No. 684,579. Patented Oct. 15, 1901.

C. J. A. MICHALKE.

MEANS FOR OPERATING ELECTRICAL MACHINES SYNCHRONOUSLY.

(Application filed Dec. 31, 1897. Renewed Mar. 1, 1901.)

(No Model.) 3 Sheets—Sheet 1.

Fig. 1.

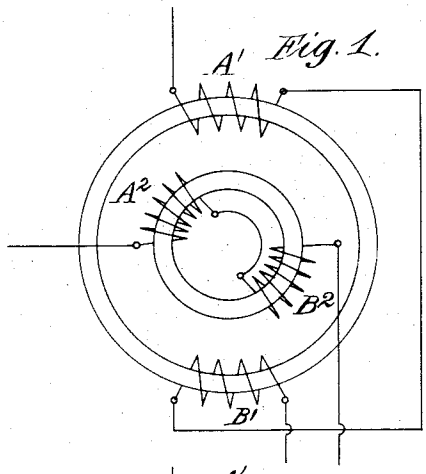


Fig. 3.

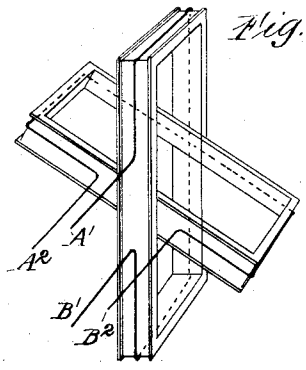
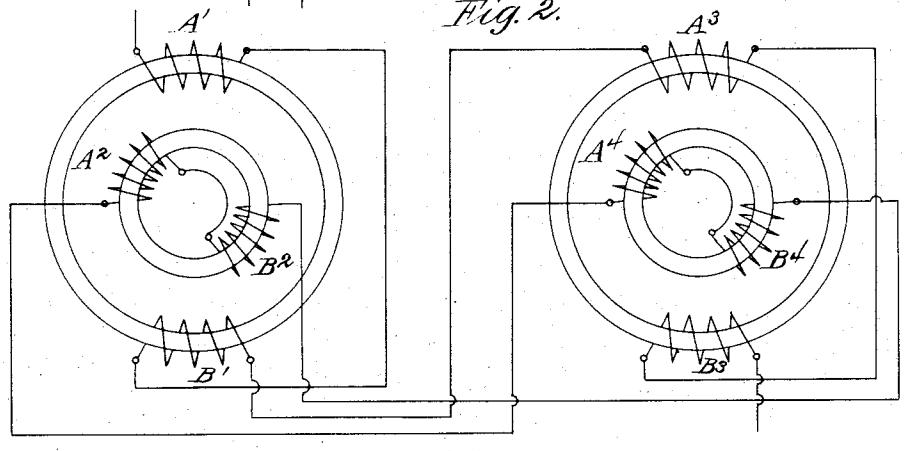


Fig. 2.



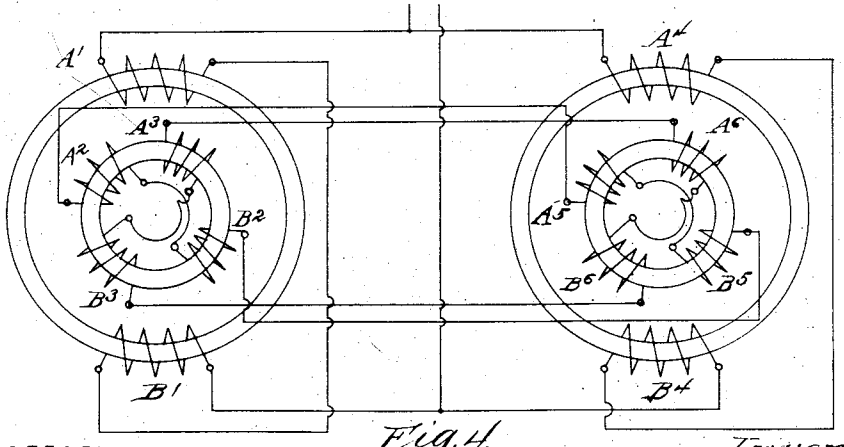


Fig. 4.

