V. A. FYNN.

ALTERNATE CURRENT MOTOR.

APPLICATION FILED MAR. 2, 1908.

**993,359.** **Patented May 30, 1911.**

7 SHEETS—SHEET 1.

*Fig. 1.*

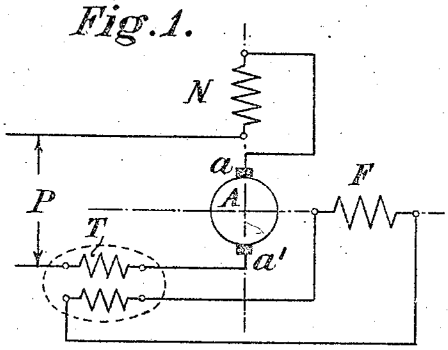



*Fig. 2.*

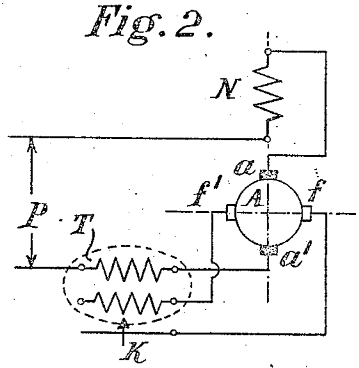



*Fig. 1a*

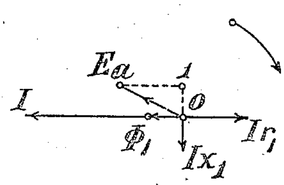



*Fig. 1b.*

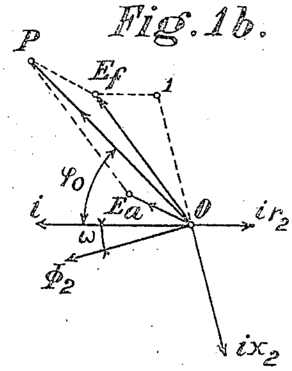



*Fig. 1c.*

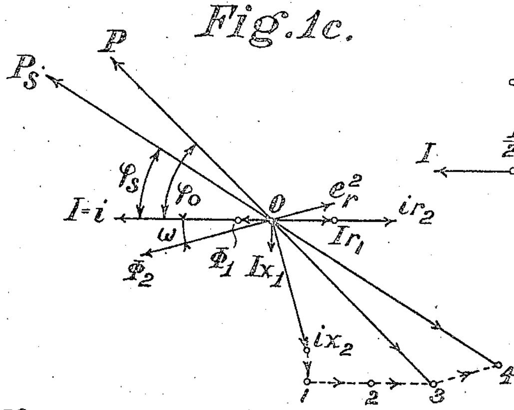
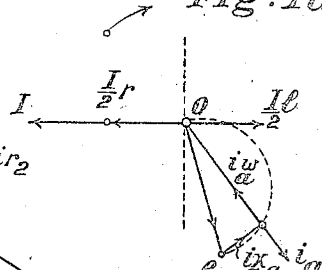



*Fig. 1d.*

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7 SHEETS—SHEET 2.

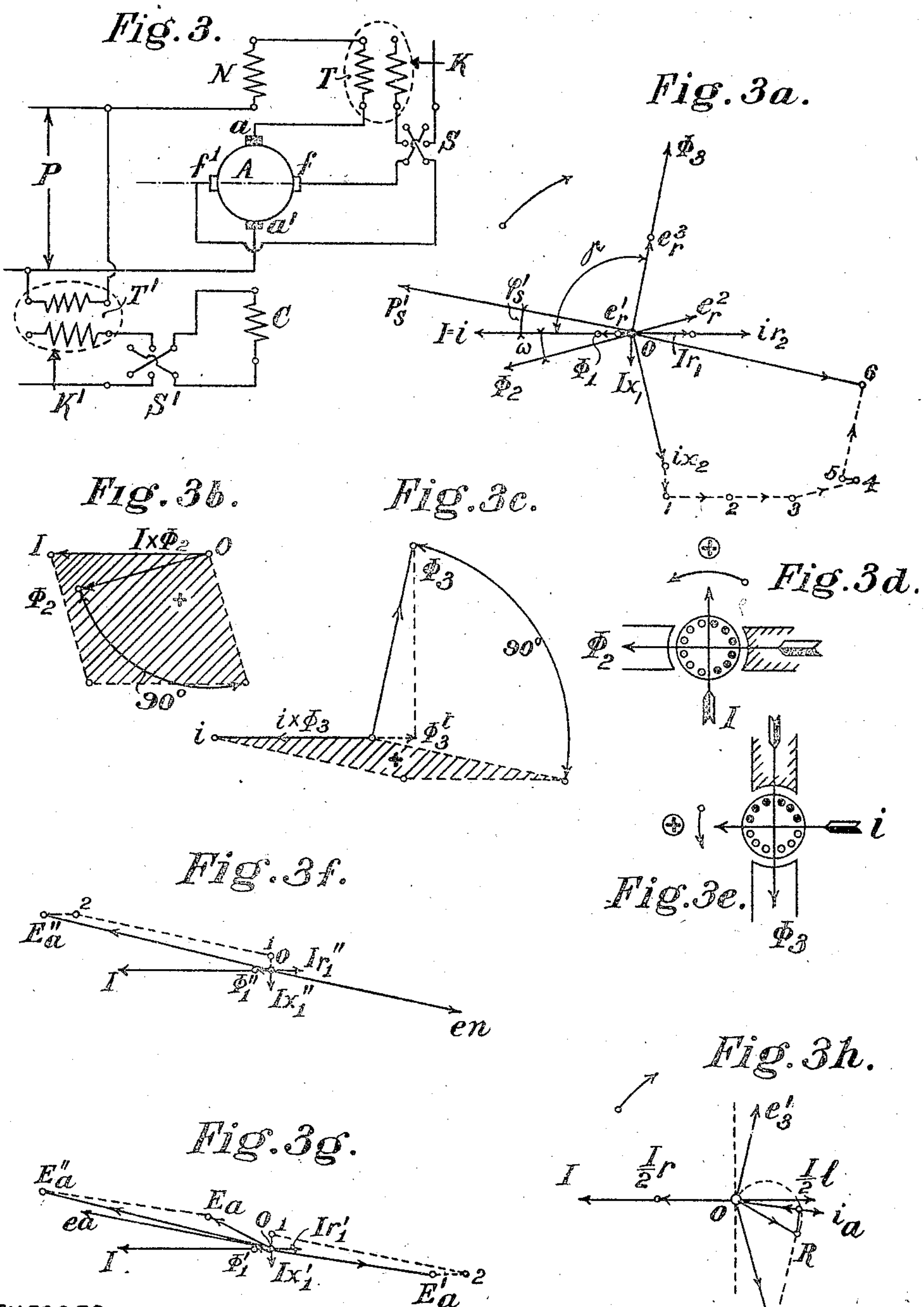


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*Fig. 4.*

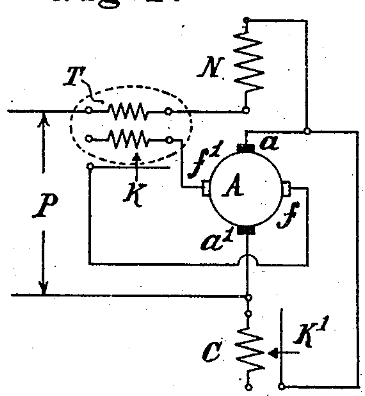
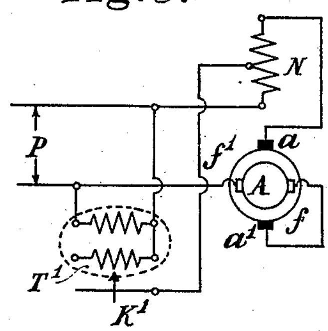



