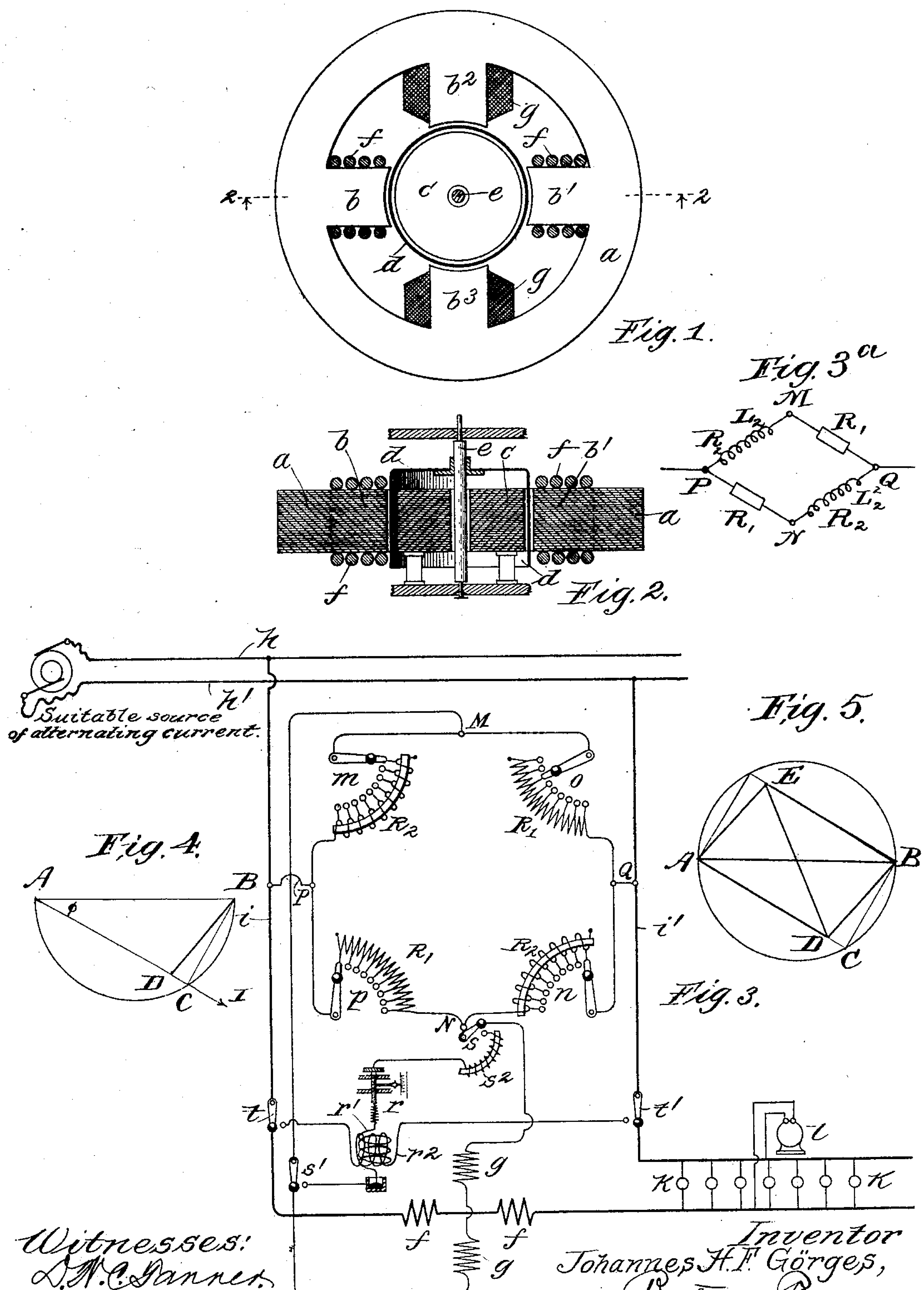
No. 611,902. Patented Oct. 4, 1898.

J. H. F. GÖRGES.

APPARATUS FOR ADJUSTING PHASES OF ALTERNATING CURRENTS.

(Application filed Dec. 27, 1897.)

(No Model.)



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UNITED STATES PATENT OFFICE.