Witnesses:
D. W. C. Sanner.
George L. Cragg

Inventor,
Carl Joseph August Michalke,
By Barton & Brown
Attorneys.

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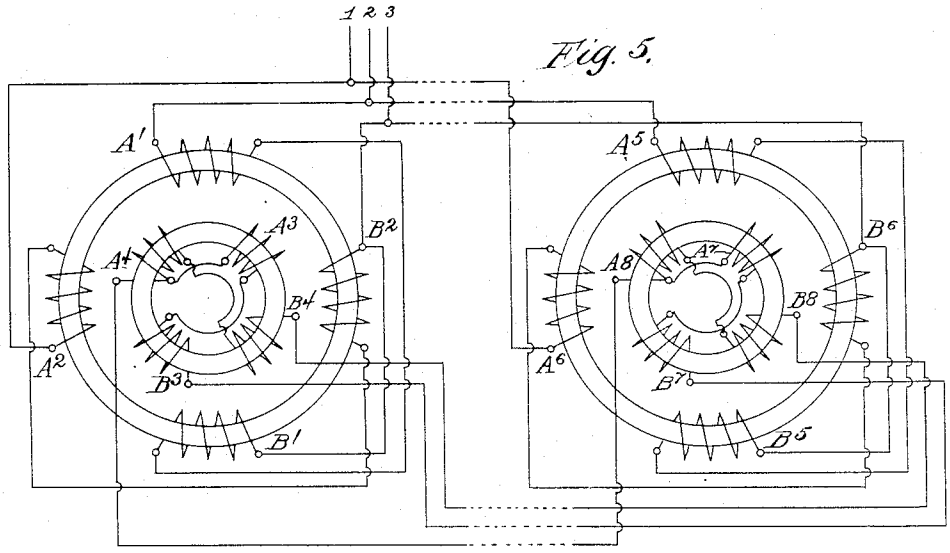
(No Model.) 3 Sheets—Sheet 2.

Fig. 5.



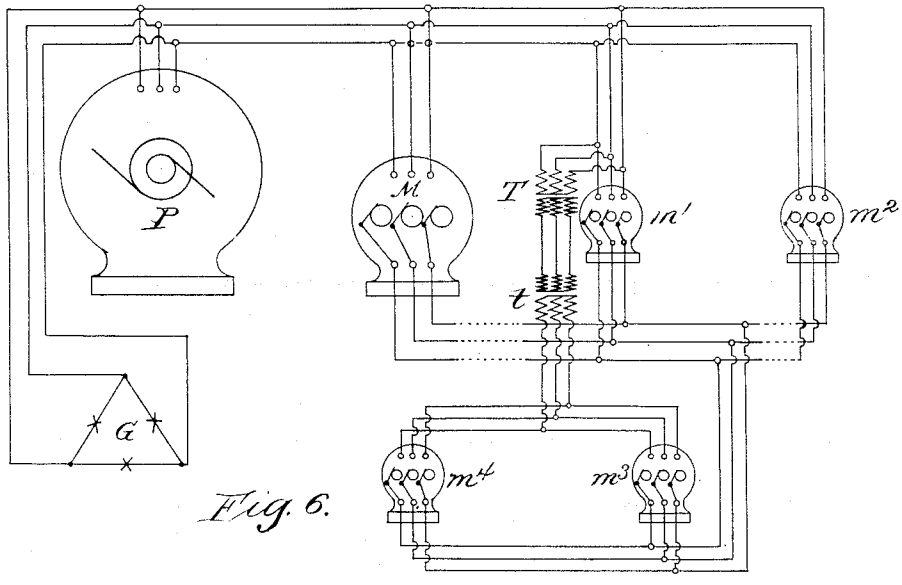


Fig. 6.