*Fig. 5.*



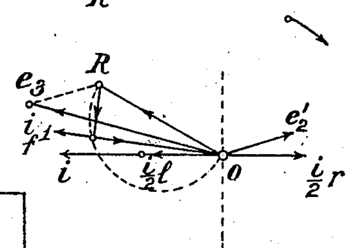




*Fig. 3i*

*Fig. 6.*

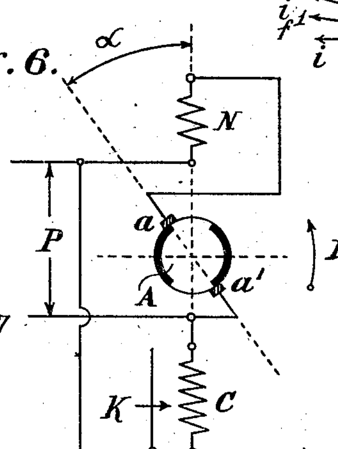



*Fig. 6b*

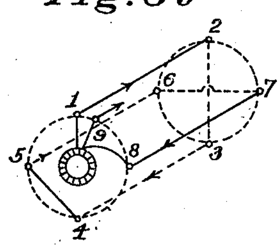



*Fig. 6a.*

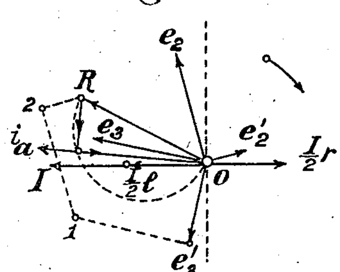



*Fig. 7.*

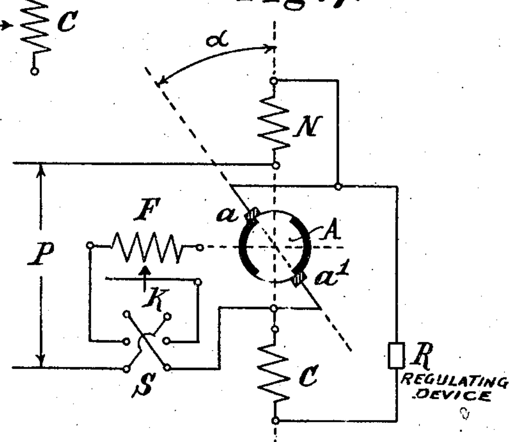



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*Fig. 8.*

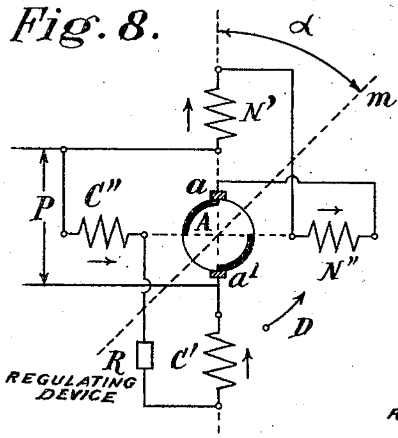



*Fig. 9.*

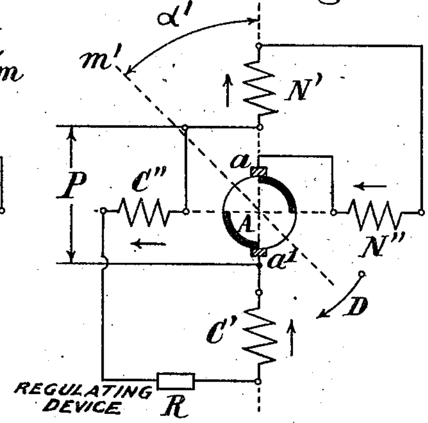



*Fig. 10.*

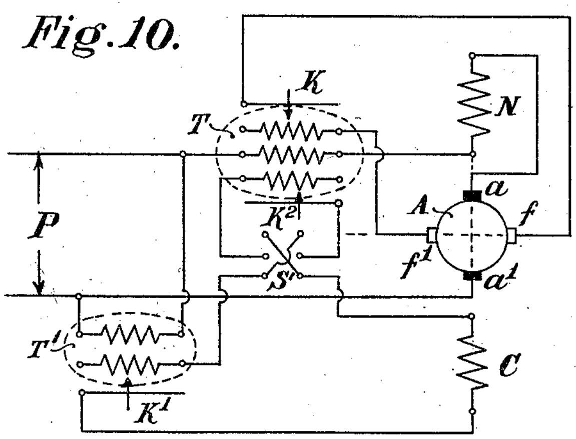
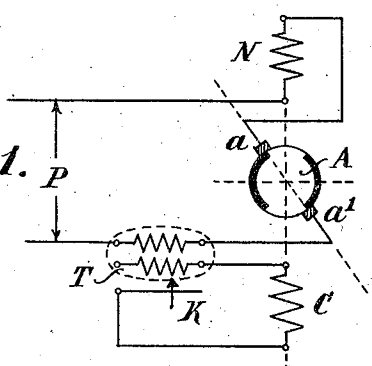



*Fig. 11.*

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993,359.

Patented May 30, 1911.

7 SHEETS—SHEET 5.

Fig. 12.

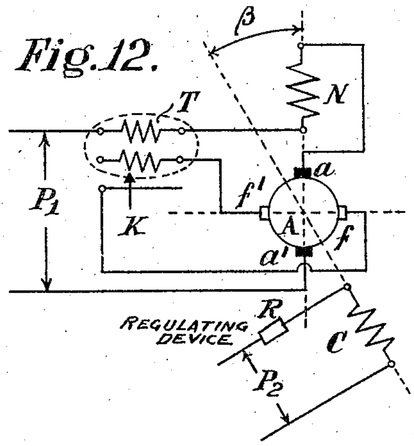



Fig. 13.

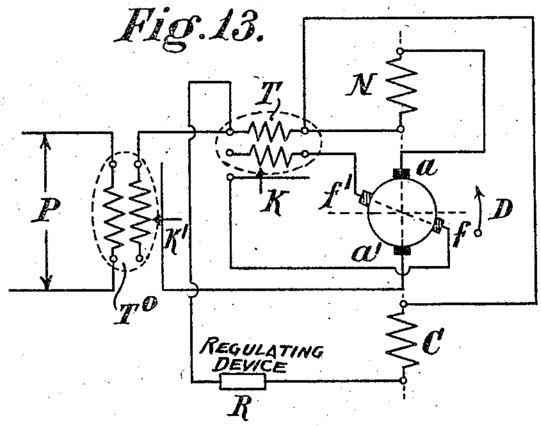
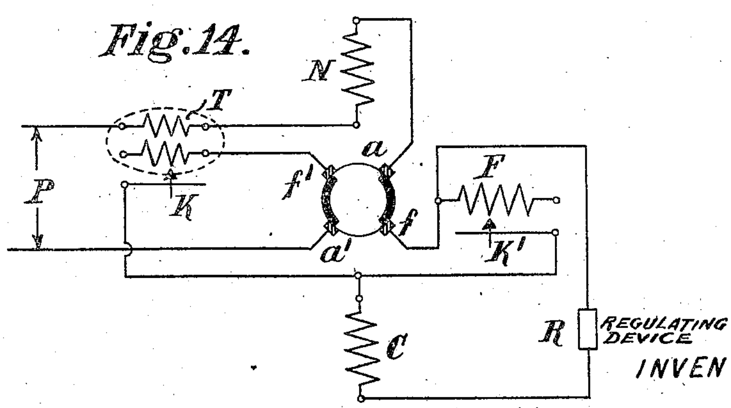



Fig. 14.

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7 SHEETS—SHEET 6.

*Fig. 15.*

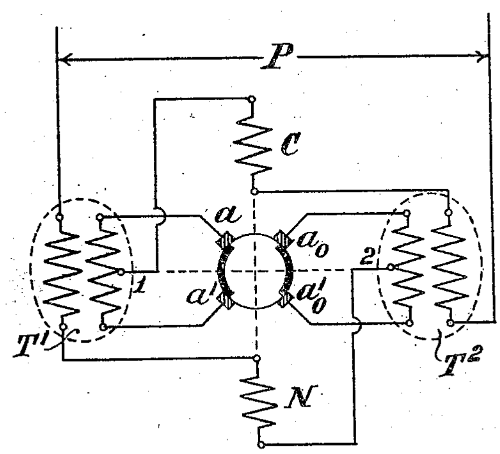



*Fig. 16.*

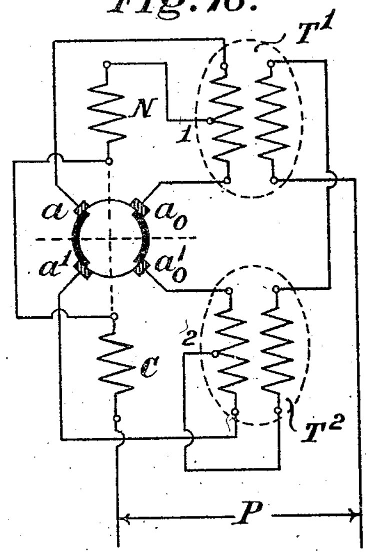



*Fig. 17.*

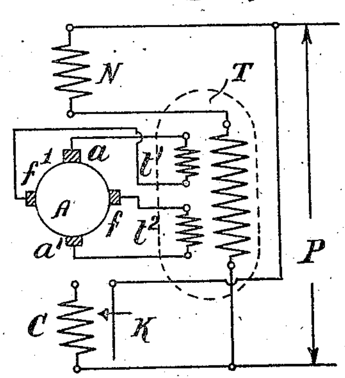
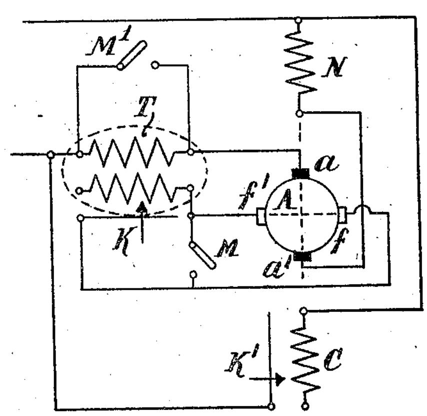



*Fig. 18.*

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993,359. Patented May 30, 1911.

