

(No Model.)

7 Sheets—Sheet 1.

M. VON DOLIVO-DOBROWOLSKY.
ELECTRIC MACHINE.

No. 469,515.

Patented Feb. 23, 1892.

Fig. 1.

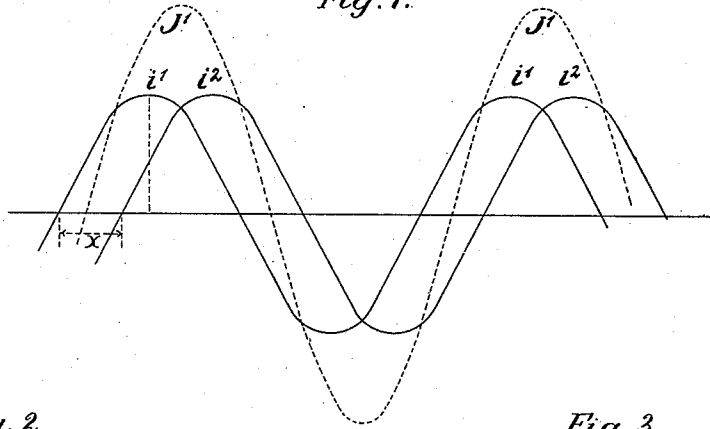


Fig. 2.

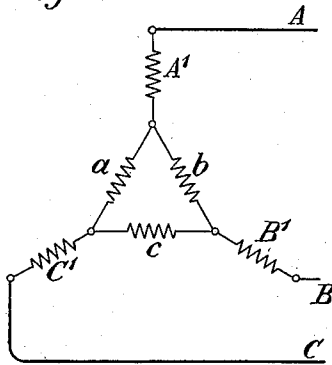


Fig. 3.

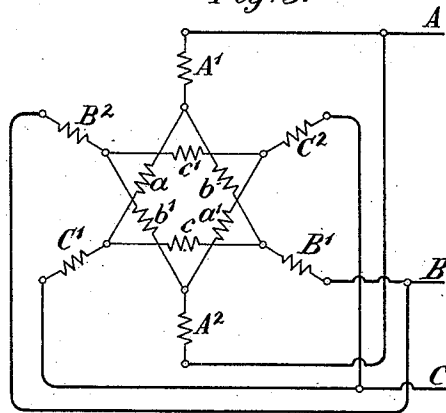
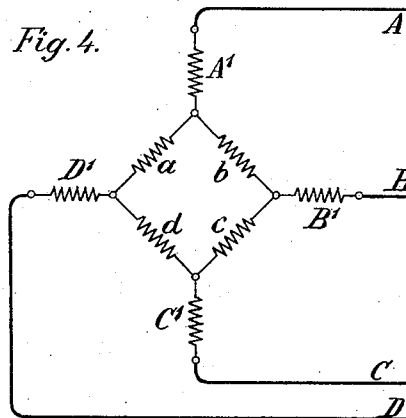


Fig. 4.



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Fig. 5.

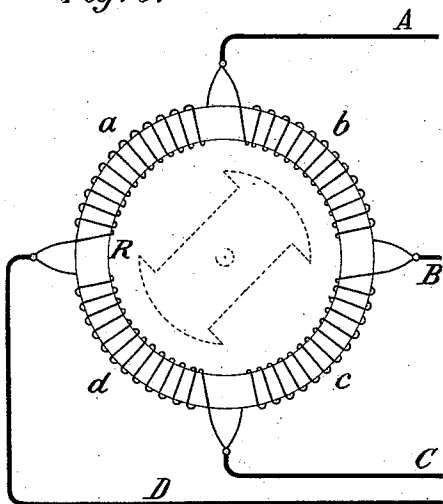


Fig. 8.