Witnesses:
D. W. C. Danner.
George L. Cragg.

Inventor,
Carl Joseph August Michalke,
By Dyrenforth & Brown
Attorneys.

No. 684,579. Patented Oct. 15, 1901.

C. J. A. MICHALKE.

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(Application filed Dec. 31, 1897. Renewed Mar. 1, 1901.)

(No Model.) 3 Sheets—Sheet 3.

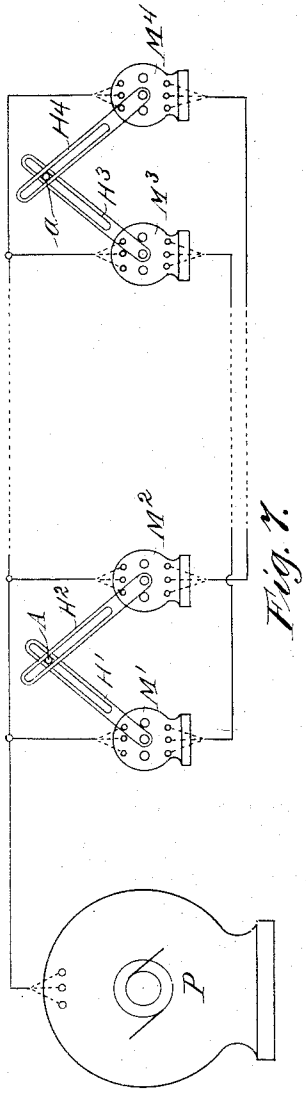

Fig. 1.

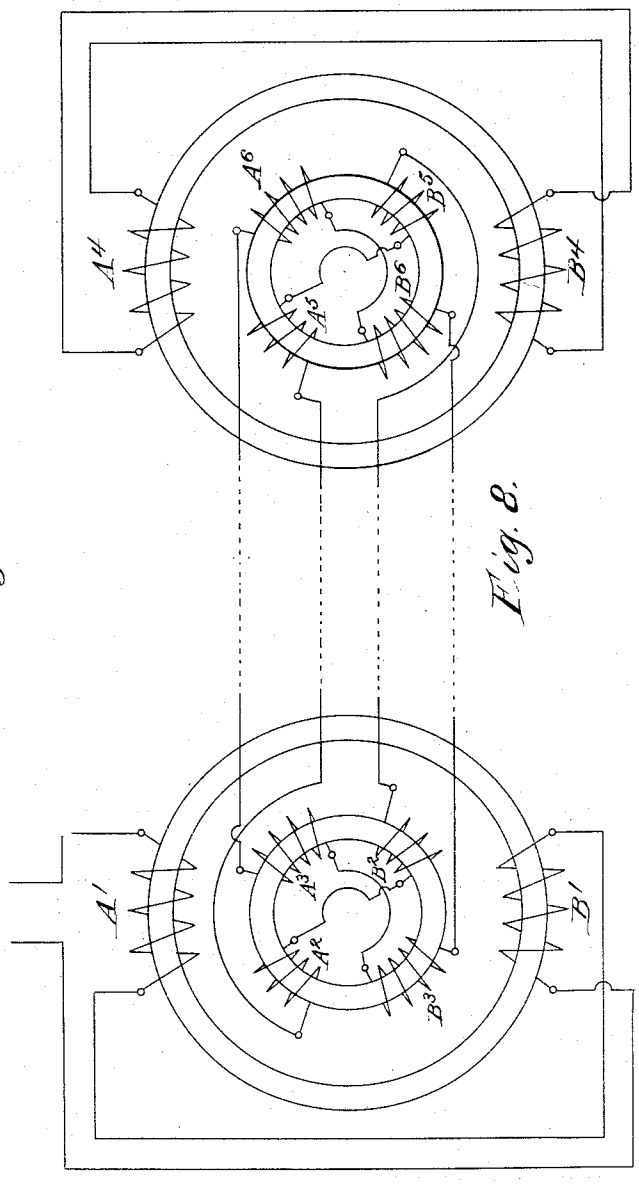

Fig. 2.