7 SHEETS—SHEET 7.

*Fig. 19.*

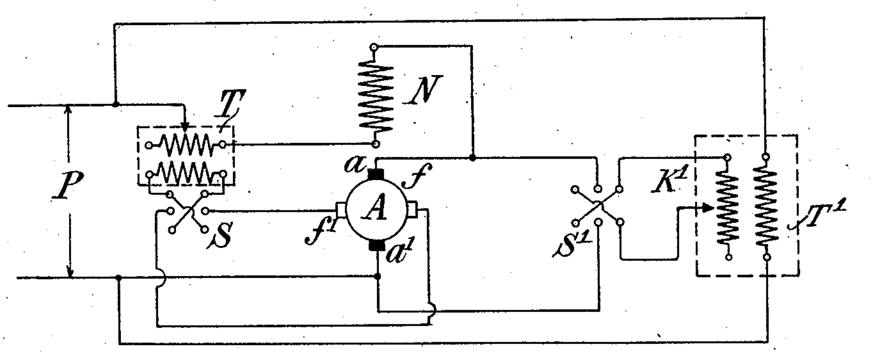
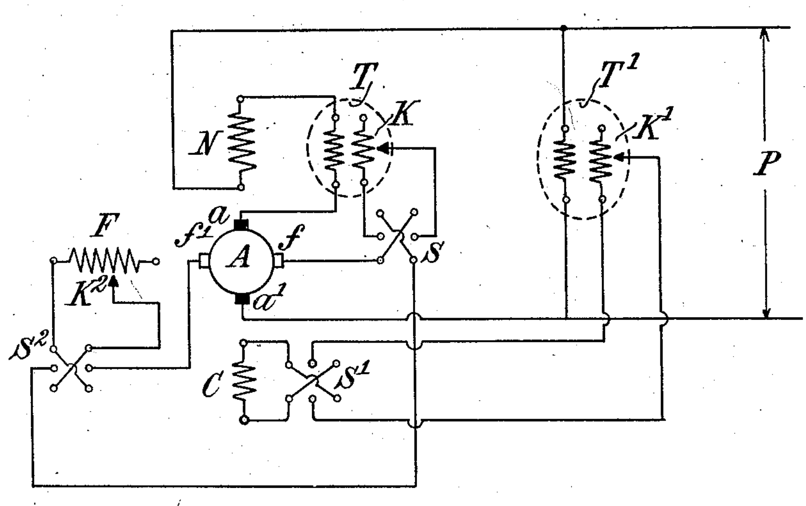



*Fig. 20.*

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# UNITED STATES PATENT OFFICE.

VALÈRE ALFRÉD FYNN, OF BLACKHEATH, ENGLAND.

ALTERNATE-CURRENT MOTOR.

993,359. Specification of Letters Patent. Patented May 30, 1911.

Application filed March 2, 1908. Serial No. 418,873.

*To all whom it may concern:*

Be it known that I, Valère Alfred Fynn, of 18 Blessington road, Blackheath, in the county of Kent, England, electrical engineer, have invented certain new and useful Improvements in Alternate-Current Motors, of which the following is a specification.

My invention relates more particularly to neutralized single-phase series conduction motors in which at least part of the field winding is disposed on the rotor, but is also applicable to single-phase generators and such machines may also be temporarily used in continuous current circuits acting either as motors or generators.

It is more particularly my object (1) to compensate such single-phase motors *i. e.* to improve their power factor (2) to increase their torque ampere, (3) to obtain a maximum torque greater than has hitherto been possible in the said type of motor (4) to improve their commutation both at the moment of starting and when running, and (5) to generally improve the operation of such machines. Generally speaking the said objects are achieved in a neutralized single-phase series conduction motor in which the normal motor field is excited by a winding at least partly disposed on the rotor, by providing an auxiliary alternating field which is not coaxial with the said normal motor field, the said auxiliary field being produced by a winding placed on the stator, on the rotor or on both, and the phase magnitude and direction of said auxiliary field being suitably chosen. This auxiliary field is preferably produced along the axis of the neutralizing winding *i. e.* along the armature axis, but it can be produced along any other axis as long as its own axis does not coincide with that of the normal motor field. The phase of this auxiliary field can be the same as the phase of the motor field or it can differ from it.

The first object of this invention is achieved by so choosing the phase, magnitude and direction of the auxiliary field that a compensating E. M. F. of proper phase, magnitude and direction may be generated at the brushes conveying the field current and by rotation in said auxiliary field of those rotor conductors which convey the field current.

The second and third objects are achieved by so choosing the phase, magnitude and direction of the auxiliary field that an additional or auxiliary torque is produced between said auxiliary field and at least part of the rotor conductors carrying the exciting current. The second and third objects are also partly achieved by so adjusting the magnetizing current of the series transformer sometimes used between armature and field winding so as to bring armature current and motor field into closer phase coincidence.

The fourth object is achieved by so choosing the phase, magnitude and direction of the auxiliary field in respect of the phase, magnitude and direction of the motor field and taking the prevailing speed into consideration, that the vector sum of the various E. M. F.'s which are present in the coils undergoing commutation may become as small as possible. The said auxiliary field not only allows the resultant E. M. F. to be reduced, but also allows if required the phase of that resultant to be so chosen that it can then conveniently be annulled by some of the known means for improving the commutation, such for instance as commutating poles.

It will be understood that all these improvements or their modifications need not necessarily be used simultaneously or all on the same machine.

In order that my invention, its scope and the possible modifications may be more fully understood, I propose to shortly state the theory which led me to discover these improvements and although I believe this theory to be substantially correct yet I wish it to be understood that I do not bind myself to this or any other theory.

My invention will be better understood by reference to the drawings, in which

Figure 1 shows a neutralized single-phase conduction motor in which the field winding is disposed on the stator and wherein a transformer is interposed between the armature and field circuit. Figs. $1^a$, $1^b$, $1^c$, $1^d$, are explanatory vector diagrams illustrating the mode of operation of the known motors shown in Figs. 1 and 2. Fig. 2 shows a known modification of Fig. 1 where the field winding is disposed on the rotor. Fig. 3 shows one way of applying the invention, the auxiliary field being excited in parallel from the mains. Figs. $3^a$ to $3^f$ illustrate the mode of operation of the improved motor shown in Fig. 3. Fig. 4 shows another way of applying the invention, the auxiliary field being excited from the armature brushes. Fig. 5 shows a way of applying the invention where the auxiliary field is excited in parallel from the mains, part of the neutralizing winding being made use of for this purpose. This figure also shows two rotor windings, one of them doing duty as armature and the other as field winding. Fig. 6 shows a way of applying this invention while only making use of one set of brushes per pole pair or their equivalent. Fig. $6^a$ illustrates certain commutating conditions of Fig. 6. Fig. $6^b$ shows a rotor winding by means of which a similar effect is obtained as that secured by displacing the brushes as shown in Fig. 6. Fig. 7 shows one way of disposing the field winding partly on the rotor and partly on the stator. Figs. 8 and 9 show an arrangement of stator windings permitting of the reversal of the direction of rotation of Fig. 6 without displacing the brushes. Fig. 10 shows a way of applying the invention, in which the auxiliary field is excited by means of shunt and series transformers. Fig. 11 shows means for exciting the auxiliary field in series with the mains. Fig. 12 shows an arrangement in which the auxiliary winding is not disposed in the armature axis and may be excited from an outside source. Fig. 13 shows a modified disposition of the field brushes. Fig. 14 shows a modified disposition of the armature and field brushes. Fig. 15 shows an arrangement of circuits and brushes by means of which part of the single rotor winding is made use of as armature and part as field winding, the armature current being derived from series transformers. Fig. 16 shows a similar arrangement, but where the field current is derived from series transformers. Fig. 17 shows an arrangement by which only a part of the rotor winding is utilized, that part doing duty both as armature and as field winding. Fig. 18 shows one means of limiting the speed of such motors by converting them into self excited shunt conduction motors. Figs. 19 and 20 are diagrams which are explained hereinafter.

In Fig. 1 is shown an ordinary neutralized series conduction motor in which N is the neutralizing winding, $aa^1$ the armature brushes, A the rotor or armature, F the field winding disposed on the stator and fed by way of example through a series transformer T the primary of which is included in the armature circuit. The potential difference at the motor terminals is supposed to be P. Assume the motor to be locked in any given position and a current I flowing through N, A and T. Assume that the transformation ratio of T is unity and that its losses and magnetizing current are so small that the secondary current $i$=I and is of exactly opposite phase to it. It will be understood that these last assumptions can be very nearly fulfilled in practice although not quite. Let $r_1$ be the ohmic resistance of A+N, while $r_2$ is the ohmic resistance of F. Let $x_1$ and $x_2$ be the reactance of A+N, and of F respectively where $x_1=x'_1+x''_1$ and $x'_1$ $x''_1$; the two latter being respectively the reactances of A and N. Let N and A be so chosen that the fields due to these two windings and which thread both windings are entirely neutralized. Under these conditions Fig. $1^a$ shows an approximately correct phase diagram at the terminals of A+N. It will be understood that $\Phi_1$, is the sum of the leakage fields around A and N thus $\Phi_1=\Phi_1'+\Phi_1''$ and by assumption $\Phi_1'=\Phi_1''$. Since $\Phi_1$, closes almost entirely through air it has been shown in phase with I; this is approximately correct. It is seen that $E_a$ is the E. M. F. required to drive I through A+N.

