No. 851,738. PATENTED APR. 30, 1907.

G. FAGET.

METHOD OF AND APPARATUS FOR TRANSFORMING SINGLE OR POLYPHASE INTO CONTINUOUS CURRENT.

APPLICATION FILED OCT. 22, 1904.

4 SHEETS—SHEET 1.

Fig. 1.

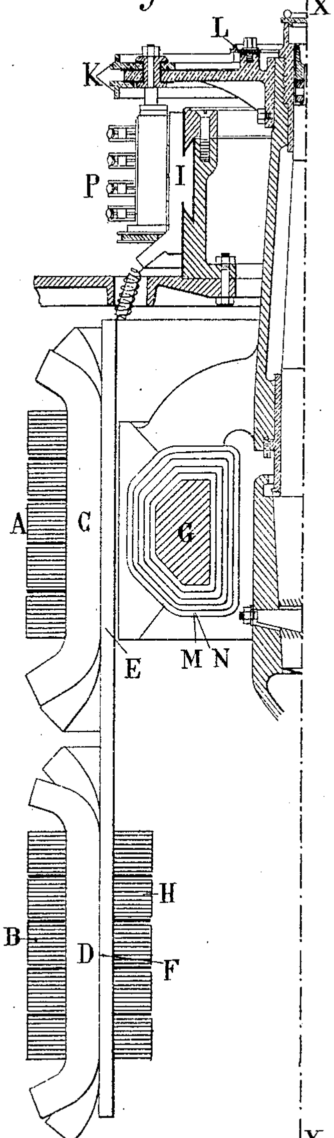


Fig. 4.

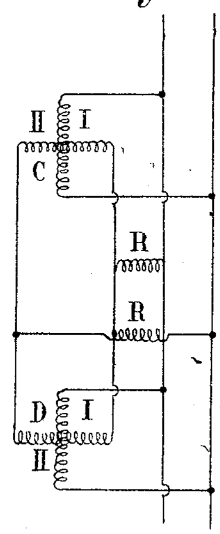


Fig. 5.

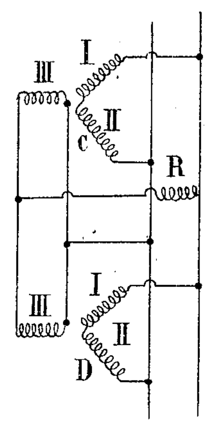
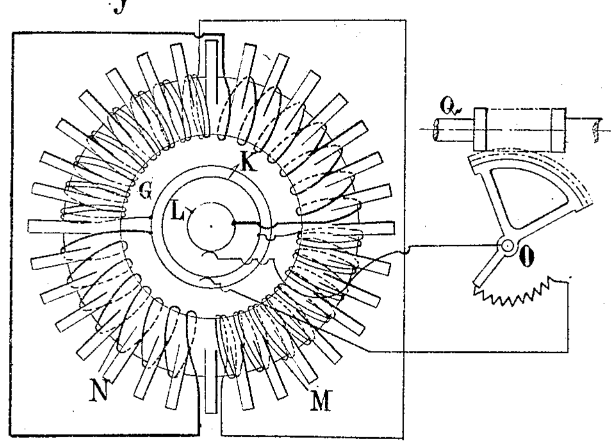


Fig. 3.