Witnesses:
D. W. C. Danner,
George L. Cragg

Inventor
Carl Joseph August Michalke,
By Parton & Brown
Attorneys.

UNITED STATES PATENT OFFICE.

CARL JOSEPH AUGUST MICHALKE, OF CHARLOTTENBURG, GERMANY, ASSIGNOR TO THE SIEMENS & HALSKE ELECTRIC COMPANY OF AMERICA, OF CHICAGO, ILLINOIS, A CORPORATION OF ILLINOIS.

MEANS FOR OPERATING ELECTRICAL MACHINES SYNCHRONOUSLY.

SPECIFICATION forming part of Letters Patent No. 684,579, dated October 15, 1901.

Application filed December 31, 1897. Renewed March 1, 1901. Serial No. 49,491. (No model.)

To all whom it may concern:

Be it known that I, CARL JOSEPH AUGUST MICHALKE, a subject of the Emperor of Germany, residing at Charlottenburg, Germany, have invented new and useful Improvements in Means for Operating Electrical Machines Synchronously, (Case No. 117,) of which the following is a specification, reference being had to the accompanying drawings, forming a part of the specification, for which Letters Patent have been granted in Germany, No. 93,912, dated October 11, 1896; in Italy, No. 44,316, dated June 3, 1897; in Belgium, No. 127,143, dated March 22, 1897; in France, No. 265,359, dated March 25, 1897; in Austria, No. 47/1,622, dated May 6, 1897, and in Switzerland, No. 14,287, dated March 16, 1897.

The present invention relates to means for operating electrical machines synchronously, and has for its object to provide an apparatus for transmitting motion from one point to another situated at a greater or less distance therefrom in such a manner that a determined movement at one point may be accurately reproduced at the distant point whether the amount of energy transmitted by such motion be great or small.

The invention is illustrated in the accompanying drawings, in which—

Figure 1 shows, diagrammatically, the relatively movable members of a dynamo-electric machine. As shown in this figure, each member is provided with a winding consisting of a coil or pair of coils, and the windings are so positioned that the polar lines of the two members are angularly displaced from one another. Fig. 2 shows the windings of two such dynamo-electric machines suitably connected for reproducing motion in accordance with my invention. Fig. 3 indicates diagrammatically that the dynamo-electric machines may, if desired, be provided with drum-windings. Figs. 4 and 5 show modified arrangements suitable for carrying out my invention. Fig. 6 illustrates a system wherein a plurality of synchronously-operating machines are connected to a common circuit. Fig. 7 illustrates a system in which both the transmitting and receiving devices comprise a plurality of machines, and Fig. 8 shows an arrangement for carrying out my invention in which one of the dynamo-electric machines is supplied with current directly and the other by induction.

Like characters refer to like parts throughout the different figures of the drawings.

In Fig. 1, A′ B′ represent a fixed winding comprising a coil or pair of coils, and A^2 B^2 a similar movable winding. If the winding A′ B′ is connected to a source of alternating currents, there will be induced in the winding A^2 B^2 an electromotive force which will depend upon an angle which the two windings form with one another. If both windings are supplied with alternating currents of the same frequency, there will be produced a turning moment, in consequence of which the two windings will reciprocally attract or repel each other. This turning moment will depend on the strength of current in the two windings, the differences of phase of the two currents, and the angle which the windings form with one another.

