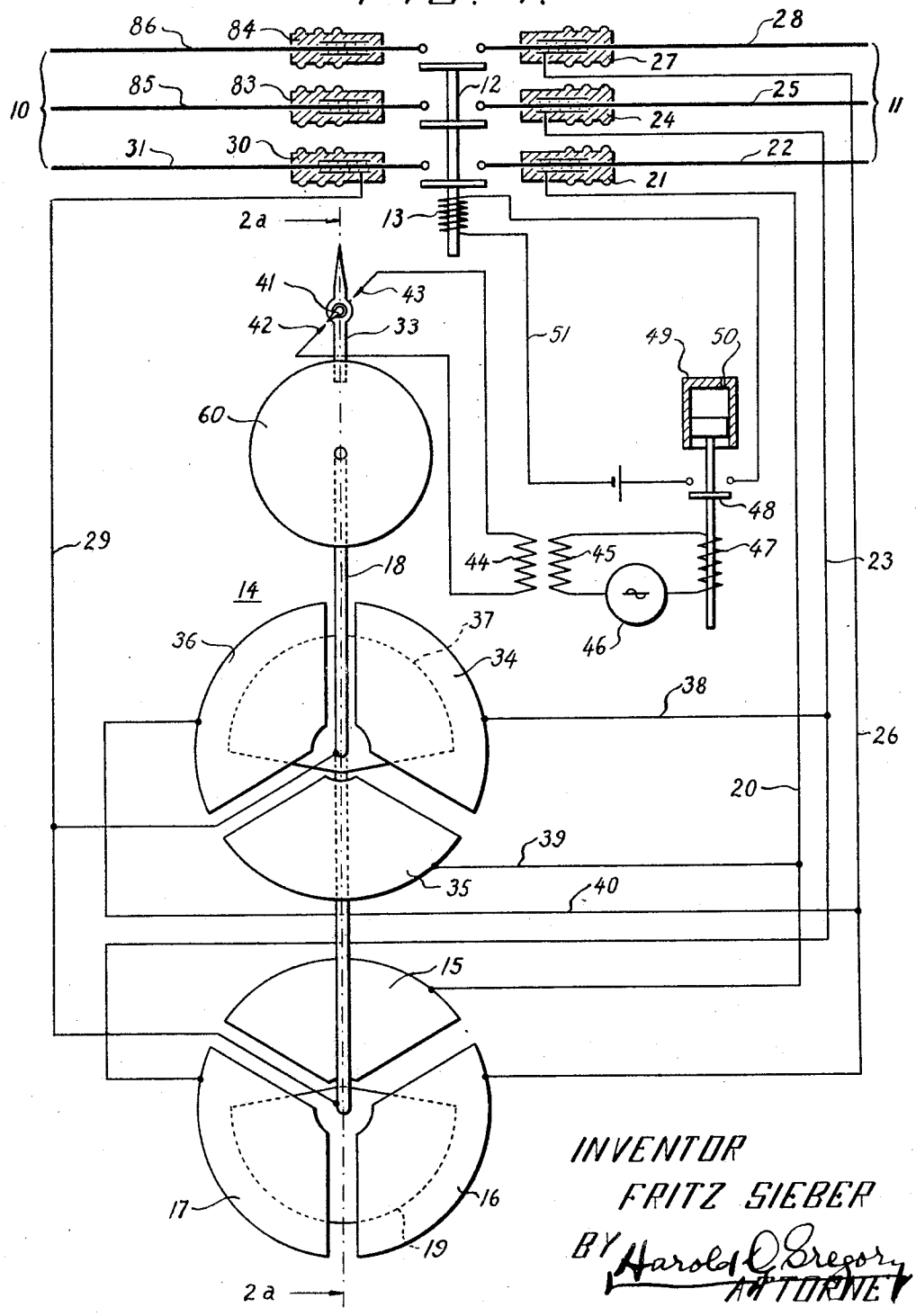
May 31, 1932. F. SIEBER 1,861,166

SYSTEM AND APPARATUS FOR SYNCHRONIZING POLYPHASE LINES

Filed Dec. 10, 1928 3 Sheets-Sheet 1

FIG. 1.



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SYSTEM AND APPARATUS FOR SYNCHRONIZING POLYPHASE LINES

Filed Dec. 10, 1928 3 Sheets-Sheet 2

FIG. 2.