Fig. $1^b$ shows the approximate phase diagram at the terminals of F and at the terminals of the machine. The field winding is of course not neutralized and consequently its reactance $x_2$ is large, a small component of this reactance which lags about 90° behind $i$ has been purposely omitted as being generally very small. Seeing that the motor field $\Phi_2$ closes almost entirely through iron it will lag appreciably behind $i$ as shown at $\omega$. It is seen that $E_f$ is the E. M. F. required at the terminals of F in order to drive $i$ through F. In view of the assumptions made $E_f$ may be taken to be equal in all but sign to the E. M. F. at the primary terminals of T. Now P must be the resultant of $E_a$ and $E_f$ as shown in Fig. $1^b$ and therefore $\phi_o$ is the phase difference between the current taken by the motor and its terminal voltage.

What happens when the motor shown in Fig. 1 is allowed to run up and reaches a speed $s$ is shown in Fig. $1^c$ where $s$ is supposed to be about one half of the synchronous speed. In this figure the two previous diagrams have been superposed and the parallelogram of E. M. F.'s constructed in a different but well known manner, O-3 is the E. M. F. which has to be equalled and opposed by P when the motor is standing still whereas O-4 must be equalled and opposed at the speed $s$ if the same torque is still to be given by the motor, in other words if I is to remain constant. The condition that I should remain constant is by no means essential, yet it greatly facilitates the comparison of the various diagrams and has been adopted for this reason. Now it is seen that although P has to be increased to $P_s$ at the speed $s$ yet $\phi_o$ is reduced to $\phi_s$, in other words the power factor of the motor in Fig. 1 increases with the speed. This power factor reaches high values such as 0.9 at say 40% to 60% above the synchronous speed in well designed motors operating on low periodicity circuits (about 25 cycles). When the current is kept constant then this improvement is chiefly brought about by the fact that the back E. M. F. appearing at the armature brushes and generated by rotation of the armature conductors in $\Phi_2$ is not in phase with the working E. M. F. impressed on the armature and is so directed as to partly counteract the various reactance voltages which lower the power factor. This back E. M. F. is shown at $e^2_r$ and is here, owing to the direction of rotation, of opposite phase to $\Phi_2$. It should be noted that if the load is increased, the terminal voltage being kept constant, the power factor will drop very rapidly in a motor such as shown in Fig. 1 for $e^2_r$ cannot increase as fast as for instance $ix_2$, if at all, for the latter is directly proportional to the current only whereas the former is directly proportional to $\Phi_2$ (therefore to the current) but also inversely proportional to the speed which must decrease with decreasing load if P is kept constant.

In Fig. 1 the series transformer T is not essential but it becomes of importance to use T if F is discarded and the armature winding itself is made use of as field winding by applying to the commutator brushes $f^1$, $f$, displaced preferably by

$$\frac{180°}{n}$$

with respect to the brushes $a^1$, $a$ as shown in Fig. 2. The number of poles is throughout designated by $n$. If T in Fig. 2 were discarded it would be necessary to connect say $a^1$ with $f^1$ and the current distribution through the armature would not be so satisfactory. It is preferable in case T is discarded to provide two independent windings on the rotor. The mere fact of transferring F from the stator, as in Fig. 1, to the rotor, as in Fig. 2, makes very little difference indeed if any, to the operation of the known motors under discussion. There is now but one other E. M. F. to consider, which is very small and has been shown in Fig. 3ª at $e^1_r$, it is not to scale, otherwise it could hardly have been seen in the diagram. In the parallelogram of E. M. F.'s it is shown at 4—5. This E. M. F. is generated at the brushes $f$, $f^1$ by rotation in the leakage field $\Phi'_1$. The character of the motor remains exactly the same whether the field winding is disposed on the stator, as in Fig. 1, or on the rotor, as in Fig. 2.

Now according to my invention and in that manner of carrying it into practice which is shown in Fig. 3, I, in order to improve the power factor produce preferably in the armature axis, and preferably by induction from the stator, an auxiliary alternating field such at $\Phi_3$. If the direction of rotation is such that the E. M. F. generated along the armature axis by rotation in the motor field is of opposite phase to the motor field then the E. M. F. generated along the field axis by rotation in an auxiliary field disposed along the armature axis will be in phase with this auxiliary field and vice versa. Thus in this case $e^3_r$ generated at the field brushes $f$, $f^1$ will be in phase with $\Phi_3$. This adds the component 5—6 to the parallelogram of E. M. F.'s in Fig. 3ª, reduces $P_s$ to $P'_s$ and reduces $\phi_s$ to $\phi'_s$ for the same speed $s$.

The diagram Fig. 3ª corresponds to the manner of carrying out my invention which is shown in Fig. 3 where C is the auxiliary winding fed by way of example from the supply by way of the shunt transformer $T^1$. In this arrangement $\Phi_3$ will always be practically in quadrature with P as shown in Fig. 3ª, whether it is to be shown in the diagram as leading P or lagging behind it depends on the position of the reversing switch $S^1$. It will be seen from the diagram that the power factor will be either improved or reduced according to the direction of $\Phi_3$. It will also be seen from Fig. 3ª that the direction of rotation can be reversed either by reversing the current through the armature or through the field winding. A reversing switch S is shown for the latter purpose. When the direction of rotation is reversed in the former manner then $\Phi_3$ must also be reversed. Both T and $T^1$ are shown as being of the variable ratio type and capable of being regulated at K and $K^1$. The diagram Fig. 3ª however reveals further facts which I will deal with before showing other ways of carrying out my invention.

It will be noted that power factor unity can be easily obtained by increasing $\Phi_3$ and without raising the speed, therefore as long as the motor revolves at all, and as long as $\Phi_3$ of suitable phase and magnitude is available it is theoretically possible to obtain unity power factor. The question of magnetic densities will however determine the lowest speed at which unity power factor can be secured with a given torque. That speed will obviously be far below the synchronous so that unity power factor can be secured over the whole practical range of speed. It is also clear from Fig. 3ª that as far as the improvement of the power factor is concerned it is better for $e^3_r$ to lead I by less than 90° rather than by more. If the lead is less than 90° then not only can the power factor be improved but $P'_s$ can also be reduced. It will be seen later however that if this lead is less than 90°, then certain disadvantages are met with.

Designating the phase difference between I and $\Phi_3$ by $\gamma$ we can say that, for either direction of rotation, the power factor will be improved for any values of $\gamma$ for which one component of $\Phi_3$ leads I by 90°, it being assumed that $\Phi_3$ is resolved into two components one of which is parallel to I and the other perpendicular to it. In other words the power factor will be improved for all values of $\gamma$ above zero but below 180°. When $\gamma=90°$ then the compensating effect of $\Phi_3$ is a maximum.

The torque conditions are of importance; it is seen from Figs. 3 and 3ᵃ that the current I in the armature axis will produce a torque with the field $\Phi_2$ in the motor field axis. This is shown in the usual way in Fig. 3ᵇ. But the field current in the motor field axis and the auxiliary field $\Phi_3$ in the armature axis will also yield a torque as shown in Fig. 3ᶜ. The direction of these torques can be found by ascertaining for any given instant the sign of the various vectors involved and then plotting the results for instance in the manner shown in Figs. 3ᵈ and 3ᵉ. The assumption underlying these two last figures are that from top to bottom and from left to right of the paper be considered positive and that the current distribution on the periphery of the rotor be such as to tend to create a field coinciding in direction with the arrow giving the direction of the current vector in Figs. 3ᵈ and 3ᵉ.

Proceeding it is seen that at any given instant, and for the conditions chosen in Fig. 3ᵃ, the torque proportional to $I\times\Phi_2$ is the greater as shown in Fig. 3ᵇ, it will therefore determine the direction of rotation, and may be referred to as the main and positive torque. The auxiliary torque proportional to $i\times\Phi_3$ is much smaller as shown in Fig. 3ᶜ but is in this instance also positive. In ascertaining the directions of these torques only those components of the one or the other factors should be taken into account which are of the same or opposite phase as the corresponding factor. Thus in Fig. 3ᶜ it is only the component $\Phi^t_3$ of the factor $\Phi_3$ which is to be considered for that purpose; it is of course also the only component of $\Phi_3$ which does give a torque in conjunction with the corresponding factor $i$.

A study of Fig. 3ᵃ at once shows that, for the particular direction of rotation chosen, the torque $i\times\Phi_3$ is zero when $\gamma=90°$. When $\gamma<90°$ then the torque becomes negative. From this point of view, and for the case of Fig. 3ᵃ, it is therefore preferable to make $\gamma<90°$ and this condition will also be quite favorable enough for compensation purposes.

