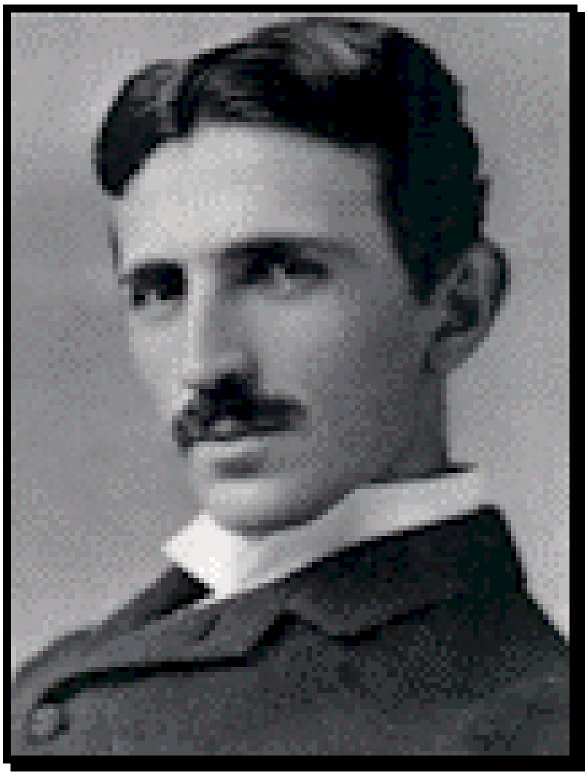

The U.S. Patents of Nikola Tesla

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(No Model.)

N. TESLA.

COMMUTATOR FOR DYNAMO ELECTRIC MACHINES.

No. 334,823. Patented Jan. 26, 1886.

Fig. 1.

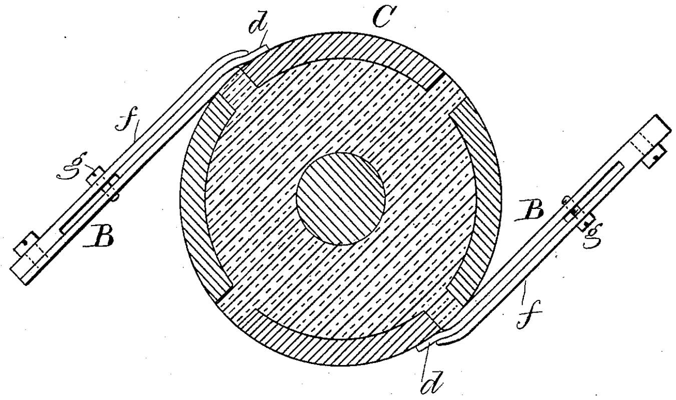
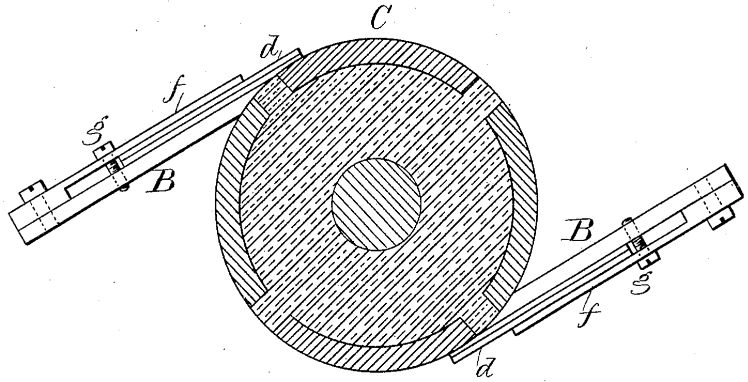


Fig. 2.



Witnesses
Chas. H. Smith
J. Stail

Inventor
Nikola Tesla.
per Lemuel W. Serrell
atty.

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF SMILJAN LIKA, AUSTRIA-HUNGARY, ASSIGNOR TO THE TESLA ELECTRIC LIGHT AND MANUFACTURING COMPANY, OF RAHWAY, NEW JERSEY.

COMMUTATOR FOR DYNAMO-ELECTRIC MACHINES.

SPECIFICATION forming part of Letters Patent No. 334,823, dated January 26, 1886.

Application filed May 6, 1885. Serial No. 164,534. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, of Smiljan Lika, border country of Austria-Hungary, have invented an Improvement in Dynamo-Electric Machines, of which the following is a specification.

My invention relates to the commutators on dynamo-electric machines, especially in machines of great electromotive force, adapted to arc lights; and it consists in a device by means of which the sparking on the commutator is prevented

It is known that in machines of great electromotive force—such, for instance, as those used for arc lights—whenever one commutator bar or plate comes out of contact with the collecting-brush a spark appears on the commutator. This spark may be due to the break of the complete circuit, or of a shunt of low resistance formed by the brush between two or more commutator-bars. In the first case the spark is more apparent, as there is at the moment when the circuit is broken a discharge of the magnets through the field-helices, producing a great spark or flash which causes an unsteady current, rapid wear of the commutator bars and brushes, and waste of power. The sparking may be reduced by various devices, such as providing a path for the current at the moment when the commutator segment or bar leaves the brush, by short-circuiting the field-helices, by increasing the number of the commutator-bars, or by other similar means; but all these devices are expensive or not fully available, and seldom attain the object desired.

My invention enables me to prevent the sparking in a simple manner. For this purpose I employ with the commutator-bars and intervening insulating material mica, asbestus paper or other insulating and preferably incombustible material, which I arrange to bear on the surface of the commutator, near to and behind the brush.

My invention will be easily understood by reference to the accompanying drawings.

In the drawings, Figure 1 is a section of a commutator with an asbestus insulating device; and Fig. 2 is a similar view, representing two plates of mica upon the back of the brush.

In Fig. 1, C represents the commutator and intervening insulating material; B B, the brushes. *d d* are sheets of asbestus paper or other suitable non-conducting material. *f f* are springs, the pressure of which may be adjusted by means of the screws *g g*.

In Fig. 2 a simple arrangement is shown with two plates of mica or other material. It will be seen that whenever one commutator-segment passes out of contact with the brush the formation of the arc will be prevented by the intervening insulating material coming in contact with the insulating material on the brush.

My invention may be carried out in many ways; and I do not limit myself to any particular device, as my invention consists, broadly, in providing a solid non-conducting body to bear upon the surface of the commutator, by the intervention of which body the sparking is partly or completely prevented.

I prefer to use asbestus paper or cloth impregnated with zinc-oxide, magnesia, zirconia, or other suitable material, as the paper and cloth are soft, and serve at the same time to wipe and polish the commutator; but mica or any other suitable material may be employed, said material being an insulator or a bad conductor of electricity.

My invention may be applied to any electric apparatus in which sliding contacts are employed.

I claim as my invention—

1. The combination, with the commutator-bars and intervening insulating material and brushes in a dynamo electric machine, of a solid insulator or bad conductor of electricity arranged to bear upon the surface of the commutator adjacent to the end of the brush, for the purpose set forth.

2. In an electric apparatus in which sliding contacts with intervening insulating material are employed, the combination, with the contact springs or brushes, of a solid insulator or bad conductor of electricity, as and for the purposes set forth.

Signed by me this 2d day of May, A. D. 1885.

NIKOLA TESLA.

Witnesses:
GEO. T. PINCKNEY,
WILLIAM G. MOTT.

(No Model.)

2 Sheets—Sheet 1.

N. TESLA.

ELECTRIC ARC LAMP.

No. 335,786. Patented Feb. 9, 1886.

Fig. 1.

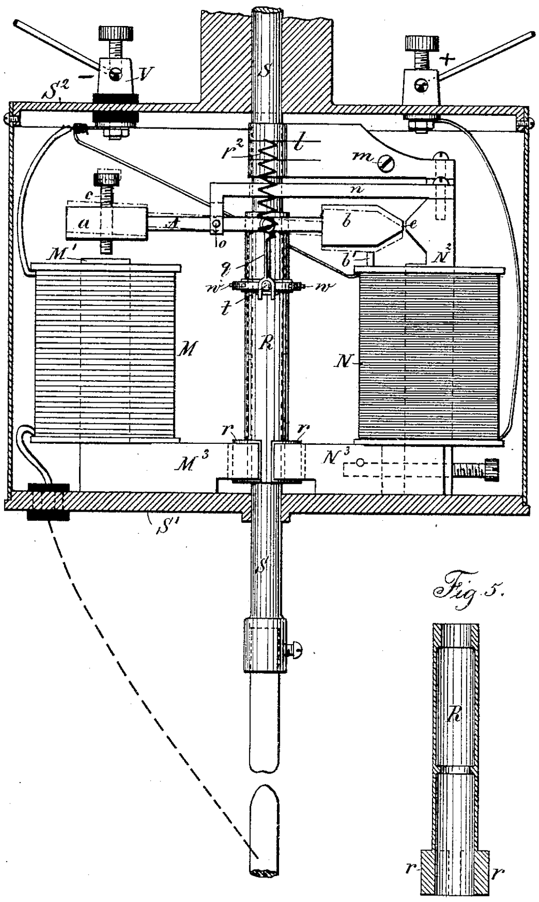
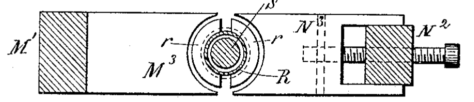


Fig. 5.

Fig. 4.



Witnesses:
J. Staib
Chas. H. Smith

Inventor:
Nikola Tesla
per Lemuel W. Serrell atty

N. PETERS, Photo-Lithographer, Washington, D. C.

(No Model.)

2 Sheets—Sheet 2.

N. TESLA.

ELECTRIC ARC LAMP.

No. 335,786. Patented Feb. 9, 1886.

Fig. 2.

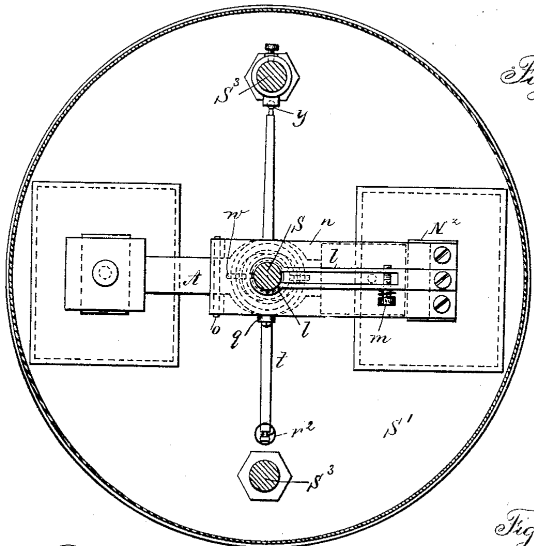
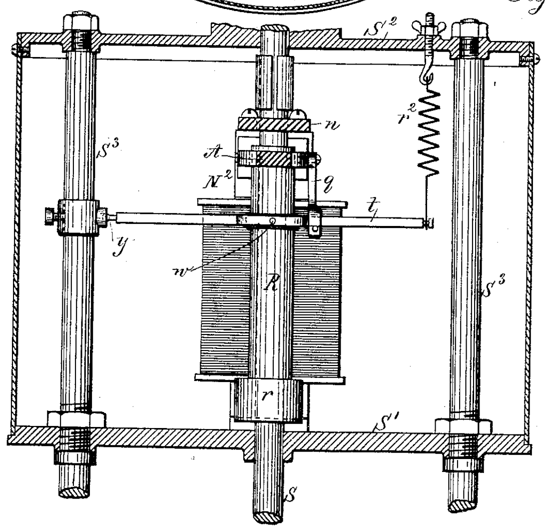


Fig. 3.



Witnesses:
J. Staib
Chas. H. Smith

Inventor:
Nikola Tesla
per Lemuel W. Serrell atty.

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF SMILJAN LIKA, AUSTRIA-HUNGARY, ASSIGNOR TO THE TESLA ELECTRIC LIGHT AND MANUFACTURING COMPANY, OF RAHWAY, NEW JERSEY.

ELECTRIC-ARC LAMP.

SPECIFICATION forming part of Letters Patent No. 335,786, dated February 9, 1886.

Application filed March 30, 1885. Serial No. 160,574. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, of Smiljan Lika, border country of Austria-Hungary, have invented certain new and useful Improvements in Electric-Arc Lamps, of which the following is a specification.

My invention relates more particularly to those arc lamps in which the separation and feed of the carbon electrodes or their equivalents is accomplished by means of electro-magnets or solenoids in connection with suitable clutch-mechanism; and it is designed to remedy certain faults common to the greater part of the lamps heretofore made.

The objects of my invention are to prevent the frequent vibrations of the movable electrode and flickering of the light arising therefrom, to prevent the falling into contact of the electrodes, to dispense with the dash-pot, clock-work, or gearing and similar devices heretofore used, and to render the lamp extremely sensitive, and to feed the carbon almost imperceptibly, and thereby obtain a very steady and uniform light.

In that class of lamps where the regulation of the arc is effected by forces acting in opposition on a free movable rod or lever directly connected with the electrode, all or some of the forces being dependent on the strength of the current, any change in the electrical condition of the circuit causes a vibration and a corresponding flicker in the light. This difficulty is most apparent when there are only a few lamps in circuit. To lessen this difficulty, lamps have been constructed in which the lever or armature, after the establishing of the arc, is kept in a fixed position and cannot vibrate during the feed operation, the feed mechanism acting independently; but in these lamps, when a clamp is employed, it frequently occurs that the carbons come into contact and the light is momentarily extinguished, and, frequently, parts of the circuit are injured. In both these classes of lamps it has been customary to use dash-pot, clock-work, or equivalent retarding devices; but these are generally unreliable and objectionable, and increase the cost of construction.

My invention is intended to effect the desired objects and to remedy the before-mentioned defects. I combine two electro-magnets—one of low resistance in the main or lamp circuit, and the other of comparatively high resistance in a shunt around the arc—a movable armature-lever, and a novel feed mechanism, the parts being arranged so that in the normal working position of the armature-lever the same is kept almost rigidly in one position, and is not effected even by considerable changes in the electric circuit; but if the carbons fall into contact the armature will be actuated by the magnets so as to move the lever and start the arc, and hold the carbons until the arc lengthens and the armature-lever returns to the normal position. After this the carbon-rod holder is released by the action of the feed mechanism, so as to feed the carbon and restore the arc to its normal length.

My invention consists, mainly, in the particular manner in which the armature is combined with the magnets and acted upon by them and in the feed-controlling mechanism.

In the drawings, Figure 1 is an elevation of the mechanism made use of in the electric lamp. Fig. 2 is a plan view of the same below the line *x x*. Fig. 3 is an elevation of the balancing lever and spring, and Fig. 4 is a detached plan view of the pole-pieces and armatures upon the friction-clamp, and Fig. 5 is a section of the clamping-tube.

M is a helix of coarse wire in a circuit from the lower-carbon holder to the negative binding-screw −.

N is a helix of fine wire in a shunt between the positive binding-screw + and the negative binding-screw −. The upper-carbon holder S is a parallel rod sliding through the plates S' S^2 of the frame of the lamp, and hence the electric current passes from the positive binding-post + through the plate S^2, carbon-holder S, and upper carbon to the lower carbon, and thence by the holder and a metallic connection to the helix M.

The carbon-holders are of any desired character, and to insure electric connections the springs *l* are made use of to grasp the upper-carbon holding rod S, but to allow the rod to slide freely through the same. These springs l may be adjusted in their pressure by the screw m, and the spring l may be sustained upon any suitable support. I have shown them as connected with the upper end of the core of the magnet N.

Around the carbon-holding rod S, between the plates S′ S^2, there is a tube, R, which forms a clamp. This tube is counterbored, as seen in the section Fig. 5, so that it bears upon the rod S at its upper end and near the middle, and at the lower end of this tubular clamp R there are armature-segments r of soft iron. A frame or arm, n, extending, preferably, from the core N^2, supports the lever A by a fulcrum-pin, o. This lever A has a hole, through which the upper end of the tubular clamp R passes freely, and from the lever A is a link, q, to the lever t, which lever is pivoted at y to a ring upon one of the columns S^3. This lever t has an opening or bow surrounding the tubular clamp R, and there are pins or pivotal connections w between the lever t and this clamp R, and a spring, r^2, serves to support or suspend the weight of the parts and balance the same, or nearly so. This spring is preferably adjustable.

At one end of the lever A is a soft-iron armature block, a, over the core M′ of the helix M, and there is preferably a limiting-screw, c, passing through this armature-block a, and at the other end of the lever A is a soft-iron armature-block, b, with the end tapering or wedge-shaped, and the same comes close to and in line with the lateral projection e on the core N^2. The lower ends of the cores M′ N^2 are made with lateral projecting pole-pieces M^3 N^3, respectively, and these pole-pieces are concave at their outer ends, and are at opposite sides of the armature-segments r at the lower end of the tubular clamp R.

The operation of these devices is as follows: In the condition of inaction the upper carbon rests upon the lower one, and when the current is turned on the electricity passes freely, by the frame and spring l, through the rod S and carbons to the coarse wire and helix M, and to the negative binding-post V, and the core M′ thereby is energized. The pole-piece M^3 attracts the armature r, and by the lateral pressure causes the clamp R to grasp the rod S′, and the lever A is simultaneously moved from the position shown by dotted lines, Fig. 1, to the normal position shown in full lines, and in so doing the link q and lever t are raised, lifting the clamp R and rod S, separating the carbons and forming the arc. The magnetism of the pole-piece e tends to hold the lever A level, or nearly so, the core N^2 being energized by the current in the shunt which contains the helix N. In this position the lever A is not moved by ordinary variation in the electric current because the armature b is strongly attracted by the magnetism of e, and these parts are close to each other, and the magnetism of e acts at right angles to the magnetism of the core M′. If, now, the arc becomes too long, the current through the helix M is lessened, and the magnetism of the core N^3 is increased by the greater current passing through the shunt, and this core N^3 attracting the segmental armature r lessens the hold of the clamp R upon the rod S, allowing the latter to slide and lessen the length of the arc, which instantly restores the magnetic equilibrium and causes the clamp R to hold the rod S. If it happens that the carbons fall into contact, then the magnetism of N^2 is lessened so much that the attraction of the magnet M will be sufficient to move the armature a and lever A so that the armature b passes above the normal position, so as to separate the carbons instantly; but when the carbons burn away a greater amount of current will pass through the shunt until the attraction of the core N^2 will overcome the attraction of the core M′ and bring the armature-lever A again into the normal horizontal position, and this occurs before the feed can take place. The segmental armature pieces r are shown as nearly semicircular. They may be square or of any other desired shape, the ends of the pole-pieces M^3 N^3 being made to correspond in shape.

I claim as my invention—

1. The combination, in an electric-arc lamp, of the electro-magnets in the main and shunt circuits, respectively, an armature-lever and connection to the movable carbon-holder, the core of the shunt-magnet passing across the end of the armature-lever, substantially as set forth, so that the two magnets act in conjunction on the armature-lever in moving the carbon to form the arc and in opposition to each other beyond the normal position of the armature-lever, substantially as specified.

2. The combination, with the carbon-holders, of two magnets, one in the main circuit and the other in a shunt-circuit, and an armature-lever to draw the arc, and a feeding mechanism and pole-pieces upon the electro-magnets to act upon the feeding mechanism, substantially as specified.

3. The combination, with the carbon-holders, of two magnets, one in the main circuit and the other in a shunt-circuit, and an armature-lever between two poles of such electro-magnets to draw the arc, and a feeding mechanism and pole-pieces upon the other two poles of the electro-magnets to act upon the feeding mechanism, substantially as specified.

4. The combination, with the carbon-holding rod in an electric-arc lamp, of the clamp R, lever t, spring r^2, armature-lever A, and electro-magnets M N in the main and shunt circuits, respectively, the pole-pieces M^3 N^3, and armature-segments r, substantially as set forth.

5. The combination, with the carbon-holder, of a tubular clamp surrounding the same, an armature-lever connected to said tubular clamp, and electro-magnets in the main and shunt circuits, respectively, and armature-seg-

ments upon the tubular clamp adjacent to the lateral poles of the electro-magnets, substantially as set forth.

6. In an electric-arc lamp, the combination, with the carbon-holding rod, of a clamp, two armatures upon the clamp, and electro-magnets in the main and shunt circuits, respectively, the poles of which act upon the armatures of the clamp for bringing the same into action or releasing it, substantially as set forth.

Signed by me this 25th day of March, A. D. 1885.

NIKOLA TESLA.

Witnesses:
GEO. T. PINCKNEY,
CHAS. H. SMITH.

(No Model.) 2 Sheets—Sheet 1.

N. TESLA.

ELECTRIC ARC LAMP.

No. 335,787. Patented Feb. 9, 1886.

Fig. 1.

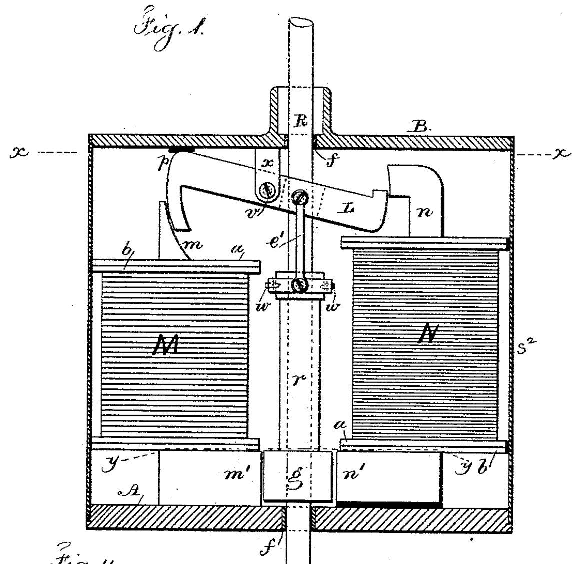


Fig. 6.