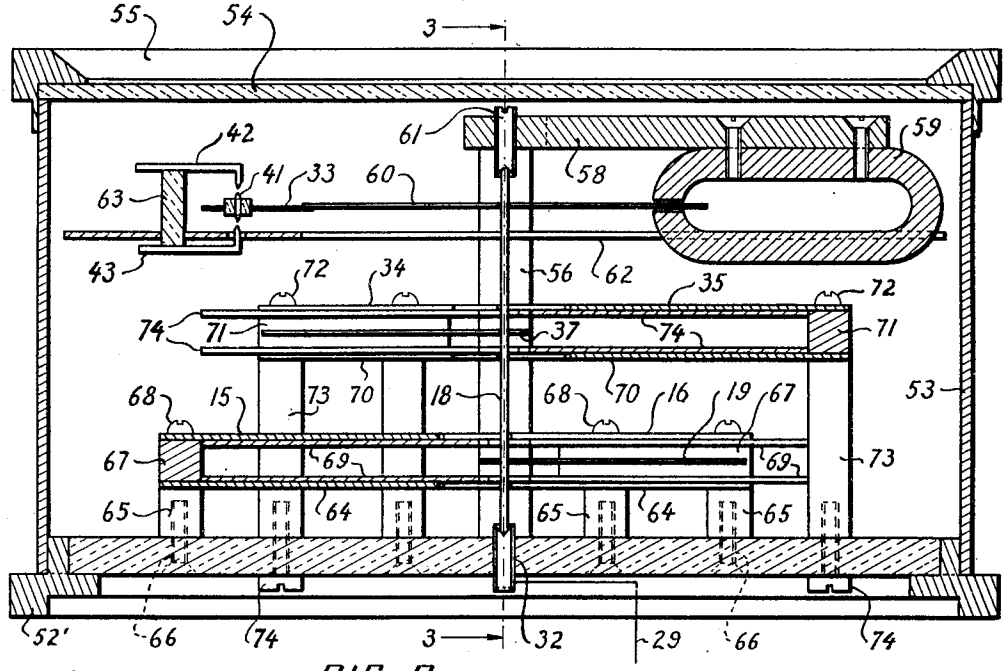
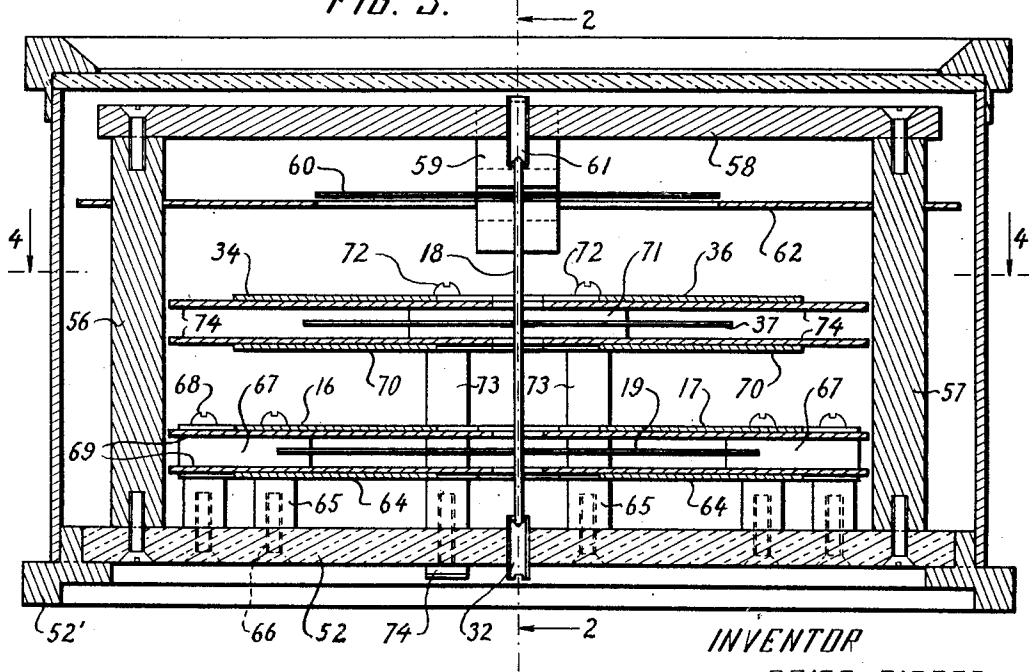


FIG. 3.



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SYSTEM AND APPARATUS FOR SYNCHRONIZING POLYPHASE LINES

Filed Dec. 10, 1928 3 Sheets-Sheet 3

FIG. 4.