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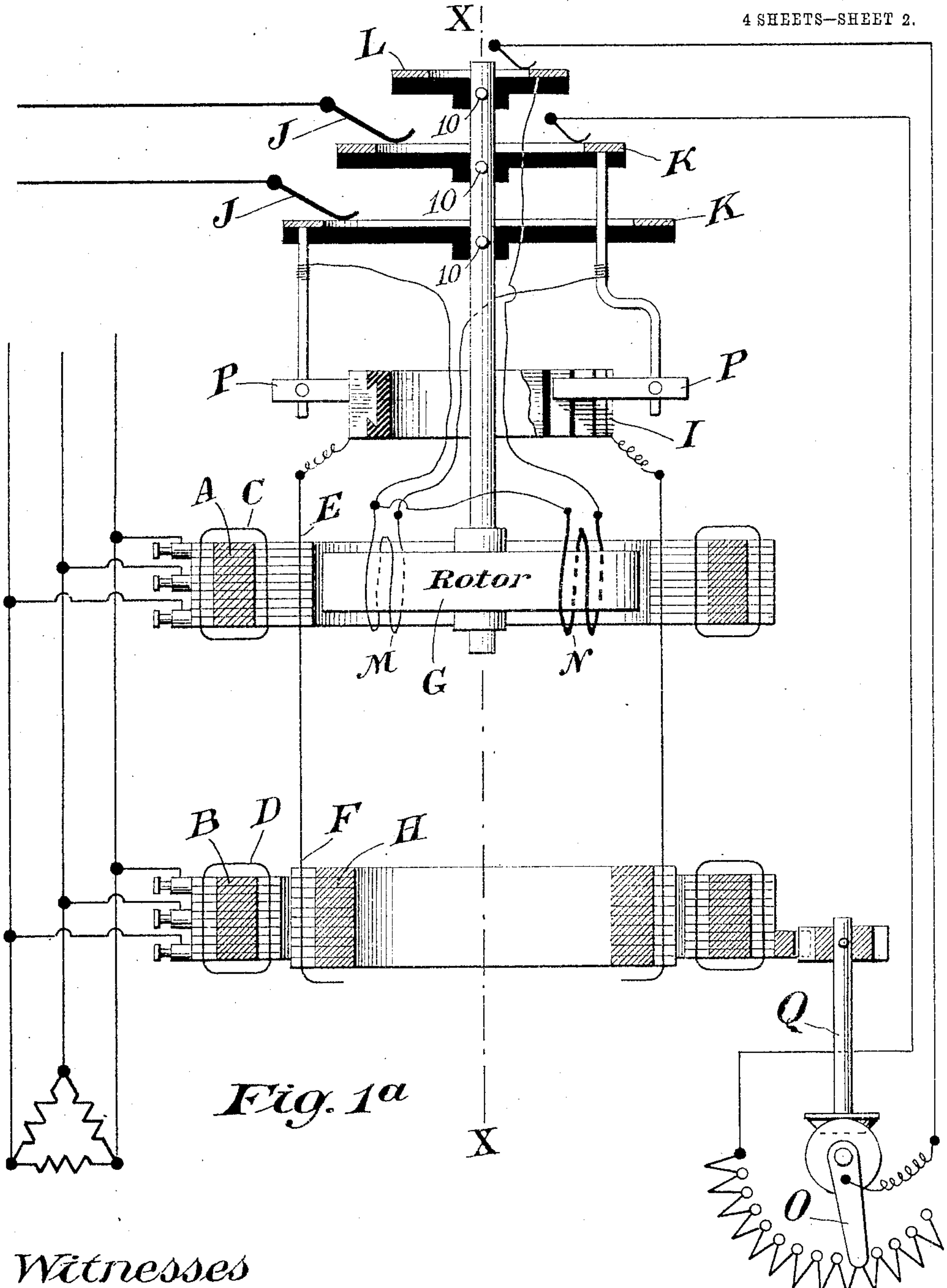