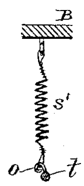


Fig. 4

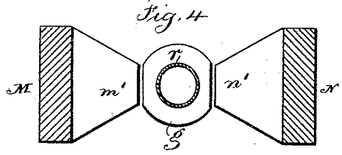
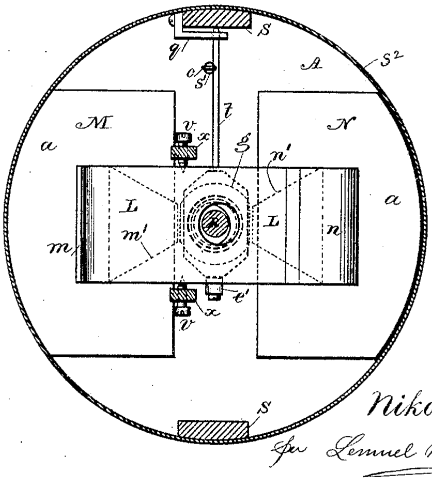


Fig. 2.



Witnesses
Chas H. Smith
Geo. T. Pinckney

Inventor
Nikola Tesla
per Lemuel W. Serrell att.

N. PETERS, Photo-Lithographer, Washington, D. C.

(No Model.)

2 Sheets—Sheet 2.

N. TESLA.

ELECTRIC ARC LAMP.

No. 335,787. Patented Feb. 9, 1886.

Fig. 5

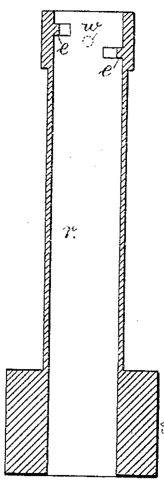


Fig. 3.

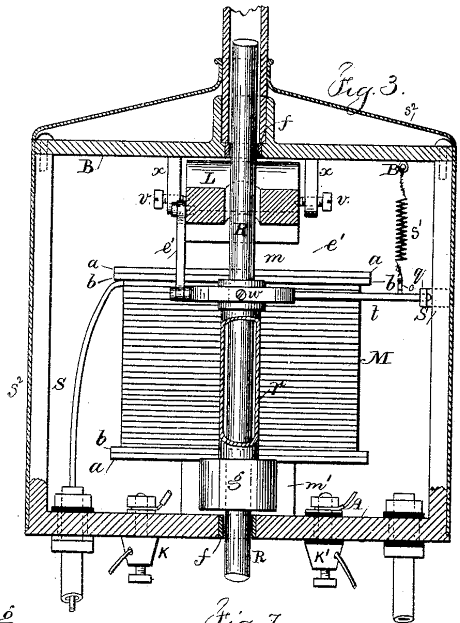
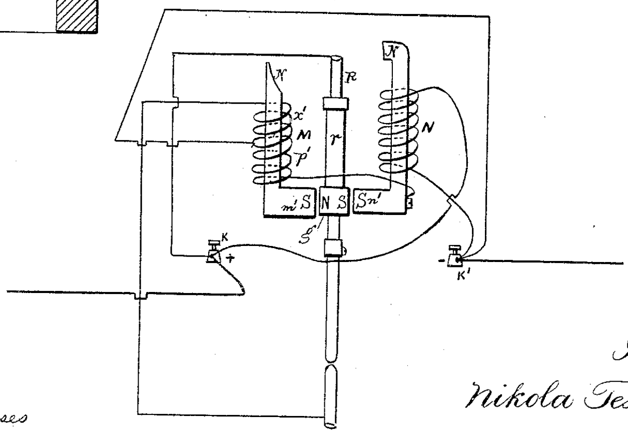


Fig. 7.



Witnesses

Chas. H. Smith

Geo. T. Pinckney

Inventor

Nikola Tesla

per Lemuel W. Serrell

att'y

N. PETERS, Photo-Lithographer, Washington, D. C.

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF SMILJAN LIKA, AUSTRIA-HUNGARY, ASSIGNOR TO THE TESLA ELECTRIC LIGHT AND MANUFACTURING COMPANY, OF RAHWAY, NEW JERSEY.

ELECTRIC-ARC LAMP.

SPECIFICATION forming part of Letters Patent No. 335,787, dated February 9, 1886.

Application filed July 13, 1885. Serial No. 171,416. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, of Smiljan Lika, border country of Austria-Hungary, have invented certain Improvements in Electric-Arc Lamps, of which the following is a specification.

In another application, No. 160,574, filed by me March 30, 1885, I have shown and described a lamp having two magnets, in the main and shunt circuits, respectively, an armature-lever, and feed-mechanism connected to the armature-lever.

My present invention consists in some modifications of and improvements upon the devices shown in the application referred to.

In my present invention I further provide means for automatically withdrawing a lamp from the circuit, or cutting out the same, when, from a failure of the feed, the arc reaches an abnormal length, and also means for automatically reinserting such lamp in the circuit when the rod drops and the carbons come into contact.

My invention will be understood with reference to the accompanying drawings.

In the drawings, Figure 1 is an elevation of the lamp with the case in section. Fig. 2 is a sectional plan at the line *x x*. Fig. 3 is an elevation, partly in section, of the lamp at right angles to Fig. 1. Fig. 4 is a sectional plan at the line *y y* of Fig. 1. Fig. 5 is a section of the clamp in about full size. Fig. 6 is a detached section illustrating the connection of the spring to the lever that carries the pivots of the clamp, and Fig. 7 is a diagram showing the circuit-connections of the lamp.

In the drawings, Fig. 1, M represents the main and N the shunt magnet, both securely fastened to the base A, which, with its side columns, S S, is preferably cast in one piece of brass or other diamagnetic material. To the magnets are soldered or otherwise fastened the brass washers or disks *a a a a*. Similar washers, *b b*, of fiber or other insulating material, serve to insulate the wires from the brass washers.

The magnets M and N are made very flat, so that their width exceeds three times their thickness, or even more. In this way a comparatively small number of convolutions is sufficient to produce the required magnetism, besides a greater surface is offered for cooling off the wires.

The upper pole-pieces, *m n*, of the magnets are curved, as indicated in the drawings, Fig. 1. The lower pole-pieces, *m′ n′*, are brought near together, tapering toward the armature *g*, as shown in Figs. 2 and 4. The object of this taper is to concentrate the greatest amount of the developed magnetism upon the armature, and also to allow the pull to be exerted always upon the middle of the armature *g*. This armature *g* is a piece of iron in the shape of a hollow cylinder, having on each side a segment cut away, the width of which is equal to the width of the pole-pieces *m′ n′*.

The armature is soldered or otherwise fastened to the clamp *r*, which is formed of a brass tube, provided with gripping-jaws *e e*, Fig. 5. These jaws are arcs of a circle of the diameter of the rod R, and are made of some hard metal, preferably of hardened German silver. I also make the guides *f f*, through which the carbon-holding rod R slides, of the same material. This has the advantage to reduce greatly the wear and corrosion of the parts coming in frictional contact with the rod, which frequently causes trouble. The jaws *e e* are fastened to the inside of the tube *r*, so that one is a little lower than the other. The object of this is to provide a greater opening for the passage of the rod when the same is released by the clamp. The clamp *r* is supported on bearings *w w*, Figs. 1, 3 and 5, which are just in the middle between the jaws *e e*. I find this disposition to be the best. The bearings *w w* are carried by a lever, *t*, one end of which rests upon an adjustable support, *q*, of the side columns, S, the other end being connected by means of the link *e′* to the armature-lever L. The armature-lever L is a flat piece of iron in Z shape, having its ends curved so as to correspond to the form of the upper pole-pieces of the magnets M and N. It is hung upon the pivots *v v*, Fig. 2, which are in the jaw *x* of the top plate, B. This plate B, with the jaw, is preferably cast in one piece and screwed to the side columns, S S, that extend up from the base A. To partly balance the overweight of the moving parts a spring, *s′*, Figs. 2 and 6, is fastened to the top plate, B, and hooked to the lever t. The hook o is toward one side of the lever or bent a little sidewise, as seen in Fig. 6. By this means a slight tendency is given to swing the armature toward the pole-piece m' of the main magnet.

The binding-posts K K' are preferably screwed to the base A. A manual switch, for short-circuiting the lamp when the carbons are renewed, is also to be fastened to the base. This switch is of ordinary character, and is not shown in the drawings.

The rod R is electrically connected to the lamp-frame by means of a flexible conductor or otherwise. The lamp-case receives a removable ornamental cover, s^2, around the same to inclose the parts.

The electrical connections are as indicated diagrammatically in Fig. 7.

The wire in the main magnet consists of two parts, x' and p'. These two parts may be in two separated coils or in one single helix, as shown in the drawings. The part x' being normally in circuit, is, with the fine wire upon the shunt-magnet, wound and traversed by the current in the same direction, so as to tend to produce similar poles, n n or s s, on the corresponding pole-pieces of the magnets M and N. The part p' is only in circuit when the lamp is cut out, and then the current being in the opposite direction produces in the main magnet magnetism of the opposite polarity.

The operation is as follows: At the start the carbons are to be in contact, and the current passes from the positive binding-post K to the lamp-frame, carbon-holder, upper and lower carbon, insulated return-wire in one of the side rods, and from there through the part x' of the wire on the main magnet to the negative binding-post. Upon the passage of the current the main magnet is energized and attracts the clamping-armature g, swinging the clamp and gripping the rod by means of the gripping-jaws e e. At the same time the armature-lever L is pulled down and the carbons separated. In pulling down the armature-lever L the main magnet is assisted by the shunt-magnet N, the latter being magnetized by magnetic induction from the magnet M.

It will be seen that the armatures L and g are practically the keepers for the magnets M and N, and owing to this fact both magnets with either one of the armatures L and g may be considered as one horseshoe-magnet, which we might term a "compound magnet." The whole of the soft-iron parts m, m', g, n', n, and L form a compound magnet.

The carbons being separated, the fine wire receives a portion of the current. Now, the magnetic induction from the magnet M is such as to produce opposite poles on the corresponding ends of the magnet N; but the current traversing the helices tends to produce similar poles on the corresponding ends of both magnets, and therefore as soon as the fine wire is traversed by sufficient current the magnetism of the whole compound magnet is diminished.

With regard to the armature g and the operation of the lamp, the pole m' may be termed as the "clamping" and the pole n' as the "releasing" pole.

As the carbons burn away, the fine wire receives more current and the magnetism diminishes in proportion. This causes the armature-lever L to swing and the armature g to descend gradually under the weight of the moving parts until the end p, Fig. 1, strikes a stop on the top plate, B. The adjustment is such that when this takes place the rod R is yet gripped securely by the jaws e e. The further downward movement of the armature-lever being prevented, the arc becomes longer as the carbons are consumed, and the compound magnet is weakened more and more until the clamping-armature g releases the hold of the gripping-jaws e e upon the rod R, and the rod is allowed to drop a little, shortening thus the arc. The fine wire now receiving less current, the magnetism increases, and the rod is clamped again and slightly raised, if necessary. This clamping and releasing of the rod continues until the carbons are consumed. In practice the feed is so sensitive that for the greatest part of the time the movement of the rod cannot be detected without some actual measurement. During the normal operation of the lamp the armature-lever L remains stationary, or nearly so, in the position shown in Fig. 1.

Should it arise that, owing to an imperfection in the rod, the same and the carbons drop too far, so as to make the arc too short, or even bring the carbons in contact, then a very small amount of current passes through the fine wire, and the compound magnet becomes sufficiently strong to act as on the start in pulling the armature-lever L down and separating the carbons to a greater distance.

It occurs often in practice that the rod sticks in the guides. In this case the arc reaches a great length, until it finally breaks. Then the light goes out, and frequently the fine wire is injured. To prevent such an accident, I provide my lamp with an automatic cut-out. This cut-out operates as follows: When, upon a failure of the feed, the arc reaches a certain predetermined length, such an amount of current is diverted through the fine wire that the polarity of the compound magnet is reversed. The clamping-armature g is now moved against the shunt-magnet N until it strikes the releasing-pole n'. As soon as the contact is established, the current passes from the positive binding-post over the clamp r, armature g, insulated shunt-magnet, and the helix p' upon the main magnet M to the negative binding-post. In this case the current passes in the opposite direction and changes the polarity of the magnet M, at the same time maintaining by magnetic induction in the core of shunt-magnet the required magnetism without reversal of polarity, and the armature g remains against the shunt-magnet pole n'. The lamp is thus cut out as long as the carbons are separated. The cut-out may be used in this form without any further improvement; but I prefer to arrange it so that if the rod drops and the carbons come in contact the arc is started again. For this purpose I proportion the resistance of the part p' and the number of the convolutions of the wire upon the main magnet so that when the carbons come in contact a sufficient amount of current is diverted through the carbons and the part x' to destroy or neutralize the magnetism of the compound magnet. Then the armature g, having a slight tendency to approach to the clamping-pole m', comes out of contact with the releasing-pole n'. As soon as this happens, the current through the part p' is interrupted, and the whole current passes through the part x. The magnet M is now strongly magnetized, the armature g is attracted, and the rod clamped. At the same time the armature-lever L is pulled down out of its normal position and the arc started. In this way the lamp cuts itself out automatically when the arc gets so long, and reinserts itself automatically in the circuit if the carbons drop together.

It will be seen that the cut-out may be modified without departing from the spirit of my invention, as long as the shunt-magnet closes a circuit including a wire upon the main magnet and continues to keep the contact closed, being magnetized by magnetic induction from the main magnet. It is also obvious to say that the magnets and armatures may be of any desired shape.

I claim as my invention—

1. The combination, in an arc-lamp, of a main and a shunt magnet, an armature-lever to draw the arc, a clamp, and an armature to act upon the clamp, a clamping-pole and a releasing-pole upon the respective cores, the cores, poles, armature-lever, and clamping-armature forming a compound electro-magnet, substantially as set forth.

2. The combination, in an electric-arc lamp, of a carbon-holder and its rod, a clamp for such carbon-holder, a clamping-armature connected to the clamp, a compound electro-magnet controlling the action of the clamping-armature, and electric-circuit connections, substantially as set forth, for lessening the magnetism of the compound magnet when the arc between the carbons lengthens and augmenting the magnetism of the same when the arc is shortened, substantially as described.

3. The combination, with the carbon-holders in an electric lamp, of a clamp around the rod of the upper-carbon holder, the clamping-armature connected with said clamp, the armature-lever and connection from the same to the clamp, the main and shunt magnets, and the respective poles of the same to act upon the clamping-armature and armature-lever, respectively, substantially as set forth.

4. In an electric-arc lamp, a cut-out consisting of a main magnet, an armature, and a shunt-magnet having an insulated pole-piece, and the cut-out circuit-connections through the pole-piece and armature, substantially as set forth.

5. In an electric-arc lamp, the combination, with the carbon-holder and magnets, of the armatures L and g, link e', clamp r, and lever t, and the spring s', for the purpose set forth.

6. In an electric-arc lamp, the combination, with two upright magnets in the main and shunt circuits, respectively, having curved pole-pieces on one end and converging pole-pieces on the other end, of a flat Z-shaped armature-lever between the curved pole-pieces and a clamping-armature between the convergent pole-pieces, substantially as described.

7. The combination, in an electric-arc lamp, of an electro-magnet in the main circuit and an electro-magnet in the shunt-circuit, an armature under the influence of the poles of the respective magnets, and circuit-connections controlled by such armature to cut out or shunt the lamp, substantially as specified, whereby the branch circuit is closed by the magnetism of the shunt-magnet, and then kept closed by induced magnetism from the main magnet, substantially as set forth.

8. The combination, with the carbon-holder and rod and the main and shunt magnets, of a feeding-clamp, an armature for the same, clamping and releasing poles upon the cores of the respective magnets, and circuit-connections through the clamping-armature, substantially as specified, for shunting the current when the electric arc between the carbons becomes abnormally long, substantially as set forth.

9. The combination, with the carbon-holding rod and a clamp for the same, of an armature upon the clamp, a shunt-magnet the pole of which acts to release the clamp, and a main magnet with a two-part helix, one portion being in the main circuit and the other portion in a shunt or cut-out circuit, the clamping-armature acting to close said cut-out circuit when the arc becomes too long and to break the shunt-circuit when the carbons come together, substantially as set forth.

Signed by me this 11th day of July, A. D. 1885.

NIKOLA TESLA.

Witnesses:
GEO. T. PINCKNEY,
WILLIAM G. MOTT.

(No Model.) 2 Sheets—Sheet 1.

N. TESLA.

REGULATOR FOR DYNAMO ELECTRIC MACHINES.

No. 336,961. Patented Mar. 2, 1886.

Fig. 1.

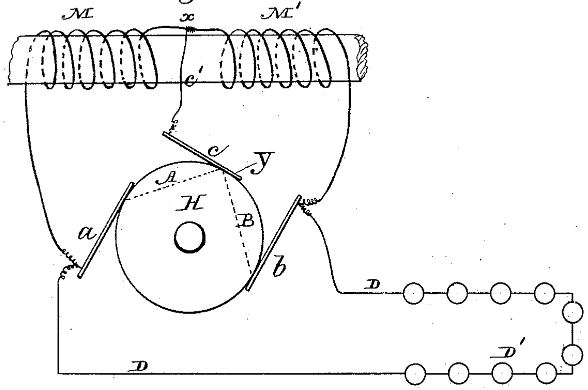


Fig. 2.

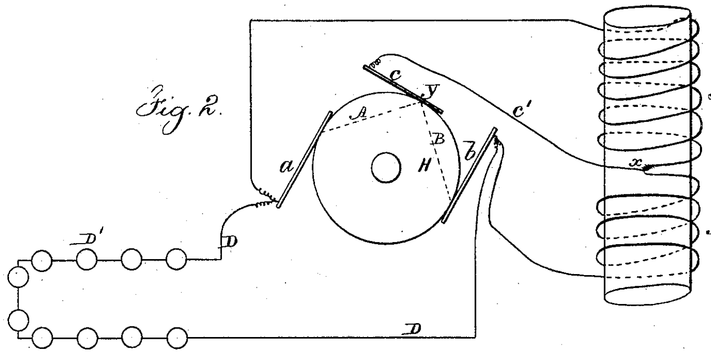
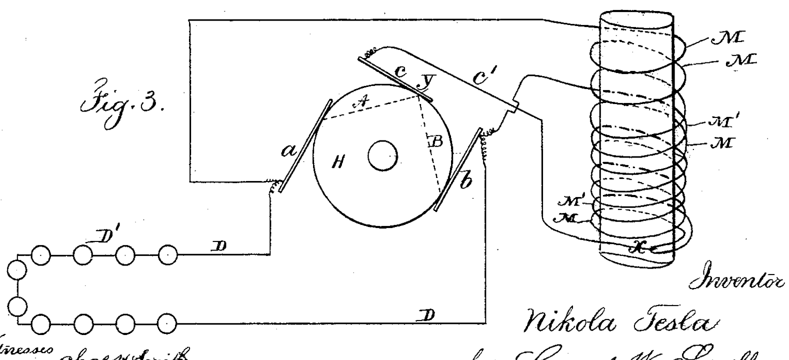


Fig. 3.



Witnesses Chas. H. Smith
Geo. T. Pinckney

Inventor
Nikola Tesla
for Lemuel W. Serrell
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(No Model.) 2 Sheets—Sheet 2.

N. TESLA.

REGULATOR FOR DYNAMO ELECTRIC MACHINES.

No. 336,961. Patented Mar. 2, 1886.

Fig. 4

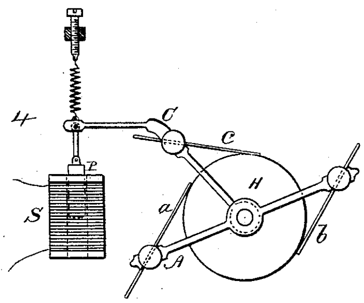


Fig. 5.

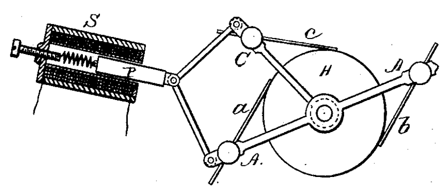
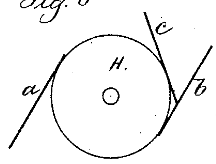


Fig. 6



Witnesses
Chas H. Smith
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per Lemuel W. Serrell
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N. PETERS, Photo-Lithographer, Washington, D. C.

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF SMILJAN LIKA, AUSTRIA-HUNGARY, ASSIGNOR TO THE TESLA ELECTRIC LIGHT AND MANUFACTURING COMPANY, OF RAHWAY, NEW JERSEY.

REGULATOR FOR DYNAMO-ELECTRIC MACHINES.

SPECIFICATION forming part of Letters Patent No. 336,961, dated March 2, 1886.

Application filed May 18, 1885. Serial No. 165,793. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, of Smiljan Lika, border country of Austria-Hungary, have invented an Improvement in Dynamo-Electric Machines, of which the following is a specification.

The object of my invention is to provide an improved method for regulating the current on dynamo-electric machines.

In my improvement I make use of two main brushes, to which the ends of the helices of the field-magnets are connected, and an auxiliary brush and a branch or shunt connection from an intermediate point of the field-wire to the auxiliary brush.

The relative positions of the respective brushes are varied, either automatically or by hand, so that the shunt becomes inoperative when the auxiliary brush has a certain position upon the commutator; but when said auxiliary brush is moved in its relation to the main brushes, or the latter are moved in their relation to the auxiliary brush, the electric condition is disturbed and more or less of the current through the field-helices is diverted through the shunt or a current passed over said shunt to the field-helices.

By varying the relative position upon the commutator of the respective brushes automatically in proportion to the varying electrical conditions of the working-circuit the current developed can be regulated in proportion to the demands in the working-circuit.

Devices for automatically moving the brushes in dynamo-electric machines are well known, and those made use of in my machine may be of any desired or known character.