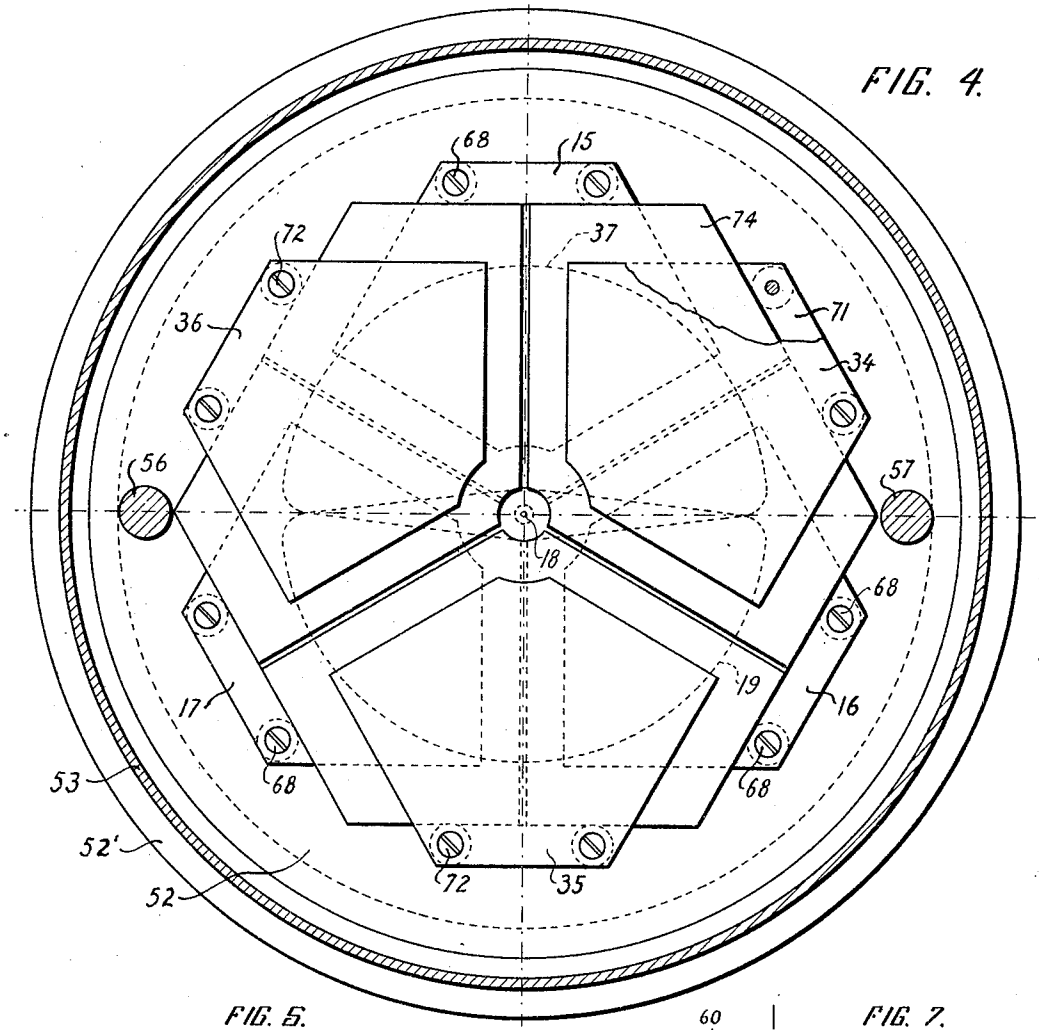


FIG. 5.

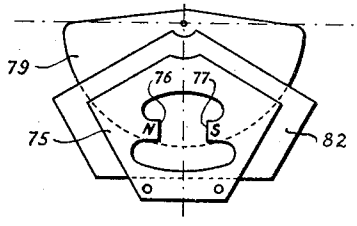


FIG. 6.

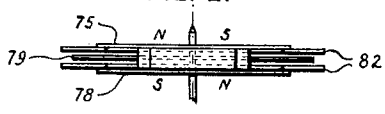


FIG. 7.

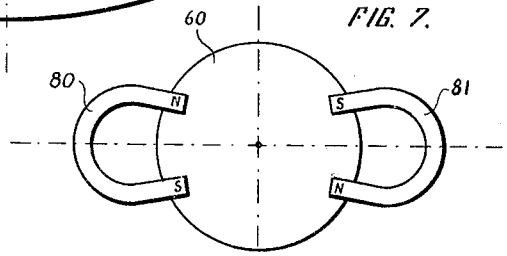


FIG. 8.



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UNITED STATES PATENT OFFICE

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SYSTEM AND APPARATUS FOR SYNCHRONIZING POLYPHASE LINES

Application filed December 10, 1928, Serial No. 325,110, and in Germany December 24, 1927.

This invention relates to improvements in systems and apparatus for synchronizing polyphase lines.