Fig. 1a

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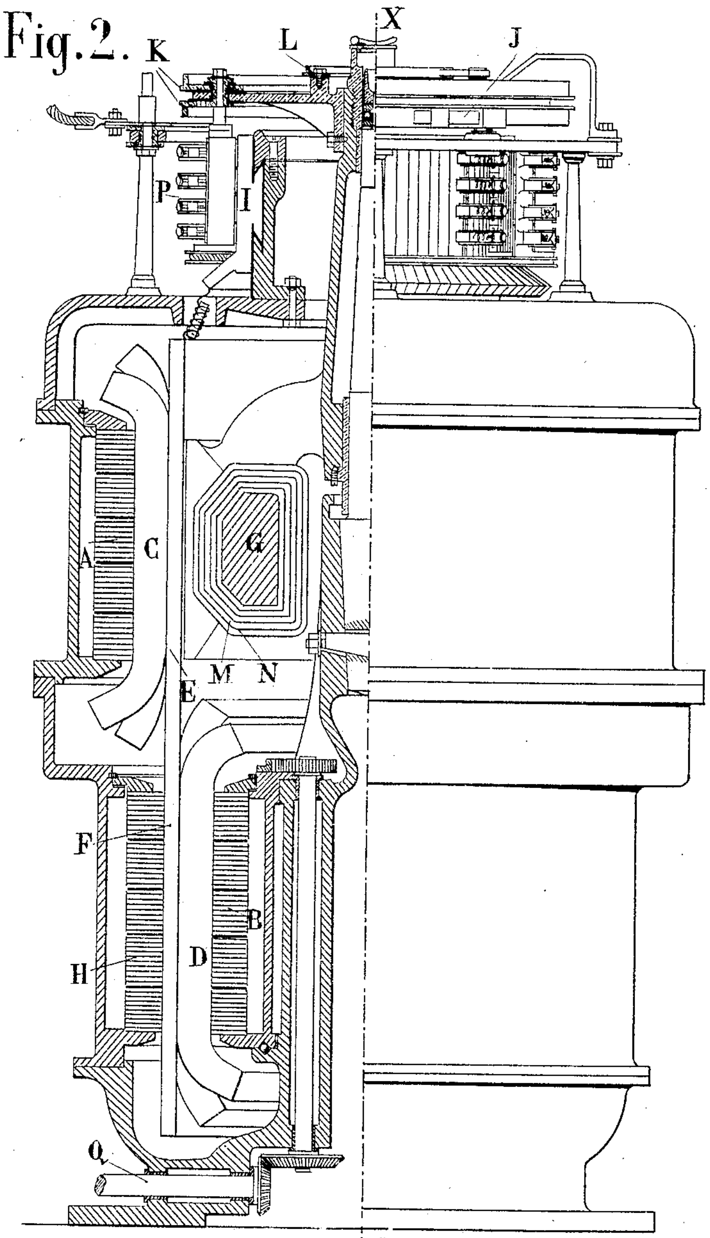
4 SHEETS—SHEET 3.

Fig. 2.



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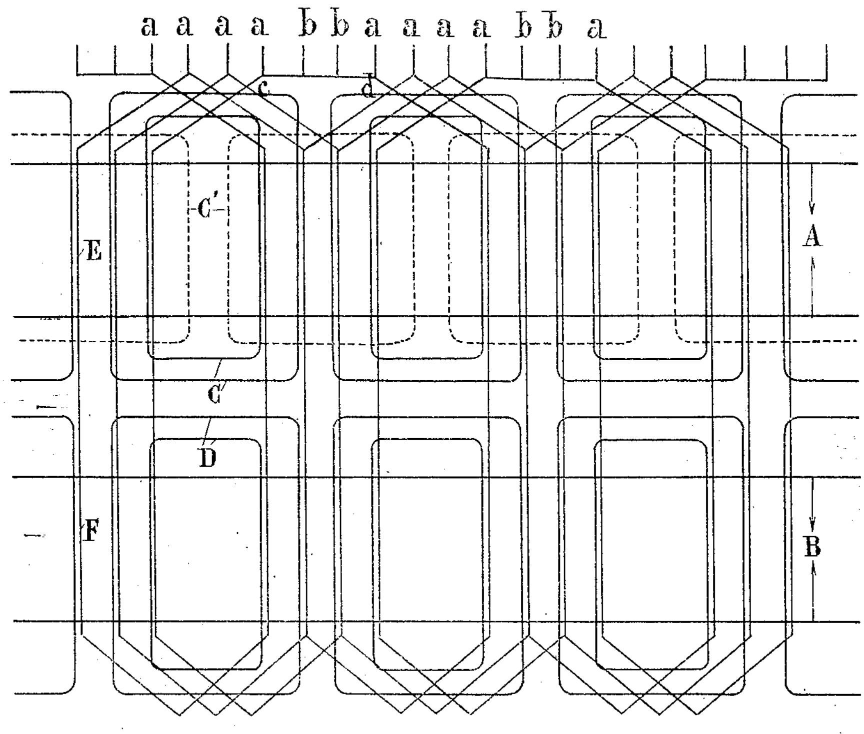
4 SHEETS—SHEET 4.

Fig. 6.



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UNITED STATES PATENT OFFICE.

GEORGES FAGET, OF PARIS, FRANCE.

METHOD OF AND APPARATUS FOR TRANSFORMING SINGLE OR POLYPHASE INTO CONTINUOUS CURRENT.

No. 851,738. Specification of Letters Patent. Patented April 30, 1907.

Application filed October 22, 1904. Serial No. 229,629.

To all whom it may concern:

Be it known that I, GEORGES FAGET, a citizen of France, residing at Paris, France, have invented a new and useful Method of and Apparatus for Transforming Single or Polyphase into Continuous Current, of which the following is a specification.