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APPARATUS FOR ADJUSTING PHASES OF ALTERNATING CURRENTS.

SPECIFICATION forming part of Letters Patent No. 611,902, dated October 4, 1898.

Application filed December 27, 1897. Serial No. 663,569. (No model.) Patented in Germany August 13, 1896, No. 94,564; in Switzerland January 18, 1897, No. 13,726; in France March 3, 1897, No. 264,623; in Austria April 4, 1897, No. 47/1,216, and in Italy May 7, 1897, No. 44,048.

To all whom it may concern:

Be it known that I, JOHANNES HEINRICH FRIEDRICH GÖRGES, a subject of the Emperor of Germany, residing at Berlin, Germany, have invented new and useful Improvements in Alternating-Current Dynamos, (Case No. 109,) of which the following is a specification, reference being had to the accompanying drawings, forming a part of this specification, and for which Letters Patent have been granted in Germany, No. 94,564, dated August 13, 1896; in Italy, No. 44,048, dated May 7, 1897; in France, No. 264,623, dated March 3, 1897; in Switzerland, No. 13,726, dated January 18, 1897, and in Austria, No. 47/1,216, dated April 4, 1897.

My invention relates to apparatus for adjusting the phases of alternating currents, and more particularly to apparatus for dividing a single alternating current into two currents displaced as to each other by a definite phase angle.

In the operation of split-phase alternating-current motors phase-adjusting apparatus is of great value for producing from a single alternating current two alternating magnetic fields differing from one another in phase by an angle of ninety degrees. The two magnetic fields thus obtained may be caused to operate at right angles to one another, whereby a rotating magnetic field is produced whose movement is truly circular. While apparatus for such a purpose is not wholly unknown, it has heretofore taken such a form that there was great difficulty in securing an exact and definite phase difference between the two magnetic fields, and this difficulty was enhanced if a motor was designed and adjusted for currents of particular value and characteristics and it became necessary to change the phase difference to adapt the motor for variations in the current characteristics impressed upon the distributing-mains of the system or for altered conditions of work.

It is the purpose of the present invention to provide means for splitting a single alternating current and deriving therefrom two alternating currents differing from one another by a definite phase angle of any required magnitude, either greater or less than ninety degrees. I have found that this may be accomplished by dividing the current into two parallel paths, each of which contains resistance and phase-modifying means and bridging a conductor across said parallel paths, whereupon by a suitable proportioning of resistance and phase-modifying means in the two branch circuits the current in the bridged circuit may be given the desired phase relation to that flowing in the main circuit. An induction-motor having two angularly-disposed windings may be operated advantageously with this arrangement by connecting one of said windings in series with the working circuit and including the other winding in the before-mentioned bridge-circuit.

Motors constructed and regulated in accordance with my invention are of particular utility when used as instruments for the measurement of electric power, the armature of the motor in such instances being suitably connected to actuate a registering mechanism. The same circuit arrangements may also be used for starting motors which normally run on a single-phase circuit.

My invention will be readily understood by reference to the accompanying drawings, which illustrate the preferred embodiment thereof.

In the drawings, Figure 1 is a plan view of one form of dynamo that may be adjusted in accordance with the invention. Fig. 2 is a sectional elevation on line 2 2 of Fig. 1. Fig. 3 is a diagrammatic view of one form of apparatus and circuits for adjusting a motor. Figs. 3ᵃ, 4, and 5 are diagrams to be used in demonstrating the solution of certain electrical problems hereinafter presented for consideration.

Like letters indicate like parts throughout the different views.

The motor herein shown is provided with a magnetic mass *a* in the form of an annulus composed of laminæ of magnetic material, such as iron, having four polar projections $b\ b'\ b^2\ b^3$, which radiate toward the center. A second stationary mass c in the form of a cylinder is disposed concentrically within the annulus, a small space intervening between the cylinder and the encircling poles, in which a copper drum d is rotatably mounted upon a shaft e. The poles $b\ b'$ are wound with coils $f\ f$ of heavy wire. The poles $b^2\ b^3$ are wound with helices $g\ g$ of fine wire, which are included in a bridge of the distributing-mains $h\ h'$, which receive current from a main source of supply.