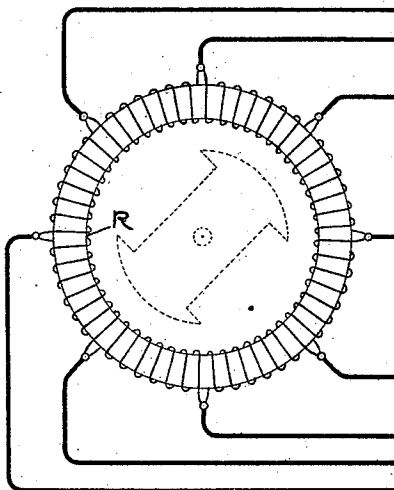
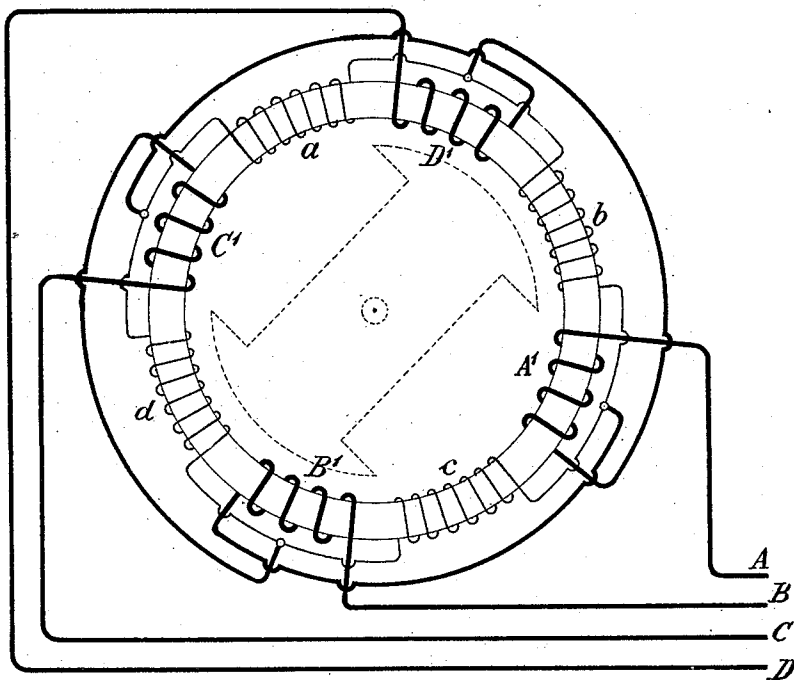


Fig. 6.



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Fig. 9.

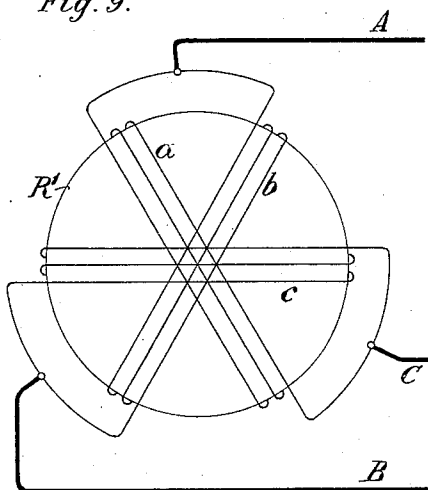


Fig. 10.

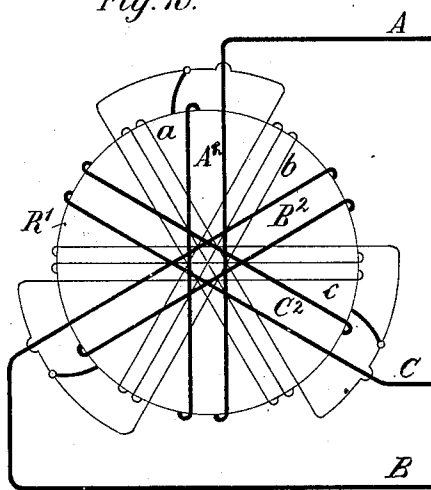
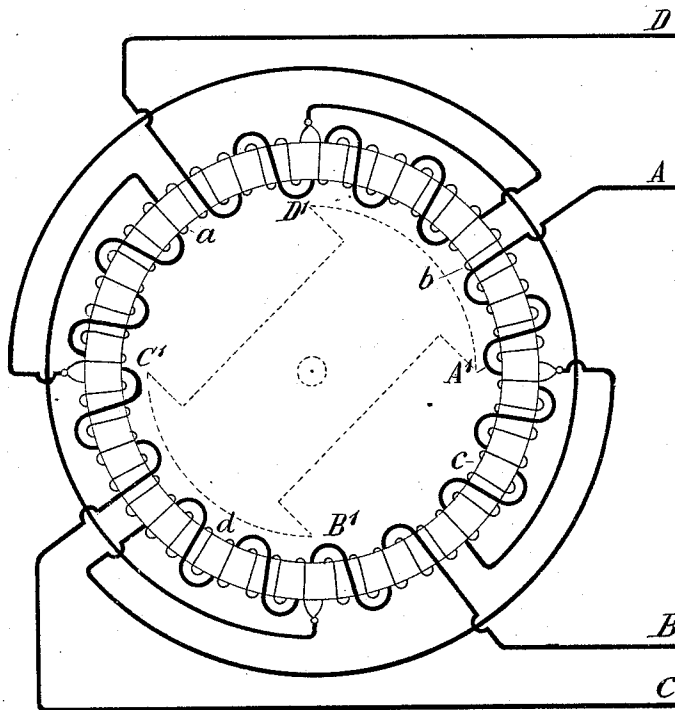