In certain branches of the electric art, and particularly in electric traction, it would be extremely useful to have certain apparatus for taking single phase or multiphase current of constant frequency and potential, as furnished by the mains, for converting the same into continuous current having a voltage variable at will for use in motors, etc. I have found that the problem could not be solved in a rational manner except by satisfying the condition of having constant densities of magnetic flux so as to secure perfect operation and high efficiency per unit of weight. For this reason the composition of fields which would change the flux densities could not be resorted to and I have solved the difficulty by using distinct constant fields and compounding only their separate effects. My new system of transformer is, therefore, combined so as to use the primary alternating currents to produce in different parts of space two rotary fields or else two elliptically rotary fields of either equal or unequal but constant strength, both fields having the same angular velocity and, therefore, a constant angular relation, which angular relation I make adjustable by any suitable means, so that the rotary fields in acting on consecutive portions of a secondary fixed winding extending through both fields shall induce therein two constant alternating electro-motive forces equal in period, but differing in phase by an amount corresponding to the angular relation given to the two fields, and, therefore, producing in the secondary a resultant alternating electro-motive force of the same frequency, but of a strength dependent upon said angular relation. The secondary windings are made in the shape of an armature with a stationary commutator and the resultant alternating electro-motive force is rectified or commuted by brushes revolved by any suitable means so as to make contact on the revolving neutral axis of commutation. The constancy of the two rotary fields is insured by the fact that they have to counterbalance the constant electro-motive force of the main or feeders, by their inductive reaction on the two primary circuits.

The annexed drawings show how the invention may be carried out in practice first as used for transforming multiphase currents and then as applied to the case of single phase currents.

Figure 1 shows one form of the invention in vertical section, with right half omitted, such form being specially adapted for illustrating the general arrangement and principles involved. Fig. 1^a is a pure diagram of the same. Fig. 2 is a preferred form shown in elevation with left half in section. Fig. 3 is a plan of the rotor, showing the two windings and the auxiliary variable resistance diagrammatically. Fig. 4 is a diagram of a form adapted to operate either with two phase current or with uniphase current. Fig. 5 is a similar diagram of a form adapted to operate either with three phase current or with uniphase current. Fig. 6 is a diagram of a form specially adapted to two phase current.

A is a fixed laminated core, similar to the stator core of an induction motor or alternator and having housed therein the primary winding C, as well as a part E of the secondary winding.

C is a high tension multiphase winding, connected with the main or feeders and producing an upper rotating field.

E is a continuous current drum winding having a fixed commutator I. On the latter rub brushes, such as P, leading the current to rings K which revolve with them; as indicated in Fig. 1^a by pins 10 and on the rings K bear brushes, such as J (Fig. 2), which collect the current for use in the motor or other local apparatus not shown. The brushes and the rings are rotated by any suitable means which in the embodiment illustrated consists in a core and winding G which bears the relation of rotor to the stator A. The secondary winding extends downwardly from E to F into a second rotary field produced by a second primary winding D housed in the core B to form a second stator. The windings C and D are identical and are fed in parallel from the same main.

H is the core of the drum winding E F.

The voltage of the continuous current is varied by increasing or by decreasing the angular relation of the two rotary fields produced by the windings C and D; and the simplest way of doing this is to revolve the stator B D (by means of a shaft O Fig. 1^a) more or less on its axis X X. In order to not interfere with such angular adjustment, the teeth of core B are made short enough (see Fig. 1[a]) to pass clear of the coils F. The same result might evidently be secured by angular adjustment of the stator A C or by opposite angular adjustments of both A C and B D.

Fig. 2 shows an embodiment of my invention in which B D is alone movable and to simplify the construction B D is here mounted inside of H F. The angular motions are imparted to B D by means of a shaft Q through suitable gearing as seen in the drawing.

It will be noted, that in the forms of Figs. 1, 1[a] and 2 the magnetic circuit of the field that is angularly adjusted or shifted (lower field) is closed through a stationary core H, while the upper magnetic circuit is closed in a revolving core G. This feature is a very important factor in the practical realization of my system.

To make the principle of my invention clear, I shall now explain how the voltage of the continuous current is related to the angular relation of the two rotary fields. In doing so I shall suppose that the fields are equal because this is the most desirable and general case.