One of the objects of the present invention is to provide an improved system and apparatus of the character referred to operable to provide for the interconnection of polyphase high-tension lines, and wherein the apparatus gives a correct indication of the relative frequencies and the phase relation of the lines to be connected, the apparatus operating independently of the absolute frequencies as well as the wave forms of the voltages in the respective lines.

Another object is to provide an improved system and apparatus of the character referred to wherein the lines are interconnected automatically when the same are substantially in synchronism and in phase with respect to each other.

Another object is to provide improved apparatus of the character referred to which has advantages over those constructed heretofore as regards simplicity and cost of construction, and reliability and sensitivity of operation.

Other objects and advantages will hereinafter appear.

For the purpose of illustrating the invention, one embodiment thereof is shown in the drawings, wherein

Figure 1 is a diagrammatic view showing the manner in which the various parts or elements are connected and disposed for cooperation with each other, certain of the parts being removed for the sake of clearness;

Fig. 2 is a sectional view of the improved apparatus, the section being taken on the line 2—2 in Fig. 3 and corresponding also to a section taken on the line 2*a*—2*a* in Fig. 1;

Fig. 3 is a sectional view, the section being taken on the line 3—3 in Fig. 2;

Fig. 4 is a sectional view, partly broken away, the section being taken on the line 4—4 in Fig. 3;

Fig. 5 is a view similar to Fig. 4, illustrating a modification;

Fig. 6 is a front elevational view of Fig. 5;

Fig. 7 is a view similar to Fig. 4, illustrating another modification; and

Fig. 8 is a front elevational view of Fig. 7.

Referring more particularly to Fig. 1, the polyphase high-tension lines 10 and 11 are interconnected upon closing operation of the switch 12 of usual construction, and which is provided with a suitable closing coil 13 or the equivalent. The lines 10 and 11 connect with polyphase supply sources of conventional design and which have the usual ground connection at some point. Synchronizing apparatus in the form of an electrostatic induction motor, and which embodies the present improvements, is indicated generally by the reference numeral 14, and includes the fixed or stationary complementary, similar, metallic members or sectors 15, 16 and 17 disposed as shown 120 degrees apart with respect to each other in a plane perpendicular to the shaft or spindle 18 supported for rotary movement about its longitudinal axis. A vane or rotor member 19 is fixed on shaft 18 for rotary movement in a plane parallel to and spaced a relatively small distance below the plane of the fixed sectors.

The line 20 provides a connection between sector 15 and a condenser bushing 21 connected as indicated in the phase 22 of line 11, so that a voltage is impressed on sector 15 corresponding exactly with the frequency and wave form of the voltage in phase line 22, but whose magnitude is only a relatively small part of that of the voltage in phase line 22. In like manner, the line 23 provides a connection between sector 17 and the condenser bushing 24 connected in phase line 25. Similarly, the line 26 provides a connection between sector 16 and the condenser bushing 27 connected in phase line 28. The bushings 21, 24 and 27, which may be of any suitable construction, are provided with metallic layers, as indicated, to form or constitute condensers, and to which the respective lines 20, 23 and 26 are connected. A constant fraction of the voltages in line 11 is accordingly impressed on apparatus 14, the disposition of sectors 15, 16 and 17, and the connections of lines 20, 23 and 26 being such as to provide for creation in the apparatus of an electrostatic field rotating about the axis of shaft 18 in synchronism and in phase with the volt-

ages of line 11 and moving through 360 degrees during each cycle.

The rotary vane 19 is connected to the condenser bushing 30 connected in phase line 31 of line 10, such that a voltage is impressed on the vane equal to a fraction of the voltage in phase line 31 and corresponding in frequency and wave form therewith. As more clearly shown in Fig. 2, the connection to vane 19 may be made through shaft 18 by connecting line 29 to the lower bearing 32 of the shaft. The vane 19, which may be made of aluminum, is free to revolve in either direction, and is under the influence of no restoring torque.

In explaining the principle or manner of operation of the improved system and apparatus so far described, it will first be assumed that only the voltages in line 11 are impressed respectively on the fixed sectors 15, 16 and 17, the line 29 being open-circuited. The movable vane 19 will, accordingly, be influenced to the greatest degree by the electrostatic field created in the fixed sectors, and will be attracted and remain opposite to the fixed sector to which it happens to be nearest. If, now, a relatively high direct-current voltage is impressed upon vane 19, such as by connecting a source of direct-current voltage between the latter and the casing of apparatus 14, the movable vane will begin to rotate, and neglecting for friction and retarding action due to damping, such rotation will be at the rate of one revolution during each cycle of line 11. If the direct-current voltage impressed on vane 19, which is of zero frequency, is now replaced by an alternating-current voltage having an increasing frequency, the rate of rotation of the vane will decrease correspondingly, as will be apparent for the reason that the slip or difference between the frequencies of the fixed sectors and the movable vane is now decreasing. When the frequency of the voltage impressed on vane 19 equals the frequency of line 11, there will be no torque on vane 19, and the latter will, accordingly, remain stationary. If the frequency of the voltage impressed on vane 19 is increased such as to be higher than the frequency of line 11, the vane will begin to rotate in the opposite direction, the rate of rotation, as before, corresponding to the difference between the respective frequencies of the vane voltage and that of line 11.