Fig. 7.



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(No Model.)

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Fig. 11.

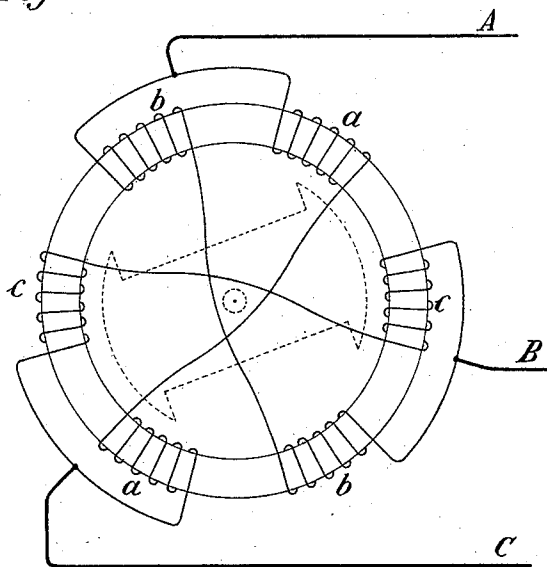
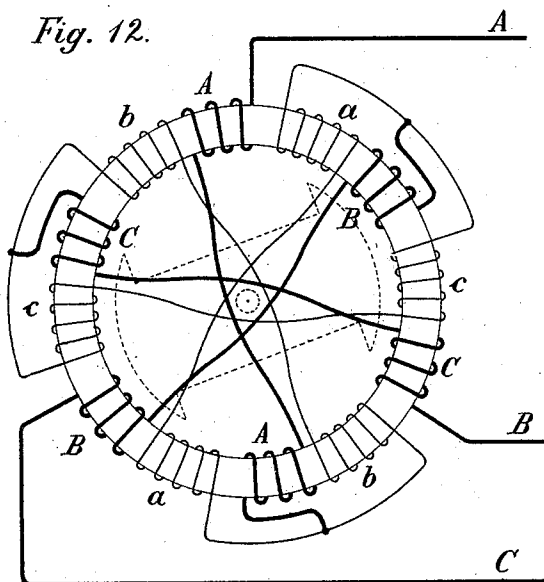


Fig. 12.



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Fig. 13.

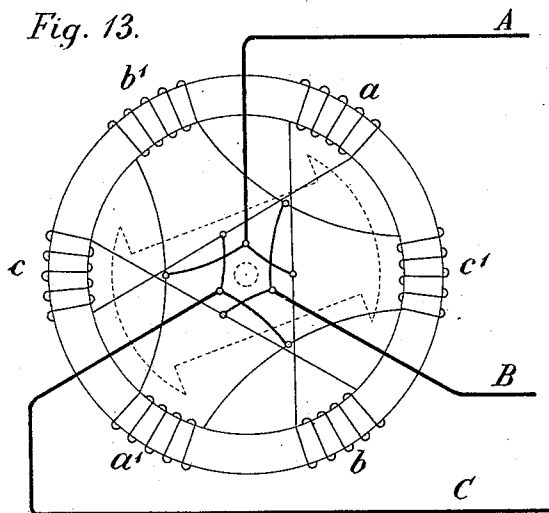
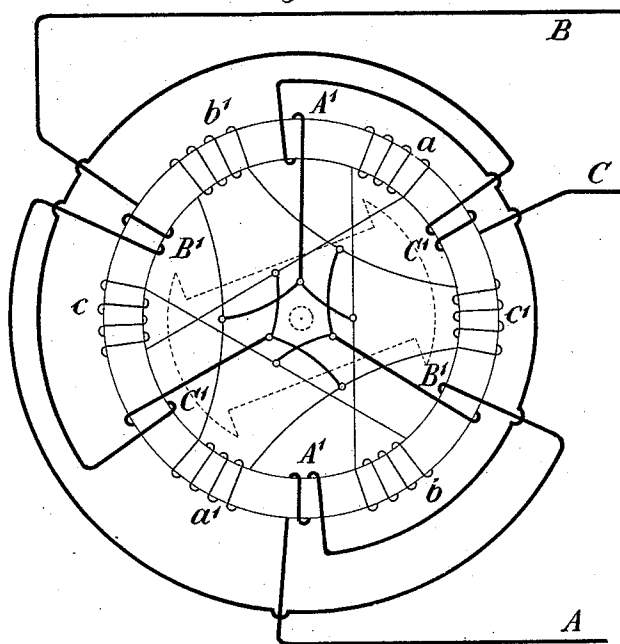