Let $\frac{V}{2}$ be the maximum potential difference produced on the commutator by either of the revolving fields acting alone; and let α be the angular relation of the two fields. The parallelogram rule of composition gives for the resultant potential difference which we shall call v.

$$v = V \cos \frac{\alpha}{2}$$

and it will be seen that v varies from V to zero as α varies from zero to π. It is evident that, in order to obtain such variation to zero, it is necessary that the fields be equal, that is to say, that the two stators shall have identical windings and the same core volumes. If such condition were not fulfilled, the variation in the voltage of the continuous current would be restricted within narrower limits. In order to collect the full value of this difference of potential on the commutator, it is necessary to keep the rotary brushes on the neutral axis of commutation. This may be done in a number of different ways, but I shall only describe the one which I have found to be the simplest and best. The brushes P, P, Fig. 1[a], are mounted on a rotor G, which is mounted in the upper rotary field. In the case where the two rotary fields are equal, the resultant neutral axis, in which the brushes must make contact, makes with the neutral axis of said upper field an angle equal to one-half of α and to obtain the proper set of the brushes, notwithstanding this difference, I provide means for correspondingly shifting the magnetic axis of the rotor within its own mass, when α is varied. To this end, as shown in Fig. 3, the rotor G is provided with a di-phase winding. One of these windings M is of thin wire and is fed directly from the brushes P, P, (Figs. 1[a] and 3) which are mounted on the rotor so as to have the proper set when α equals zero. The resistance of this winding M is calculated to yield the necessary field for the maximum voltage V. The other winding N is of thicker wire and produces the field necessary for the lowest desired voltage, say, one-tenth of V. In series with winding N, I place through ring L a rheostat O, the lever of which is mechanically connected with shaft Q so that the resistance of circuit N and angle α are varied simultaneously and in such manner that the resultant field of windings M and N shall remain constant when α varies, but shall be shifted angularly in the core G through the angle required to keep the brushes in the neutral axis. I have found that this is obtained when the total resistance of circuit N is kept proportional to the cotangent of angle $\frac{1}{2}\alpha$.

The apparatus as just described fully realizes all the conditions which I consider to be desirable and necessary; that is to say, in the lower part of the apparatus the cores H and B are the seat of a rotary field of constant strength, for the reaction of this field on the invariable circuit D must at all times balance the constant fall of potential of the main or feeders. For similar reasons the core A of the upper part of the apparatus is also the seat of a constant rotary field. Moreover, as the rotor G is wound to secure constant magneto-motive force, the parasitic fluxes due to the reactions of circuits C E and M N will also remain constant for all adjustments of the apparatus and the flux in G will, therefore, be constant. This last condition is so much the more important that the part G M N acts as the rotor of a synchronous motor and the constancy of its operation depends substantially on the value of the ampere turns which excite it.

The desirable and necessary conditions realized by my apparatus may be summarized as follows: first, to keep the brushes on the neutral axis of the potentials distributed about the commutator, that is, at the points which have the greatest potential difference; secondly, to preserve (thanks to the constancy of the fields in all parts) a constant and invariable flux density in all parts subjected to periodic or to fixed magnetization.

Where the feeders supply only a single phase current, the upper part of my apparatus, being, in fact, a synchronous motor, may generate, with a part of the energy taken from the main in one phase, the auxiliary phase required to produce the regular rotation of the field in the lower part. For example, supposing the apparatus to have primary diphase windings (Fig. 4), all that will be necessary will be to connect the first phase winding I of winding C and of winding D in parallel on the main as seen in the figure and then to connect the second phase windings II of the two fields. For starting, the second phase circuit is connected with the main through a suitable resistance, self induction or capacity arrangement R R in the well known manner to create the lag or lead which is required by the momentary inaction of rotor G. Similarly, if the apparatus has primary tri-phase windings C and D (Fig. 5), phase windings I and II are connected in parallel on the main, and the two phase windings III are connected together in series, and on the main through the resistance, self induction or capacity R. Finally, it should be noted that, as the variation in the resultant voltage does not affect the flux densities, I may use any one of the devices known in alternator apparatus to increase the power of my apparatus by increasing the flux density above the economical value, although, as well understood, such gain in power entails a loss in efficiency and power factor.