In Fig. 2 I have illustrated two dynamo-electric machines provided with windings similar to those shown in Fig. 1. The fixed windings A′ B′ and A^3 B^3 are connected in series, so that current will flow in the same direction through both of them, and the windings A^2 B^2 and A^4 B^4 are so connected that their electromotive forces oppose each other. Assuming for the sake of simplicity that the windings of the two machines are identical in size and arrangement of coils, then if an alternating current is passed through the fixed windings A′ B′ and A^3 B^3 there will be produced in the windings A^2 B^2 and A^4 B^4 electromotive forces which will be equal to each other if these windings occupy the same relative position with respect to the windings of the fixed members, but which will be of different value if the respective fixed and movable windings form different angles with each other. In the latter case an equalizing-current will flow through the leads joining the windings on the movable members and this current will be proportional to the difference between the electromotive forces developed in the windings of the movable members. The equalizing-current will produce a turning moment,

in consequence of which the movable members will be caused to shift until their windings assume identical positions relatively to the windings of the fixed members. As soon as this condition obtains the current in the connecting-leads, and consequently the turning moment, will disappear and the members will remain in the position to which they have been brought. The above-described arrangement will therefore have this effect, that the movable members will always be brought into the same position relatively to the fixed members, so that if one member—for example, the member having the winding $A^2 B^2$—be moved through a small angle the other member—in this case the member having the winding $A^4 B^4$—will turn in the same direction through the same angle. Consequently any movement of the movable member of one machine will be transmitted to the movable member of the other machine. Instead of constructing the windings as ring-windings in the manner illustrated in Fig. 1, they may evidently be constructed as drum-windings, and this I have indicated in Fig. 3 of the drawings. Furthermore, it is not necessary that the windings of the two machines should be exactly alike. It is only necessary to so proportion them that with the same relative positions of the fixed and movable members the same electromotive forces will be induced. Instead of connecting the windings A' B' and $A^3 B^3$ in series they may also be connected in parallel without in any way affecting the above-described action. Also the positions of the fixed and movable coils may be reversed. With the arrangement above described there occur positions of the movable windings relatively to the fixed windings in which a change of position produces no alteration of the electromotive forces, so that no mechanical action will take place. Instead, therefore, of providing the movable members with a winding consisting of a single coil or a pair of coils it is preferable to employ a large number of coils or pairs of coils symmetrically arranged, in which case the turning moment will be substantially uniform in all positions of the movable members.

Fig. 4 shows an arrangement in which the winding of the movable members comprises two pairs of movable coils crossing each other at right angles. The corresponding pairs A^2 B^2 and A^5 B^5, A^3 B^3 and A^6 B^6 are respectively connected together and the fixed pairs of coils A' B' and A^4 B^4 are connected in parallel. The same effect would of course be produced if the latter pairs were connected in series instead of parallel The fixed members may be provided with windings adapted to be supplied with polyphase currents, and in Fig. 5 I have shown such an arrangement. In this figure the fixed and movable members of both machines are provided with two pairs of coils crossing each other at right angles, the corresponding coils on the fixed members being connected in parallel and the corresponding coils on the movable members being connected in opposition in the manner already explained. The windings on the fixed members are arranged to be supplied with current from a two-phase generator through the leads 1, 2, and 3. Two leads are combined in one in a well-known manner, so that only three supply-leads and three connecting-leads are required. The receiving apparatus will move accurately synchronously with the transmitting apparatus, the motion being quite independent of the direction of rotation of the rotary field, so that whether the transmitting apparatus be turned in the direction of the rotating field or in the contrary direction the receiving apparatus will always move in the same direction through a corresponding angle. Instead of two-phase current any polyphase current may be employed, and in Fig. 6 I have illustrated an arrangement in which the transmitter and receivers are supplied with three-phase current from the generator P. As shown in this figure, there may be a number of machines so connected that when one of them is moved through a certain angle all the others will follow through the same angle. The machine supplying the primary current may be any ordinary generator supplying current at the same time to other translating devices, and this I have indicated by showing the generator P supplying current to lighting-circuits at G.

In Fig. 6 the machines M and $m' m^2 m^3 m^4$ have their fixed members supplied with current from a common source and the windings of their movable members are connected together, so that every movement in one machine is followed by a corresponding movement in all the other machines. If one of the machines is rotated continuously, all the other machines will follow in exactly the same manner, or if one of the machines is moved with a step-by-step motion through a certain angle the others will be similarly moved step by step. If the distance between the transmitting and receiving apparatus is great, transformers may be included in the circuits to increase the pressure in the transmission-line. I have indicated such an arrangement in Fig. 6, in which the transformer T raises the potential of the current supplied to the machines m^3 and m^4, the potential being again reduced at the machines by the transformer *t*.