The working conductors $i\ i'$ are connected with the mains $h\ h'$, translating devices $k\ l$ being connected in multiple between the conductors $i\ i'$. The motor is shown with its series coils connected in series with the conductor i. Two branches P M Q and P N Q are shown connected between the conductors $i\ i'$ or $h\ h'$. In the sides P M and N Q are illustrated adjustable inductive resistances $m\ n$, preferably of little ohmic resistance. In the sides M Q and P N are included adjustable ohmic resistances $o\ p$, preferably having practically no self-induction. The shunt-coils $g\ g$ are shown as being connected at the points M N. The conductors P M Q and P N Q, together with the shunt-coils bridged across the same, form a circuit similar to a Wheatstone bridge. Between the points P and Q there are thus two branches or parallel circuits P M Q and P N Q, the sides P M and Q N each having great self-induction but little true resistance, while the sides P N and Q M, on the contrary, have much resistance and are almost free from self-induction. Under such circumstances there will be a considerable difference of potential or electromotive force between the points M and N, whose phase may be adjusted by the choice of suitable quantities of resistance and self-induction in the branches P M Q and P N Q until it is in any desired angular relation to the phase of the pressure between the points P and Q. This assertion may be demonstrated by the help of Figs. 3ª, 4, and 5, whereby it will be understood that such phase difference may be made ninety degrees or greater or less, as desired.

Fig. 3ª simply shows an arrangement of circuits analogous to those of a Wheatstone bridge corresponding to the circuits P M Q and P N Q of Fig. 3 and lettered accordingly. This figure is simply given to present clearly to the eye the disposition of the resistances and self-induction coils.

Consider now Fig. 4. Let the line A B represent, graphically, the difference of potential between the points P and Q of Fig. 3ª. If the points P and Q, then, were joined by a conductor having self-induction, a current I would flow through such conductor, lagging in phase behind the impressed electromotive force by a definite angle $\emptyset$. Let P N Q be such a conductor, including the resistances R_1 and R_2 and having a coefficient of self-induction L_2 in the branch N Q. Drop a perpendicular B C from B to the line A I. Then the line A C will graphically represent an electromotive force sufficient to generate a current I in the true resistance, $(R_1+R_2,)$ while B C will represent the reactive electromotive force caused by the self-induction L_2. Now divide the line A C by the point D, so that A D will be proportionate to D C as the resistance R_1 is to the resistance R_2. Then A D will represent the electromotive force between P and N. Let the points P and Q be joined by a second conductor P M Q, the side P M whereof is similar to the side N Q of conductor P N Q, having equal resistance R_2 and self-induction L_2, and the side M Q whereof is similar to P N, having equal non-inductive resistance R_1. To find the electromotive force between the points M and N—that is, in the "bridge"—we must find the resultant of the electromotive forces between P and Q, P and N, and Q and M. Join, Fig. 5, A B and A D as in Fig. 4, and from B extend B E (representing the pressure between Q and M) equal to A D, but in the opposite direction. The electromotive force between P and M is then represented by the line A E, and similarly that between N and Q is represented by the line D B. Join E and D and the line will represent the difference of potential between the points M and N. Now the angle $\emptyset$ may be given any desired value within the theoretical limit of ninety degrees, so that the point C may be given any location within the semicircle which is described on A B as a diameter. Therefore D may be given any location within the semicircle, and the same is true of E with respect to the other semicircle.

In the hypothetical division of resistance and self-induction D lies below A B and E above A B, so that the line E D will intersect A B at a definite angle, which may be given any desired value by properly proportioning the resistances and self-induction coefficients.

Since it is of great value to obtain a phase difference of ninety degrees, it may be well at this point to show how the resistances and self-induction coefficients should be proportioned to one another in the special case assumed in order to secure this result. In order that E D may be at right angles with A B according to geometrical propositions, it must be true that

$$\text{(I.)} \qquad A\,D^2 - D\,B^2 = A\,E^2 - E\,B^2.$$

Since in the case assumed A D=E B and D B=A E, in order that the diagonal E D of the figure A E B D may be at right angles to the diagonal A B the figure must be a rhombus and A D must equal D B. Considering now the right triangle D B C, we know that

$$\text{(II.)} \qquad D\,B^2 = D\,C^2 + C\,B^2.$$

The line D C, it will be remembered, represents an electromotive force which bears the same relation to the electromotive force A C that the resistance R_2 bears to the resistance