It should be noted that as soon as a phase difference is introduced between $i$ and I or the direction of rotation is reversed then the simple rule given for the choice of the phase of $\Phi_3$ as referred to the phase of I no longer holds good as far as the direction of the auxiliary torque is concerned. In order to define the direction of the latter independently of any phase difference between I and $i$, the phase of $\Phi_3$ must be referred to that of $i$. We may then say that the auxiliary torque will be positive, for the direction of rotation assumed in Fig. 3ᵃ (*i. e.* when $i$ and I are of about the same direction), as long as $\Phi_3$ leads $i$ by at least 90°. If the direction of rotation is reversed, for instance by reversing $i$ (*i. e.* when in Fig. 3ᵃ $i$ is of about opposite direction to I), then the auxiliary torque will be positive as long as $\Phi_3$ does not lag behind $i$ by more than 90°. In either case $\gamma$ must be less than 180° if $\Phi_3$ is to help to compensate the motor. The main torque would be increased if $\Phi_2$ were in phase with I. The angle $\omega$ by which $\Phi_2$ lags behind $i$ depends, as is known, on the iron losses and may assume very appreciable dimensions when the densities are high or the iron quality poor. One of my improvements consists in eliminating this phase difference. I achieve this by interposing a series transformer between armature and field circuit, as shown in Fig. 2 or 3 and by so choosing the magnitude of the magnetizing current of that transformer that, in Fig. 3ᵃ for instance, $i$ shall lead I by that same angle $\omega$.

One more point is of importance, when $\Phi_3$ is due to P as in Figs. 3 and 3ᵃ, then it is obvious that $\Phi_3$ will always lag behind P by practically 90°. Now the very presence of $\Phi_3$ alters the phase relation between P and I or $i$. At the moment of starting and as will be seen from Fig. 1ᵇ there is a large phase difference between P and I or $i$, and $\gamma$ will therefore be larger than 90° in other words the torque $i\times\Phi_3$ will be large and in this manner yet another object of my invention will be achieved for the motor will now start like a machine with two very effective armature and two very effective field axes per pole pair. As the speed increases the conditions in Fig. 3ᵃ will obtain and with a still higher speed $P'_s$ may easily come to lag behind I or $i$, in other words the machine will take a leading current, when $\gamma$ will become less than 90° and this would determine a negative torque. This negative torque may be made use of to limit the speed of the motor even at no load. If it is desired to avoid this negative torque then $P'_s$ must not be allowed to lag appreciably behind I or $i$; this can be prevented for instance by reducing $\Phi_3$ which at starting and at low speed is advantageously chosen large. Or a negative torque can be avoided and even a positive torque secured while allowing $P'_s$ to lag behind I and $i$ by changing the phase of the E. M. F. impressed on C (Fig. 3) or generally by changing the phase of $\Phi_3$ as the speed increases; this can for instance be achieved by impressing more than one E. M. F. on C, these E. M. F.'s being of differing phase, and by changing their relative magnitudes, or directions of both. A glance at Fig. $1^b$ will show that such E. M. F.'s of differing phase are available in the motor itself; thus $E_a$ at the terminals of A—N in Fig. 3, also $E_f$ at the brushes $f\ f'$ in Fig. 3 or at the primary or secondary terminals of T in Fig. 3 and finally P, the difference of potential of the mains. The E. M. F.'s at the terminals of A and N respectively are also available for the said purpose. They are the components of $E_a$ the E. M. F. at the terminals A—N they are not shown in Fig. $1^b$ and may be designated by $E'_a$ and $E''_a$ respectively. These components of $E_a$ are however shown in Figs. $3^g$ and $3^f$ for the case illustrated in Fig. $3^a$; the effect of $\Phi_3$ on A and N has been taken into account in Figs. $3^g$ and $3^f$. These figures will be referred to in greater detail a little later. Any one or more of these E. M. F.'s may be made use of in order to excite $\Phi_3$, if one such E. M. F. only is used it is obvious from Fig. $1^b$ and from what has been said that $E_a$ and P are generally more suitable than $E_f$ if phase compensation is principally aimed at. These E. M. F.'s may be derived directly from the various points mentioned or through transformers embodied in the motor itself or separate therefrom. It will be understood that an E. M. F. or E. M. F.'s of suitable phase and derived from any other or external source can be used with equal success; although this is not necessary it may be sometimes convenient or desirable. Such an external source may be a polyphase supply or a phase converter, either rotary or static or the like. Any phase splitting device may also be used for the purpose.

The magnitude of the auxiliary field $\Phi_3$ should, as has been explained, vary with the speed if the power factor is to be kept constant, decreasing with increasing speed; it should also vary with the current taken by the motor, increasing as the current increases. The phase which $\Phi_3$ should occupy relatively to the phase of I or $i$ if a negative auxiliary torque is to be avoided and phase compensation secured has already been fully defined. The considerations which determine the manner in which the magnitude and if required also the phase of $\Phi_3$ should be regulated are therefore now known. This regulation can be carried out by hand or electromagnetically, by means of known devices, or by means of centrifugal or other automatic devices, or by a combination of all or any of the said means. At this stage yet another factor must be introduced which so far has been left out of consideration in order to not unduly complicate the diagrams. This factor is the effect produced by $\Phi_3$ on the armature winding and on the neutralizing winding N. If it is assumed that the number of turns of N and their inductive relation to $\Phi_3$ be so chosen that the E. M. F. (*en*) induced in N by $\Phi_3$ is of the same magnitude as the E. M. F. (*ea*) induced in A along the axis $a\ a^1$ then Figs. $3^f$ and $3^g$ will show the actual phase and value of $E''_a$, $E'_a$ and $E_a$ when C in Fig. 3 is made use of. Under the conditions named *en* equals and opposes *ea* since N and A are in series and in opposition and that is why this factor has not so far been considered. It is of course not necessary that *en* shall be equal to *ea* and the effect of a difference between these two E. M. F.'s is easily seen from Figs. $3^f$ and $3^g$. In most cases it will be preferable to so dimension N and A that the motor is as fully neutralized as possible; under these conditions *en* and *ea* will be nearly if not quite equal and opposed.

Referring to diagram $3^f$, the current I flowing through N of Fig. 3 gives rise to a leakage flux $\Phi''_1$, the latter induces the reactance voltage $Ix_1''$ in N; the current I also occasions the ohmic drop $Ir_1''$. In addition $\Phi_3$ induces $e\ n$ in N. Now there must exist at the terminals of N an E. M. F. $E''_a$ which equals and opposes the three E. M. F.'s $Ix''_1$, $Ir''_1$ and $e\ n$. Similarly we have in the rotor winding, and appearing at the brushes $a\ a'$, the E. M. F.'s $Ix'_1$, $Ir'_1$ and $e\ a$. These must be equaled and opposed at the brushes $a\ a'$ by the E. M. F. $E'_a$ shown in Fig. $3^g$. The rotor A and the stator winding N being connected in series relation, an E. M. F. $E_a$ must be present at the terminals of A plus N which equals and opposes the vectorial sum of $E'_a+E''_a$ if the current I is to flow through the combination.

It should be pointed out that the magnetizing current required by C in order to produce $\Phi_3$ could very much reduce the overall power factor particularly at slow speeds although the power factor at the terminals of the motor, and not including the C winding, might be high. In order to avoid this drawback in all cases, the exciting winding is not only disposed on the rotor but also on the stator and preferably along the motor field axis. If these two parts of the exciting winding are now connected in opposition then a high overall $\cos\phi$ can be maintained with a much smaller $\Phi_3$ whereas the current $i$ for a given magnitude of $\Phi_2$ must now be chosen greater than before thus securing a larger auxiliary torque.

The conditions of commutation will now be considered.

All commutation diagrams are drawn to a much larger scale than any of the others so as to make them clearer; all the E. M. F.'s induced or generated by $\Phi'_1$ have been neglected as being very small. The commutation diagrams are, and can only be, approximate only.