Fig. 14.



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(No Model.)

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Fig. 15.

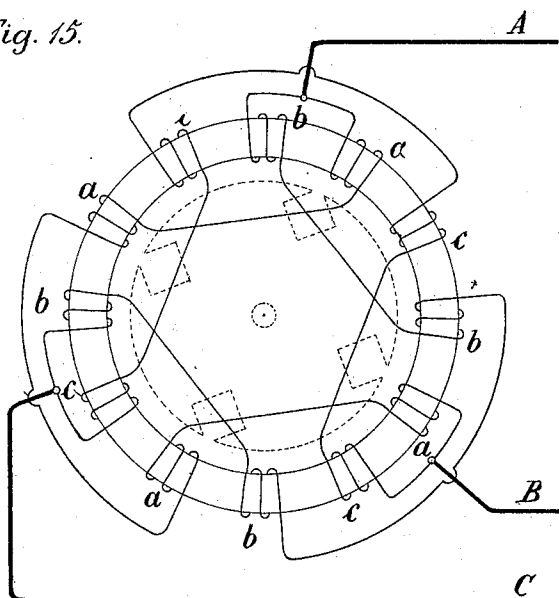
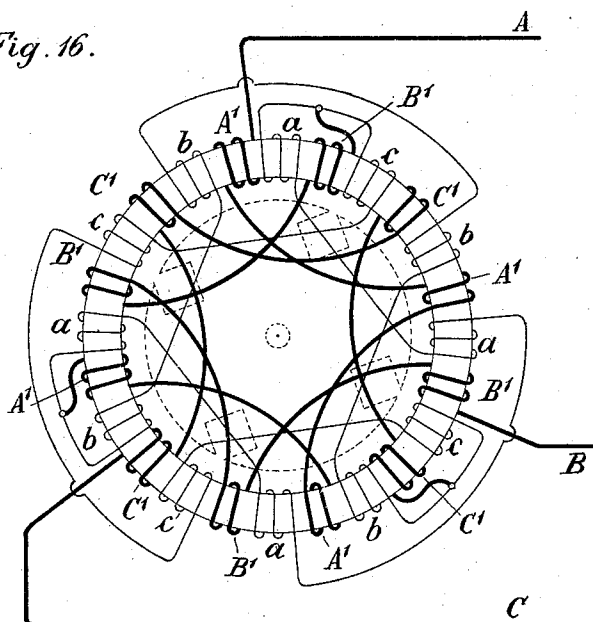


Fig. 16.



