between the said sources, interconnected discharge circuits for said discharge devices, and electro-responsive means disposed in said discharge circuit operable to effect the closing of the paralleling switch, only when current flows simultaneously in both of said discharge circuits.

7. In a system for paralleling alternating current sources at substantially the incidence of phase coincidence, the combination of a paralleling switch, a closing coil for said paralleling switch, an electrical discharge device responsive to control potentials proportional to the phase angle displacement between the voltages of the said sources, an electrical discharge device responsive to control potentials proportional to the frequency difference between the said sources, a discharge circuit for each of said discharge devices, a source of current for each of said devices, and electro-responsive means disposed in one of said discharge circuits for energizing said closing coil of said paralleling switch at a phase displacement in advance of phase coincidence

proportional to the frequency difference between the current sources, said discharge circuits being so interlocked as to permit energization of said electro-responsive means only when said discharge devices are simultaneously conducting current.

8. In a system for paralleling alternating current sources at substantially the incidence of phase coincidence, the combination of a paralleling switch, a closing coil for said paralleling switch, an electrical discharge device responsive to control potentials proportional to the phase angle displacement between the voltages of the said sources, an electric discharge device responsive to control potentials proportional to the frequency difference between the said sources, a discharge circuit for each of said discharge devices, a source of current for said discharge circuits, electro-responsive means disposed in one of said discharge circuits for energizing said closing coil of said paralleling switch at a phase displacement in advance of phase coincidence proportional to the frequency difference between the current sources, and means for varying the advanced angle at which said electro-responsive means is energized, said discharge circuits being so interlocked as to permit energization of said electro-responsive means only when both of said discharge devices are simultaneously conducting current.

9. In a system for paralleling alternating current sources, the combination of a paralleling switch and means for initiating the closing of said paralleling switching at a phase displacement in advance of phase coincidence proportional to the frequency difference between the said current sources comprising an electrical discharge device responsive to control potentials proportional to the phase angle displacement between the voltages of the said sources, and an electrical discharge device responsive to control potentials proportional to the frequency difference between the said sources and proportional to the difference in voltages between the said sources at zero phase angle displacement, said discharge devices being so electrically interconnected as to prevent closing of said paralleling switch while either of said discharge devices remain non-conductive.

10. In a system for paralleling alternating current sources at substantially the incidence of phase coincidence, the combination of a paralleling switch, a closing coil for said paralleling switch, an electrical discharge device responsive to control potentials proportional to the phase angle displacement between the voltages of the said sources, an electrical discharge device responsive to control potentials proportional to the frequency difference between the said sources and proportional to the difference in voltages between the said sources at zero phase angle displacement, a discharge circuit for each of said discharge devices, a source of current for each of said discharge circuits, and electro-responsive means disposed in one of said discharge circuits for energizing said closing coil of said paralleling switch at a phase displacement in advance of phase coincidence proportional to the frequency difference between the current sources, said discharge circuits being so interlocked as to permit energization of said electro-responsive means only when said discharge devices are simultaneously conducting current.

11. In a system of electrical control, the combination of a first and second electrical discharge device, discharge circuits for each of said devices, the discharge circuit of said first discharge device including an electro-responsive means and the anode-cathode terminals of said second discharge device in series circuit relation therewith, a source of potential for producing a flow of current, in said discharge circuits when said discharge devices become conductive, and a grid circuit for each of said discharge devices, said grid circuit of said first discharge device including as a part thereof potential drop means connected in the discharge circuit of said second discharge device and being effective to so control the grid bias of the first discharge device as to render it non-conductive and thereby ineffective to energize said electro-responsive means in the event that the second discharge device is rendered conductive before the first discharge device is rendered conductive.

12. In a system of control, in combination, a control circuit, a pair of electrical discharge devices having their anode-cathode terminals connected in series circuit relation in said control circuit and including an impedance connected therebetween, discharge circuits for said devices, a source of current for said devices, and a grid system including means for producing grid bias to render said devices conductive, the grid circuit of one of said devices and the discharge circuit of the other device including said impedance as an element thereof, said impedance being effective in response to the flow of current in the discharge circuit of said other device before the said one device becomes conductive to prevent said one device from becoming conductive.

13. In a system of electrical control, in combination, a plurality of eelctrical discharge devices, grid circuits for each of said discharge devices including sources of voltage to control the grid bias and thereby the conductivity of said devices, electrically interconnected discharge circuits for said devices arranged so that the discharge circuit of one of said devices extends through another of said devices, an impedance connected in the grid circuit of one of said devices and also in the discharge circuit of the other, said impedance being effective by the voltage drop thereacross in response to current flow in the discharge circuit of said other device to so control the grid bias of the device in whose grid circuit it is connected as to prevent said device from becoming conductive in response to the other device being rendered conductive first, whereby said devices may be only rendered conductive at the same time by rendering them separately conductive in a predetermined order.