In the drawings, Figure 1 is a diagram illustrating my invention, showing one core of the field-magnets with one helix wound in the same direction throughout. Figs. 2 and 3 are diagrams showing one core of the field-magnets with a portion of the helices wound in opposite directions. Figs. 4 and 5 are diagrams illustrating the electric devices that may be employed for automatically adjusting the brushes, and Fig. 6 is a diagram illustrating the positions of the brushes when the machine is being energized on the start.

a and *b* are the positive and negative brushes of the main or working circuit, and *c* the auxiliary brush. The working-circuit D extends from the brushes *a* and *b*, as usual, and contains electric lamps or other devices, D′, either in series or in multiple arc.

M M′ represent the field-helices, the ends of which are connected to the main brushes *a* and *b*. The branch or shunt wire *c′* extends from the auxiliary brush *c* to the circuit of the field-helices, and is connected to the same at an intermediate point, X.

H represents the commutator, with the plates of ordinary construction. It is now to be understood that when the auxiliary brush *c* occupies such a position upon the commutator that the electro-motive force between the brushes *a* and *c* is to the electro-motive force between the brushes *c* and *b* as the resistance of the circuit *a* M *c′ c* A to the resistance of the circuit *b* M′ *c′ c* B, the potentials of the points X and Y will be equal, and no current will flow over the auxiliary brush; but when the brush *c* occupies a different position the potentials of the points X and Y will be different, and a current will flow over the auxiliary brush to or from the commutator, according to the relative position of the brushes. If, for instance, the commutator-space between the brushes *a* and *c*, when the latter is at the neutral point, is diminished, a current will flow from the point Y over the shunt C to the brush *b*, thus strengthening the current in the part M′, and partly neutralizing the current in the part M; but if the space between the brushes *a* and *c* is increased, the current will flow over the auxiliary brush in an opposite direction, and the current in M will be stregthened, and in M′ partly neutralized.

By combining with the brushes *a*, *b*, and *c* any known automatic regulating mechanism the current developed can be regulated in proportion to the demands in the working-circuit. The parts M and M′ of the field-wire may be wound in the same direction. (In this case they are arranged as shown in Fig. 1; or, the part M may be wound in the opposite direction, as shown in Figs. 2 and 3.)

It will be apparent that the respective cores of the field-magnets are subjected to the neutralizing or intensifying effects of the current in the shunt through c', and the magnetism of the cores will be partially neutralized or the point of greatest magnetism shifted, so that it will be more or less remote from or approaching to the armature, and hence the aggregate energizing actions of the field magnets on the armature will be correspondingly varied.

In the form indicated in Fig. 1 the regulation is effected by shifting the point of greatest magnetism, and in Figs. 2 and 3 the same effect is produced by the action of the current in the shunt passing through the neutralizing-helix.

The relative positions of the respective brushes may be varied by moving the auxiliary brush or the brush *c* may remain quiescent and the core *p* be connected to the main-brush holder A′, so as to adjust the brushes *a b* in their relation to the brush *c*. If, however, an adjustment is applied to all the brushes, as seen in Fig. 5, the solenoid should be connected to both A and C, so as to move them toward or away from each other.

There are several known devices for giving motion in proportion to an electric current. I have shown the moving cores in Figs. 4 and 5 as convenient devices for obtaining the required extent of motion with very slight changes in the current passing through the helices. It is understood that the adjustment of the main brushes causes variations in the strength of the current independently of the relative position of said brushes to the auxiliary brush. In all cases the adjustment may be such that no current flows over the auxiliary brush when the dynamo is running with its normal load.

In Figs. 4 and 5, A A indicate the main-brush holder, carrying the main brushes, and C the auxiliary-brush holder, carrying the auxiliary brush. These brush-holders are movable in arcs concentric with the center of the commutator-shaft. An iron piston, P, of the solenoid S, Fig. 4, is attached to the auxiliary-brush holder C. The adjustment is effected by means of a spring and screw or tightener.

In Fig. 5, instead of a solenoid, an iron tube inclosing a coil is shown. The piston of the coil is attached to both brush-holders A A and C. When the brushes are moved directly by electrical devices, as shown in Figs. 4 and 5, these are so constructed that the force exerted for adjusting is practically uniform through the whole length of motion.

I am aware that auxiliary brushes have been used in connection with the helices of the field-wire; but in these instances the helices received the entire current through the auxiliary brush or brushes, and said brushes could not be taken off without breaking the circuit through the field. These brushes caused, however, a great sparking upon the commutator. In my improvement the auxiliary brush causes very little or no sparking, and can be taken off without breaking the circuit through the field-helices.

My improvement has, besides, the advantage to facilitate the self-exciting of the machine in all cases where the resistance of the field-wire is very great comparatively to the resistance of the main circuit at the start—for instance, on arc-light machines. In this case I place the auxiliary brush *c* near to or in preference in contact with the brush *b*, as shown in Fig. 6. In this manner the part M′ is completely cut out, and as the part M has a considerably smaller resistance than the whole length of the field-wire the machine excites itself, whereupon the auxiliary brush is shifted automatically to its normal position.

I claim as my invention—

The combination, with the commutator having two or more main brushes and an auxiliary brush, of the field-helices having their ends connected to the main brushes, and a branch or shunt connection from an intermediate point of the field-helices to the auxiliary brush, and means for varying the relative position upon the commutator of the respective brushes, substantially as set forth.

Signed by me this 13th day of May, A. D. 1885.

NIKOLA TESLA.

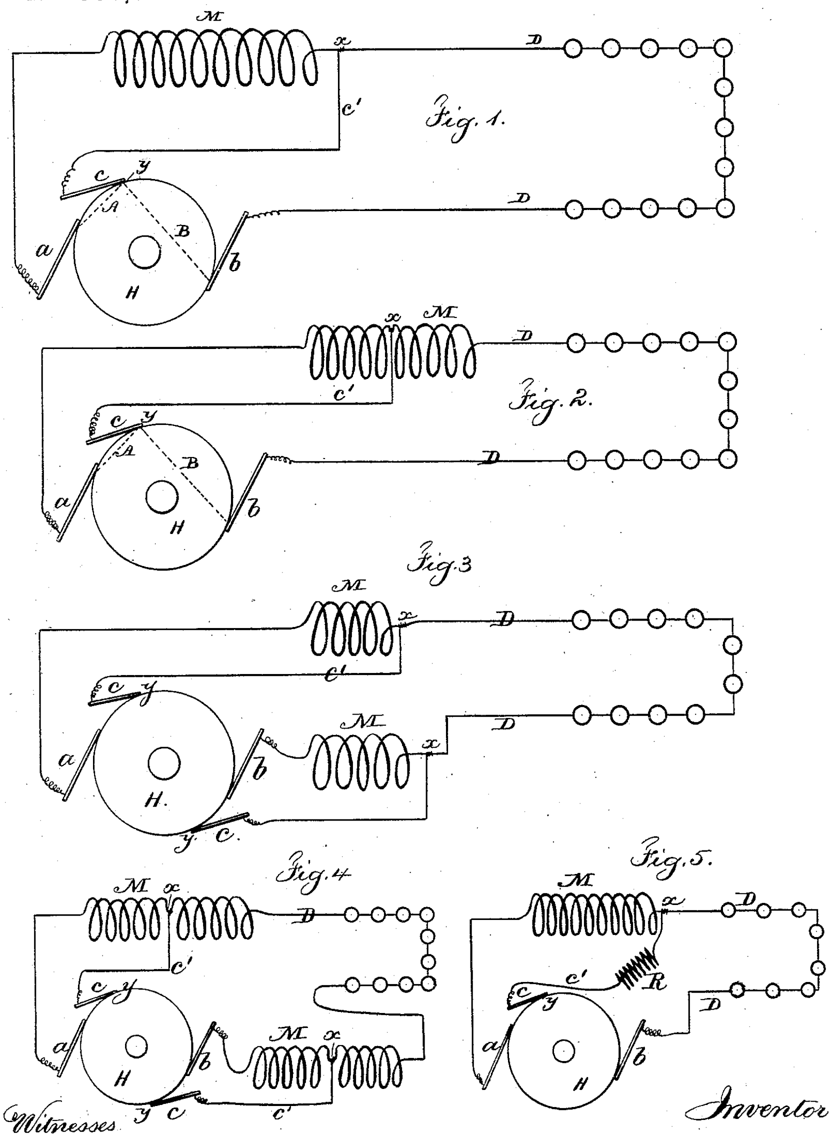
Witnesses:
GEO. T. PINCKNEY,
WALLACE L. SERRELL.

(No Model.) 2 Sheets—Sheet 1.

N. TESLA.

REGULATOR FOR DYNAMO ELECTRIC MACHINES.

No. 336,962. Patented Mar. 2, 1886.



Witnesses
Chas H Smith
J. Stail

Inventor
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(No Model.) 2 Sheets—Sheet 2.

N. TESLA.

REGULATOR FOR DYNAMO ELECTRIC MACHINES.

No. 336,962. Patented Mar. 2, 1886.

Fig. 6

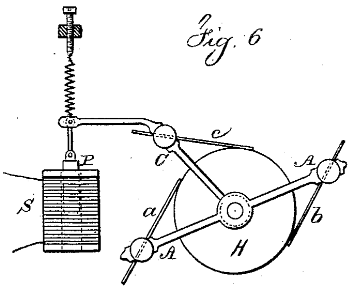
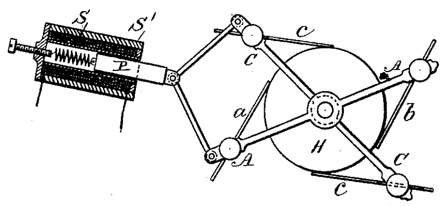


Fig. 7



Witnesses
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N. PETERS, Photo-Lithographer, Washington, D. C.

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF SMILJAN LIKA, AUSTRIA-HUNGARY, ASSIGNOR TO THE TESLA ELECTRIC LIGHT AND MANUFACTURING COMPANY, OF RAHWAY, NEW JERSEY.

REGULATOR FOR DYNAMO-ELECTRIC MACHINES.

SPECIFICATION forming part of Letters Patent No. 336,962, dated March 2, 1886.

Application filed June 1, 1885. Serial No. 167,136. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, of Smiljan Lika, border country of Austria-Hungary, have invented an Improvement in Dynamo-Electric Machines, of which the following is a specification.

My invention is designed to provide an improved method for regulating the current in dynamo-electric machines.

In another application, No. 165,793, filed by me May 18, 1885, I have shown a method for regulating the current in a dynamo having the field-helices in a shunt. My present application relates to a dynamo having its field-helices connected in the main circuit.

In my improvement I employ one or more auxiliary brushes, by means of which I shunt a portion or the whole of the field-helices. According to the relative position upon the commutator of the respective brushes more or less current is caused to pass through the helices of the field, and the current developed by the machine can be varied at will by varying the relative positions of the brushes.

In the drawings the present invention is illustrated by diagrams, which are hereinafter separately referred to.

In Figure 1, *a* and *b* are the positive and negative brushes of the main circuit, and *c* an auxiliary brush. The main circuit D extends from the brushes *a* and *b*, as usual, and contains the helices M of the field-wire and the electric lamps or other working devices. The auxiliary brush *c* is connected to the point *x* of the main circuit by means of the wire *c'*. H is a commutator of ordinary construction.

From that which has been said in the application above referred to it will be seen that when the electro-motive force between the brushes *a* and *c* is to the electro-motive force between the brushes *c* and *b* as the resistance of the circuit *a* M *c' c* A to the resistance of the circuit *b* C B *c c'* D, the potentials of the points *x* and *y* will be equal, and no current will pass over the auxiliary brush *c*; but if said brush occupies a different position relatively to the main brushes the electric condition is disturbed, and current will flow either from *y* to *x* or from *x* to *y*, according to the relative position of the brushes. In the first case the current through the field-helices will be partly neutralized and the magnetism of the field-magnets diminished. In the second case the current will be increased and the magnets will gain strength. By combining with the brushes *a b c* any automatic regulating mechanism the current developed can be regulated automatically in proportion to the demands in the working-circuit.

In Figs. 6 and 7 I have represented some of the automatic means that may be used for moving the brushes. The core P, Fig. 6, of the solenoid-helix S, is connected with the brush *c* to move the same, and in Fig. 7 the core P is shown as within the helix S, and connected with both brushes *a* and *c*, so as to move the same toward or from each other, according to the strength of the current in the helix, the helix being within an iron tube, S', that becomes magnetized and increases the action of the solenoid.

In practice it is sufficient to move only the auxiliary brush, as shown in Fig. 6, as the regulation is very sensitive to the slightest changes; but the relative position of the auxiliary brush to the main brushes may be varied by moving the main brushes, or both main and auxiliary brushes may be moved, as illustrated in Fig. 7. In the latter two cases, it will be understood, the motion of the main brushes relatively to the neutral line of the machine causes variations in the strength of the current independently of their relative position to the auxiliary brush. In all cases the adjustment may be such that when the machine is running with the ordinary load no current flows over the auxiliary brush.

The field-helices may be connected as shown in Fig. 1, or a part of the field-helices may be in the outgoing and the other part in the return circuit, and two auxiliary brushes may be employed as shown in Figs. 3 and 4. Instead of shunting the whole of the field-helices, a portion only of such helices may be shunted, as shown in Figs. 2 and 4.

The arrangement shown in Fig. 4 is advantageous, as it diminishes the sparking upon the commutator, the main circuit being closed through the auxiliary brushes at the moment of the break of the circuit at the main brushes.

The field-helices may be wound in the same direction, or a part may be wound in opposite directions.

The connection between the helices and the auxiliary brush or brushes may be made by a wire of small resistance, or a resistance may be interposed (R, Fig. 5) between the point x and the auxiliary brush or brushes to divide the sensitiveness when the brushes are adjusted.

I am aware that it is not new to use auxiliary brushes on the commutator, and that auxiliary brushes have been connected to the field helices; but I am not aware that the helices of a series dynamo have been shunted by means of auxiliary brushes, and that the relative position of the respective brushes has been varied for the purpose of regulating the current developed by the machine.

In instances where auxiliary brushes have been used in connection with the field-helices said auxiliary brushes received the current continuously and caused great sparking, whereas in my invention the auxiliary brush receives current only when the normal electrical conditions of the circuit are disturbed.

I claim as my invention—

The combination, with the commutator and main brushes and one or more auxiliary brushes, of the field-helices in the main circuits and one or more shunt-connections from the field-helices to the auxiliary brushes, the relative positions upon the commutator of the respective brushes being adjustable, for the purpose set forth.

Signed by me this 16th day of May, A. D. 1885.

NIKOLA TESLA.

Witnesses:
GEO. T. PINCKNEY,
WALLACE L. SERRELL.

(No Model.)

N. TESLA.

REGULATOR FOR DYNAMO ELECTRIC MACHINES.

No. 350,954. Patented Oct. 19, 1886.

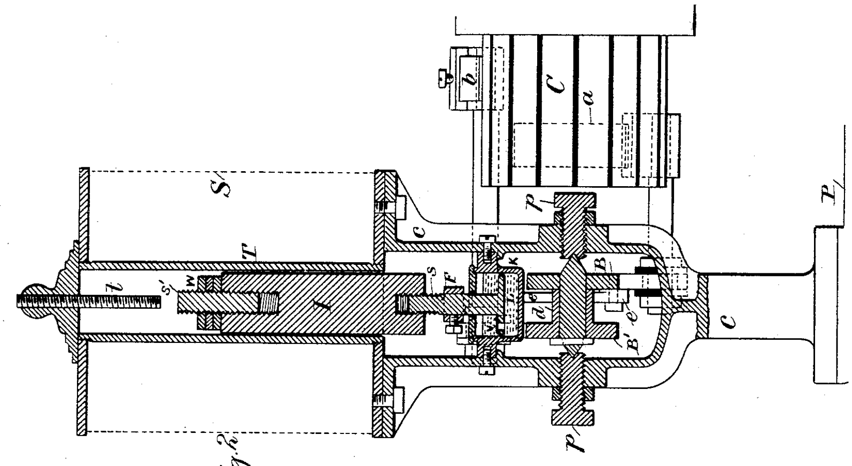


Fig. 2.

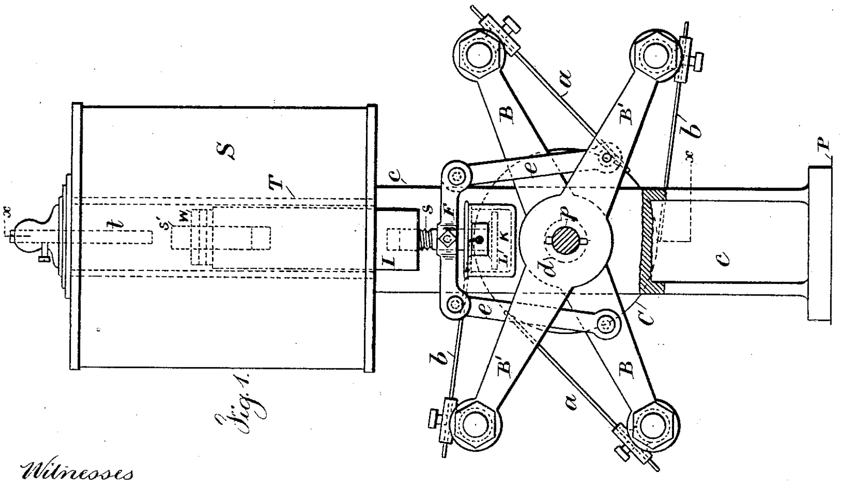


Fig. 1.

Witnesses

Chas H. Smith

J. Stail

Inventor

Nikola Tesla.

per Lemuel W. Serrell atty

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF SMILJAN LIKA, AUSTRIA-HUNGARY, ASSIGNOR TO THE TESLA ELECTRIC LIGHT AND MANUFACTURING COMPANY, OF RAHWAY, NEW JERSEY.

REGULATOR FOR DYNAMO-ELECTRIC MACHINES.

SPECIFICATION forming part of Letters Patent No. 350,954, dated October 19, 1886.

Application filed January 14, 1886. Serial No. 188,539. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, from Smiljan Lika, border country of Austria-Hungary, have invented certain Improvements in Dynamo-Electric Machines, of which the following is a specification.

In other applications I have shown the commutator of a dynamo-machine with the main brushes connected in an electric circuit, and one or more auxiliary brushes serving to shunt a part or the whole of the field-coils, the regulation of the current being effected by shifting the respective brushes automatically upon the commutator in proportion to the varying resistances of the circuit.

My present invention relates to the mechanical devices which I employ to effect the shifting of the brushes.

My invention is clearly shown in the accompanying drawings, in which Figure 1 is an elevation of the regulator with the frame partly in section; and Fig. 2 is a section at the line *xx*, Fig. 1.

C is the commutator; B and B', the brush-holders, B carrying the main brushes *a a'* and B' the auxiliary or shunt brushes *b b*. The axis of the brush-holder B is supported by two pivot-screws, *p p*. The other brush-holder, B', has a sleeve, *d*, and is movable around the axis of the brush-holder B. In this way both brush-holders can turn very freely, the friction of the parts being reduced to a minimum. Over the brush-holders is mounted the solenoid S, which rests upon a forked column, *c*. This column also affords a support for the pivots *p p*, and is fastened upon a solid bracket or projection, P, which extends from the base of the machine, and is preferably cast in one piece with the same. The brush-holders B B' are connected by means of the links *e e* and the cross-piece F to the iron core I, which slides freely in the tube T of the solenoid. The iron core I has a screw, *s*, by means of which it can be raised and adjusted in its position relatively to the solenoid, so that the pull exerted upon it by the solenoid is practically uniform through the whole length of motion which is required to effect the regulation. In order to effect the adjustment with a greater precision the core I is provided with a small iron screw, *s'*. The core being first brought very nearly in the required position relatively to the solenoid by means of the screw *s*, the small screw *s'* is then adjusted until the magnetic attraction upon the core is the same when the core is in any position. A convenient stop, *t*, serves to limit the upward movement of the iron core.

To check somewhat the movement of the core I, a dash-pot, K, is used. The piston L of the dash-pot is provided with a valve, V, which opens by a downward pressure and allows an easy downward movement of the iron core I, but closes and checks the movement of the core when the same is pulled up under the action of the solenoid.

To balance the opposing forces, the weight of the moving parts, and the pull exerted by the solenoid upon the iron core, the weights W W may be used. The adjustment is such that when the solenoid is traversed by the normal current it is just strong enough to balance the downward pull of the parts.

The electrical circuit-connections are substantially the same, as indicated in my former applications, the solenoid being in series with the circuit when the translating devices are in series and in a shunt when the devices are in multiple arc.

The operation of the device is as follows: When upon a decrease of the resistance of the circuit or some other reason the current is increased, the solenoid S gains in strength and pulls up the iron core I, thus shifting the main brushes in the direction of rotation and the auxiliary brushes in the opposite way. This diminishes the strength of the current until the opposing forces are balanced and the solenoid is traversed by the normal current; but if from any cause the current in the circuit is diminished, then the weight of the moving parts overcomes the pull of the solenoid, the iron core I descends, thus shifting the brushes the opposite way and increasing the current to the normal strength. The dash-pot connected to the iron core I may be of ordinary construction; but I prefer, especially in machines for arc lights, to provide the piston of the dash-pot with a valve, as indicated in the drawings. This valve permits a comparatively easy downward movement of the iron core, but checks its movement when it is drawn up by the solenoid. Such an arrangement has the advantage that a great number of lights may be put on without diminishing the light-power of the lamps in the circuit, as the brushes assume at once the proper position. When lights are cut out, the dash-pot acts to retard the movement; but if the current is considerably increased the solenoid gets abnormally strong and the brushes are shifted instantly.

The regulator being properly adjusted, lights or other devices may be put on or out with scarcely any perceptible difference.

It is obvious that instead of the dash-pot any other retarding device may be used.

I claim as my invention—

1. The combination, with the main and auxiliary brushes, of two brush-holders, an axis fastened to one of the brush-holders, supporting-screws for the same, a support for the other brush-holder surrounding the axis, a solenoid, a core for the same, and links connecting the core to the respective brush-holders, substantially as set forth.