The conditions prevailing under the armature brushes $aa^1$ of the known motor shown in Fig. 1 are illustrated by the diagram Fig. $1^d$, it being assumed that the machine is standing still. Fig. $1^d$ particularly refers to the conditions under brush $a$. The total armature current I is only shown by way of reference; it is the current in each half of the armature which is of importance, in this case. If

$$\frac{I_r}{2} \text{ and } \frac{I_1}{2}$$

are the respective currents in the right and left halves and if rotation is counter clockwise, then the current in the coil undergoing commutation must be reversed from

$$\frac{I_r}{2} \text{ to } \frac{I_1}{2}$$

within the time $t$ during which the coil undergoing commutation is short circuited by the brush $a$. The motor field $\Phi_2$ will induce $e_2$ in the shortcircuited coil and that E. M. F. will cause a current $i_a$ to flow therein. The phase of $i_a$ with respect to $e_2$ can be determined in the usual way if $w$ is the ohmic resistance and $x_a$ the reactance of each coil. The brush contact resistance (whether varying or not) as well as the brush resistance are assumed to be included in $w$. The shortcircuited current $i_a$ may be greatly in excess of the working current I; it will cause local heating and when the rotor begins to rotate, then the interruption of this current each time a segment leaves the brush, will cause sparking. The permissible sparking during the first few revolutions sets the limit for the magnitude of $\Phi_2$ at the moment of starting and therefore determines the maximum starting torque. The same diagram also holds good for the brushes $aa^1$ of the new motor shown in Fig. 3 as long as the rotor is at rest. A similar diagram holds good for the brushes $f\ f'$ of that last motor when at rest. $\Phi_2$ has however no inductive effect on the coils shortcircuited by the brushes $f\ f'$ whereas $\Phi_3$ is fully effective. The E. M. F. induced in these coils is $e_3$ the shortcircuited current is $i_f$. The E. M. F. $e_3$ corresponds to $e_2$ of Fig. $1^d$ and $i_f$ corresponds to $i_a$ of that figure.

Suppose now that the known motor shown in Fig. 1 is allowed to reach that same speed $s$ which was taken as a basis for Fig. $1^c$, while the current taken by the motor is kept the same as at starting, which assumption was also made for Fig. $1^c$, then $\Phi_2$ and therefore $e_2$ and $i_a$ must remain unaltered in the coil undergoing commutation so that Fig. $1^d$ will still correctly represent the commutating conditions for the speed $s$, at least toward the end of the commutating time $t$. The commutating conditions shown in Fig. $1^d$ are obviously bad, at the instant considered, $i_a$ should be equal to

$$\frac{I_1}{2}$$

both in phase and magnitude, whereas it leads the latter considerably and is very much greater. If the current I diminishes as the speed increases then the commutation will improve, for then $\Phi_2$, $e_2$ and $i_a$ will all diminish and $i_a$ will lag farther behind $e_2$ on account of the increased frequency of commutation. Indeed as the commutation frequency increases, the shortcircuited current will not be able, within the time $t$, to reach that value which corresponds to $e_2$, therefore $i_a$ will with increasing speed approach

$$\frac{I_1}{2}$$

both in phase and magnitude. With the help of the contact resistance commutation may become quite good but only at the speeds considerably above the synchronous. These remarks will also show what phase and magnitude an auxiliary commutating E. M. F. impressed on the coil in question should have in order to secure a good commutation at somewhat lower speeds; its phase and magnitude cannot very well be constant.

Fig. $3^h$ refers to the conditions under the brush $a$ of the new motor shown in Fig. 3 when running with the same current I and at the same speed S. In this motor there are two E. M. F.'s in the short circuited coil. $e_2$ induced by $\Phi_2$ and $e'_3$ generated by rotation in $\Phi_3$. Their resultant OR is the true commutating E. M. F. and happens to be of nearly the correct phase and magnitude. Although the ohmic drop $i_a\ w$ and the reactance voltage $i_a\ x_a$ are shown in all the diagrams these vectors are not always lettered. Fig. $3^h$ shows that commutation can always be made sufficiently good by altering $\Phi_3$ in one of two ways. Either choose $\Phi_3$, therefore $e'_3$ so that $i_a$ equals

$$\frac{I_1}{2}$$

in phase and magnitude, or choose it so that $e'_3$ equals and opposes $e_2$ when OR will be equal to zero. In the first case the contact resistance will only be called upon to rectify the unavoidable little irregularities which will occur during commutation; in the second, the commutation will be due to contact resistance only. But the motor shown in Fig. 3 has another set of brushes $ff'$ and the commutation under these must also be considered. Fig. $3^1$ shows the condition under brush $f^1$ for the same assumptions as underlie Fig. $3^h$. Here $e_3$ is induced by $\Phi_3$

and $e'_2$ generated by rotation in $\Phi_2$. The resultant OR, happens to be a little too large but is nearly of the correct phase for $i_1$ nearly coincides with

$$\frac{I_1}{2}$$

—as it should. It is seen that if $\Phi_3$ is so chosen that OR under the brush $a$ is of quite correct phase and magnitude to insure good commutation, then OR under the brush $f^1$ will in some cases be of nearly, in others of quite, correct phase and magnitude. But if OR is reduced to zero under $a$, it will also, at the same time, be reduced to zero under $f^1$. This last condition is satisfied when $\Phi_2 = \Phi_3$, when their phase difference is nearly 90° and when the motor speed is near to or equal to the synchronous. A study of the diagrams shown in Figs. $3^h$ and $3^i$ will disclose all the other possible combinations which will conduce to the improvement of the commutation under the one or the other set of brushes or under both simultaneously.

In both axes the values of $e'_2$ and $e'_3$ can be varied to some extent by locally concentrating or strengthening or locally weakening the fields by rotation in which these E. M F.'s are generated or by superimposing on these fields auxiliary fields of the same or nearly the same phase and direction and produced in any known or suitable manner and with the help of special commutating poles or with the help of one or more stator teeth situated in the neighborhood of or in the commutating zone itself. These poles or teeth may be excited by means of shunt or series transformers or in any equivalent manner.

In all cases it is at starting that the greatest commutating difficulty generally occurs; now my improved motor has this advantage over the one shown in Figs. 1 or 2 for instance, that it can be started with two effective armature and field axes per pole pair. Since there are two torque producing fields in my motor, then, assuming the same current to flow through both motors, it is only necessary, in order to get the same torque in both cases, that the sum of the effective components of the said two fields in my motor be equal to the effective field component in the known motor. Obviously then each individual field in my motor, *i. e.* $\Phi_2$ and $\Phi_3$ will be smaller than the motor field required in the known motor, thus in Fig. $3^h$ $e_2$ will be much smaller than $e_2$ of Fig. $1^d$ and $e_3$ of Fig. $3^i$ will be much smaller than $e_2$ of Fig. $1^d$. At starting therefore the individual short circuit current under the brushes, in that form of my improved motor which is shown in Fig. 3 for instance, will be considerably smaller torque for torque and hence the commutation will be much better. It is hardly necessary to call attention to the many other deductions to be drawn from the diagrams given; those skilled in the art should easily see all the remaining points.

Having thus fully stated the theory upon which this invention is based and explained with the help of that theory some way of carrying the invention into practice particularly in connection with the example shown in Fig. 3, it will not be necessary to describe the further examples given in great detail and other modifications which are not described or illustrated should be easily recognized by those skilled in the art with the help of this description and the diagrams. It is to be understood that modification shown in connection with one example may be used with any of the other examples as far as they apply. All the drawings show two pole motors but the invention is equally well applicable to motors with any number of pole pairs. The stationary member may be of the stator type or it may have more or less defined polar projections and it may carry any suitable type of winding although a concentrated winding has been shown throughout for the sake of convenience. The revolving member may carry any suitable winding such as used in this type of machine; such winding will be connected to a commutator in the usual way. In the figures Gramme windings have been assumed throughout for the sake of simplicity and the brushes are supposed to bear directly on those windings.

Turning now to the description of further examples, Fig. 4 shows one way of carrying out the invention in which the auxiliary winding is excited by an E. M. F. directly derived from the terminals of A. The method of regulating $\Phi_3$ which is shown consists in varying the number of turns of C.

In Fig. 5, a part of N is made use of as C winding and is excited from the mains through T', while the rotor carries two independent windings the one on which bear the brushes $a$ $a^1$ and which does duty as armature winding, the other on which bear the brushes $f$ $f^1$ and which does duty as field winding.

In Fig. 6, one set of brushes only and one rotor winding only are used, and the latter does duty as armature and as field winding. This is brought about by displacing the brushes from the neutral position coinciding with the axis of the neutralizing winding N and shifting them forward or in the direction of the intended rotation indicated by the arrow D. In that case that portion of the rotor winding which is shown in heavy lines acts as armature winding whereas that shown in thin lines act as field winding. This manner of carrying out my invention has the advantage among others that the armature winding can be neutralized much more effectively by means of N, which is then preferably distributed on the stator so as to correspond as closely as possible with that part of the rotor winding which acts as armature winding. By way of example C is excited directly from the mains.

The diagram Fig. 6[a] illustrates the commutation conditions toward the end of the time $t$ in the coil under brush $a$ of the motor in Fig. 6 on the assumption that the machine is running at a speed $s$ and taking a current I. These assumptions are therefore the same as those underlying all other commutating diagrams. In this case there are four E. M. F.'s which are unavoidably present in the short circuited coil. The motor field induces $e_2$ and $e'_2$ is generated by rotation in $\Phi_2$; the auxiliary field induces $e_3$ and $e'_3$ is generated by rotation in $\Phi_3$. The resultant OR is again the true commutating E. M. F. For the conditions chosen it is nearly of the correct phase but of too great a magnitude. Fig. 6[a] together with what has already been said on this subject of commutation will show what steps must be taken in order to improve the commutation. One new factor must however be considered in this case and that is the angular displacement $\alpha$ of the brush line from the axis of the neutralizing winding N. When $aa^1$ nearly coincides with N, then $e_2$ and $e'_3$ are at a maximum whereas $e_3$ and $e'_2$ are nearly zero. When $aa^1$ is nearly at right angles to N, then $e_2$ and $e'_3$ are nearly zero and $e_3$ and $e'_2$ at a maximum. This gives an additional and simple means of adjusting the phase and magnitude of OR. At synchronism OR becomes zero for all values of the current taken by the motor if $\alpha$ is chosen equal to 45°, the phase difference between $\Phi_2$ and $\Phi_3$ is about 90°, $\Phi_2$ about equals $\Phi_3$ and the fluxes are still proportional to the E. M. F.'s.