Assuming now that the line or connection 29 between vane 19 and phase line 31 of system 10 is complete, as is the case in normal operation of the apparatus, it will be seen from the foregoing analysis that vane 19 will rotate at a rate corresponding to the so-called slip or difference between the respective frequencies of the voltages of lines 10 and 11 and in a direction depending upon which frequency is greater than the other, the vane completing, theoretically, one revolution for each increase in the slip by one cycle. In actual operation, however, the rate of rotation of the movable vane 19 will be slightly at variance with the degree of slip, because of damping action and friction between the moving parts. When the respective voltages of the two lines 10 and 11 are of equal frequency, the vane 19 will assume and remain in a position indicative of any phase difference between these lines.

If the respective voltages at bushings 21 and 30 are in phase, the same reach their positive maximum values at the same instant, at which time vane 19, positively charged from bushing 30, is repelled by sector 15, positively charged from bushing 21, the vane, at such moment, being also attracted in equal degree by sectors 16 and 17 negatively charged from bushings 27 and 24, respectively, so that the vane and the indicating pointer 33 carried thereby, take up and remain in the position shown in Fig. 1, indicating not only that the respective voltages in phase lines 22 and 31 are in phase, but that the same are of the same frequency and in synchronism. The vane 19 may be considered as part of a polyphase condenser of variable capacitance, and will always take a position which causes it to form a condenser of maximum capacity with the fixed sector of opposite voltage. Variation in the voltages of lines 10 and 11, the same, however, remaining in phase with each other, will cause no deflection or movement of pointer 33 from the position thereof in Fig. 1, since the forces acting on the pointer are proportional to the voltages.

When switch 12 is open, the flow of current may be traced as follows: from phase line 31, the space charge in condenser bushing 30, line 29, the space charge between vane 19 and sectors 15, 16, and 17, lines 20, 23, and 26, the space charges in condenser bushings 21, 24, and 27, line 11, and ground, back to phase line 31.

For the purpose of doubling the torque on pointer 33, with only a relatively small increase in the weight of apparatus 14, a second set of fixed sectors 34, 35 and 36, similar to the first set of sectors 15, 16 and 17, is provided, and is disposed in a plane perpendicular to shaft 18 and above the plane of the first set, a second movable vane 37 being fixed on shaft 18 for rotary movement in a plane parallel to and disposed a relatively small distance below the plane of sectors 34, 35 and 36. The fixed sectors 34, 35 and 36, and the associated movable vane 37, are shifted 180 degrees with respect to the corresponding first set of sectors 15, 16 and 17 and the associated vane 19, and cooperate with each other in the same manner and for the same purpose as the latter. Sector 34 is connected in parallel with the oppositely-related sector 17 by connection 38, while sector 35 is connected in parallel with the correspond-

of one of said lines and providing for creation of an electrostatic field rotating in said members about said axis at a rate corresponding to frequency conditions in said line, another member cooperating with said first-named members and disposed in such field, and means providing an operating connection between said last-named member and one of the phases of the other of said lines.

2. In a system of the character described, a first polyphase line, a second polyphase line, and electrostatic apparatus including a rotor member responsive to voltage conditions in one of the phases of one of said lines and relatively fixed complementary members connected respectively to the phases of the other of said lines and disposed to provide an electrostatic field effective with respect to said rotor member to induce rotary movement thereof.

3. In electrostatic apparatus, members supported for relative movement with respect to each other, certain of said members provided with magnetic pole portions providing a magnetic field effective to oppose such movement.

4. In a system of the character described, a first polyphase line, a second polyphase line, switch means operable to provide an operating connection between said lines, means operable to effect closing operation of said switch means and including complementary spaced electrodes and an element supported for movement into the gap between said electrodes out of contact therewith and arranged to substantially bridge such gap, and means responsive to conditions of synchronization of said lines and being operable upon occurrence of substantially such conditions to effect movement of said element into bridging relation with said electrodes.