2. The combination, with the brushes, brush-holders, and the axis upon which the brush-holders swing, of a solenoid and core, connections from the same to the brush-holders, and an adjusting-screw to limit the movements of the core, substantially as set forth.

3. The combination, with the brush-holders and their axes, of a solenoid and core, and a connection from the core to the brush-holders, and an iron screw at the inner end of the core to adjust the action of the magnetism on the core, substantially as set forth.

4. The combination, with the brushes, the brush-holders and their axes, of a solenoid and core, and connections to move the brush-holders, and a dash-pot provided with a valve, substantially as described, to diminish the speed of movement of the core in one direction more than the other, substantially as set forth.

5. The combination, with the brushes, the brush-holders and their axes, of a solenoid and core, and connections to move the brush-holders, and a dash-pot to diminish the speed of movement of the core, substantially as set forth.

6. The combination, with the brush-holders and the solenoid and core, of links connecting to the holders, and a screw to adjust the position of the core in relation to the solenoid, substantially as set forth.

Signed by me this 12th day of January, A. D. 1886.

NIKOLA TESLA.

Witnesses:
GEO. T. PINCKNEY,
WILLIAM G. MOTT.

(No Model.)

3 Sheets—Sheet 1.

N. TESLA.

DYNAMO ELECTRIC MACHINE.

No. 359,748. Patented Mar. 22, 1887.

Fig. 1.

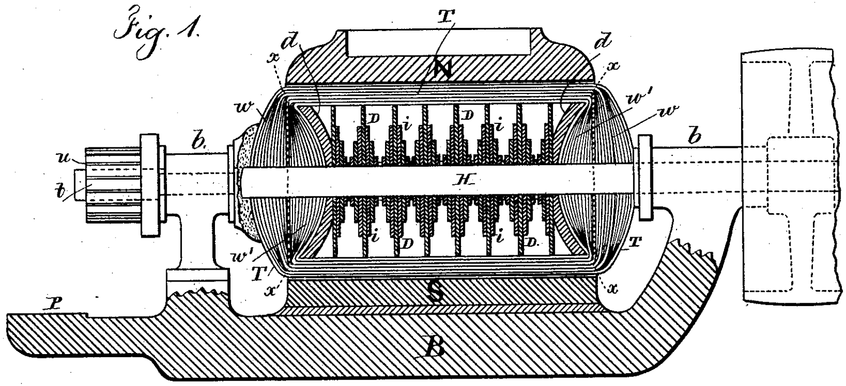
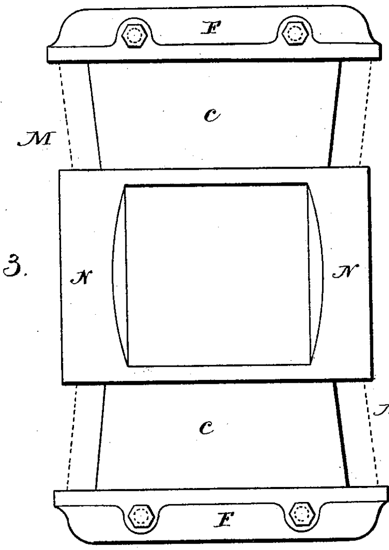


Fig. 3.



Witnesses
Chas H. Smith
J. Stail

Inventor
Nikola Tesla
for Lemuel W. Serrell
att

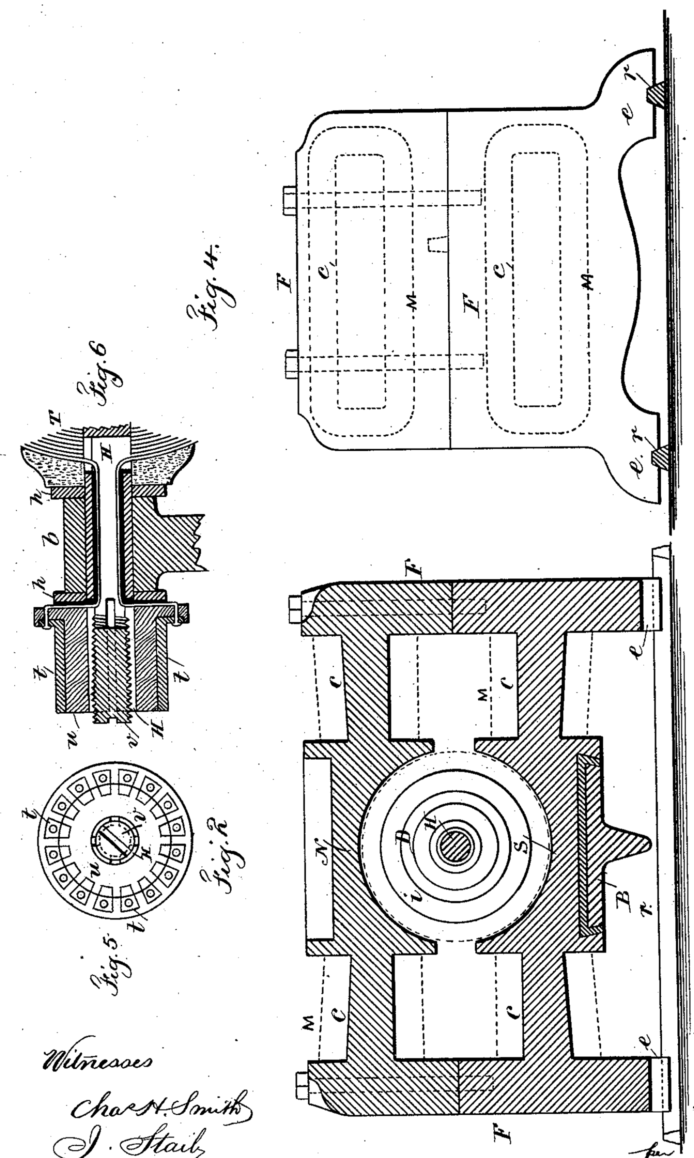
N. PETERS, Photo-Lithographer, Washington, D. C.

(No Model.) 3 Sheets—Sheet 2.

N. TESLA.

DYNAMO ELECTRIC MACHINE.

No. 359,748. Patented Mar. 22, 1887.



Witnesses
Chas H. Smith
J. Stail

Inventor
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per L. W. Serrell atty

N. PETERS, Photo-Lithographer, Washington, D. C.

(No Model.)

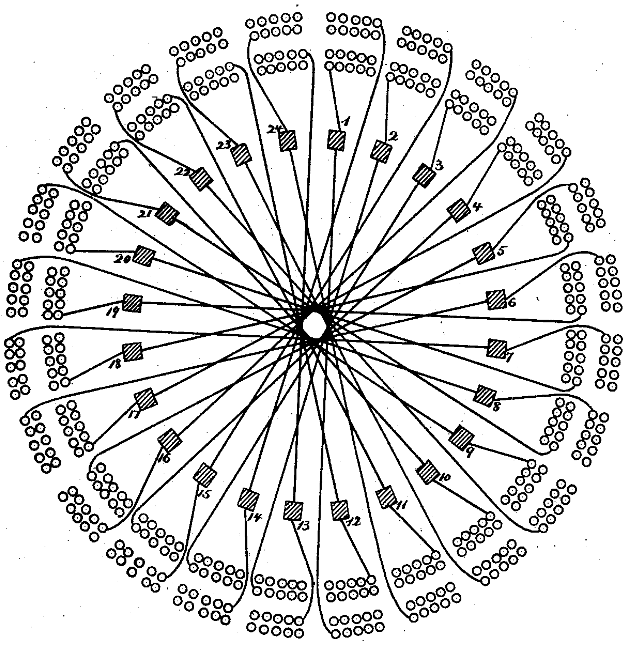
3 Sheets—Sheet 3.

N. TESLA.

DYNAMO ELECTRIC MACHINE.

No. 359,748. Patented Mar. 22, 1887.

Fig. 7.



Inventor

Witnesses

Chas. H. Smith
Geo. T. Pinckney

Nikola Tesla

per Lemuel W. Serrell

atty

N. PETERS, Photo-Lithographer, Washington, D. C.

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF SMILJAN LIKA, AUSTRIA-HUNGARY, ASSIGNOR TO THE TESLA ELECTRIC LIGHT AND MANUFACTURING COMPANY, OF RAHWAY, NEW JERSEY.

DYNAMO-ELECTRIC MACHINE.

SPECIFICATION forming part of Letters Patent No. 359,748, dated March 22, 1887.

Application filed January 14, 1886. Renewed December 1, 1886. Serial No. 220,370. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, of Smiljan Lika, border country of Austria-Hungary, have invented certain Improvements in Dynamo-Electric Machines, of which the following is a specification.

The main objects of my invention are to increase the efficiency of the machine and to facilitate and cheapen the construction of the same; and to this end my invention relates to the magnetic frame and the armature, and to other features of construction, hereinafter more fully explained.

My invention is illustrated in the accompanying drawings, in which Figure 1 is a longitudinal section, and Fig. 2 a cross-section, of the machine. Fig. 3 is a top view, and Fig. 4 a side view, of the magnetic frame. Fig. 5 is an end view of the commutator-bars, and Fig. 6 is a section of the shaft and commutator-bars. Fig. 7 is a diagram illustrating the coils of the armature and the connections to the commutator-plates.

The cores *c c c c* of the field-magnets may be tapering in both directions, as shown, for the purposes of concentrating the magnetism upon the middle of the pole-pieces.

The connecting-frame F F of the field-magnets is in the form indicated in the side view, Fig. 4, the lower part being provided with the spreading curved cast legs *e e*, so that the machine will rest firmly upon two base-bars, *r r*.

To the lower pole, S, of the field-magnet M is fastened, preferably by means of Babbitt or other fusible diamagnetic material, the base B, which is provided with bearings *b* for the armature-shaft H. The base B has a projection, P, which supports the brush-holders and the regulating devices, which may be of any ordinary character, or may be such as shown in an application of like date herewith.

The armature is constructed with the view to reduce to a minimum the loss of power due to the transversal or Foucault currents and to the change of polarity, and also to shorten as much as possible the length of the inactive wire wound upon the armature-core.

It is well known that when the armature is revolved between the poles of the field-magnets currents are generated in the iron body of the armature which develop heat, and consequently cause a waste of power. Owing to the mutual action of the lines of force, the magnetic properties of iron, and the speed of the different portions of the armature-core, these currents are generated principally on and near the surface of the armature-core, diminishing in strength gradually toward the center of the core. Their quantity is under same conditions proportional to the length of the iron body in the direction in which these currents are generated. By subdividing the iron core electrically in this direction the generation of these currents can be reduced to a great extent. For instance, if the length of the armature-core is twelve inches, and by a suitable construction the same is subdivided electrically, so that there are in the generating direction six inches of iron and six inches of intervening air-spaces or insulating material, the currents will be reduced to fifty per cent.

As shown in the drawings, the armature is constructed of thin iron disks D D D, of various diameters, fastened upon the armature-shaft in a suitable manner and arranged according to their sizes, so that a series of iron bodies, *i i i*, is formed, each of which diminishes in thickness from the center toward the periphery. At both ends of the armature the inwardly-curved disks *d d*, preferably of cast-iron, are fastened to the armature-shaft.

The armature-core being constructed as shown, it will be easily seen that on those portions of the armature that are the most remote from the axis, and where the currents are principally developed, the length of iron in the generating direction is only a small fraction of the total length of the armature-core, and besides this the iron body is subdivided in the generating direction, and therefore the Foucault currents are greatly reduced. Another cause of heating is the shifting of the poles of the armature-core. In consequence of the subdivision of the iron in the armature and the increased surface for radiation the risk of heating is lessened.

The iron disks D D D may be insulated or coated with some insulating-paint, a very careful insulation being unnecessary, as an electrical contact between several disks can only occur on places where the generated currents are comparatively weak. An armature-core constructed in the manner described may be revolved between the poles of the field-magnets without showing the slightest increase of temperature.

The end disks, *d d*, which are of sufficient thickness and, for the sake of cheapness, preferably of cast-iron, are curved inwardly, as indicated in the drawings. The extent of the curve is dependent on the amount of wire to be wound upon the armatures. In my present invention the wire is wound upon the armature in two superimposed parts, and the curve of the end disks, *d d*, is so calculated that the first part—that is, practically half of the wire—just fills up the hollow space to the line *x x*; or, if the wire is wound in any other manner, the curve is such that when the whole of the wire is wound the outside mass of wires, *w*, and the inside mass of wires, *w'*, are equal at each side of the plane *x x*. In this case it will be seen the passive or electrically-inactive wires are of the smallest length practicable. The arrangement has further the advantage that the total lengths of the crossing wires at the two sides of the plane *x x* are practically equal.

To further equalize the armature-coils at both sides of the plates that are in contact with the brushes, the winding and connecting-up is effected in the following manner: The whole wire is wound upon the armature-core in two superimposed parts, which are thoroughly insulated from each other. Each of these two parts is composed of three separated groups of coils. The first group of coils of the first part of wire being wound and connected to the commutator-bars in the usual manner, this group is insulated and the second group wound; but the coils of this second group instead of being connected to the next following commutator-bars, are connected to the directly-opposite bars of the commutator. The second group is then insulated and the third group wound, the coils of this group being connected to those bars to which they would be connected in the usual way. The wires are then thoroughly insulated and the second part of wire wound and connected in the same manner. Suppose, for instance, that there are twenty-four coils—that is, twelve in each part—and consequently twenty-four commutator-plates. There will be in each part three groups, each containing four coils, and the coils will be connected as follows:

	Groups.	*Commutator-bars.*
First part of wire	First	1— 5
	Second	17—21
	Third	9—13
Second part of wire	First	13—17
	Second	5— 9
	Third	21— 1

In constructing the armature-core and winding and connecting the coils in the manner indicated, the passive or electrically-inactive wire is reduced to a minimum, and the coils at each side of the plates that are in contact with the brushes are practically equal, and in this way the electrical efficiency of the machine is increased.

The commutator-plates *t* are shown as outside the bearing *b* of the armature-shaft. The shaft H is tubular and split at the end portion, and the wires are carried through the same in any usual manner and connected to the respective commutator-plates. The commutator-plates are upon a cylinder, *u*, and insulated, and this cylinder is to be properly placed and secured by expanding the split end of the shaft by a tapering screw-plug, *v*.

I do not claim herein the cores of the field-magnets converging toward the pole-pieces; nor do I claim the method of fastening the base to the lower field-magnet, as this has been claimed in my former application on dynamo-electric machines.

What I claim is—

1. In a dynamo-electric machine, the armature constructed of iron disks of various diameters arranged upon the shaft in such a manner that a series of iron bodies is formed, each diminishing in thickness from the center to the periphery, substantially as and for the purposes set forth.

2. In a dynamo-electric machine, the armature-core having iron disks of various diameters, in combination with inwardly-curved end disks, for the purposes and substantially as set forth.

3. In a dynamo-electric machine, an armature-core having inwardly-curved ends, in combination with the armature-coils, the crossing wires of which coils pass into the concave heads and project equally, substantially as set forth.

4. In a dynamo-electric machine, an armature having separate coils superimposed and connected to the commutator-plates in alternating groups, substantially as set forth.

5. An armature for dynamo-electric machines, having a core composed of disks of various diameters, in combination with separate superimposed coils connected to the commutator-plates in alternate groups, substantially as set forth.

6. In a dynamo-electric machine, the magnetic frame composed of the cores *c c c c*, the curved pole-pieces N S, and the connecting-frame with the curved and outwardly-projecting legs *e e*, substantially as described.

Signed by me this 12th day of January, A. D. 1886.

NIKOLA TESLA.

Witnesses:
GEO. T. PINCKNEY,
WALLACE L. SERRELL.

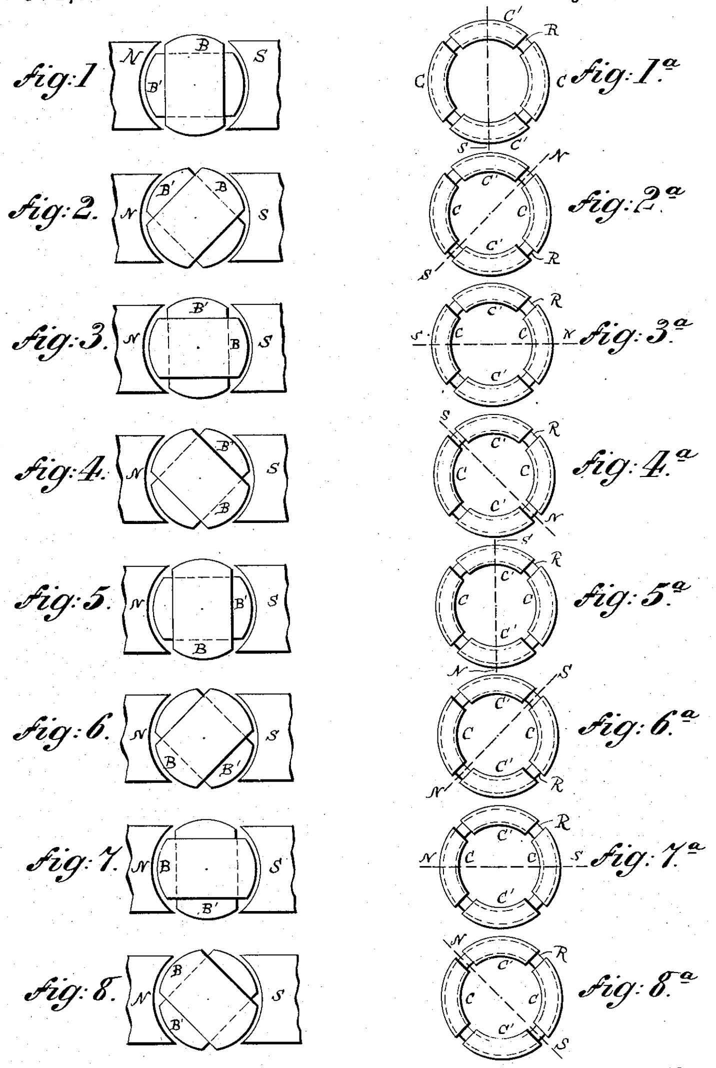
(No Model.)

4 Sheets—Sheet 1.

N. TESLA.

ELECTRO MAGNETIC MOTOR.

No. 381,968. Patented May 1, 1888.



WITNESSES:

Frank E. Hartley
Frank B. Murphy

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Nikola Tesla,

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ATTORNEYS.

(No Model.) 4 Sheets—Sheet 2.

N. TESLA.

ELECTRO MAGNETIC MOTOR.

No. 381,968. Patented May 1, 1888.

Fig: 9.

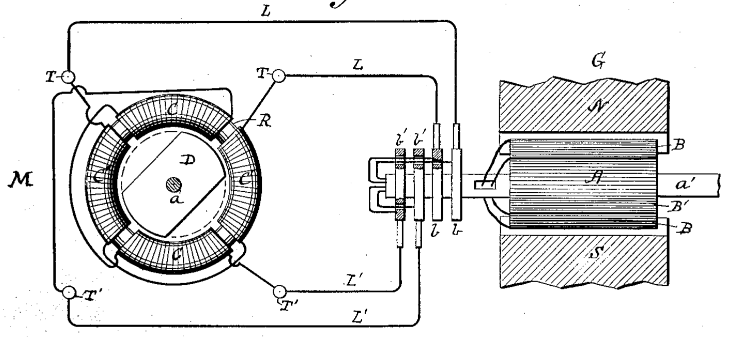


Fig: 10.

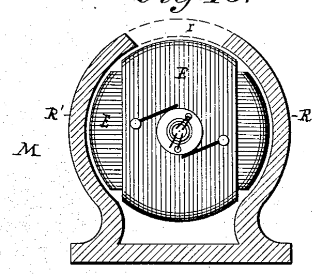


Fig: 11.

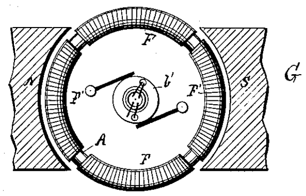
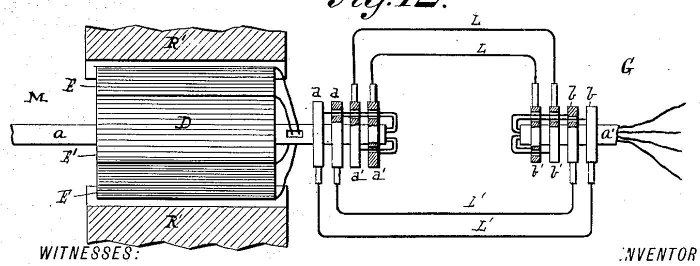


Fig: 12.



WITNESSES:

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(No Model.) 4 Sheets—Sheet 3.

N. TESLA.

ELECTRO MAGNETIC MOTOR.

No. 381,968. Patented May 1, 1888.

Fig: 13.