Instead of using an ordinary continuous current winding on the rotor and displacing the brushes in the manner shown in Fig. 6, the rotor winding may be suitably altered so as to achieve the same purpose without however having to displace the brushes or to use more than one set of them per pole pair. Such a winding is shown for a two-pole machine in Fig. 6[b], where each coil of the rotor winding consists of two turns 1-2-3-4 and 5-6-7-8, these two turns are disposed in two planes preferably displaced by $180/n$ degrees with respect to each other. When the axis of N is parallel to the plane of the turn 1-2-3-4 then this turn acts as field winding and the other turn then acts as armature winding. The current in the first produces $\Phi_2$ and yields a torque with $\Phi_3$, the current in the second yields a torque with $\Phi_2$ and is neutralized by N. Each coil of this winding may consist of more than two turns and they may be equally divided between the two planes or not; if they are, then the arrangement corresponds to a displacement of 45° of the brushes in the example shown in Fig. 6 where an ordinary rotor winding is made use of.

The proportion of field to armature turns in Fig. 6 is fixed as long as the brushes remain in a fixed position. It is generally preferable not to displace the brushes while operating the machine although this can of course be done. When it is nevertheless desired to vary the motor field strength independently of the armature current some such arrangement can be used as is shown in Fig. 7 where by way of example the winding F is disposed on the stator and in the motor field axis and so arranged that the number of its turns can be varied as for instance at K, also that it can be reversed as at S and be thus made to produce a magnetization in the same or in the opposite direction to that produced by that part of the rotor winding which does duty as field winding. This method of varying $\Phi_2$ is not only applicable to the example shown in Fig. 6 but to any one of the other examples. It is easier to improve the power factor of the motor as a whole when that portion of the field winding which is disposed on the stator is connected in opposition to that portion of the field winding which is disposed on the rotor. The auxiliary winding C is here connected by way of example across the armature and across part of the field winding, some known and suitable regulating means being inserted at R.

The direction of rotation can be changed in the example shown in Fig. 6, by moving the brushes beyond the neutral position or that coinciding with the axis of N. Or it can be changed by providing two sets of brushes these sets being positioned on opposite sides of the neutral position, the one set being used for one direction of rotation and the other for the other. According to another modification two sets of windings $N_1C_1$ and $N_2C_2$, can be disposed on either side of the brush axis $aa^1$ when the one or the other set of windings may be used according to the direction of rotation required. It is not necessary although preferable that $\alpha$ be the same for both directions of rotation. According to a fourth modification $\alpha$ is chosen equal to say 45° and the two sets of stator windings are placed at right angles to each other. If $N_1$ and $C_1$ are used for operating in one direction then $N_2$ or $C_2$ or $N_2+C_2$ can at the same time do duty as F winding (see Fig. 7) for the purpose of regulating the motor field and vice versa. A fifth modification which is illustrated for both directions of rotation in Figs. 8 and 9 consists in separating each winding N and C into two independent units N′, and N″ and C′, C″ so arranged that the current through at least one unit of each set of units can be reversed. The necessary connections are clearly seen from the two figures. If $N'=N''$ and $C'=C''$ then $a$ is equal to 45° for both directions of rotation. If $N''<N'$ then $a<45°$ when $C''$ can with advantage also be smaller than $C'$. That part of the rotor winding which is marked with thick lines does duty as armature, the rest as field winding. According to a sixth modification both N and C can be distributed windings and the direction of rotation can be changed or the field turns varied by simply changing the diameter of entry of the current into such windings.

In Fig. 10 is given one example in which the resultant E. M. F. impressed on the auxiliary winding C is derived from two sources, means being provided by way of example for regulating both components at $K^1$ and $K^2$ and for reversing one of them at $S^1$. One component is derived from the mains through the transformer T′ and the other from the series transformer T feeding the field circuit. That transformer is shown by way of example as having two secondaries.

In all the examples so far considered the auxiliary winding C has been fed by a shunt or a shunt and a series transformer; it will be understood that more than one of such transformers may be used simultaneously. Fig. 11 shows a further modification in which C is fed from a series transformer only. This manner of feeding C has by way of example, been shown in combination with that disposition of the brushes which is shown in Figs. 6, 7, 8 and 9; it can of course and as has already been stated, be used in combination with any of the other examples shown or described. The magnetization produced by C can be regulated by means of K as shown in Fig. 11.

A further modification, which is not illustrated, consists in exciting C directly by means of the current passing through the motor and without the interposition of a series transformer. In this last modification the motor can work very well on a continuous current circuit and without a change of connections.

All the examples described show the auxiliary winding disposed on the stationary member and in the axis of the neutralizing winding. Although this arrangement is generally preferred it is not necessary that the auxiliary winding C should be disposed in that particular axis; it may be disposed in any other axis making an angle $\beta$ with N as long as the axis of C does not coincide with the axis of the motor field $\Phi_2$. Such an arrangement is shown in Fig. 12 where C is by way of example supposed to be connected to some external source with an E. M. F. ($D_2$).

The auxiliary winding C can at least in part be disposed on the rotor; this either necessitates an additional set of brushes and an additional rotor winding or that part of the rotor winding can be made use of for the purpose which does duty as armature winding. The auxiliary E. M. F., wherever derived from, can then be applied to the brushes $aa^1$ thus entirely dispensing with a stator winding C. This is shown in Fig. 19. It is further not necessary that when two sets of brushes are used as for instance in Fig. 3, that these should be displaced by exactly

$$\frac{180}{n}$$

degrees although this particular spacing is as a rule preferred. The brushes $f$, $f^1$, can for instance be displaced somewhat as shown in Fig. 13. In this example C is shown connected to the primary terminals of the series transformer T. The ampere-turns due to the exciting or field current passing through the brushes $f$ $f^1$ do not all act as field turns in this case. Similarly to Fig. 6 one part of these ampere-turns does duty as field the rest as armature ampere-turns. The latter may, according to the direction in which the field brushes have been displaced from the axis of the motor field and relatively to the direction of rotation of the motor, act with or against the armature ampere-turns due to the armature current passing through the brushes $a$, $a^1$. The armature brushes can also be displaced from the armature axis similarly to the manner in which the field brushes have been displaced in Fig. 13. By way of example a variable ratio transformer T° has been interposed in this case between the motor and the mains; it is well understood that such a transformer can be used whenever convenient.

Fig. 14 shows one modification in which both sets of brushes have by way of example been displaced by about 45° from the axis of N. In this case C is being fed by way of example from that part F of the motor field winding which is disposed on the stator. It will be understood that in this case the result obtained is a differential one.

In Fig. 3, for instance, the armature winding, between the brushes $a$, $a^1$ is distributed over the pole pitch and this is also the case with the field winding between the brushes $f$, $f^1$. The so-called winding coefficient for such a space distribution is poor, and magnetic saturation is easily set up in some portions of the polar embrace. In order to avoid these drawbacks the disposition of the brushes on the rotor may be modified as shown in Figs. 15 and 16.

In Fig. 15 it is only that part of the rotor winding which is shown in heavy lines which does duty as armature winding, whereas the rest acts as field winding. In order to make such a current distribution possible, I, according to one modification, feed those parts of the rotor winding which are to do duty as armature winding, through series transformers $T^1$ and $T^2$ and connect these to the brushes $a$, $a^1$ and $a_0$ $a^1_0$ respectively, and in such a manner that no current will tend to pass from $a_0$ to $a$ or from $a^1_0$ to $a^1$ or vice versa. This is achieved by connecting the secondaries of these transformers in opposition with reference to those portions of the rotor winding which lie between the brushes $a$, $a_0$ and $a^1_0$ and $a^1$. In order to send a current through the rotor winding lying between the brushes $a^1_0$, $a^1$ and $a_0$, $a$, I send it in at the center point 1 of the secondary of $T^1$ and out at the center point 2 of the secondary of $T^2$. Since this field current traverses each half of these secondaries in opposite directions, these secondaries will be non-inductive as far as the field current is concerned. This field current must of course flow from $a$ to $a_0$, and from $a^1$ to $a^1_0$ or vice versa. The rest of the connections are by way of example similar to those shown in Fig. 11.

According to a further modification shown in Fig. 16 it is the field current which is derived from the transformers $T^1$ and $T^2$ whereas the armature current is led through their secondaries non-inductively. In any case $T^1$ and $T^2$ may have the same iron core and any suitable regulating devices may be introduced.