In Fig. 7 both the transmitting and receiving devices comprise two machines. The movable members of the machines M' and M^2 carry the arms H' and H^2, each provided with longitudinal slots engaging a common pin A. At a distant point two other machines M^3 and M^4 have their movable members provided with similar slotted arms H^3 and H^4, engaging a pin *a*. Any movement of either of these pins will cause the pin at the distant point to move in exactly the same manner, so that one pin will exactly reproduce the movement of

the other. In this way the configuration of designs may be readily transmitted through any distances. In the arrangements thus far described both the transmitter and the receiver have been directly connected to the source of alternating current. It is, however, not necessary to magnetize directly both the transmitter and receiver, and in Fig. 8 I have shown that one member of the receiver may be magnetized by induction. The advantage obtained by this is that the number of wires connecting the receiver and transmitter is diminished and that sliding contacts may be dispensed with in one machine, since either member may be made the rotating member.

In Fig. 8 the winding A′ B′ is arranged to be connected to any appropriate source of alternating current, and electromotive forces are induced in the windings A^2 B^2 and A^3 B^3, dependent upon the angles which these windings make with the winding A′ B′. The windings A^5 B^5 and A^6 B^6 on the other machine are connected to the corresponding windings A^2 B^2 and A^3 B^3, and the other member of this machine is provided with a winding A^4 B^4, short-circuited on itself. The combined action of the two windings A^2 B^2 and A^3 B^3 of one machine will produce in the corresponding member of the other machine a combined field, the position of which will depend on the magnitude of the separate pressures at the terminals of the windings A^2 B^2 and A^3 B^3. Since the magnitude of these pressures depends upon the position of the stationary member relatively to the movable member, the position of the field in the other machine—that is to say, the resultant magnetization due to the windings A^5 B^5 and A^6 B^6—will depend on the position of the movable member relatively to the fixed member of the first machine. If the machine having the winding A′ B′ is made the transmitter, and if the windings A^2 B^2 and A^3 B^3 as well as A^5 B^5 and A^6 B^6 are equal, the field strength in the receiver will be constant in magnitude, but will have a position dependent upon the relative position of the fixed and movable members of the transmitter. If the winding A^4 B^4 of the receiver is short-circuited, the movable member of the receiver will always tend to come to rest in that position which induces the minimum current in the short-circuited winding. When, therefore, the movable member of the transmitter is turned, the poles in the receiver are shifted and the receiver is turned to a corresponding degree. The movements of the transmitter are conveyed to the receiver, and, conversely, movements of the receiver may be conveyed to the transmitter.

This invention is not to be mistaken for the known arrangements for transmitting synchronous motion, in which alternating currents, either polyphase or single phase, produced in a member of one machine by its rotation with respect to a direct-current field are transmitted to the similar member of another machine provided with a direct-current field. In this case a determined movement of one member of one of the machines does not produce a corresponding movement of a member in the other machine, as in the present invention, and there is no tendency for the corresponding members of the transmitting and receiving machines to assume the same position of rest.

In the arrangement constituting my invention the transmitting device, whether in motion or at rest, operates to impress upon the winding of the receiving device electromotive forces which produce a flow of current in the said winding whenever the receiving device does not occupy a position corresponding to that of the transmitting device, this flow of current being in such a direction as to cause the receiving device to move into a position corresponding to the position occupied by the transmitting device. When the movable member of the transmitting device is continuously rotated, the electromotive forces impressed upon the winding of the receiving device are progressively varied and the receiving device is caused to rotate continuously at the same rate that the transmitting device is rotated.