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E. M. Adrik
F. B. Kefer

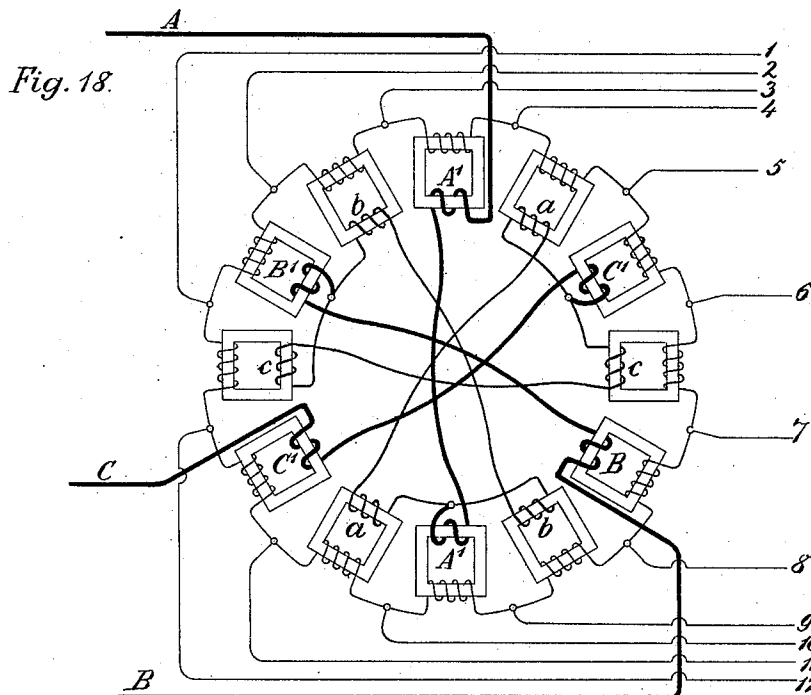
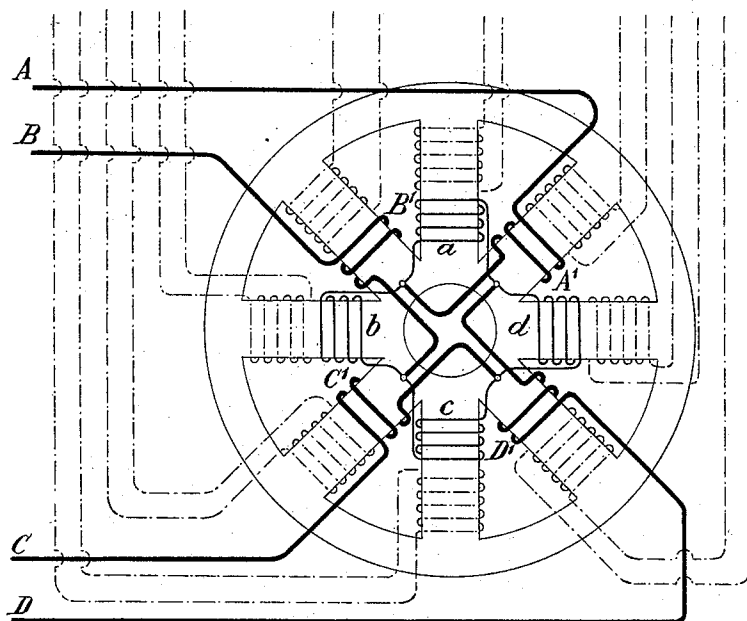
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M. VON DOLIVO-DOBROWOLSKY.
ELECTRIC MACHINE.

No. 469,515. *Fig. 17.*

Patented Feb. 23, 1892.



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UNITED STATES PATENT OFFICE.

MICHAEL VON DOLIVO-DOBROWOLSKY, OF BERLIN, GERMANY, ASSIGNOR TO
THE ALLGEMEINE ELEKTRICITÄTS-GESELLSCHAFT, OF SAME PLACE.

ELECTRIC MACHINE.

SPECIFICATION forming part of Letters Patent No. 469,515, dated February 23, 1892.

Application filed August 3, 1891. Serial No. 401,525. (No model.)

To all whom it may concern:

Be it known that I, MICHAEL VON DOLIVO-DOBROWOLSKY, a subject of the Emperor of Russia, residing in Berlin, Kingdom of Prussia, Germany, have invented new and useful Improvements in Electric Machines and Apparatuses for Differential-Phase Alternating Currents, whereof the following is a specification.

My invention is designed to replace the system of connections of electric devices (such as coils and lamps) for generating and receiving differential-phase alternating currents described in the specifications of the United States Patents No. 390,414 to Tesla, and No. 390,439 to Bradley, the said system consisting in this, that the current-generating and the current-receiving devices, which are equal in number, are severally connected to form closed circuits, while the conducting or line wires are connected to equidistant points of the said circuits or (what amounts to the same thing) to the united terminals of the respective devices. This system consequently requires but as many line-wires as there are currents to be transmitted, and each of these wires forms a circuit with one of the other wires and one or more of the generating devices on one hand and receiving devices on the other hand. The same may therefore be called the system of "concatenated circuits;" or if its effect of producing in motors and transformers a rotating magnetic field is taken into account it may also be termed the "rotation-current" system.