A further modification is shown in Fig. 17; the two sets of brushes are preferably disposed as shown, the one set $aa^1$ coaxially with N, the other $ff^1$ displaced by $180/n$ degrees with respect to the first. A transformer T the primary of which is connected in series with N carries by way of example two independent secondaries $t^1$ and $t^2$, the first is connected to the brushes $a$, $f^1$, the second to $f$, $a^1$ and in such a manner that $t^1$ and $t^2$ are in opposition with respect to those portions of the rotor winding which are comprised between the brushes $a$, $f$, and $a^1$, $f^1$. The current flowing between the brushes $a$, $f^1$ and $f$, $a^1$ acts partly as an armature and partly as a field current. In order to reverse the direction of rotation it is necessary either to connect $t^2$ to $a$ and $t^1$ to $a^1$, which corresponds to a reversal of the armature current, or to connect $t^2$ to $f^1$ and $t^1$ to $f$, which corresponds to a reversal of the field current. In the first instance the current through N, in the second that through C should be reversed.

By shortcircuiting the brushes $f$, $f^1$ which carry the field current the motor can at any time be converted into a self-excited machine as described in my previous U. S. applications Nos. 348,659 and 348,907. By "self-excited" machine is meant one which generates its own exciting E. M. F. or current when rotating.

If at the time of the conversion the auxiliary field is excited by a varying current, say in series relation to the mains, then the speed of the motor will also vary and its speed characteristic will be similar to that of a series machine after the brushes $f$, $f^1$ have been shortcircuited. If the auxiliary field is however then excited by a constant E. M. F. or current, say in parallel to the mains, then the machine will assume a shunt characteristic as soon as the brushes $f$, $f^1$ are shortcircuited and this may be useful in some cases. Means for carrying out this conversion are by way of example shown in Fig. 18 where the switch M is provided for the purpose of shortcircuiting the field brushes $f$, $f^1$. Another switch $M^1$ is also provided by means of which the primary of T may also be shortcircuited if desired.

Fig. 20 shows a neutralized series conduction motor in which the field winding is partly disposed on the rotor, being the rotor winding itself between the brushes $f$ and $f^1$, and partly disposed on the stator at F. These two parts of the field winding are connected in series with each other and in series relation with the working circuit by means of the transformer T. The stator field winding F can be regulated at $K^2$ and the direction of the current through F can be reversed at $S^2$. The working circuit comprises the neutralizing winding N, the primary of T and the revolving member A connected in series with N and in opposition thereto by way of the brushes $a$, $a^1$. The auxiliary winding C is disposed on the stator and in the axis of N it is connected in parallel to the supply by way of the variable ratio shunt transformer $T^1$.

Motors constituted as described in this specification can of course be made use of as generators or as brakes for instance when employed for traction or similar work. The speed of these motors can be varied for a given current by varying the terminal voltage or the magnitude of the motor field or by varying the magnitude or phase of the auxiliary field. These motors can when required be operated with continuous current for instance when a car or a train equipped with such machines passes from an alternating on to a continuous current system. The alterations in the connections sometimes required at the moment of such a transition will be understood without further explanation. It must be noted that although $\Phi_3$ sometimes loses much of its importance when motors constituted as here described are operated on continuous current, yet this auxiliary field can often be used with advantage and will always increase the torque whether C is connected in series or in parallel to the supply.

The motors here described can be operated on the series parallel or any other system of grouping.

What I claim and desire to secure by Letters Patent is:—

1. In an alternate current motor the combination with a stationary member provided with a neutralizing winding and a field winding displaced from said neutralizing winding and connected in series relation therewith, of a revolving member connected in series relation with the neutralizing winding along one axis and in series relation with the field winding along another axis, and means for producing an alternating flux along an axis approximately coinciding with that of the neutralizing winding.

2. In an alternating current motor, the combination with a stationary member provided with a neutralizing winding and a field winding displaced from said neutralizing winding, of a revolving member provided with a commuted winding connected in series relation with the neutralizing winding, means in series relation with the neutralizing winding for conveying an exciting current through said stator field winding and through said revolving member along an axis displaced from that of the neutralizing winding, and means for producing an auxiliary flux through the motor along an axis displaced from that of the stator field winding.

3. In an alternating current motor, the combination with a stationary member provided with a neutralizing winding and a field winding displaced from the neutralizing winding, of a revolving member carrying a conductively supplied working current along an axis approximately coinciding with that of the neutralizing winding, and a conductively supplied exciting current along another axis said exciting current being in series relation with the working current, and means for producing an auxiliary field through the motor along an axis displaced from that of the exciting current.

4. In an alternating current motor, the combination with a stationary member provided with a neutralizing winding and a field winding displaced from the neutralizing winding, of means for varying the number of turns in said stator field winding, a revolving member carrying a conductively supplied working current along an axis approximately coinciding with that of the neutralizing winding, and a conductively supplied exciting current along another axis said exciting current being in series relation with the working current, and means for producing an auxiliary flux through the motor along an axis displaced from that of the exciting current.

5. In an alternating current motor, the combination of a stationary member provided with a neutralizing winding, a field winding displaced by about $180/n$ degrees with respect to the neutralizing winding, and an auxiliary winding disposed along an axis approximately coinciding with that of said neutralizing winding, a revolving member provided with a commuted winding connected in series relation with said neutralizing winding along an axis approximately coinciding with that of the neutralizing winding, and an exciting circuit on the revolving member connected in series relation with said neutralizing winding and said stator field winding along an axis displaced by about $180/n$ degrees with respect to that of the neutralizing winding.

6. In an alternating current motor, the combination of a stationary winding member provided with a neutralizing winding and an auxiliary winding connected in parallel with the circuit containing said neutralizing winding, and disposed along an axis approximately coinciding with that of the neutralizing winding, a revolving member provided with a commuted winding connected in series relation with said neutralizing winding along an axis approximately coinciding with that of the neutralizing winding and an exciting circuit on the revolving member connected in series relation with said neutralizing winding along an axis displaced with respect to that of the neutralizing winding.

7. In an alternating current motor, the combination of a stationary member provided with a neutralizing winding, a field winding displaced with respect to the neutralizing winding, and an auxiliary winding connected in parallel to the mains and disposed along an axis approximately coinciding with that of the neutralizing winding, a revolving member provided with a commuted winding connected in series relation with said neutralizing winding along an axis approximately coinciding with that of the neutralizing winding and an exciting circuit on the revolving member connected in series relation with said neutralizing winding and said stator field winding along an axis displaced with respect to that of the neutralizing winding.

8. In an alternating current motor, the combination of a stationary member provided with a neutralizing winding, a field winding displaced from the neutralizing winding, and an auxiliary winding disposed along an axis approximately coinciding with that of said neutralizing winding, a series transformer, a revolving member provided with a winding connected to a commutator, a set of

working brushes on said commutator approximately in line with and connected in series relation with the neutralizing winding, a set of exciting brushes on said commutator displaced with respect to the working brushes and connected by way of said transformer in series relation with the neutralizing and the stator field winding.

9. In an alternating current motor, the combination with a stationary member provided with a neutralizing winding, of a revolving member connected in series relation with the neutralizing winding along two axes, and means for producing an alternating flux along an axis approximately coinciding with that of the neutralizing winding but differing in phase from the flux produced by said neutralizing winding.

10. In an alternating current motor, the combination with a stationary member provided with a neutralizing winding, of a revolving member provided with a commuted winding connected in series relation with the neutralizing winding along an axis approximately coinciding with the axis of said neutralizing winding, means connected in series relation with the neutralizing winding for conveying an exciting current through the revolving member along an axis displaced from that of the neutralizing winding, and means for producing an auxiliary flux threading both members of the motor along an axis displaced from the axis along which the exciting current is conveyed through the revolving member, said auxiliary flux differing in phase from the flux produced by the neutralizing winding.

11. In an alternating current motor, the combination with a stationary member provided with a neutralizing winding, of a revolving member provided with a commuted winding connected in series relation with the neutralizing winding along two axes one of which is displaced by about $180/n$ degrees from the axis of the neutralizing winding, and means for producing an alternating flux along an axis approximately coinciding with that of the neutralizing winding but differing in phase from the flux produced by said neutralizing winding.

12. In an alternating current motor, the combination with a stationary member provided with a neutralizing winding and an auxiliary winding connected to produce a flux differing in phase from the flux produced by the neutralizing winding, said auxiliary winding being disposed along an axis approximately coinciding with that of the neutralizing winding, a series transformer, a revolving member provided with a winding connected to a commutator, a set of working brushes on said commutator approximately in line with and connected in series relation with the neutralizing winding, a set of exciting brushes on said commutator displaced with respect to the working brushes and connected in series relation with the neutralizing winding by way of said series transformer.

In witness whereof, I have hereunto signed my name in the presence of two subscribing witnesses.

VALÈRE ALFRED FYNN.

Witnesses:

ROBERT MILTON SPEARPOINT,
HERBERT D. JAMESON.