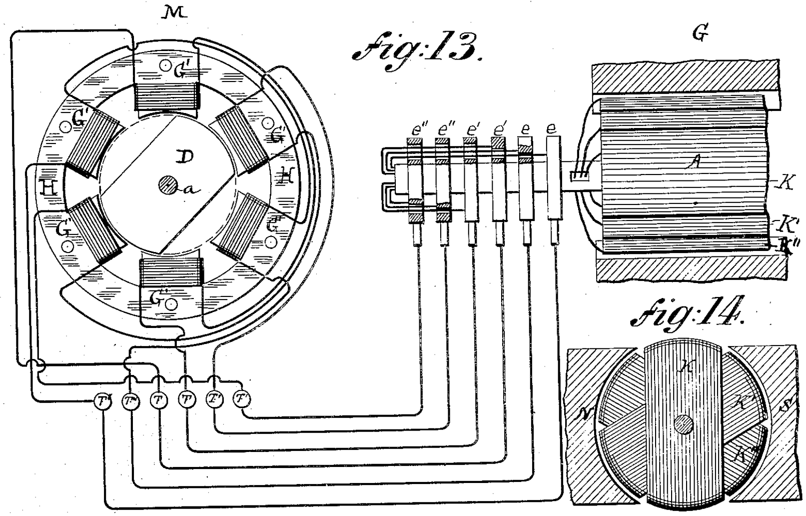
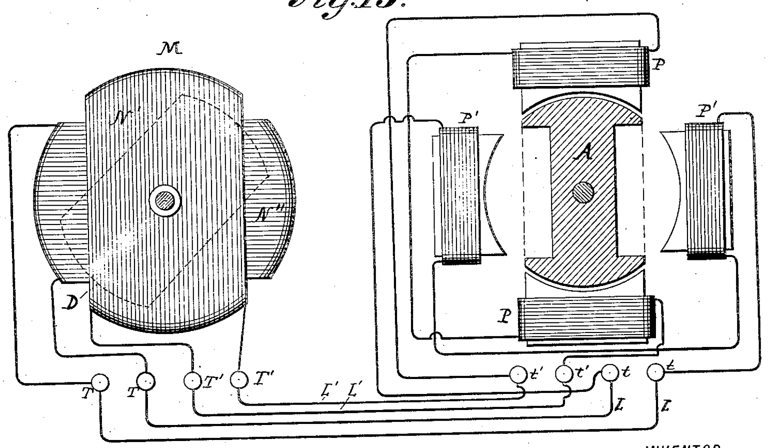


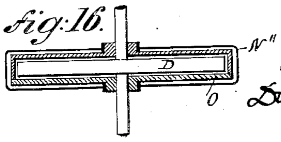
Fig: 15.



WITNESSES:

Frank E. Hartley.
Frank B. Murphy.

Fig: 16.



INVENTOR.

Nikola Tesla.

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Duncan, Curtis & Page

ATTORNEYS.

(No Model.) 4 Sheets—Sheet 4.

N. TESLA.

ELECTRO MAGNETIC MOTOR.

No. 381,968. Patented May 1, 1888.

Fig: 17.

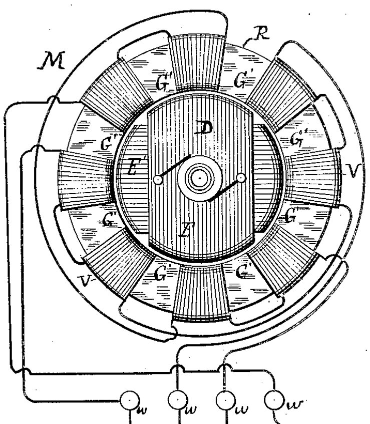


Fig: 18.

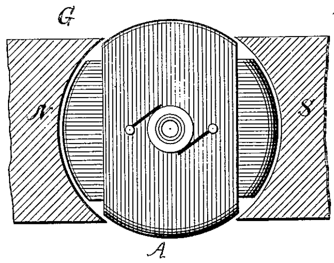
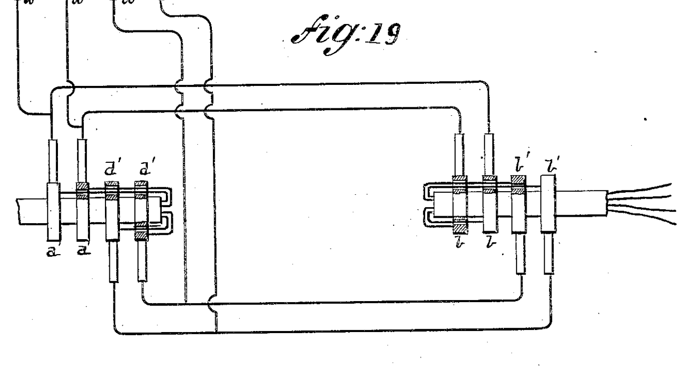


Fig: 19



WITNESSES:

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Frank B. Murphy.

INVENTOR.

Nikola Tesla,

BY

Duncan, Curtis & Page

ATTORNEYS.

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y., ASSIGNOR OF ONE-HALF TO CHARLES F. PECK, OF ENGLEWOOD, NEW JERSEY.

ELECTRO-MAGNETIC MOTOR.

SPECIFICATION forming part of Letters Patent No. 381,968, dated May 1, 1888.

Application filed October 12, 1887. Serial No. 252,132. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, from Smiljan Lika, border country of Austria-Hungary, residing at New York, N. Y., have invented certain new and useful Improvements in Electro-Magnetic Motors, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

The practical solution of the problem of the electrical conversion and transmission of mechanical energy involves certain requirements which the apparatus and systems heretofore employed have not been capable of fulfilling. Such a solution, primarily, demands a uniformity of speed in the motor irrespective of its load within its normal working limits. On the other hand, it is necessary, to attain a greater economy of conversion than has heretofore existed, to construct cheaper and more reliable and simple apparatus, and, lastly, the apparatus must be capable of easy management, and such that all danger from the use of currents of high tension, which are necessary to an economical transmission, may be avoided.

My present invention is directed to the production and improvement of apparatus capable of more nearly meeting these requirements than those heretofore available, and though I have described various means for the purpose, they involve the same main principles of construction and mode of operation, which may be described as follows: A motor is employed in which there are two or more independent circuits through which alternate currents are passed at proper intervals, in the manner hereinafter described, for the purpose of effecting a progressive shifting of the magnetism or of the "lines of force" in accordance with the well-known theory, and a consequent action of the motor. It is obvious that a proper progressive shifting of the lines of force may be utilized to set up a movement or rotation of either element of the motor, the armature, or the field-magnet, and that if the currents directed through the several circuits of the motor are in the proper direction no commutator for the motor will be required; but to avoid all the usual commutating appliances in the system I prefer to connect the motor-circuits directly with those of a suitable alternate-current generator. The practical results of such a system, its economical advantages, and the mode of its construction and operation will be described more in detail by reference to the accompanying diagrams and drawings.

Figures 1 to 8 and 1^a to 8^a, inclusive, are diagrams illustrating the principle of the action of my invention. The remaining figures are views of the apparatus in various forms by means of which the invention may be carried into effect, and which will be described in their order.

Referring first to Fig. 9, which is a diagrammatic representation of a motor, a generator, and connecting-circuits in accordance with my invention, M is the motor, and G the generator for driving it. The motor comprises a ring or annulus, R, preferably built up of thin insulated iron rings or annular plates, so as to be as susceptible as possible to variations in its magnetic condition. This ring is surrounded by four coils of insulated wire symmetrically placed, and designated by C C C′ C′. The diametrically-opposite coils are connected up so as to co-operate in pairs in producing free poles on diametrically-opposite parts of the ring. The four free ends thus left are connected to terminals T T T′ T′, as indicated. Near the ring, and preferably inside of it, there is mounted on an axis or shaft, *a*, a magnetic disk, D, generally circular in shape, but having two segments cut away, as shown. This disk is mounted so as to turn freely within the ring R. The generator G is of any ordinary type, that shown in the present instance having field-magnets N S and a cylindrical armature-core, A, wound with the two coils B B′. The free ends of each coil are carried through the shaft *a′* and connected, respectively, to insulated contact-rings *b b b′ b′*. Any convenient form of collector or brush bears on each ring and forms a terminal by which the current to and from a ring is conveyed. These terminals are connected to the terminals of the motor by the wires L and L′ in the manner indicated, whereby two complete circuits are formed—one including, say, the coils B of the generator C′ C′ of the motor, and the other the remaining coils B′ and C C of the generator and the motor.

It remains now to explain the mode of operation of this system, and for this purpose I refer to the diagrams, Figs. 1 to 8, and 1ª to 8ª, for an illustration of the various phases through which the coils of the generator pass when in operation, and the corresponding and resultant magnetic changes produced in the motor. The revolution of the armature of the generator between the field-magnets N S obviously produces in the coils B B′ alternating currents, the intensity and direction of which depend upon well-known laws. In the position of the coils indicated in Fig. 1 the current in the coil B is practically *nil*, whereas the coil B′ at the same time is developing its maximum current, and by the means indicated in the description of Fig. 9 the circuit including this coil B′ may also include, say, the coils C C of the motor, Fig. 1ª. The result, with the proper connections, would be the magnetization of the ring R′, the poles being on the line N S. The same order of connections being observed between the coil B and the coils C′, the latter, when traversed by a current, tend to fix the poles at right angles to the line N S of Fig. 1ª. It results, therefore, that when the generator-coils have made one eighth of a revolution, reaching the position shown in Fig. 2, both pairs of coils C and C′ will be traversed by currents and act in opposition, in so far as the location of the poles is concerned. The position of the poles will therefore be the resultant of the magnetizing forces of the coils—that is to say, it will advance along the ring to a position corresponding to one-eighth of the revolution of the armature of the generator. In Fig. 3 the armature of the generator has progressed to one-quarter of a revolution. At the point indicated the current in the coil B is maximum, while in B′ it is *nil*, the latter coil being in its neutral position. The poles of the ring R in Fig. 3ª will, in consequence, be shifted to a position ninety degrees from that at the start, as shown. I have in like manner shown the conditions existing at each successive eighth of one revolution in the remaining figures. A short reference to these figures will suffice for an understanding of their significance. Figs. 4 and 4ª illustrate the conditions which exist when the generator-armature has completed three eighths of a revolution. Here both coils are generating current; but the coil B′, having now entered the opposite field, is generating a current in the opposite direction, having the opposite magnetizing effect; hence the resultant pole will be on the line N S, as shown. In Fig. 5 one-half of one revolution of the armature of the generator has been completed, and the resulting magnetic condition of the ring is shown in Fig. 5ª. In this phase coil B is in the neutral position while coil B′ is generating its maximum current, which is in the same direction as in Fig. 4. The poles will consequently be shifted through one half of the ring. In Fig. 6 the armature has completed five-eighths of a revolution. In this position coil B′ develops a less powerful current, but in the same direction as before. The coil B, on the other hand, having entered a field of opposite polarity, generates a current of opposite direction. The resultant poles will therefore be in the line N S, Fig. 6ª, or, in other words, the poles of the ring will be shifted along five-eighths of its periphery. Figs. 7 and 7ª in the same manner illustrate the phases of the generator and ring at three-quarters of a revolution, and Figs. 8 and 8ª the same at seven-eighths of a revolution of the generator-armature. These figures will be readily understood from the foregoing. When a complete revolution is accomplished, the conditions existing at the start are re-established and the same action is repeated for the next and all subsequent revolutions, and, in general, it will now be seen that every revolution of the armature of the generator produces a corresponding shifting of the poles or lines of force around the ring. This effect I utilize in producing the rotation of a body or armature in a variety of ways—for example, applying the principle above described to the apparatus shown in Fig. 9. The disk D, owing to its tendency to assume that position in which it embraces the greatest possible number of the magnetic lines, is set in rotation, following the motion of the lines or the points of greatest attraction.

The disk D in Fig. 9 is shown as cut away on opposite sides; but this, I have found, is not essential to effecting its rotation, as a circular disk, as indicated by dotted lines, is also set in rotation. This phenomenon I attribute to a certain inertia or resistance inherent in the metal to the rapid shifting of the lines of force through the same, which results in a continuous tangential pull upon the disk, causing its rotation. This seems to be confirmed by the fact that a circular disk of steel is more effectively rotated than one of soft iron, for the reason that the former is assumed to possess a greater resistance to the shifting of the magnetic lines.

In illustration of other forms of my invention, I shall now describe the remaining figures of the drawings.

Fig. 10 is a view in elevation and part vertical section of a motor. Fig. 12 is a top view of the same with the field in section and a diagram of connections. Fig. 11 is an end or side view of a generator with the fields in section. This form of motor may be used in place of that shown above. D is a cylindrical or drum-armature core, which, for obvious reasons, should be split up as far as practicable to prevent the circulation within it of currents of induction. The core is wound longitudinally with two coils, E and E′, the ends of which are respectively connected to insulated contact-rings *d d d′ d′*, carried by the shaft *a*, upon which the armature is mounted. The armature is set to revolve within an iron shell, R′, which constitutes the field-magnet, or other element of the motor. This shell is preferably formed with a slot or opening, *r*, but it may be continuous, as shown by the dotted lines, and in this event it is preferably made of steel. It is also desirable that this shell should be divided up similarly to the armature and for similar reasons. As a generator for driving this motor I may use the device shown in Fig. 11. This represents an annular or ring armature, A, surrounded by four coils, F F F′ F′, of which those diametrically opposite are connected in series, so that four free ends are left, which are connected to the insulated contact-rings *b b b′ b′*. The ring is suitably mounted on a shaft, *a′*, between the poles N S. The contact-rings of each pair of generator-coils are connected to these of the motor, respectively, by means of contact-brushes and the two pairs of conductors L L and L′ L′, as indicated diagrammatically in Fig. 12. Now it is obvious from a consideration of the preceding figures that the rotation of the generator-ring produces currents in the coils F F′, which, being transmitted to the motor-coils, impart to the core of the latter magnetic poles constantly shifting or whirling around the core. This effect sets up a rotation of the armature owing to the attractive force between the shell and the poles of the armature, but inasmuch as the coils in this case move relative to the shell or field-magnet the movement of the coils is in the opposite direction to the progressive shifting of the poles.

Other arrangements of the coils of both generator and motor are possible, and a greater number of circuits may be used, as will be seen in the two succeeding figures.

Fig. 13 is a diagrammatic illustration of a motor and a generator constructed and connected in accordance with my invention. Fig. 14 is an end view of the generator with its field-magnets in section. The field of the motor M is produced by six magnetic poles, G′ G′, secured to or projecting from a ring or frame, H. These magnets or poles are wound with insulated coils, those diametrically opposite to each other being connected in pairs so as to produce opposite poles in each pair. This leaves six free ends, which are connected to the terminals T T T′ T′ T″ T″. The armature, which is mounted to rotate between the poles, is a cylinder or disk, D, of wrought-iron, mounted on the shaft *a*. Two segments of the same are cut away, as shown. The generator for this motor has in this instance an armature, A, wound with three coils, K K′ K″, at sixty degrees apart. The ends of these coils are connected, respectively, to insulated contact-rings *e e e′ e′ e″ e″*. These rings are connected to those of the motor in proper order by means of collecting-brushes and six wires, forming three independent circuits. The variations in the strength and direction of the currents transmitted through these circuits and traversing the coils of the motor produce a steadily-progressive shifting of the resultant attractive force exerted by the poles G′ upon the armature D, and consequently keep the armature rapidly rotating. The peculiar advantage of this disposition is in obtaining a more concentrated and powerful field. The application of this principle to systems involving multiple circuits generally will be understood from this apparatus.

Referring, now, to Figs. 15 and 16, Fig. 15 is a diagrammatic representation of a modified disposition of my invention. Fig. 16 is a horizontal cross-section of the motor. In this case a disk, D, of magnetic metal, preferably cut away at opposite edges, as shown in dotted lines in Fig. 15, is mounted so as to turn freely inside two stationary coils, N′ N″, placed at right angles to one another. The coils are preferably wound on a frame, O, of insulating material, and their ends are connected to the fixed terminals T T T′ T′. The generator G is a representative of that class of alternating-current machines in which a stationary induced element is employed. That shown consists of a revolving permanent or electro magnet, A, and four independent stationary magnets, P P′, wound with coils, those diametrically opposite to each other being connected in series and having their ends secured to the terminals *t t t′ t′*. From these terminals the currents are led to the terminals of the motor, as shown in the drawings. The mode of operation is substantially the same as in the previous cases, the currents traversing the coils of the motor having the effect to turn the disk D. This mode of carrying out the invention has the advantage of dispensing with the sliding contacts in the system.

In the forms of motor above described only one of the elements, the armature or the field-magnet, is provided with energizing-coils. It remains, then, to show how both elements may be wound with coils. Reference is therefore had to Figs. 17, 18, and 19. Fig. 17 is an end view of such a motor. Fig. 18 is a similar view of the generator with the field-magnets in section, and Fig. 19 is a diagram of the circuit-connections. In Fig. 17 the field-magnet of the motor consists of a ring, R, preferably of thin insulated iron sheets or bands with eight pole pieces, G′, and corresponding recesses, in which four pairs of coils, V, are wound. The diametrically-opposite pairs of coils are connected in series and the free ends connected to four terminals, *w*, the rule to be followed in connecting being the same as hereinbefore explained. An armature, D, with two coils, E E′, at right angles to each other, is mounted to rotate inside of the field-magnet R. The ends of the armature-coils are connected to two pairs of contact-rings, *d d d′ d′*, Fig. 19. The generator for this motor may be of any suitable kind to produce currents of the desired character. In the present instance it consists of a field-magnet, N S, and an armature, A, with two coils at right angles, the ends of which are connected to four contact-rings, *b b b′ b′*, carried by its shaft. The circuit-connections are established between the rings on the generator-shaft and those on the motor-shaft by collecting brushes and wires, as previously explained. In order to properly energize the field-magnet of the motor, however, the connections are so made with the armature coils or wires leading thereto that while the points of greatest attraction or greatest density of magnetic lines of force upon the armature are shifted in one direction those upon the field-magnet are made to progress in an opposite direction. In other respects the operation is identically the same as in the other cases cited. This arrangement results in an increased speed of rotation. In Figs. 17 and 19, for example, the terminals of each set of field-coils are connected with the wires to the two armature-coils in such way that the field-coils will maintain opposite poles in advance of the poles of the armature.

In the drawings the field-coils are in shunts to the armature, but they may be in series or in independent circuits.

It is obvious that the same principle may be applied to the various typical forms of motor hereinbefore described.

Having now described the nature of my invention and some of the various ways in which it is or may be carried into effect, I would call attention to certain characteristics which the applications of the invention possess and the advantages which the invention secures.

In my motor, considering for convenience that represented in Fig. 9, it will be observed that since the disk D has a tendency to follow continuously the points of greatest attraction, and since these points are shifted around the ring once for each revolution of the armature of the generator, it follows that the movement of the disk D will be synchronous with that of the armature A. This feature by practical demonstrations I have found to exist in all other forms in which one revolution of the armature of the generator produces a shifting of the poles of the motor through three hundred and sixty degrees.

In the particular construction shown in Fig. 15, or in others constructed on a similar plan, the number of alternating impulses resulting from one revolution of the generator armature is double as compared with the preceding cases, and the polarities in the motor are shifted around twice by one revolution of the generator-armature. The speed of the motor will, therefore, be twice that of the generator. The same result is evidently obtained by such a disposition as that shown in Fig. 17, where the poles of both elements are shifted in opposite directions.

Again, considering the apparatus illustrated by Fig. 9 as typical of the invention, it is obvious that since the attractive effect upon the disk D is greatest when the disk is in its proper relative position to the poles developed in the ring R—that is to say, when its ends or poles immediately follow those of the ring—the speed of the motor for all the loads within the normal working limits of the motor will be practically constant. It is clearly apparent that the speed can never exceed the arbitrary limit as determined by the generator, and also that within certain limits at least the speed of the motor will be independent of the strength of the current.

It will now be more readily seen from the above description how far the requirements of a practical system of electrical transmission of power are realized in my invention. I secure, first, a uniform speed under all loads within the normal working limits of the motor without the use of any auxiliary regulator; second, synchronism between the motor and generator; third, greater efficiency by the more direct application of the current, no commutating devices being required on either the motor or generator; fourth, cheapness and simplicity of mechanical construction and economy in maintenance; fifth, the capability of being very easily managed or controlled; and, sixth, diminution of danger from injury to persons and apparatus.

These motors may be run in series, multiple arc or multiple series, under conditions well understood by those skilled in the art.

The means or devices for carrying out the principle may be varied to a far greater extent than I have been able to indicate; but I regard as within my invention, and I desire to secure by Letters Patent in general, motors containing two or more independent circuits through which the operating-currents are led in the manner described. By "independent" I do not mean to imply that the circuits are necessarily isolated from one another, for in some instances there might be electrical connections between them to regulate or modify the action of the motor without necessarily producing a new or different action.

I am aware that the rotation of the armature of a motor wound with two energizing-coils at right angles to each other has been effected by an intermittent shifting of the energizing effect of both coils through which a direct current by means of mechanical devices has been transmitted in alternately-opposite directions; but this method or plan I regard as absolutely impracticable for the purposes for which my invention is designed—at least on any extended scale—for the reasons, mainly, that a great waste of energy is necessarily involved unless the number of energizing-circuits is very great, and that the interruption and reversal of a current of any considerable strength by means of any known mechanical devices is a matter of the greatest difficulty and expense.

In this application I do not claim the method of operating motors which is herein involved, having made separate application for such method.

I therefore claim the following:

1. The combination, with a motor containing separate or independent circuits on the armature or field-magnet, or both, of an alternating-current generator containing induced

circuits connected independently to corresponding circuits in the motor, whereby a rotation of the generator produces a progressive shifting of the poles of the motor, as herein described.

2. In a system for the electrical transmission of power, the combination of a motor provided with two or more independent magnetizing-coils and an alternating-current generator containing induced coils corresponding to the motor-coils, and circuits connecting directly the motor and generator coils in such order that the currents developed by the generator will be passed through the corresponding motor-coils, and thereby produce a progressive shifting of the poles of the motor, as herein set forth.

3. The combination, with a motor having an annular or ring-shaped field-magnet and a cylindrical or equivalent armature, and independent coils on the field-magnet or armature, or both, of an alternating-current generator having correspondingly independent coils, and circuits including the generator-coils and corresponding motor-coils in such manner that the rotation of the generator causes a progressive shifting of the poles of the motor in the manner set forth.

4. In a system for the electrical transmission of power, the combination of the following instrumentalities, to wit: a motor composed of a disk or its equivalent mounted within a ring or annular field-magnet, which is provided with magnetizing-coils connected in diametrically-opposite pairs or groups to independent terminals, a generator having induced coils or groups of coils equal in number to the pairs or groups of motor-coils, and circuits connecting the terminals of said coils to the terminals of the motor, respectively, and in such order that the rotation of the generator and the consequent production of alternating currents in the respective circuits produces a progressive shifting of the poles of the motor, as hereinbefore described.

NIKOLA TESLA.

Witnesses:
FRANK E. HARTLEY,
FRANK B. MURPHY.

(No Model.) 2 Sheets—Sheet 1.