R_1+R_2 of the path P N Q, so that by Ohm's law D C=J R_2, J signifying the current flowing through the path P N Q, (or the path P M Q, either, since we have assumed both branches to contain the same resistance.) Similarly A D=J R_1; and, since C B represents the reactive electromotive force caused by the alternating current J flowing through a circuit having a coefficient of self-induction L_2, if n represents the frequency of the alternating current C B=$2 \pi n L_2 J$, the expression $2 \pi n L_2$ being used in its ordinary significance to denote the inductance. Substituting the values for D C and C B in equation II we have

$$\text{(III.)} \quad D\,B^2=J^2\,R_2^2+(2\,\pi\,n\,L_2)^2\,J^2.$$

Now since D B=A D=J R_1, we may substitute $J^2 R_1^2$ for D B^2 in equation III, whence, eliminating the factor J^2 and transposing R_2^2 to the left-hand member, we have

$$R_1^2-R_2^2=(2\,\pi\,n)^2\,L_2^2.$$

By proportioning the resistance and self-induction in accordance with this formula we can secure a difference of phase of exactly ninety degrees, and the formulæ for a phase difference of ninety degrees, with various arrangements other than the special case considered, in which the equality of the self-induction coefficients and resistances in the parts of the bridge opposite each other was assumed only for simplicity, may be derived, generally speaking, from the equation I, whereupon the values of R_1, R_2, and L_2 may be approximately determined.

If the bridge-circuit between M and N be of high resistance, so that little current will flow in proportion to that which flows between P and Q, the shifting of phase in the bridge will be inconsiderable, so that by changing the resistances or self-induction the phase angle may be brought back to ninety degrees. Therefore if the high-resistance windings g g are bridged between the points M and N (preferably with a high non-inductive resistance also included in the same circuit) it is always possible, by the proper choice of resistances and self-inductions in the branches P M Q and P N Q, to secure a phase difference of exactly ninety degrees between the current flowing through the windings g g and the operating electromotive force between P and Q.

It is evident that the result aimed at may be accomplished in a great variety of ways. Capacity may take the place of non-inductive resistance and the self-induction may be omitted.

In adjusting the phase of the motor I preferably employ a dynamometer r of any well-known form. The one illustrated is a torsion dynamometer having two angularly-disposed coils. Switches s s' are employed for cutting the coil r' of the dynamometer into the bridge between the points M N, the shunt-coils g g being at the same time cut out of circuit. To make the new bridge-circuit similar to the one including the shunt-coils, a compensating-resistance s^2 may be cut into circuit with the coil r'. The other coil of the dynamometer is connected between the points P Q by switches t t'.

The phase of the current in coil r^2 coincides with that of the working voltage, while the phase in coil r' coincides with that which normally flows through the coils g g and depends upon the adjustment of resistances and self-induction in the branches P M Q and P N Q.

Since the dynamometer measures the product of the currents in its two coils with the cosine of the angle $\emptyset$ of phase difference between them, it will be seen that when $\emptyset$ becomes ninety degrees, the cosine value whereof is zero, the dynamometer will show no deflection. It is apparent that the desired shifting of phase may thus be easily and accurately determined. When the dynamometer indicates a difference of ninety degrees by showing no deflection, it may be cut out of circuit by switches s s' t t' and the coils g g and f f of the motor substituted therefor.

It will be apparent to those skilled in the art that the required phase angle may be determined with great accuracy. While I have shown the preferred embodiment of the invention and the application thereof to one type of dynamo, I do not wish to be limited to the precise arrangement and construction of parts herein shown and described whereby the phase adjustment is secured. The preferred embodiment of the invention is shown to enable those skilled in the art to practice the invention. Other apparatus may be devised for accomplishing the same results without departing from the invention. To set forth modifications and adaptations of the preferred form of the apparatus embodying the invention would obscure, rather than make clear, the essential features.

Having, however, fully described the preferred embodiment of the invention and the method of practicing the same, I claim as new, and desire to secure by Letters Patent, only with the limitations expressed or by law implied, the following:

1. The combination with a circuit for conveying alternating current, of a dynamo-electric machine adapted to be operated by magnetic effects differing in phase, a Wheatstone-bridge circuit connected with the aforesaid circuit, the dynamo-electric machine having a winding which is included in the bridge of the Wheatstone-bridge circuit, and adjustable induction and resistance devices included in the branches of the Wheatstone-bridge circuit, substantially as described.