The arrangement of Fig. 4 is particularly suited for use where the same apparatus is to be used generally with di-phase current and occasionally with uni-phase current. Likewise the arrangement of Fig. 5 is specially suited for use where the same apparatus must be able to work generally with tri-phase current or occasionally with uni-phase current. But when the apparatus is to be specially established for use with uni-phase current the arrangement of Fig. 6 is to be preferred. Here E and F, as in Figs. 1 and 2, refer, respectively, to the upper and lower parts of the secondary and *a* and *b* are the commutator bars to which the secondary is connected as seen in the figure. C, D are, respectively, the upper and lower primary coils which receive current from the main, and C′ is an auxiliary winding of secondary importance intended to create a field shifted with respect to the field of the principal winding C to produce with it a resultant partially rotating or elliptically rotating field to start the rotor G. The diagram Fig. 6 shows that the principal windings C are arranged to leave a few notches free for the auxiliary windings C′, and the lower windings D correspond in arrangement with windings C. The secondary winding E F is reduced to the conductors which, in the position of maximum tension, are subjected to the inductive action of the two principal windings C and D. These conductors E F are connected to the corresponding bars *a*, *a*, *a*, of the commutator I. The suppressed turns of E F are replaced by direct connections *c d* connected to the bars *b* of the commutator, which bars would normally correspond to the suppressed turns.

What I claim as my invention and desire to secure by Letters Patent is:

1. In an apparatus for transforming either single or polyphase current into continuous current of variable voltage, the combination with distinct primaries adapted to receive polyphase current from the same main to produce distinct rotatory fields rotating at the same angular speed; of means for varying the angular relation of said primaries to adjust the angular relation of said rotatory fields; a secondary extending into said distinct rotatory fields to compound the separate effects thereof; and means for rectifying the resultant alternating currents induced in said secondary.

2. In an apparatus for transforming either single or polyphase current into continuous current of variable voltage, the combination with distinct primaries adapted to receive polyphase current from the same main to produce distinct rotatory fields rotating at the same angular speed; of means for varying the angular relation of said primaries to adjust the angular relation of said rotatory fields; a secondary extending into said distinct rotatory fields to compound the separate effects thereof, said secondary having a commutator in fixed relation thereto and brushes mounted to revolve on said commutator; and means to maintain the bearing points of said brushes substantially in coincidence with the revolving neutral line of commutation.

3. In an apparatus for transforming either single or polyphase current into continuous current of variable voltage, the combination with two separate primaries adapted to receive polyphase current from the same main to produce two distinct rotatory fields rotating at the same angular speed; of means for varying the angular relation of said primaries to adjust the angular relation of said rotatory fields; a secondary extending into said distinct rotatory fields to compound the separate effects thereof, said secondary having a commutator in fixed relation thereto, and brushes mounted to revolve on said commutator, and a rotor mounted in one of said fields, said rotor being bodily connected with said brushes to revolve the same; and means to magnetize said rotor in a direction dependent upon the angular adjustment of the said rotary fields.

4. In an apparatus for transforming either single or polyphase current into continuous current or variable voltage, the combination with two separate primaries adapted to receive polyphase current from the same main to produce two distinct rotatory fields rotating at the same angular speed; of means for varying the angular relation of said primaries to adjust the angular relation of said rotatory fields; a secondary extending into said distinct rotatory fields to compound the sepa-

rate effects thereof, said secondary having a commutator in fixed relation thereto, and brushes mounted to revolve on said commutator, and a rotor mounted in one of said fields, said rotor being bodily connected with said brushes and having two windings fed from the said brushes to produce differently directed fluxes, and means for adjusting the relative strength of such fluxes to adjust the direction of the resultant flux in said rotor.

5. In an apparatus for transforming either single or polyphase current into continuous current of variable voltage, the combination with two separate primaries adapted to receive polyphase current from the same main to produce two distinct rotatory fields rotating at the same angular speed; of means for varying the angular relation of said primaries to adjust the angular relation of said rotatory fields; a secondary extending into said distinct rotatory fields to compound the separate effects thereof, said secondary having a commutator in fixed relation thereto, and brushes mounted to revolve on said commutator, and a rotor mounted in one of said fields, said rotor being bodily connected with said brushes and having two windings, one being of thin wire and calculated to yield the necessary field with the maximum voltage, the other of thick wire in series with an adjustable resistance.