N. TESLA.

ELECTRO MAGNETIC MOTOR.

No. 381,969. Patented May 1, 1888.

Fig: 1.

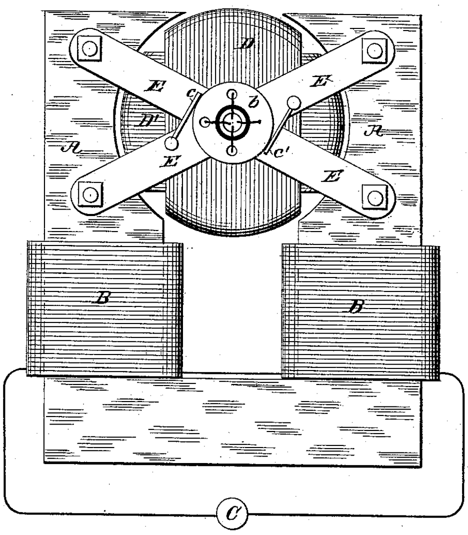
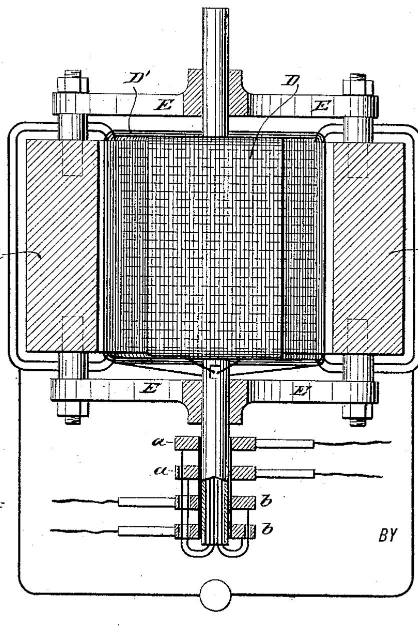


Fig: 2.



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Frank B. Murphy.

INVENTOR.

Nikola Tesla.

BY Duncan, Curtis & Page

ATTORNEYS.

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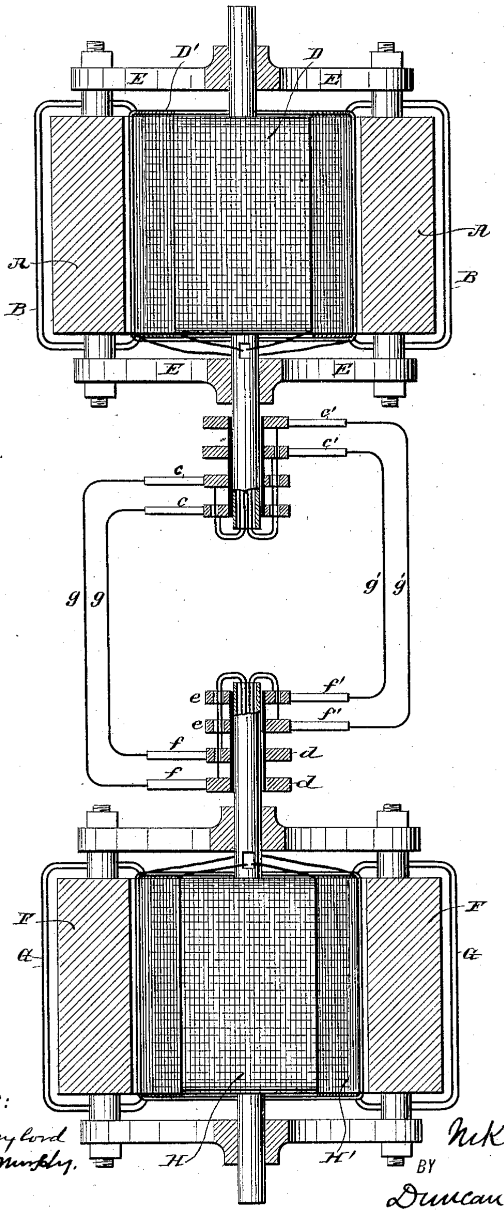
(No Model.) 2 Sheets—Sheet 2.

N. TESLA.

ELECTRO MAGNETIC MOTOR.

No. 381,969. Patented May 1, 1888.

Fig: 3



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INVENTOR.

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UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y., ASSIGNOR OF ONE-HALF TO CHARLES F. PECK, OF ENGLEWOOD, NEW JERSEY.

ELECTRO-MAGNETIC MOTOR.

SPECIFICATION forming part of Letters Patent No. 381,969, dated May 1, 1888.

Application filed November 30, 1887. Serial No. 256,562. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, from Smiljan Lika, border country of Austria-Hungary, now residing in New York, in the county and State of New York, have invented certain new and useful Improvements in Electro-Magnetic Motors, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

In an application filed by me October 12, 1887, No. 252,132, I have shown and described a novel form of electro-magnetic motor and a mode of operating the same, which may be generally described as follows: The motor is wound with coils forming independent energizing-circuits on either the armature or field magnet, or both, (it is sufficient for present purposes to consider the case in which the coils are on the armature alone,) and these coils are connected up with corresponding circuits on an alternating-current generator. As the result of this, currents of alternately-opposite direction are sent through the energizing-coils of the motor in such manner as to produce a progressive shifting or rotation of the magnetic poles of the armature. This movement of the poles of the armature obviously tends to rotate the armature in the opposite direction to that in which the movement of the poles takes place, owing to the attractive force between said poles and the field-magnets, and the speed of rotation increases from the start until it equals that of the generator, supposing both motor and generator to be alike.

As the poles of the armature are shifted in a direction opposite to that in which the armature rotates, it will be apparent that when the normal speed is attained the poles of the armature will assume a fixed position relative to the field-magnet, and that in consequence the field-magnets will be energized by magnetic induction, exhibiting two distinct poles, one in each of the pole-pieces. In starting the motor, however, the speed of the armature being comparatively slow, the pole-pieces are subjected to rapid reversals of magnetic polarity; but as the speed increases these reversals become less and less frequent, and finally cease when the movement of the armature become synchronous with that of the generator. This being the case, the field-cores and the pole-pieces of the motor become a magnet, but by induction only.

I have found that advantageous results are secured by winding the field-magnets with a coil or coils and passing a continuous current through them, thus maintaining a permanent field, and in this feature my present invention consists.

I shall now describe the apparatus which I have devised for carrying out this invention and explain the mode of using or operating the same.

Figure 1 is an end view in elevation of my improved motor. Fig. 2 is a part horizontal central section, and Fig. 3 is a diagrammatic representation of the motor and generator combined and connected for operation.

Let A A in Fig. 1 represent the legs or pole-pieces of a field-magnet, around which are coils B B, included in the circuit of a continuous-current generator, C, which is adapted to impart magnetism to the said poles in the ordinary manner.

D D′ are two independent coils wound upon a suitable cylindrical or equivalent armature-core, which, like all others used in a similar manner, should be split or divided up into alternate magnetic and insulating parts in the usual way. This armature is mounted in non-magnetic cross-bars E E, secured to the poles of the field-magnet. The terminals of the armature-coils D D′ are connected to insulated sliding contact-rings *a a b b*, carried by the armature shaft, and brushes *c c′* bear upon these rings to convey to the coils the currents which operate the motor.

The generator for operating this motor is or may be of precisely identical construction; and for convenience of reference I have marked in Fig. 3 its parts, as follows: F F, the field-magnets, energized by a continuous current passing in its field-coils G G; H H′, the coils carried by the cylindrical armature; *d d e e*, the friction or collecting rings, carried by the armature-shaft and forming the terminals of the armature-coils; and *f f′*, the collecting-brushes which deliver the currents developed in the armature-coils to the two circuits *g g′*, which connect the generators with the motor.

The operation of this system will be understood from the foregoing. The action of the generator, by causing a progressive shifting of the poles in the motor-armature, sets up in the latter a rotation opposite in direction to that in which the poles move. If, now, the continuous current be directed through the field-coils, so as to strongly energize the magnet A A, the speed of the motor, which depends upon that of the generator, will not be increased, but the power which produces its rotation will be increased in proportion to the energy supplied through the coils B B.

It is characteristic of this motor that its direction of rotation is not reversed by reversing the direction of the current through its field-coils, for the direction of rotation depends not upon the polarity of the field, but upon the direction in which the poles of the armature are shifted. To reverse the motor, the connections of either of the circuits *g g'* must be reversed.

I have found that if the field-magnet of the motor be strongly energized by its coils B B and the circuits through the armature-coils closed, assuming the generator to be running at a certain speed, the motor will not start; but if the field be but slightly energized or in general in such condition that the magnetic influence of the armature preponderates in determining its magnetic condition the motor will start and, with sufficient current, will reach its maximum or normal speed. For this reason it is desirable to keep at the start and until the motor has attained its normal speed, or nearly so, the field-circuit open or to permit but little current to pass through it. I have found, however, if the fields of both the generator and motor be strongly energized that starting the generator starts the motor, and that the speed of the motor is increased in synchronism with the generator. Motors constructed and operated on this principle maintain almost absolutely the same speed for all loads within their normal working-limits; and in practice I have observed that if the motor be overloaded to such an extent as to check its speed the speed of the generator, if its motive power be not too great, is diminished synchronously with that of the motor.

I have in other applications shown how the construction of these or similar motors may be varied in certain well-known ways—as, for instance, by rotating the field about a stationary armature or rotating conductors within the field; but I do not illustrate these features further herein, as with the illustration which I have given I regard the rest as within the power of a person skilled in the art to construct.

The present form of motor is cheap, simple, reliable, and easy to maintain. It requires the simplest type of generator for its operation, and when properly constructed shows a high efficiency.

I do not claim herein the method of transmitting power which this system involves, having made it the subject of another application for patent.

What I claim is—

The combination, with a motor having independent energizing or armature circuits, of an alternating-current generator with corresponding induced circuits connected with the motor for effecting a progressive shifting of the poles of the motor-armature, and a source of continuous current for energizing the field of said motor, as set forth.

NIKOLA TESLA.

Witnesses:

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FRANK E. HARTLEY.

(No Model.) 2 Sheets—Sheet 1.

N. TESLA.

SYSTEM OF ELECTRICAL DISTRIBUTION.

No. 381,970. Patented May 1, 1888.

Fig: 1.

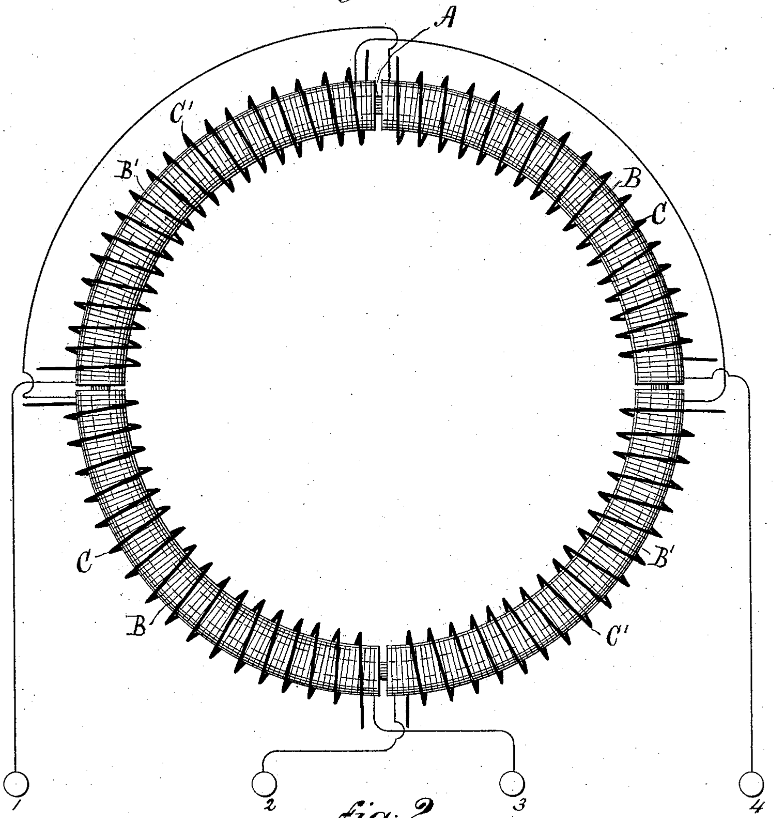
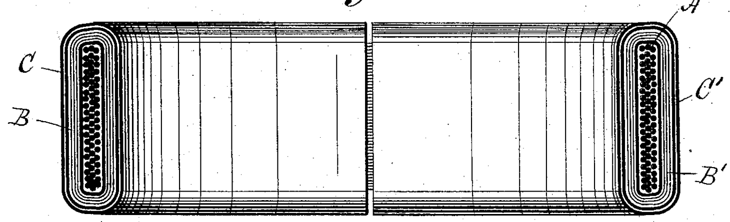


Fig: 2.



WITNESSES:

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N. PETERS, Photo-Lithographer, Washington, D. C.

(No Model.)

2 Sheets—Sheet 2.

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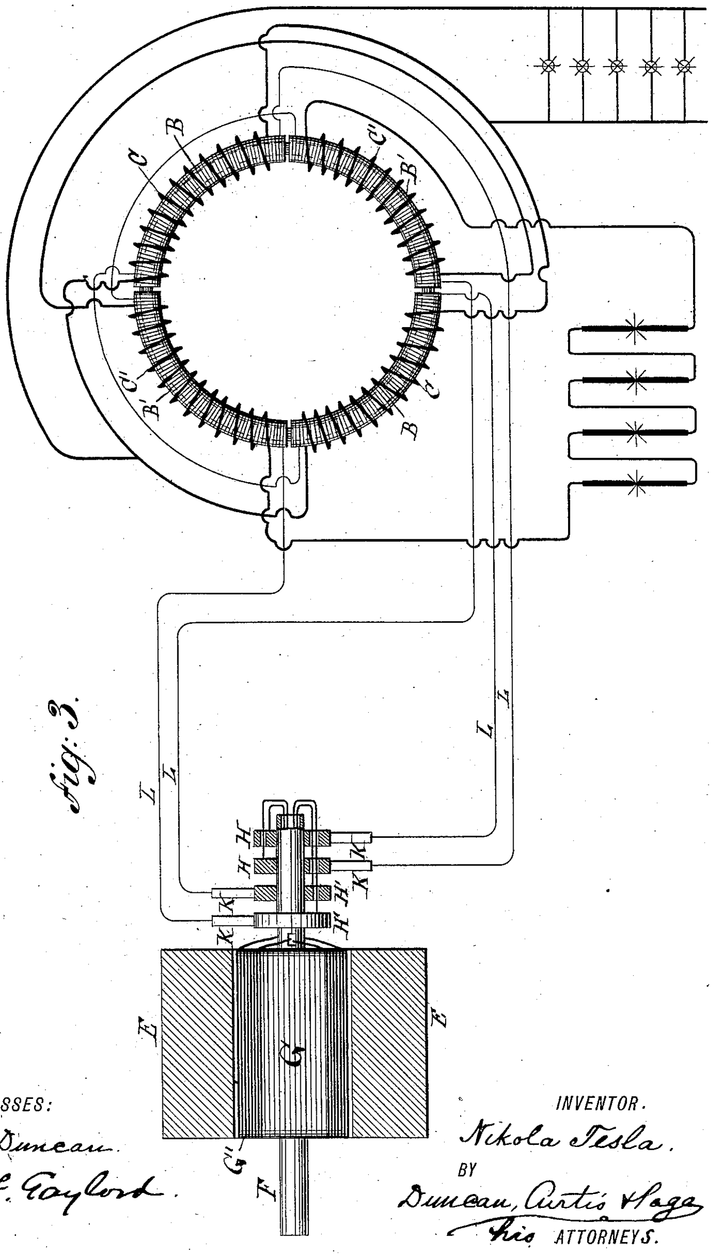

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UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y., ASSIGNOR OF ONE-HALF TO CHARLES F. PECK, OF ENGLEWOOD, NEW JERSEY.

SYSTEM OF ELECTRICAL DISTRIBUTION.

SPECIFICATION forming part of Letters Patent No. 381,970, dated May 1, 1888.

Application filed December 23, 1887. Serial No. 258,787. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, from Smiljan Lika, border country of Austria-Hungary, now residing at New York, in the county and State of New York, have invented certain new and useful Improvements in Systems of Electrical Distribution, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

This invention relates to those systems of electrical distribution in which a current from a single source of supply in a main or transmitting circuit is caused to induce by means of suitable induction apparatus a current or currents in an independent working circuit or circuits.

The main objects of the invention are the same as have been heretofore obtained by the use of these systems—viz., to divide the current from a single source, whereby a number of lamps, motors, or other translating devices may be independently controlled and operated by the same source of current, and in some cases to reduce a current of high potential in the main circuit to one of greater quantity and lower potential in the independent consumption or working circuit or circuits.

The general character of the devices employed in these systems is now well understood. An alternating-current magneto-machine is used as the source of supply. The current developed thereby is conducted through a transmission-circuit to one or more distant points at which the transformers are located. These consist of induction-machines of various kinds. In some cases ordinary forms of induction-coil have been used with one coil in the transmitting-circuit and the other in a local or consumption circuit, the coils being differently proportioned according to the work to be done in the consumption-circuit—that is to say, if the work requires a current of higher potential than that in the transmission-circuit the secondary or induced coil is of greater length and resistance than the primary, while, on the other hand, if a quantity current of lower potential is wanted the longer coil is made the primary. In lieu of these devices various forms of electro-dynamic induction-machines, including the combined motors and generators, have been devised. For instance, a motor is constructed in accordance with well-understood principles, and on the same armature are wound induced coils which constitute a generator. The motor-coils are generally of fine wire and the generator-coils of coarser wire, so as to produce a current of greater quantity and lower potential than the line-current, which is of relatively high potential, to avoid loss in long transmission. A similar arrangement is to wind coils corresponding to those described in a ring or similar core, and by means of a commutator of suitable kind to direct the current through the inducing-coils successively, so as to maintain a movement of the poles of the core and of the lines of force which set up the currents in the induced coils.

Without enumerating the objections to these systems in detail, it will suffice to say that the theory or the principle of the action or operation of these devices has apparently been so little understood that their proper construction and use have up to the present time been attended with various difficulties and great expense. The transformers are very liable to be injured and burned out, and the means resorted to for curing this and other defects have almost invariably been at the expense of efficiency.

The form of converter or transformer which I have devised appears to be largely free from the defects and objections to which I have alluded. While I do not herein advance any theory as to its mode of operation, I would state that, in so far as the principal of construction is concerned, it is analogous to those transformers which I have above described as electro-dynamic induction-machines, except that it involves no moving parts whatever, and is hence not liable to wear or other derangement, and requires no more attention than the other and more common induction-machines.

In carrying out my invention I provide a series of inducing-coils and corresponding induced coils, which, by preference, I wind upon a core closed upon itself—such as an annulus or ring subdivided in the usual manner. The two sets of coils are wound side by side or superposed or otherwise placed in well-known ways to bring them into the most effective relations to one another and to the core. The inducing or primary coils wound on the core are divided into pairs or sets by the proper electrical connections, so that while the coils of one pair or set to co-operate in fixing the magnetic poles of the core at two given diametrically-opposite points, the coils of the other pair or set—assuming, for sake of illustration, that there are but two—tend to fix the poles ninety degrees from such points. With this induction device I use an alternating-current generator with coils or sets of coils to correspond with those of the converter, and by means of suitable conductors I connect up in independent circuits the corresponding coils of the generator and converter. It results from this that the different electrical phases in the generator are attended by corresponding magnetic changes in the converter; or, in other words, that as the generator-coils revolve the points of greatest magnetic intensity in the converter will be progressively shifted or whirled around. This principle I have applied under variously-modified conditions to the operation of electro-magnetic motors, and in previous applications, notably in those having Serial Nos. 252,132 and 256,561, I have described in detail the manner of constructing and using such motors. In the present application my object is to describe the best and most convenient manner of which I am at present aware of carrying out the invention as applied to a system of electrical distribution; but one skilled in the art will readily understand from the description by the modifications proposed in said applications, wherein the form of both the generator and converter in the present case may be modified.

In illustration therefore of the details of construction which my present invention involves, I now refer to the accompanying drawings.

Figure 1 is a diagrammatic illustration of the converter and the electrical connections of the same. Fig. 2 is a horizontal central cross-section of Fig. 1. Fig. 3 is a diagram of the circuits of the entire system, the generator being shown in section.

I use a core, A, which is closed upon itself—that is to say, of an annular cylindrical or equivalent form—and as the efficiency of the apparatus is largely increased by the subdivision of this core I make it of thin strips, plates, or wires of soft iron electrically insulated as far as practicable. Upon this core, by any well-known method, I wind, say, four coils, B B B′ B′, which I use as primary coils, and for which I use long lengths of comparatively fine wire. Over these coils I then wind shorter coils of coarser wire, C C C′ C′, to constitute the induced or secondary coils. The construction of this or any equivalent form of converter may be carried further, as above pointed out, by inclosing these coils with iron—as, for example, by winding over the coils a layer or layers of insulated iron wire.