If in this system the number of circuits conducting currents of consecutive phases is increased, the distance between the phases of the individual currents will be diminished and the prejudicial pulsations of the composite current—operating, for instance, in lamps, as well as those of any magnetic field excited by the current—will become smaller. With two currents having their phases shifted by ninety degrees or one-quarter of a phase the pulsations are still well observable. With three currents whose phases are shifted by sixty degrees or one hundred and twenty degrees the oscillations of the magnetic field have only about fourteen per cent. of the mean in-

tensity; but if twelve currents are employed having phasial differences of thirty degrees—that is to say, if there are six consecutive impulses—the variations do not amount to more than about four per cent. The employment of very many currents with such small phasial differences has, however, heretofore rendered necessary a great number of line-wires, which make the system very expensive. If six currents pulsating successively—that is to say, currents having thirty degrees of phasial difference—are led off independently of each other, twelve conducting-wires are required. If, however, the circuits are connected together in the manner described for three and four circuits by Bradley and Tesla in the aforesaid specifications, one-half the number of wires is done away with, so that for six currents only six wires are wanted and for eight currents of forty-five degrees phasial difference eight wires.

Now the object of my invention is to reduce the number of line-wires still further—namely, to one-half, as compared with the foregoing—so that with but four wires eight currents of a phasial difference of forty-five degrees and with but three wires six currents of a phasial difference of thirty degrees may be transmitted. For this purpose I combine with a number of generating or receiving devices placed in closed circuit other like devices inserted between the points of connection of the former and the line-wires. In a dynamo, a motor, or a transformer these devices will consist in coils placed on the respective cores in suitable position relatively to the other coils, while for lighting purposes the said devices consist in lamps alike to those contained in the closed circuit. This system I shall call the system of "doubly-concatenated" circuits. The advantages of the same are that with a given number of line-wires it allows of obtaining in generators a more quiet and unvarying production and delivery of energy of producing in motors and transformers circumrotating magnetic fields, being as far as possible free from pulsations, and consequently of higher efficiency and of attaining in lamps and other electric apparatuses a steadier light or other effect.

In the annexed drawings, Figures 1 to 4 are diagrams serving to explain the theory of the invention and the combination of the parts in general. Fig. 5 is a view of an annular core of iron, which may be the armature of a dynamo or the field-magnet of a motor, having four coils placed in concatenated circuits with four line-wires, according to the system of Bradley and Tesla. Figs. 6 and 7 show two different arrangements of my new system of double concatenation applied to a closed circuit comprising four coils. Fig. 8 represents an annular core with eight coils connected to the line-wires in like manner as in Fig. 5. Figs. 9 and 10 are views of a cylindrical armature of a motor provided with coils, respectively, according to the old and the new system. Fig. 11 represents an annular core with three sets of two coils each in concatenated connection with the line-wires. Fig. 12 shows the new arrangement with three like sets of coils. In Fig. 13 there are two separate sets of three coils each connected to three line-wires, while in Fig. 14 these sets of coils are connected to three sets of two coils each of the new system. Fig. 15 represents a combination of three sets of four coils each in connection with three line-wires, and Fig. 16 the new arrangement to be substituted therefor. Fig. 17 is a view of a transformer with four coils placed in circuit and four other coils for the primary currents and eight coils for the secondary currents. Fig. 18 shows a plurality of separate transformers connected together according to my new system. In Figs. 5 to 8 and 11 to 16 the pieces shown in dotted lines inside of the rings denote armatures such as would be applicable in case the rings and coils were to serve as field-magnets of motors.

The new system of connections rests on the following principle: If two alternating currents of an equal number of alternations and equal mean strength, but of different phases, are added together, a current will result having phases intermediate to the former, and whose strength I is computed by the formula: $I = 2i \cos \frac{\alpha}{2}$, in which i denotes the strength of the separate original currents and α the angle of phasial difference. The result of such addition is shown graphically by Fig. 1, in which the wave-lines $i' i''$ represent the phases of the two original currents and the dotted wave-line I' the phases of the resulting current. In view of utilizing this resulting current, together with the original currents, the current-conductors are arranged in general as shown by the diagrams Figs. 2 to 4. According to Fig. 2 three like coils $a b c$ (indicated by zigzag lines) are connected together to form a closed circuit. $A B C$ are the line-wires, and $A' B' C'$ are the new or additional coils interposed between the latter and the points of connection of the coils $a b c$ with each other. These coils may be the generating-coils of a dynamo, or the magnetizing-coils of a motor, or the coils of a transformer, whether primary or secondary. Fig. 3 shows

two closed circuits formed by the respective coils $a b c$ and $a' b' c'$ in combination with six additional or new coils $A' B' C' A^2 B^2 C^2$, the coils A' and A^2 being connected to the line-wire A , the coils $B' B^2$ to the wire B , and the coils $C' C^2$ to the wire C . Fig. 4 represents a system alike to that in Fig. 2, except that the closed circuit is formed by four coils $a b c d$ and that there are four new coils $A' B' C' D'$. In Figs. 2, 3, and 4 the zigzag lines may, however, also represent lamps or sets of lamps.