5. In electrostatic apparatus, members supported for relative movement with respect to each other, certain of said members being magnetic and having poles of opposite polarity, a pole of a given polarity in one of said certain members being disposed in complementary relation with respect to a pole of opposite polarity in another of said certain members and cooperating therewith to provide a magnetic field effective to oppose such movement.

6. In electrostatic apparatus, a plurality of members disposed in different planes and angularly related with respect to each other, and units associated respectively with said members and angularly related in substantially the same degree as the latter, said members and said units being supported for relative rotary movement, each of said units comprising parts disposed in the same plane about the axis of such rotary movement and cooperable with each other to provide for creation of an electrostatic field effective with respect to the associated member to induce such movement.

7. In electrostatic apparatus, a shaft supported for rotary movement about its longitudinal axis, members carried by said shaft and spaced along the same, said members being angularly related to each other by substantially 180 degrees, and relatively fixed units associated respectively with said members and angularly related in substantially the same degree as the latter, each of said units comprising parts disposed in the same plane about said axis and cooperable with each other to provide for creation of an electrostatic field effective with respect to the associated member to induce such movement thereof.

8. In electrostatic apparatus, a shaft supported for rotary movement about its longitudinal axis, a single vane disposed in a plane substantially transversely to said shaft and carried thereby and eccentrically related thereto in pronounced degree such that the major portion of said vane is located on one side of said shaft, and a plurality of similarly shaped relatively fixed sectors arranged to substantially entirely encircle said shaft and disposed in a plane substantially transverse thereto and in proximity to said first-mentioned plane, said sectors being operable to provide for creation of an electrostatic field rotating about said axis and effective with respect to said vane to induce rotary movement of the same about said axis.

9. In a system of the character described, a first polyphase supply line, a second polyphase supply line, switch means operable to provide an operating connection between said lines, electrostatic apparatus; said apparatus comprising a shaft supported for rotary movement about its longitudinal axis, a single vane disposed in a plane substantially transverse to said shaft and carried thereby and eccentrically related thereto in pronounced degree such that the major portion of said vane is located on one side of said shaft, and a plurality of similarly shaped relatively fixed sectors arranged to substantially entirely encircle said shaft and disposed in a plane substantially transverse thereto and in proximity to said first-mentioned plane; means providing an operating connection between said vane and one of the phases of one of said lines, and means providing operating connections between said sectors and the respective phases of the other of said lines, said sectors cooperating to create an electrostatic field effective with respect to said vane to induce rotary movement thereof about said axis to an extent corresponding to differences in the respective voltage conditions in said lines.

10. In the art of synchronizing polyphase lines, the method which comprises deriving a rotating electrostatic field from one of said lines and subjecting to the influence of said field an electrostatic force corresponding to

conditions of frequency in another of said lines.

11. In a system of the character described, a first polyphase supply line, a second polyphase supply line, switch means operable to provide an operating connection between said lines, a plurality of complementary members disposed about a fixed axis, connections between said members and certain of the phases of one of said lines and providing for creation of an electrostatic field rotating in said members about said axis at a rate corresponding to frequency conditions in said line, another member cooperating with said first-named members and disposed in such field and supported for free rotation substantially about said axis through more than a complete revolution.

12. In a system of the character described, a first polyphase line, a second polyphase line, and electrostatic apparatus including a rotor member responsive to voltage conditions in one of the phases of one of said lines and relatively fixed complementary members connected respectively to the phases of the other of said lines and disposed to provide an electrostatic field effective with respect to said rotor member to induce rotary movement thereof, said rotor member supported for free rotation through more than a complete revolution.

13. Electrostatic apparatus comprising a single vane supported for free and continuous rotation through complete revolutions thereof about a given axis, and sectors disposed in proximity to said vane and about said axis, said vane supported with the major portion thereof on one side of its support.

14. Electrostatic apparatus comprising a single vane supported for free and continuous rotation through complete revolutions thereof about a given axis, a group of sectors disposed in substantially concentric relation with respect to said axis and disposed in proximity to said vane on one side thereof, said vane supported with the major portion thereof on one side of its support, and a second group of sectors disposed in substantially concentric relation with respect to said axis and disposed in proximity to said vane on the other side thereof.

15. Electrostatic apparatus comprising a single vane supported for free and continuous rotation through complete revolutions thereof about a given axis, a group of sectors disposed in substantially concentric relation with respect to said axis and disposed in proximity to said vane on one side thereof, said vane supported with the major portion thereof on one side of its support, and a second group of sectors disposed in substantially concentric relation with respect to said axis and disposed in proximity to said vane on the other side thereof, the respective sectors of said groups disposed in superposed relation with respect to each other, the respective pairs of superposed sectors electrically connected.