6. In an apparatus for transforming either single or polyphase current into continuous current of variable voltage, the combination with two separate primaries adapted to receive polyphase current from the same main to produce two distinct rotatory fields rotating at the same angular speed; of means for varying the angular relation of said primaries to adjust the angular relation of said rotatory fields; a secondary extending into said distinct rotatory fields to compound the separate effects thereof, said secondary having a commutator in fixed relation thereto, and brushes mounted to revolve on said commutator, and a rotor mounted in one of said fields, said rotor being bodily connected with said brushes and having two windings, one being of thin wire and calculated to yield the necessary field with the maximum voltage, the other of thick wire in series with an adjustable resistance, and means for varying the value of such resistance.

7. In an apparatus for transforming either single or polyphase current into continuous current of variable voltage, the combination with two separate primaries adapted to receive polyphase current from the same main to produce two distinct rotatory fields rotating at the same angular speed; of means for varying the angular relation of said primaries to adjust the angular relation of said rotatory fields; a secondary extending into said distinct rotatory fields to compound the separate effects thereof, said secondary having a commutator in fixed relation thereto, and brushes mounted to revolve on said commutator, and a rotor mounted in one of said fields, said rotor being bodily connected with said brushes and having two windings, one being of thin wire and calculated to yield the necessary field with the maximum voltage, the other of thick wire in series with an adjustable resistance, and mechanism for connecting the said resistance adjusting means and the said rotatory field adjusting means to cause said two adjusting means to act simultaneously.

8. In an apparatus for transforming either single or polyphase current into continuous current of variable voltage, the combination with two separate primaries adapted to receive polyphase current from the same main to produce two distinct rotatory fields rotating at the same angular speed; of means for varying the angular relation of said primaries to adjust the angular relation of said rotatory fields; a secondary extending into said distinct rotatory fields to compound the separate effects thereof, said secondary having a commutator in fixed relation thereto, and brushes mounted to revolve on said commutator, and a rotor mounted in one of said fields, said rotor being bodily connected with said brushes and having two windings, one being of thin wire and calculated to yield the necessary field with the maximum voltage, the other of thick wire in series with an adjustable resistance, and mechanism for connecting the said resistance adjusting means and the said rotatory field adjusting means to cause said two adjusting means to act simultaneously so that the total resistance of the adjustable rotor circuit shall remain proportional to the cotangent of the angle between the two rotatory fields.

9. In an apparatus for transforming either single or polyphase current into continuous current of voltage variable at will to any desirable value between certain limits, the combination of a stationary primary adapted to receive polyphase current from a main to produce a rotatory field; and an angularly adjustable primary adapted to receive polyphase current from the same main to produce a second rotatory field rotating at the same speed as the first; a secondary extending into said distinct rotary fields and having a commutator in fixed relation therewith; a stationary iron core to close said adjustable rotary field; and a revolving iron core to close said fixed rotary field; brushes carried by said revolving core, and windings on said core, said windings being connected with the said brushes to polarize the core in a direction dependent upon the angular relation of the two rotary fields; and slip rings connected both electrically and mechanically with such brushes.

10. In an apparatus for transforming single

phase current into continuous current of variable voltage, the combination with two distinct primaries having polyphase windings, one phase winding of one of said primaries being connected with the corresponding phase winding of the other primary, and means for producing a lag or lead in the current supplied to the circuit so formed in order to produce two separate rotary fields; of means for adjusting the angular relation of said primaries; a secondary extending into said distinct rotary fields to compound the separate effects thereof; and means for rectifying the resultant alternating currents induced in said secondary.

11. The combination with means for creating two distinct rotatory fields; and means for varying their angular relation at will; of a stationary secondary winding extending into both of said fields to compound the separate inductive effects of the said two rotatory fields; and a fixed commutator connected with the said stationary winding and having brushes adapted to revolve substantially in coincidence with the resultant inductive effect of the said two rotatory fields.

12. The method of transforming single or polyphase current into continuous current which consists in distributing the polyphase currents in the primary circuit so as to generate distinct rotatory fields in separate parts of space, to produce separate inductive effects on different parts of the secondary; and rectifying the currents so generated in the secondary.

13. The method of transforming single or polyphase current into continuous current of variable voltage, consisting in:—distributing the polyphase current in the primary circuit so as to generate distinct rotatory fields rotating at the same speed in separate parts of space, to produce separate inductive effects on different parts of the secondary; varying the angular relation of these distinct fields to vary the phase relation of such induced effects; and rectifying the current due to the joint action of these two effects.

In testimony whereof I have signed this specification in the presence of two subscribing witnesses.

GEORGES FAGET.

Witnesses:

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