14. In an electrical control system, in combination, a pair of electrical discharge devices, discharge circuits for said devices, said discharge circuits being electrically interconnected so that the discharge circuit of one of said devices extends through both of said devices in series circuit relation, grid control circuits for controlling the conductivity of said devices by means of grid bias, one of said grid circuits including an impedance which is also connected in each discharge circuit intermediate the said devices, said impedance being effective in response to the flow of current in the discharge circuit of one of said devices to produce a grid bias on the device in whose grid control circuit it is connected to prevent said device from being rendered conductive in response to the said other device being rendered conductive first.

15. In a synchronizing device for paralleling alternating current sources within preselected

maximum values of phase-angle and frequency differentials, the combination of an electrical discharge device responsive to control potentials proportional to the phase angle displacement between the voltages of the said sources, an electrical discharge device responsive to control potentials proportional to the frequency difference between the said sources, interconnected discharge circuits for said devices, and electro-responsive means disposed in the discharge circuit of the said device which is responsive to control potentials proportional to said phase angle displacement, said electro-responsive means being energized only when both discharge devices are simultaneously conducting current.

16. In a synchronizer for controlling the closing operation of a circuit breaker to parallel alternating current sources within preselected limits of frequency and phase angle differentials between said sources, the combination of first and second discharge devices having their anode-cathode terminals connected in series circuit relation and including an impedance connected in series between said devices, said first device being responsive to control circuit potentials proportional to the phase angle differential and including said impedance as a part of said control circuit, said second device being responsive to control circuit potentials proportional to the said frequency differential, interconnected discharge circuits for said devices, and electro-responsive means disposed in said discharge circuit of said first device for initiating the closure of said circuit breaker, said impedance being included in the discharge circuit of said second device and effective to prevent said first device from becoming conductive to energize said electro-responsive means while current is flowing in the discharge circuit of said second device.

17. In an automatic synchronizer for controlling the closing operation of a circuit breaker for paralleling alternating current sources, in combination, an electro-responsive control switch, a pair of electrical discharge devices for controlling the energization of said control switch, electrically interconnected discharge circuits for said devices, means operative when connected to said sources for controlling the conductivity of one device in accordance with the phase angle displacement of the voltages thereof, and means operative when connected to said sources for controlling the conductivity of the other device in accordance with the frequency difference between the sources, said devices being connected in series circuit relation through their electrically interconnected discharge circuits to effect energization of the control switch only in response to both of said devices becoming conductive at the same time.

18. In a synchronizer for controlling the closing operation of a circuit breaker to parallel alternating current sources within preselected limits of a frequency and phase angle differentials between said sources, a combination of first and second discharge devices having their anode-cathode terminals connected in series circuit relation and including an impedance connected in series between said devices, said first device being responsive to grid control potentials comprising in series, said impedance, an adjustable positive bias, a pulsating negative bias variable between zero and maximum values in accordance with the phase angle displacement between said sources, said second device being responsive to grid control potential comprising in series an adjustable negative potential, a positive potential to compensate for differences in voltage values between said sources when said sources are in phase with each other, a pulsating negative potential variable between values of zero and maximum dependent upon the phase angle displacement between said sources, and a pulsating positive potential variable between values of zero and maximum in accordance with the difference in frequency between said sources, interconnected discharge circuits for said devices, and electro-responsive means disposed in said discharge circuit of said first device for initiating the closing operation of said circuit breaker, said impedance being included in the discharge circuit of said second device and effective to prevent said grid control of said first device from rendering said first device conductive to energize said electro-responsive means while current is flowing in the discharge circuit of said second device.

19. Synchronizing apparatus for controlling the closing operation of a connecting device to parallel alternating current sources comprising in combination a first and second electrical discharge device, interconnected discharge circuits for said devices, means disposed in the discharge circuit of said first device and operable in response to current flow in the discharge circuit of said first device to initiate the closing operation of said connecting device, control potentials responsive to the phase angle displacement between said sources for rendering said first device conductive, and control potentials responsive to the difference in frequencies between said sources for rendering said second device conductive, said devices being operable when simultaneously conductive within preselected limits of phase angle and frequency differential to produce a flow of current in the discharge circuit of said first device and thereby initiate the closing of said connecting device.

20. A synchronizer for closing a circuit breaker to parallel alternating current sources within preselected limits of phase angle displacement and differences in frequency between said sources, comprising first and second discharge devices, grid control means responsive to phase angle displacement for rendering said first discharge device conductive, grid control means responsive to frequency differential for rendering said second discharge device conductive, and a control relay the operation of which is effected when both of said discharge devices are rendered conductive at the same time.

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