In witness whereof I hereto affix my signature this 26th day of November, A. D. 1928.

FRITZ SIEBER.

ing and oppositely-related sector 15 by connection 39, the sector 36 being connected in parallel with the corresponding and oppositely-related sector 16 by connection 40. The vane 37 is connected in parallel with the corresponding and oppositely-related vane 19 through shaft 18, the disposition of the vanes on the shaft providing for balancing thereof without recourse to the use of counterweights.

For the purpose of providing for automatic closing operation of switch 12 when lines 10 and 11 are in synchronism and in phase with each other, a metallic element or pin 41 is fixed in pointer 33 and insulated therefrom, as indicated in Fig. 2, the pin being disposed to substantially bridge the gap between the spaced electrodes 42 and 43 connected, respectively, to the terminals of the transformer secondary 44. The transformer primary 45 is connected, as shown, to a suitable alternating current supply 46 and to the operating coil 47 of the switch 48, the latter being provided with a suitable retarding device shown as being in the form of a dash-pot arrangement 49 provided with the vent opening 50 of such area as to effect the desired degree of retarding action. Upon closure of switch 48, the local circuit 51 provides for excitation of closing coil 13 to effect closing operation of switch 12. When lines 10 and 11 are in synchronism and in phase, and point 33 accordingly assumes the position shown in Fig. 1, pin 41 bridges the gap between electrodes 42 and 43, causing sparks between the latter and the adjacent ends of pin 41, resulting in an increase in the current in primary 45 such as to effect excitation of coil 47 in such degree as to start closing movement of switch 48 against the retarding action of dash-pot 49. If lines 10 and 11 remain substantially in synchronism and in phase a length of time equal at least to the time-delay period of dash-pot 49, switch 48 will reach its closed position, and through local circuit 51 and the associated closing coil 13, effect closing operation of switch 12 to establish interconnection of lines 10 and 11.

The construction of the improved electrostatic apparatus or motor will now be more fully described, referring particularly to Figs. 2, 3 and 4. The casing of the apparatus comprises the base 52 seated in the annular frame member 52′, the cylindrical portion 53 and the glass top or front 54 held in place by the annular frame member 55, the parts being fitted and secured together as shown. The base 52 is of insulating material, the base being tapped centrally to receive the threaded lower bearing 32 for shaft 18. Posts 56 and 57 are secured to base 52 and are arranged as shown, and provide a support for the T-shaped brass part 58 to which is secured the damping magnet 59 receiving and cooperating with the damping disk 60 fixed on shaft 18 and which carries pointer 33. The brass part 58 is tapped to receive the threaded upper bearing 61 for shaft 18. A suitable scale 62 is disposed as shown below and in proximity to pointer 33, and is provided with suitable openings to receive posts 56 and 57, as more clearly shown in Fig. 3, such that the latter provide a support therefor.

The insulating element 63, which separates and to which are secured electrodes 42 and 43, may be carried by scale 62 and secured thereto in any suitable manner, as indicated. The fixed sectors 15, 16 and 17 are arranged respectively above identical and correspondingly disposed sectors 64. Insulating posts 65 are secured to base 52 by studs 66, and provide a support for the lower set of fixed sectors, metallic pieces 67 being interposed between the upper sectors 15, 16 and 17 and the similar and corresponding lower sectors 64 to hold the same in spaced parallel relation and to provide an electrical connection between the opposite sets of sectors, such that sector 15 is electrically connected to the sector 64 directly below it, sector 16 electrically connected to the sector 64 directly below, etc. Bolts 68 extend through the various sectors and the spacing parts 67, and are threaded into the upper adjacent ends of posts 65 to hold the various parts in assembled relation with respect to each other.

The construction just described provides box-shaped metallic sector units disposed 120 degrees apart and within which the vane 19 is disposed for cooperating action with respect thereto. Each of the sectors 15, 16, 17 and 64 are covered on their inner sides with mica sheets 69 corresponding in shape to the sectors, and projecting beyond their edges, the mica providing for a substantial increase in the torque on moving vane 19 by permitting of increase in the electrostatic field beyond the value which would otherwise be permissible without the mica and in air at atmospheric pressure. The torque on the moving vane may also be substantially increased by using partly solid, or liquid, or gaseous dielectrics between the fixed sectors and the vane, and increasing the electrostatic field. For example, the desired increase in torque may be obtained by placing the air in the casing under pressures either a substantial degree above or a substantial degree below atmospheric pressure, or by filling the casing with oil, and increasing the electrostatic field. If the apparatus is filled with oil, the mica insulation may be omitted. The damping magnet 59 and associated parts may also be omitted, as the oil would provide for sufficient damping action.