The device is provided with suitable binding-posts, to which the ends of the coils are led. The diametrically-opposite coils B B and B′ B′ are connected, respectively, in series, and the four terminals are connected to the binding-posts 1 2 3 4. The induced coils are connected together in any desired manner. For example, as shown in Fig. 3, C C may be connected in multiple arc when a quantity current is desired—as for running a group of incandescent lamps, D—while C′ C′ may be independently connected in series in a circuit including arc lamps or the like. The generator in this system will be adapted to the converter in the manner illustrated. For example, in the present case I employ a pair of ordinary permanent or electro magnets, E E, between which is mounted a cylindrical armature on a shaft, F, and wound with two coils, G G′. The terminals of these coils are connected, respectively, to four insulated contact or collecting rings, H H H′ H′, and the four line circuit-wires L connect the brushes K, bearing on these rings, to the converter in the order shown. Noting the results of this combination, it will be observed that at a given point of time the coil G is in its neutral position and is generating little or no current, while the other coil, G′, is in a position where it exerts its maximum effect. Assuming coil G to be connected in circuit with coils B B of the converter, and coil G′ with coils B′ B′, it is evident that the poles of the ring A will be determined by coils B′ B′ alone; but as the armature of the generator revolves, coil G develops more current and coil G′ less, until G reaches its maximum and G′ its neutral position. The obvious result will be to shift the poles of the ring A through one-quarter of its periphery. The movement of the coils through the next quarter of a turn, during which coil G′ enters a field of opposite polarity and generates a current of opposite direction and increasing strength, while coil G, in passing from its maximum to its neutral position generates a current of decreasing strength and same direction as before, causes a further shifting of the poles through the second quarter of the ring. The second half-revolution will obviously be a repetition of the same action. By the shifting of the poles of the ring A a powerful dynamic inductive effect on the coils C C′ is produced. Besides the currents generated in the secondary coils by dynamo-magnetic induction other currents will be set up in the same coils in consequence of any variations in the intensity of the poles in the ring A. This should be avoided by maintaining the intensity of the poles constant, to accomplish which care should be taken in designing and proportioning the generator and in distributing the coils in the ring A and balancing their effect. When this is done, the currents are produced by dynamo-magnetic induction only, the same result being obtained as though the poles were shifted by a commutator with an infinite number of segments.

The modifications which are applicable to other forms of converter are in many respects applicable to this. I refer more particularly to the form of the core, the relative lengths and resistances of the primary and secondary coils, and the arrangements for running or operating the same.

The new method of electrical conversion which this system involves I have made the subject of another application, and I do not claim it therefore herein.

Without limiting myself therefore to any specific form, what I claim is—

1. The combination, with a core closed upon itself, inducing or primary coils wound thereon and connected up in independent pairs or sets, and induced or secondary coils wound upon or near the primary coils, of a generator of alternating currents and independent connections to the primary coils, whereby by the operation of the generator a progressive shifting of the poles of the core is effected, as set forth.

2. The combination, with an annular or similar magnetic core and primary and secondary coils wound thereon, of an alternating-current generator having induced or armature coils corresponding to the primary coils, and independent circuits connecting the primary coils with the corresponding coils of the generator, as herein set forth.

3. The combination, with independent electric transmission-circuits, of transformers consisting of annular or similar cores wound with primary and secondary coils, the opposite primary coils of each transformer being connected to one of the transmission-circuits, an alternating-current generator with independent induced or armature coils connected with the transmission-circuits, whereby alternating currents may be directed through the primary coils of the transformers in the order and manner herein described.

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Witnesses:
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(No Model.) 2 Sheets—Sheet 1.

N. TESLA.

ELECTRO MAGNETIC MOTOR.

No. 382,279. Patented May 1, 1888.

Fig: 1.

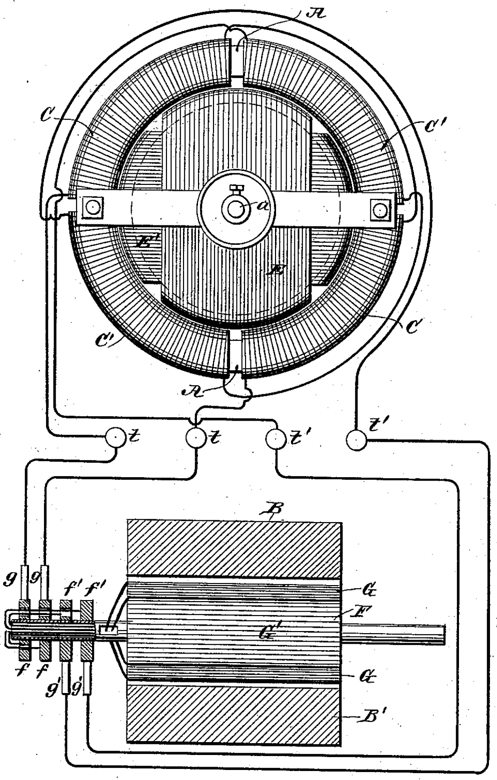
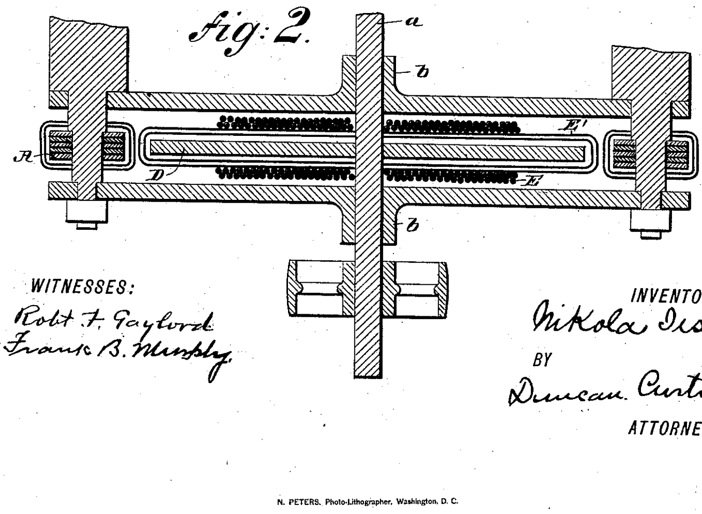


Fig: 2.



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Frank B. Murphy

INVENTOR.

Nikola Tesla.

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ATTORNEYS.

N. PETERS, Photo-Lithographer, Washington, D. C.

(No Model.)

2 Sheets—Sheet 2.

N. TESLA.

ELECTRO MAGNETIC MOTOR.

No. 382,279. Patented May 1, 1888.

Fig: 3.

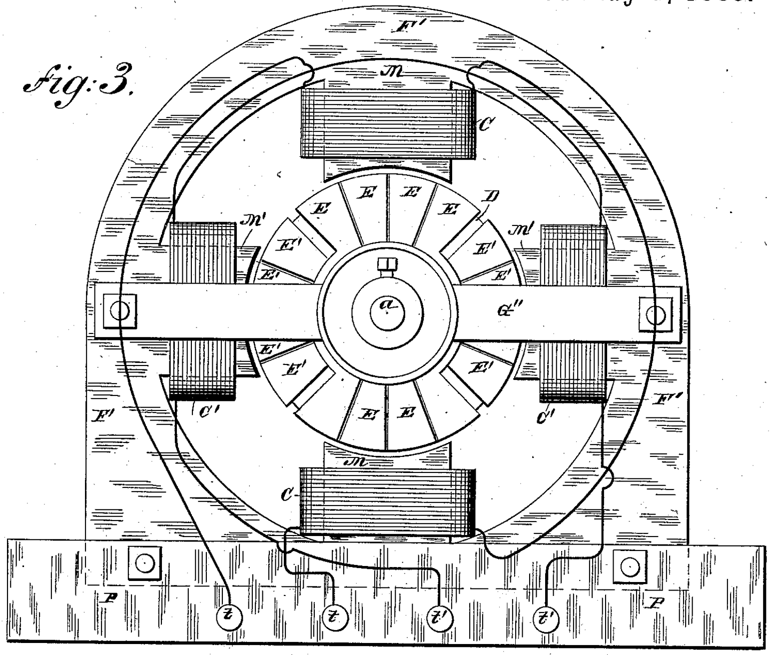
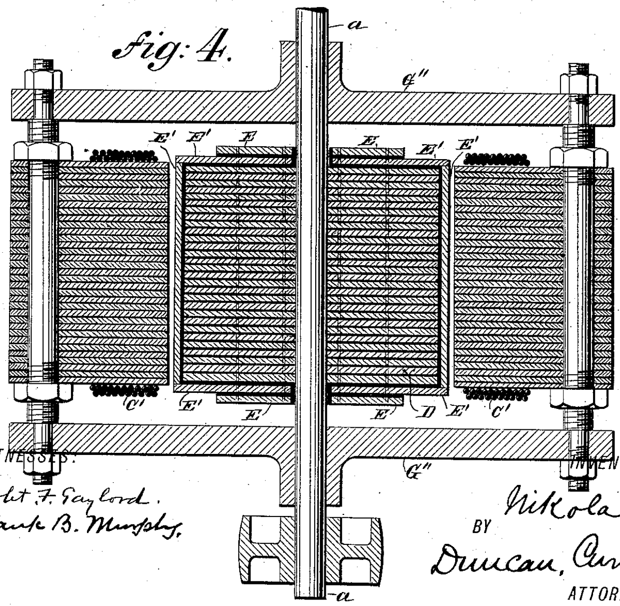


Fig: 4.



WITNESSES:

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UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y., ASSIGNOR OF ONE-HALF TO CHARLES F. PECK, OF ENGLEWOOD, NEW JERSEY.

ELECTRO-MAGNETIC MOTOR.

SPECIFICATION forming part of Letters Patent No. 382,279, dated May 1, 1888.

Application filed November 30, 1887. Serial No. 256,561. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a subject of the Emperor of Austria, from Smiljan, Lika, border country of Austria-Hungary, now residing at New York, in the county and State of New York, have invented certain new and useful Improvements in Electro-Magnetic Motors, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

In a former application, filed October 12, 1887, No. 252,132, I have shown and described a mode or plan of operating electric motors by causing a progressive shifting of the poles of one or both of the parts or elements of a motor—that is to say, of either the field magnet or magnets or armature, or both. I accomplish this by constructing a motor with two or more independent energizing-circuits, on the field-magnets, for example, and I connect these up with corresponding induced or generating circuits in an alternating-current generator, so that alternating currents are caused to traverse the motor-circuits. By so doing the poles of the field-magnet of the motor are progressively shifted, and by their attraction upon a rotary armature set up a rotation in the latter in the direction of the movement of the poles. In this case, however, the rotation is produced and maintained by the direct attraction of the magnetic elements of the motor. I have discovered that advantageous results may be secured in this system by utilizing the shifting of the poles primarily to set up currents in a closed conductor located within the influence of the field of the motor, so that the rotation may result from the reaction of such currents upon the field.

To illustrate more fully the nature of the invention I refer to the accompanying drawings.

Figure 1 represents in side elevation the operative parts or elements of a motor embodying the principles of my invention, and in section the generator for operating the same. Fig. 2 is a horizontal central section of the motor in Fig. 1, the circuits being shown partly in diagram. Fig. 3 is a modified form of motor in side elevation. Fig. 4 is a central horizontal cross-section of Fig. 3.

In Figs. 1 and 2, A is an annular core of soft iron, preferably laminated or formed of insulated sections, so as to be susceptible to rapid variations of magnetism. This core is wound with four coils, C C C′ C′, the diametrically-opposite coils being connected in the same circuit, and the two free ends of each pair being brought to the terminals t and t', respectively, as shown. Within this annular field-magnet A is mounted a soft-iron cylinder or disk, D, on an axis, a, in bearings b b, properly supported by the frame-work of the machine. The disk carries two coils, E E′, of insulated wire, wound at right angles to one another, and having their respective ends joined, so that each coil forms a separate closed circuit.

In illustration of the action or mode of operation of this apparatus, let it be assumed that the annular field-magnet A is permanently magnetized, so as to present two free poles diametrically opposite. If suitable mechanical provision be now made for rotating the field-magnet around the disk, the apparatus exemplifies the conditions of an ordinary magneto-generator, and currents would be set up in the coils or closed conductors E E′ on the disk D. Evidently these currents would be the most powerful at or near the points of the greatest density of the lines of force, and they would, as in all similar cases, tend, at least theoretically, to establish magnetic poles in the disk D at right angles to those in the annular field-magnet A. As a result of the well-known reaction of these polarities upon each other, a more or less powerful tendency in the disk to rotate in the same direction as that of the field-magnet would be established. If, on the other hand, the ring or annular field-magnet A be held stationary and its magnetic poles progressively shifted by passing through its coils C C′ properly-alternated currents, it is obvious that similar results will follow, for the passage of the currents causing the shifting or whirling of the poles of the field-magnet A induces currents in the closed circuits of the armature coils E E′, with the result of setting up a rotation of the disk D in the same direction of such shifting. Inasmuch as the currents are always induced or generated in the coils E E′ in the same manner, the poles of the disk or cylinder follow continuously the poles of the annular field-magnet, maintaining, at least theoretically, the same relative positions. This results in an even and perfect action of the apparatus.

In order that the system as a whole may be better understood, I shall now describe the mode or plan devised by me for producing the currents that effect the progressive shifting of the poles of the motor.

In Fig. 1, B B′ are the poles or pole-pieces of an alternating-current generator. They are permanently magnetized and of opposite polarity. F is a cylindrical or other armature containing the independent coils G G′. These coils are wound at right angles, so that while one is crossing the strongest portion of the field of force the other is at the neutral point. The coils G G′ terminate in the two pairs of insulated collecting-rings f and f', upon which bear the brushes g g'. Four wires connect the motor-terminals t and t' with the brushes g and g', respectively. When the generator is rotated, the coil G will at the certain point shown in the drawings be generating its maximum current, while coil G′ is neutral. Let it be assumed that this current is conveyed from the rings f f to the terminals t t and through the coils C C. Its effect will be to establish poles in the ring midway between the two coils. By the further rotation of the generator the coil G′ is brought within the influence of the field and begins to produce a current, which grows stronger as the said coil approaches the maximum points of the field, while the current produced in the coil G diminishes as the said coil recedes from those points. The current from the coil G′, being conveyed to the terminals t' t' and through coils C′ C′, has a tendency to establish poles at right angles to those set up by the coils C C; but owing to the greater effect of the current in coils C C the result is merely to advance the poles from the position in which they would remain if due to the magnetizing influence of coils C C alone. This progression continues for a quarter-revolution until coil G G becomes neutral and coil G′ G′ produces its maximum current. The action described is then repeated, the poles having been shifted through one-half of the field, or a half-revolution. The second half-revolution is accomplished in a similar way, the same polarity being maintained in the shifting poles by the movement of the generator-coils alternately through fields of opposite polarity.

The same principle of operation may be applied to motors of various forms, and I have shown one of such modified forms in Figs. 3 and 4 of the drawings. In these figures, M M′ are field-magnets secured to or forming part of a frame, F′, mounted on a base, P. These magnets should be laminated or composed of a number of electrically-insulated magnetic sections, to prevent the circulation of induced currents and to render them capable of rapid magnetic changes. These magnetic cores or poles are wound with insulated coils C C′, the diametrically-opposite coils being connected together in series and their free ends brought to terminals t t', respectively. Between the poles there is mounted, in bearings in the cross-pieces G″, a cylindrical iron core, D, which, in order to prevent the formation of eddying currents, and the loss consequent thereon, is subdivided in the usual way. Insulated conductors or coils are applied to the cylinder D longitudinally, and for these I may employ copper plates E E′, which are secured to the sides and ends of the cylindrical core in well-known ways. These plates or conductors may form one or preferably several independent circuits around the core. In the drawings two of such circuits are shown, formed respectively by the conductors E and E′, which are insulated from each other. It is advantageous also to slot these plates longitudinally, to prevent the formation of eddy currents and waste of energy.

From what has now been given the operation of this apparatus will be readily understood. To the binding-posts t t' are connected the proper circuits from the generator to cause a progressive shifting of the resultant magnetic poles produced by the magnets M upon the armature. Thus currents are induced in the closed circuits on the core, which, energizing the core strongly, maintain a powerful attraction between the same and the field, which causes a rotation of the armature in the direction in which the resultant poles are shifted.

The particular advantage of the construction illustrated in Figs. 3 and 4 is that a concentrated and powerful field is obtained and a remarkably powerful tendency to rotation in the armature secured. The same results may be obtained in the form illustrated in Figs. 1 and 2, however, by forming polar projections on the field and armature cores.

When these motors are not loaded, but running free, the rotation of the armature is nearly synchronous with the rotation of the poles of the field, and under these circumstances very little current is perceptible in the coils E E′; but if a load is added the speed tends to diminish and the currents in coils E E′ are augmented, so that the rotary effort is increased proportionately.

Obviously the principle of this invention is capable of many modified applications, most of which follow as a matter of course from the constructions described. For instance, the armature-coils, or those in which the currents are set up by induction, may be held stationary and the alternating currents from the generator conducted through the rotating inducing or field coils by means of suitable sliding contacts. It is also apparent that the induced coils may be movable and the magnetic parts of the motor stationary; but I have illustrated these modifications fully in the application to which reference has herein been made.

In the case of motors wound with independent field and armature circuits and operated by shifting their poles, as described in my said prior application, I may by short-circuiting the armature-coils apply the present invention in order to obtain greater power on starting.

An advantage and characteristic feature of motors constructed and operated in accordance with this invention is their capability of almost instantaneous reversal by a reversal of one of the energizing-currents from the generator. This will be understood from a consideration of the working conditions. Assuming the armature to be rotating in a certain direction following the movement of the shifting poles, then reverse the direction of the shifting, which may be done by reversing the connections of one of the two energizing-circuits. If it be borne in mind that in a dynamo-electric machine the energy developed is very nearly proportionate to the cube of the speed, it is evident that at such moment an extraordinary power is brought to play in reversing the motor. In addition to this the resistance of the motor is very greatly reduced at the moment of reversal, so that a much greater amount of current passes through the energizing-circuits.

The phenomenon alluded to—viz., the variation of the resistance of the motor apparently like that in ordinary motors—I attribute to the variation in the amount of self-induction in the primary or energizing circuits.

These motors present numerous advantages, chief among which are their simplicity, reliability, economy in construction and maintenance, and their easy and dangerless management. As no commutators are required on either the generators or the motors, the system is capable of a very perfect action and involves but little loss.

I do not claim herein the mode or plan of producing currents in closed conductors in a magnetic field which is herein disclosed, except in its application to this particular purpose; but

What I claim is—

1. The combination, with a motor containing independent inducing or energizing circuits and closed induced circuits, of an alternating-current generator having induced or generating circuits corresponding to and connected with the energizing-circuits of the motor, as set forth.

2. An electro-magnetic motor having its field-magnets wound with independent coils and its armature with independent closed coils, in combination with a source of alternating currents connected to the field-coils and capable of progressively shifting the poles of the field-magnet, as set forth.

3. A motor constructed with an annular field-magnet wound with independent coils and a cylindrical or disk armature wound with closed coils, in combination with a source of alternating currents connected with the field-magnet coils and acting to progressively shift or rotate the poles of the field, as herein set forth.

NIKOLA TESLA.

Witnesses:
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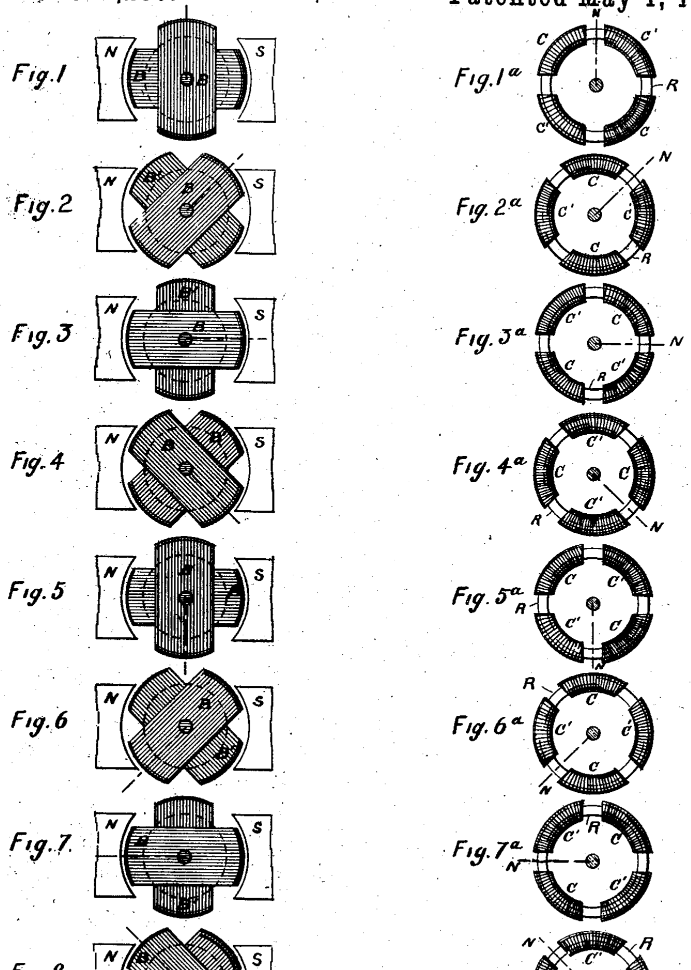
Model.)

4 Sheets—Sheet 1.

N. TESLA.

ELECTRICAL TRANSMISSION OF POWER.

No. 382,280. Patented May 1, 1888.



WITNESSES:

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(No Model.) 4 Sheets—Sheet 2.

N. TESLA.

ELECTRICAL TRANSMISSION OF POWER.

No. 382,280. Patented May 1, 1888.

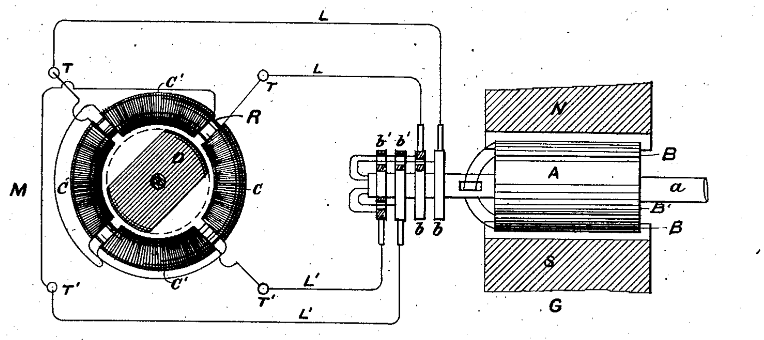

Fig. 9

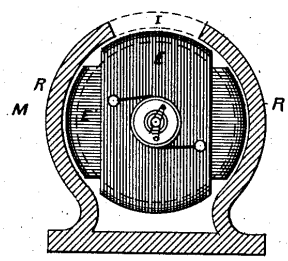

Fig. 10

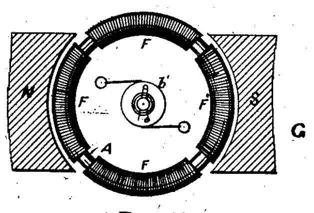

Fig. 11

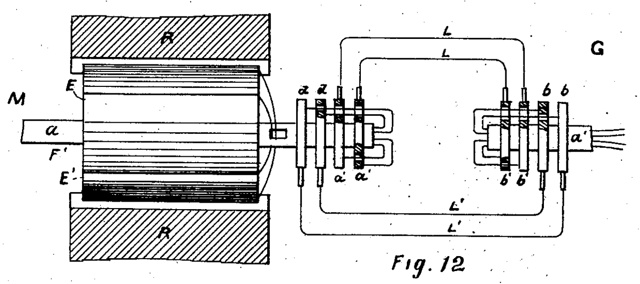

Fig. 12

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ELECTRICAL TRANSMISSION OF POWER.