While I have herein shown and particularly described certain embodiments of my invention, I do not wish to limit myself to the precise arrangements shown, and I aim to cover in the appended claims all modified arrangements which embody the essence of my invention.

Having thus described the invention, what I claim as new, and desire to secure by Letters Patent, is—

1. In an alternating-current power-circuit, the combination with a plurality of armatures each provided with an alternating-current winding, of field-windings for each of said armatures deriving their current from any suitable source of alternating current independently of the armatures, and leads for electrically interconnecting the said armatures for the purpose of producing equalizing-currents therein when the armatures do not occupy corresponding relative positions, substantially as described.

2. In an alternating-current power-circuit, the combination with a plurality of armatures, each provided with an alternating-current winding, of field-windings for each of said armatures deriving their current from any suitable source of alternating current independently of the armatures, and leads for electrically interconnecting the said armatures, the mechanical rotation of one armature creating equalizing-currents in the said leads whereby the armatures are brought to corresponding relative positions, substantially as described.

3. In an alternating-current power-circuit, the combination with a plurality of alternating-current generators, of a like number of alternating-current motors, the field-coils of

the machines receiving their current from a common source, and the armature of each generator being short-circuited through an armature of a motor, slotted arms rigidly fastened to the shaft of each armature, a pin for engaging the slotted arms of the generator-armatures, and a pin for engaging the slotted arms of the motor-armatures, the movement of the generator-pin occasioning a corresponding movement of the motor-pin, substantially as described.

4. In an alternating-current power-circuit, the combination with a plurality of armatures, each provided with a single alternating-current winding, of field-windings for each of said armatures deriving their current from any suitable source of alternating current independently of the armatures, and leads for electrically interconnecting the said armatures for the purpose of producing equalizing-currents therein when the armatures do not occupy corresponding relative positions, substantially as described.

5. In an alternating-current power-circuit, the combination with a plurality of armatures, each provided with an alternating-current winding, of field-windings for each of said armatures deriving their current from any suitable source of alternating current independently of the armatures, and leads for electrically interconnecting the said armatures for the purpose of producing equalizing-currents therein when the armatures do not occupy corresponding relative positions, whereby the said armatures are brought into corresponding relative positions, substantially as described.

6. In an alternating-current power-circuit, the combination with a plurality of armatures, each provided with an alternating-current winding, of field-windings for said armatures receiving their current from a common source of alternating current independently of the armatures, and leads for electrically interconnecting the said armatures for the purpose of producing equalizing-currents therein when the armatures do not occupy corresponding relative positions, substantially as described.

7. In an alternating-current power-circuit, the combination with a plurality of armatures, each provided with an alternating-current winding, of field-windings for said armatures receiving their current from a common source of alternating current independently of the armatures, and leads for electrically interconnecting the said armatures, the mechanical rotation of one armature creating equalizing-currents in the said leads whereby the armatures are brought to corresponding relative positions, substantially as described.

8. In an alternating-current power-circuit, the combination with a plurality of armatures, each provided with a single alternating-current winding, of field-windings for said armatures receiving their current from a common source of alternating current independently of the armatures, and leads for electrically interconnecting the said armatures for the purpose of producing equalizing-currents therein when the armatures do not occupy corresponding relative positions, substantially as described.

9. In an alternating-current power-circuit, the combination with a plurality of armatures, each provided with an alternating-current winding, of field-windings for said armatures receiving their current from a common source of alternating current independently of the armatures, and leads for electrically interconnecting the said armatures for the purpose of producing equalizing-currents therein when the armatures do not occupy corresponding relative positions, whereby the said armatures are brought into corresponding relative positions, substantially as described.

10. A means for transmitting a determined movement to a distance, comprising, in combination, a transmitting device having relatively movable members provided with suitable windings, a receiving device having relatively movable members provided with similar windings, means for supplying alternating currents to the winding on one of the members of each device, and leads electrically interconnecting corresponding points in the windings of the other members for the purpose of producing equalizing-currents therein when the members of the said devices do not occupy corresponding relative positions.