As in the construction just described, fixed sectors 70, identical in shape and disposed similarly to sectors 34, 35 and 36, are disposed below the latter and are spaced therefrom and

electrically connected thereto by metallic pieces 71 through which the retaining bolts 72 pass into the upper ends of supporting posts 73 secured to base 52 by studs 74. Mica sheets 74, similar to the sheets 69, cover the inner adjacent faces of sectors 34, 35, 36 and 70, and extend beyond the edges thereof. The construction and arrangement of the upper set of fixed sectors 34, 35, 36 and 70, and the associated vane or rotary member 37, and the manner of cooperation of these parts with respect to each other, is the same as that of the lower set or unit of fixed sectors and the vane 19 associated therewith.

The improved apparatus or electrostatic motor may be slightly unbalanced, such that pointer 33 assumes a position at the lowest point of scale 62 behind damping magnet 59 when the apparatus is idle, and the apparatus calibrated to account for this unbalance, if necessary. The casing of the apparatus may be grounded, if desired.

The damping magnet 59 and its associated parts may be omitted, and the damping action provided by the arrangement shown in Figs. 5 and 6, in which case the fixed sectors 75 provide the damping action and are made of steel plates stamped out as shown to provide the magnetic poles 76 and 77, the former being a north pole and the latter being a south pole, as indicated. In such construction, the opposite sector 78 is identical in shape to its associated sector 75, but the magnetic poles are reversed, as indicated in Fig. 6, that is, the north pole of sector 75 is vertically opposite the south pole of sector 78, while the south pole of sector 75 is vertically opposite the north pole of sector 78. Such construction provides magnetic fields passing through the outer edge portion of the interposed vane 79, and provides a damping action with respect thereto in accordance with the well-known principle. The removal of the central portions of the fixed, steel sectors 75 and 78 in the construction just described, for the purpose of providing the magnetic poles 76 and 77, might be found to have an appreciable effect in the way of detracting from the effectiveness of these sectors in providing the proper amount of electrostatic field. In such case, it is contemplated to replace the removed or stamped-out steel portions by similarly-shaped inserts of non-magnetic material such as brass. The brass inserts would then provide for substantially the same amount of electrostatic field as in the construction of Fig. 4, without interferring or detracting from the influence of the magnetic poles 76 and 77 with respect to the associated vanes 79. In addition to the use of such brass or other non-metallic inserts, or in lieu thereof, the mica sheets 82 might be provided with metallic coatings on the faces thereof directly adjacent the associated sectors 75 and 78 and extending over an area equal substantially to the projected areas of the sectors.

In the construction of Figs. 7 and 8, two sets of horseshoe magnets 80 and 81, disposed as shown and supported in any suitable manner, are substituted for the damping magnet 59 in Fig. 2 and provide a damping action with respect to the interposed damping disk 60, the respective poles of the horseshoe magnets being related as indicated.

While the movable vanes or rotor members 19 and 37 have been shown as being connected to bushing 30 in phase line 31 of line 10, the same may be connected instead to either of the bushings 83 and 84 in the phase lines 85 and 86, respectively, in which case it will be appreciated that either the various connections between the fixed sectors and the respective phase lines of line 11 will be changed accordingly, or the angular position of scale 62 changed correspondingly. For example, if the various connections between the fixed sectors and the respective phase lines of line 11 are changed, assuming that vanes 19 and 37 are connected to bushing 83 instead of bushing 30, the fixed sectors 15 and 35 will be connected to bushing 24 in phase line 25, the fixed sectors 16 and 36 will be connected to bushing 21 in phase line 22, and the fixed sectors 17 and 34 will be connected to bushing 27 in phase line 28.

From the foregoing it will be seen that an improved system and apparatus has been provided for synchronizing polyphase lines, and wherein automatic interconnection of the latter is provided for when the same are substantially in synchronism and in phase with respect to each other, the improved apparatus, during the synchronizing operation, providing an indication as to any difference in frequency or phase which might exist between the two lines, and, more particularly, an indication as to which line is higher in frequency than another when the respective frequencies of the two differ.

Furthermore, the indications of the present improved synchronoscope are independent of the magnitudes of the two network line voltages.

While but one embodiment of the invention has been shown and described for the purpose of illustrating the same, it will be understood that various changes may be made such as in the size, shape and arrangement of the parts without departing from the spirit of the invention or the scope of the claims.

The invention claimed is:

1. In a system of the character described, a first polyphase supply line, a second polyphase supply line, switch means operable to provide an operating connection between said lines, a plurality of complementary members disposed about a fixed axis, connections between said members and certain of the phases