I shall now proceed to describe how the coils $A' B' C'$, &c., are to be arranged together with the coils $a b c$, &c., on the core of an armature or of a field-magnet under different conditions.

Taking in view Fig. 5, it will be perceived that the core-ring R is wound with four coils $a b c d$ placed at right angles to each other (alike to the same coils in Fig. 4) and connected at their points of junction to the line-wires $A B C D$, according to the known system hereinbefore referred to. Supposing the ring R to be the armature of a dynamo, it is evident that the phases of the currents induced in the said coils are shifted one relatively to the other by ninety degrees, provided these currents are of equal strength, which will ordinarily be the case, the current in wire A , resulting as the sum of the currents in coils a and b , will have the mean strength $I = 2i \cos \frac{90}{2} = 1.4i$. The maxima of strength of the current in wire A are, however, intermediate to the maxima of the currents in coils a and b . Between each of the currents in wires $A B C D$ and the respective composing currents in coils $a b c d$ there is therefore a phasial difference of forty-five degrees. Now if a portion of each of the wires $A B C D$ conducting the currents I is also wound on the armature-ring R , so as to form the coils $A' B' C' D'$, as shown in two different arrangements in Figs. 6 and 7, eight coils with currents of phasial differences of forty-five degrees are obtained. If the number of convolutions of the coils $A' B' C' D'$ is made smaller relatively to that of the coils $a b c d$ in the proportion of 1 to 1.4, while the wires of the said coils $A' B' C' D'$ are of correspondingly larger sectional area, the product of the number of ampères multiplied by the number of convolutions will be in all eight coils about the same, and the effect of the wire-wound ring will be alike to that of a ring of Bradley and Tesla having eight coils, as represented by Fig. 8, though there are but four line-wires connected to the former against eight to the latter.

Fig. 9 shows a cylindrical core R' , having three coils $a b c$ arranged at angles of sixty degrees to each other and connected in concatenated circuits to the three line-wires $A B C$. Supposing this core to be the core of a motor-armature, the currents to be employed for driving the same and flowing through the said line-wires must have a phasial difference of one hundred and twenty degrees. The

current in wire A on passing over into the coils a and b will split into two currents, the phases whereof differ by thirty degrees from the former. In like manner the currents in wires B and C split on passing over into the respective coils $b c$ and $c a$. Therefore if a portion of each of the wires A B C is coiled around the cylinder R' between the coils $a b c$, as shown in Fig. 10, an armature will be obtained in which the phasial difference of the currents is but half as large as in the armature, Fig. 9.

Fig. 11 represents an annular core with six coils connected in the old manner for three currents of three different phases, while with the new system (shown by Fig. 12) twelve coils are obtained, from which six currents of six different phases are led off in the three line-wires.

The same difference of results is obtained by the new arrangement represented by Fig. 14 as compared with the old one shown by Fig. 13. In both there are two closed circuits with the respective coils $a b c a' b' c'$ instead of the single circuit in the preceding figures; but these circuits are substantially connected parallel and may therefore be considered as one. By the combination of the coils, as in Fig. 13, however, only three currents, with phasial differences of one-third of a phase, are obtained, while by the combination of the pairs of coils A' B' C' with the coils $a b c a' b' c'$ a doubling of the number of consecutive impulsions (or bisection of phasial difference) is brought about. In a similar manner, as described with reference to Figs. 11 and 12, representing armatures or field-magnets of bipolar machines in which the opposite coils $a a' b b' c c'$ are connected to form virtually one coil, all those coils of multipolar machines whose position relatively to the poles is the same and which convey currents of the same phase may be united to form one set of coils. By these means the new system of connections may be applied in like manner to multipolar machines as to the bipolar ones. One-half of the sets of coils (instead of single coils) are in this case again connected to form a closed circuit, and from this circuit the other sets of coils (instead of single coils) are branched off at different points. Thus Fig. 15 shows a coil-carrying ring adapted to be used as field-magnet in a four-pole motor or an armature of a four-pole generator, the coils being arranged in the ordinary concatenated connection for currents of phasial differences of sixty degrees, while Fig. 16 represents the same ring with application of the new system of double concatenation for a phasial difference of thirty degrees.