11. A means for transmitting a determined movement to a distance, comprising, in combination, a transmitting device having relatively movable members provided with suitable windings, a receiving device having relatively movable members provided with similar windings, means for supplying alternating currents to the winding on one of the members of each device, leads for electrically interconnecting corresponding points in the windings of the other members, and means for producing a relative rotation between the members of the transmitting device.

12. A means for transmitting a determined movement to a distance, comprising, in combination, a transmitting device and a receiving device, each of said devices having relatively movable members provided with suitable windings, means for producing a single-phase alternating current in the winding on one of the members of each of said devices, and leads electrically interconnecting corresponding points in the windings of the other members.

13. A means for transmitting a determined movement to a distance, comprising, in combination, a transmitting device and a receiving device, each of said devices having relatively movable members provided with suitable windings, means for producing a single-phase alternating current in the winding on one of the members of each of said devices, leads for electrically interconnecting corre-

sponding points in the windings of the other members, and mechanical means for producing a relative rotation between the members of the transmitting device.

14. A means for transmitting a determined movement to a distance, comprising, in combination, a transmitting device consisting of a plurality of dynamo-electric machines, a receiving device consisting of a like number of dynamo-electric machines, means for supplying alternating currents to the windings on one of the members of each of said devices, means for electrically interconnecting corresponding points in the windings on the other members of the corresponding machines of the transmitting and receiving devices, a movable device operatively connected to each of the dynamo-electric machines constituting the transmitting device, and a device to be moved operatively connected to each of the dynamo-electric machines constituting the receiving device.

15. A means for transmitting a determined movement to a distance, comprising, in combination, a transmitting device consisting of a plurality of dynamo-electric machines, a receiving device consisting of a like number of similar machines, means for supplying alternating currents to the winding on the fixed members of each of said devices, means for electrically interconnecting corresponding points in the windings on the rotatable members of the corresponding machines of the transmitting and receiving devices, a slotted arm rigidly fastened to the rotatable member of each machine, a pin for engaging the slotted arms of the transmitting device, and a pin for engaging the slotted arms of the receiving device, whereby a movement of one of the pins will occasion a corresponding movement of the other pin.

16. In combination, a plurality of dynamo-electric machines, each comprising relatively movable members provided with suitable windings, means for electrically interconnecting corresponding points in the windings of one of the members of each machine, means for supplying alternating currents to the windings of the remaining member of each machine, and means for producing any desired relative movement between the members of one of said machines and thereby obtaining a corresponding relative movement between the members of the other machines.

17. In combination, a plurality of dynamo-electric machines, each comprising relatively movable members provided with suitable windings, means for supplying alternating currents to one of the windings of each of said machines, means for electrically interconnecting corresponding points in the remaining windings of said machines, and means for producing any desired relative movement between the members of one of said machines and thereby obtaining a corresponding relative movement between the members of the other machines.

18. A means for transmitting a determined movement to a distance, comprising, in combination, a receiving device having relatively movable members provided with suitable windings, means for supplying alternating currents to the winding on one of the members of said device, and a transmitting device for supplying alternating currents of the same frequency to the winding on the other member, the said transmitting device being constructed and arranged to progressively vary, at any desired rate, the electromotive forces at the terminals of the winding on the receiving device to which it is connected.

19. A means for transmitting a determined movement to a distance, comprising, in combination, a receiving device having relatively movable members provided with suitable windings, means for supplying alternating currents to the winding on one of the members of said device, and a transmitting device connected to an alternating-current source of the same frequency and arranged to supply current to the winding on the other member of the receiving device, the said transmitting device being constructed and arranged to progressively vary, at any desired rate, the electromotive forces impressed upon the terminals of the winding on the receiving device.

In testimony whereof I affix my signature in the presence of two witnesses.

CARL JOSEPH AUGUST MICHALKE.

Witnesses:

JOHANNES GÖRGES,

PAUL ROEDIZER.