2. The combination with a source of alternating current, of a dynamo-electric machine having two windings angularly disposed as to each other, whereby, if said windings are traversed by alternating currents of suitable phase difference a rotating magnetic field will be produced, a Wheatstone-bridge circuit having branches P M Q and P N Q which are

connected in parallel across the terminals of said source of current, one of the windings of said dynamo being connected directly in circuit with said source of current and the other of said windings being bridged across said Wheatstone-bridge circuit, and resistance and phase-modifying means included in said Wheatstone-bridge circuit, substantially as and for the purpose set forth.

3. The combination with a source of alternating current, of a motor adapted to be operated by magnetic effects differing in phase, a Wheatstone-bridge circuit having two branches P M Q and P N Q connected in parallel, a winding for said motor connected in parallel with said branches, a second winding of said motor included in the bridge-circuit M N and resistances and phase-modifying devices in the branches P M Q and P N Q of said Wheatstone-bridge circuit, substantially as set forth.

4. The combination with a source of alternating current, of a Wheatstone-bridge circuit having branches P M Q and P N Q connected in parallel, a motor adapted to be operated by magnetic effects differing in phase, a series winding for said motor for connection in circuit with said source of alternating current, a second winding for said motor included in the bridge M N of said Wheatstone-bridge circuit, and adjustable resistance and phase-modifying means included in said Wheatstone-bridge circuit, whereby the phase of the current in said bridged winding may be given a definite angle with respect to the phase of the current in said series winding, substantially as described.

5. The combination with a source of alternating current, of a motor, adapted to be operated by magnetic effects differing in phase, branch circuits P M Q and P N Q connected in parallel across the terminals of said source of alternating current, a series winding for said motor for connection in circuit with said source of alternating current, a second winding for said motor bridged across said branch circuits, said branch circuits containing self-induction and resistance, and means for adjusting said self-induction and resistance, whereby the current in said bridged winding may be given a definite phase relation to the current in said series winding, substantially as set forth.

6. The combination with a source of alternating current, of a series circuit wherein the current flowing is derived from and substantially coincides in phase with such alternating current, branch circuits P M Q and P N Q connected in parallel and included in circuit with said source of alternating current, a circuit bridged between said branch circuits, resistance and phase-modifying means included in said branch circuits, and means for adjusting said resistance or phase-modifying means or both, whereby the current in said bridged circuit may be given a definite phase relation to the current in said series circuit, substantially as described.

7. The combination with a source of alternating current, of a series circuit wherein the current flowing is derived from said alternating current and substantially coincides in phase therewith, a Wheatstone-bridge circuit having branches P M Q and P N Q, a circuit bridged across the terminals M and N of said Wheatstone-bridge circuit, resistances R_1 R_1 included in the sides P N and Q M of said Wheatstone-bridge circuit, and phase-modifying means included in the sides P M and Q M thereof, substantially as described.

8. The combination with a source of alternating current, of a motor adapted to be operated by magnetic effects differing in phase, said motor having two windings, one of said windings being connected to receive current of a given phase from said source, two parallel branch circuits adapted also to receive current from said source, the second winding of said motor being connected in bridge across said branch circuits, and resistances and self-induction coils included in each of said branch circuits, whereby the current in said second winding may be given a definite phase relation to the current in said first-mentioned winding, substantially as described.

9. The combination with a source of alternating current, of a motor having two windings, one of said windings being connected in series with said source of alternating current, a Wheatstone-bridge circuit having branches P M Q and P N Q connected in parallel across the terminals of said source of current, the second winding of said motor being bridged across the terminals M and N of said Wheatstone-bridge circuit, adjustable resistances included in each of the opposite sides P N and Q M of said Wheatstone-bridge circuit, and adjustable phase-modifying means included in each of the opposite sides P M and and Q M thereof, whereby the current in the bridged winding of said motor may be given a definite phase relation to the current in said series winding, substantially as set forth.

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

JOHANNES HEINRICH FRIEDRICH GÖRGES.

Witnesses:
CHARLES H. DAY,
PAUL ROEDIGER.