As has already been stated, the doubly-concatenated circuits for producing a rotation current and obtained by the new system of connections are to be applied in current-generators if the highest performance and efficiency and a steady delivery of current, free from vibrations, is desired. The system is

likewise particularly useful for electric motors, and in these the field-coils or the armature-coils, or both, may be connected in the manner described. Moreover, the system may often be applied with advantage in current-transformers constructed for currents of different phases, and the double concatenation may be made use of for the primary coils or for the secondary coils, or for both.

Fig. 17 represents a transformer for converting four currents of ninety degrees phasial difference into eight independent currents of forty-five degrees difference, or vice versa.

By Fig. 18 it is designed to show that a number of separate current-transformers of common construction may also be connected according to the double-concatenation system. There is here represented the special case in which twelve currents—1 to 12—differing from each other by one-twelfth of a phase are to be obtained from three currents flowing through the wires A B C and having a difference of one-third of a phase. The circuits for the former are simply concatenated in the manner also shown by Fig. 8, while the circuits for the latter—i. e., the inducing-currents—are doubly concatenated, as in Fig. 12, in view of reducing the phasial difference.

It is evident that the currents obtained by the transformer in double number and of a phasial difference of one-half may again be doubled in another transformer or sets of transformers. It is therefore easy to produce a large number of currents of minimal phasial difference by repeated double concatenation of the circuits for a small number of currents differing in their phases—for instance, one-third of a phase.

By means of the new system of double concatenation applied to transformers it is, moreover, possible to produce currents differing in their phases by ninety degrees from currents of sixty degrees or one hundred and twenty degrees phasial difference, whereby it is rendered feasible to drive two-phasal current-motors with three-phase currents. To this end the currents of sixty degrees or one hundred and twenty degrees difference are first converted into currents differing by thirty degrees, such as the currents flowing in the circuits 1 to 12, Fig. 18, and from these the currents of ninety degrees phasial difference are selected and brought into co-operation. In Fig. 18, for instance, the combination of the circuits 1 2 and 4 5 and that of the circuits 7 8 and 10 11 would answer this purpose.

I claim as my invention—

1. In the armature of an electric generator, the combination of an iron core, three or more coils or sets of coils, such as $a b c a' b' c'$, surrounding the said core and connected together to form a closed circuit or circuits, other coils or sets of coils, such as A' B' C', being alike in number to that of the coils or sets of coils $a b c$, &c., and also surrounding the core and severally connected at one end to equidistant points of the said closed cir-

cuit or circuits, and line-wires connected to the other ends of the coils A' B' C', substantially as described.

2. The combination of three or more electric-current-receiving devices or sets of devices, such as described, connected together to form a closed circuit or circuits, other electric devices or sets of devices of the same kind, being alike in number to that of the former and severally connected at one terminal to equidistant points of the said closed circuit or circuits, line-wires connected to the other terminals of the latter devices or sets of devices, and means for producing in the line-wires currents of relatively differing phases, substantially as specified.

3. The combination of three or more electric-current-receiving devices or sets of devices (such as magnetizing-coils and lamps) connected together to form a closed circuit or circuits, other electric devices or sets of devices of the same kind, being alike in number to that of the former and severally connected at one terminal to equidistant points of the

said closed circuit or circuits, line-wires connected to the other terminals of the latter devices or sets of devices, an electric generator having an armature consisting in the combination of an iron core, three or more coils or sets of coils, such as *a b c a' b' c'*, surrounding the said core and connected together to form a closed circuit or circuits, and other coils or sets of coils, such as A' B' C', being alike in number to that of the coils or sets of coils *a b c*, &c., and also surrounding the core and severally connected at one end to equidistant points of the circuit or circuits formed by the coils *a b c*, &c., and with the other ends to the line-wires, substantially as described.

In testimony whereof I have hereunto set my hand in the presence of two subscribing witnesses.

MICHAEL VON DOLIVO-DOBROWOLSKY.

Witnesses:

V. GOEBEN,

MARGGRAFF,

Both Engineers, Berlin.