No. 382,280. Patented May 1, 1888.

Fig. 13

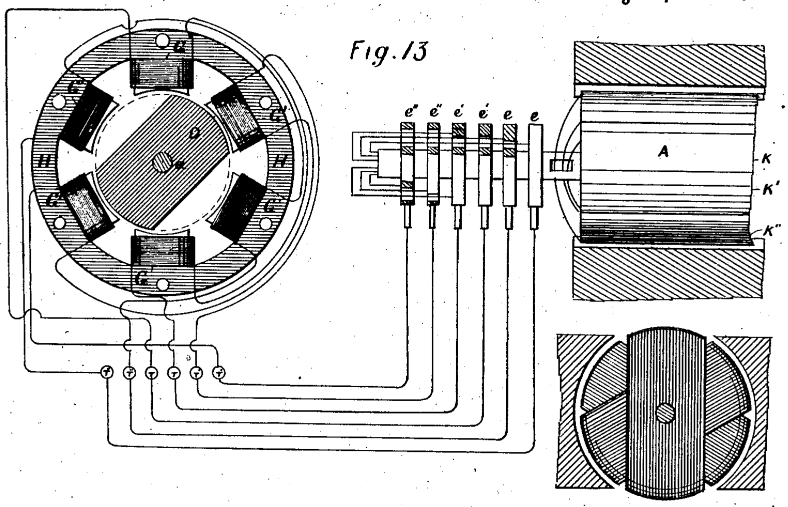


Fig. 14

Fig. 15

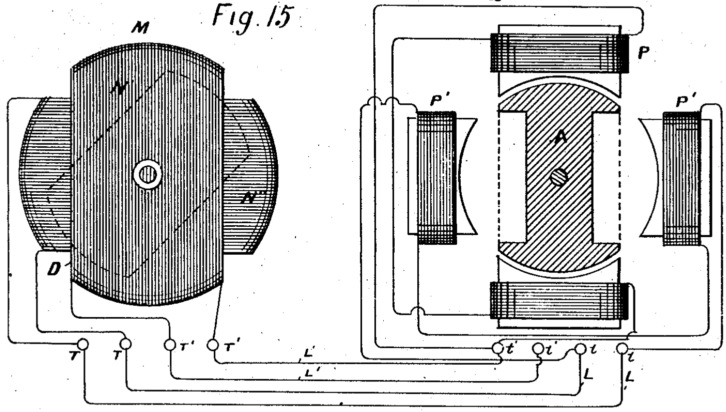
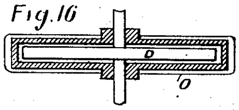


Fig. 16



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(No Model.) 4 Sheets—Sheet 4.

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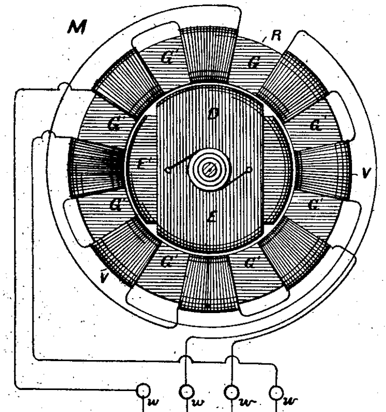
ELECTRICAL TRANSMISSION OF POWER.

No. 382,280. Patented May 1, 1888.

Fig. 17



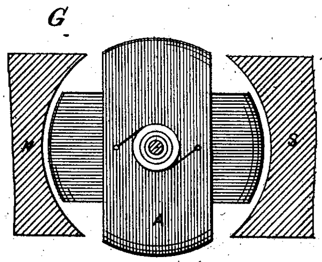
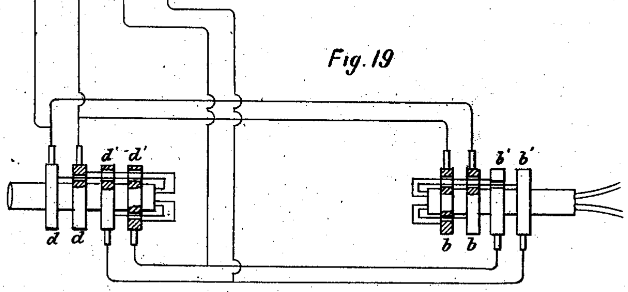


Fig. 18

Fig. 19



WITNESSES:

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UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

ELECTRICAL TRANSMISSION OF POWER.

SPECIFICATION forming part of Letters Patent No. 382,280, dated May 1, 1888.

Original application filed October 12, 1887. Serial No. 252,132. Divided and this application filed March 9, 1888. Serial No. 266,755. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, from Smiljan, Lika, border country of Austria-Hungary, and residing in the city, county, and State of New York, have invented certain new and useful Improvements in the Transmission of Power, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

This application is a division of an application filed by me October 12, 1887, No. 252,132.

The practical solution of the problem of the electrical conversion and transmission of mechanical energy involves certain requirements which the apparatus and systems heretofore employed have not been capable of fulfilling. Such a solution primarily demands a uniformity of speed in the motor irrespective of its load within its normal working limits. On the other hand, it is necessary, to attain a greater economy of conversion than has heretofore existed, to construct cheaper and more reliable and simple apparatus, and such that all danger from the use of currents of high tension, which are necessary to an economical transmission, may be avoided.

My present invention is a new method or mode of effecting the transmission of power by electrical agency, whereby many of the present objections are overcome and great economy and efficiency secured.

In carrying out my invention I employ a motor in which there are two or more independent energizing-circuits, through which I pass, in the manner hereinafter described, alternating currents, effecting thereby a progressive shifting of the magnetism or of the "lines of force," which, in accordance with well-known theories, produces the action of the motor.

It is obvious that a proper progressive shifting of the lines of force may be utilized to set up a movement or rotation of either element of the motor, the armature, or the field-magnet, and that if the currents directed through the several circuits of the motor are in proper direction no commutator for the motor will be required; but to avoid all the usual commutating appliances in the system I connect the motor-circuits directly with those of a suitable alternating-current generator. The practical results of such a system, its economical advantages, and the mode of its construction and operation will be described more in detail by reference to the accompanying diagrams and drawings.

Figures 1 to 8 and 1^a to 8^a, inclusive, are diagrams illustrating the principle of the action of my invention. The remaining figures are views of the apparatus in various forms by means of which the invention may be carried into effect, and which will be described in their order.

Referring first to Fig. 9, which is a diagrammatic representation of a motor, a generator, and connecting-circuits in accordance with my invention, M is the motor, and G the generator for driving it. The motor comprises a ring or annulus, R, preferably built up of thin insulated iron rings or annular plates, so as to be as susceptible as possible to variations in its magnetic condition. This ring is surrounded by four coils of insulated wire symmetrically placed and designated by C C C' C'. The diametrically-opposite coils are connected up so as to co-operate in pairs in producing free poles on diametrically-opposite parts of the ring. The four free ends thus left are connected to terminals T T T' T', as indicated. Near the ring, and preferably inside of it, there is mounted on an axis or shaft a magnetic disk, C, generally circular in shape, but having two segments, cut away as shown. This disk is mounted so as to turn freely within the ring R. The generator G is of any ordinary type, that shown in the present instance having field-magnets N S and a cylindrical armature-core, A, wound with the two coils B B'. The free ends of each coil are carried through the shaft a' and connected, respectively, to insulated contact-rings b b b' b'. Any convenient form of collector or brush bears on each ring and forms a terminal by which the current to and from a ring is conveyed. These terminals are connected to the terminals of the motor by the wires L and L' in the manner indicated, whereby two complete circuits are formed, one including, say, the coils B of the generator and C C of the motor and the other the remaining coils B' and C' C' of the generator and the motor.

It remains now to explain the mode of operation of this system, and for this purpose I refer to the diagrams, Figs. 1 to 8 and 1^a to 8^a, for an illustration of the various phases through which the coils of the generator pass when in operation, and the corresponding and resultant magnetic changes produced in the motor. The revolution of the armature of the generator between the field-magnets N S obviously produces in the coils B B′ alternating currents the intensity and direction of which depend upon well-known laws. In the position of the coils indicated in Fig. 1 the current in the coil B is practically *nil*, whereas the coil B′ at the same time is developing its maximum current, and by the means indicated in the description of Fig. 9 the circuit including this coil may also include, say, the coils C C of the motor, Fig. 1^a. The result, with the proper connections, would be the magnetization of the ring R, the poles being on the line N S. The same order of connections being observed between the coil B and the coil C′, the latter when traversed by a current tend to fix the poles at right angles to the line N S of Fig. 1^a. It results, therefore, that when the generator-coils have made one-eighth of a revolution, reaching the position shown in Fig. 2, both pairs of coils, C and C′, will be traversed by current and act in opposition in so far as the location of the poles is concerned. The position of the poles will therefore be the resultant of the magnetizing forces of the coils—that is to say, it will advance along the ring to a position corresponding to one-eighth of the revolution of the armature of the generator.

In Fig. 3 the armature of the generator has progressed to one-fourth of a revolution. At the point indicated the current in the coil B is maximum, while in B′ it is *nil*, the latter coil being in its neutral position. The poles of the ring R in Fig. 3^a will in consequence be shifted to a position ninety degrees from that at the start, as shown. I have in like manner shown the conditions existing at each successive eighth of one revolution in the remaining figures. A short reference to these figures will suffice to an understanding of their significance.

Figs. 4 and 4^a illustrate the conditions which exist when the generator-armature has completed three-eighths of a revolution. Here both coils are generating currents; but the coil B′, having now entered the opposite field, is generating a current in the opposite direction having the opposite magnetizing effect; hence the resultant pole will be on the line N S, as shown.

In Fig. 5 one-half of one revolution of the armature of the generator has been completed, and the resulting magnetic condition of the ring is shown in Fig. 5^a. In this phase coil B is in the neutral position, while coil B′ is generating its maximum current, which is in the same direction as in Fig. 4. The poles will consequently be shifted through one half of the ring.

In Fig. 6 the armature has completed five-eighths of a revolution. In this position coil B′ develops a less powerful current, but in the same direction as before. The coil B, on the other hand, having entered a field of opposite polarity, generates a current of opposite direction. The resultant poles will therefore be in the line N S, Fig. 6^a; or, in other words, the poles of the ring will be shifted along five-eighths of its periphery.

Figs. 7 and 7^a in the same manner illustrate the phases of the generator and ring at three-quarters of a revolution, and Figs. 8 and 8^a the same at seven eighths of a revolution of the generator-armature. These figures will be readily understood from the foregoing.

When a complete revolution is accomplished, the conditions existing at the start are re-established, and the same action is repeated for the next and all subsequent revolutions, and in general it will now be seen that every revolution of the armature of the generator produces a corresponding shifting of the poles or lines of force around the ring. This effect I utilize in producing the rotation of a body or armature in a variety of ways—for example, applying the principle above described to the apparatus shown in Fig. 9. The disk D, owing to its tendency to assume that position in which it embraces the greatest possible number of the magnetic lines, is set in rotation, following the motion of the lines or the points of greatest attraction.

The disk D in Fig. 9 is shown as cut away on opposite sides; but this I have found is not essential to effecting its rotation, as a circular disk, as indicated by dotted lines, is also set in rotation. This phenomenon I attribute to a certain inertia or resistance inherent in the metal to the rapid shifting of the lines of force through the same, which results in a continuous tangential pull upon the disk, causing its rotation. This seems to be confirmed by the fact that a circular disk of steel is more effectively rotated than one of soft iron, for the reason that the former is assumed to possess a greater resistance to the shifting of the magnetic lines.

In illustration of other forms of apparatus by means of which I carry out my invention, I shall now describe the remaining figures of the drawings.

Fig. 10 is a view in elevation and part vertical section of a motor. Fig. 12 is a top view of the same with the field in section and a diagram of connections. Fig. 11 is an end or side view of a generator with the fields in section. This form of motor may be used in place of that shown.

D is a cylindrical or drum armature-core, which, for obvious reasons, should be split up as far as practicable to prevent the circulation within it of currents of induction. The core is wound longitudinally with two coils, E and E′, the ends of which are respectively connected to insulated contact-rings *d d d′ d′*, carried by the shaft *a*, upon which the armature is mounted.

The armature is set to revolve within an iron shell, R, which constitutes the field-magnet or other element of the motor. This shell is preferably formed with a slot or opening, *r*; but it may be continuous, as shown by the dotted lines, and in this event it is preferably made of steel. It is also desirable that this shell should be divided up similarly to the armature, and for similar reasons. As a generator for driving this motor, I may use the device shown in Fig. 11. This represents an annular or ring armature, A, surrounded by four coils, F F F' F', of which those diametrically opposite are connected in series, so that four free ends are left, which are connected to the insulated contact-rings *b b b' b'*. The ring is suitably mounted on a shaft, *a'*, between the poles N S. The contact-rings of each pair of generator coils are connected to those of the motor, respectively, by means of contact-brushes and the two pairs of conductors, L L and L' L', as indicated diagrammatically in Fig. 13.

Now, it is obvious from a consideration of the preceding figures that the rotation of the generator-ring produces currents in the coils F F', which, being transmitted to the motor-coils, impart to the core of the latter magnetic poles constantly shifting or whirling around the core. This effect sets up a rotation of the armature, owing to the attractive force between the shell and the poles of the armature; but inasmuch as the coils in this case move relatively to the shell or field-magnet the movement of the coils is in the opposite direction to the progressive shifting of the poles.

Other arrangements of the coils of both generator and motor are possible, and a greater number of circuits may be used, as will be seen in the two succeeding figures.

Fig. 13 is a diagrammatic illustration of a motor and a generator connected and constructed in accordance with my invention. Fig. 14 is an end view of the generator with its field-magnets in section.

The field of the motor M is produced by six magnetic poles, G' G', secured to or projecting from a ring or frame, H. These magnets or poles are wound with insulated coils, those diametrically opposite to each other being connected in pairs, so as to produce opposite poles in each pair. This leaves six free ends, which are connected to the terminals T T T' T' T'' T''. The armature which is mounted to rotate between the poles is a cylinder or disk, D, of wrought-iron, mounted on the shaft *a*. Two segments of the same are cut away, as shown. The generator for this motor has in this instance an armature, A, wound with three coils, K K' K'', at sixty degrees apart. The ends of these coils are connected, respectively, to insulated contact rings *e e e' e' e'' e''*. These rings are connected to those of the motor in proper order by means of collecting-brushes and six wires, forming three independent circuits. The variations in the strength and direction of the currents transmitted through these circuits and traversing the coils of the motor produce a steadily-progressive shifting of the resultant attractive force exerted by the poles G' upon the armature D, and consequently keep the armature rapidly rotating. The peculiar advantage of this disposition is in obtaining a more concentrated and powerful field. The application of this principle to systems involving multiple circuits generally will be understood from this apparatus.

Referring now to Figs. 15 and 16, Fig. 15 is a diagrammatic representation of a modified disposition of my invention. Fig. 16 is a horizontal cross-section of the motor. In this case a disk, D, of magnetic metal, preferably cut away at opposite edges, as shown in dotted lines in the figure, is mounted so as to turn freely inside two stationary coils, N' N'', placed at right angles to one another. The coils are preferably wound on a frame, O, of insulating material, and their ends are connected to the fixed terminals T T T' T'. The generator G is a representative of that class of alternating-current machines in which a stationary induced element is employed. That shown consists of a revolving permanent or electro-magnet, A, and four independent stationary magnets, P P', wound with coils, those diametrically opposite to each other being connected in series and having their ends secured to the terminals *t t t' t'*. From these terminals the currents are led to the terminals of the motor, as shown in the drawings. The mode of operation is substantially the same as in the previous cases, the currents traversing the coils of the motor having the effect to turn the disk D. This mode of carrying out the invention has the advantage of dispensing with the sliding contacts in the system.

In the forms of motor above described only one of the elements—the armature or the field-magnet—is provided with energizing-coils. It remains, then, to show how both elements may be wound with coils. Reference is therefore had to Figs. 17, 18, and 19. Fig. 17 is an end view of such a motor. Fig. 18 is a similar view of the generator, with the field-magnets in section; and Fig. 19 is a diagram of the circuit-connections. In Fig. 17 the field-magnet of the motor consists of a ring, R, preferably of thin insulated iron sheets or bands, with eight pole-pieces, G, and corresponding recesses in which four pairs of coils, V, are wound. The diametrically-opposite pairs of coils are connected in series and the free ends connected to four terminals, *w*, the rule to be followed in connecting being the same as hereinbefore explained. An armature, D, with two coils, E E', at right angles to each other, is mounted to rotate inside of the field-magnet R. The ends of the armature-coils are connected to two pairs of contact-rings, *d d d' d'*. The generator for this motor may be of any suitable kind to produce currents of the desired character. In the present instance it consists of a field-magnet, N S, and an armature, A, with two coils at right angles, the ends of which are connected to four contact-rings, *b b b' b'*, carried by its shaft. The circuit-connections are established between the rings on the generator-shaft and those on the motor-shaft by collecting brushes and wires, as previously explained. In order to properly energize the field-magnet of the motor, however, the connections are so made with the armature-coils by wires leading thereto that while the points of greatest attraction or greatest density of magnetic lines of force upon the armature are shifted in one direction those upon the field-magnet are made to progress in an opposite direction. In other respects the operation is identically the same as in the other cases cited. This arrangement results in an increased speed of rotation.

In Figs. 17 and 19, for example, the terminals of each set of field-coils are connected with the wires to the two armature-coils in such a way that the field-coils will maintain opposite poles in advance of the poles of the armature.

In the drawings the field-coils are in shunts to the armature; but they may be in series or in independent circuits.

It is obvious that the same principle may be applied to the various typical forms of motor hereinbefore described.

Having now described the nature of my invention and some of the various ways in which it is or may be carried into effect, I would call attention to certain characteristics which the applications of the invention possess, and the advantages which it offers.

In my motor, considering, for convenience, that represented in Fig. 9, it will be observed that since the disk D has a tendency to follow continuously the points of greatest attraction, and since these points are shifted around the ring once for each revolution of the armature of the generator, it follows that the movement of the disk D will be synchronous with that of the armature A. This feature by practical demonstration I have found to exist in all other forms in which one revolution of the armature of the generator produces a shifting of the poles of the motor through three hundred and sixty degrees.

In the particular modification shown in Fig. 15, or in others constructed on a similar plan, the number of alternating impulses resulting from one revolution of the generator-armature is double as compared with the preceding cases, and the polarities in the motor are shifted around twice by one revolution of the generator-armature. The speed of the motor will therefore be twice that of the generator. The same result is evidently obtained by such a disposition as that shown in Fig. 17, where the poles of both elements are shifted in opposite directions.

Again, considering the apparatus illustrated by Fig. 9 as typical of the invention, it is obvious that since the attractive effect upon the disk D is greatest when the disk is in its proper relative position to the poles developed in the ring R—that is to say, when its ends or poles immediately follow those of the ring—the speed of the motor for all loads within the normal working limits of the motor will be practically constant.

It is clearly apparent that the speed can never exceed the arbitrary limit as determined by the generator, and also that within certain limits, at least, the speed of the motor will be independent of the strength of the current.

It will now be more readily seen from the above description how far the requirements of a practical system of electrical transmission of power are realized in my invention. I secure, first, a uniform speed under all loads within the normal working limits of the motor without the use of any auxiliary regulator; second, synchronism between the motor and the generator; third, greater efficiency by the more direct application of the current, no commutating devices being required on either the motor or the generator; fourth, cheapness and simplicity of mechanical construction; fifth, the capability of being very easily managed or controlled, and, sixth, diminution of danger from injury to persons and apparatus.

These motors may be run in series—multiple arc or multiple series—under conditions well understood by those skilled in the art.

I am aware that it is not new to produce the rotations of a motor by intermittently shifting the poles of one of its elements. This has been done by passing through independent energizing-coils on one of the elements the current from a battery or other source of direct or continuous currents, reversing such current by suitable mechanical appliances, so that it is directed through the coils in alternately opposite directions. In such cases, however, the potential of the energizing-currents remains the same, their direction only being changed. According to my invention, however, I employ true alternating currents; and my invention consists in the discovery of the mode or method of utilizing such currents.

The difference between the two plans and the advantages of mine are obvious. By producing an alternating current each impulse of which involves a rise and fall of potential I reproduce in the motor the exact conditions of the generator, and by such currents and the consequent production of resultant poles the progression of the poles will be continuous and not intermittent. In addition to this, the practical difficulty of interrupting or reversing a current of any considerable strength is such that none of the devices at present could be made to economically or practically effect the transmission of power by reversing in the manner described a continuous or direct current. In so far, then, as the plan of acting upon one element of the motor is concerned, my invention involves the use of an alternating as distinguished from a reversed current, or a current which, while continuous and direct, is shifted from coil to coil by any form of commutator, reverser, or interrupter. With regard to that part of the invention which consists in acting upon both elements of the motor simultaneously, I regard the use of either alternating or reversed currents as within the scope of the invention, although I do not consider the use of reversed currents of any practical importance.

What I claim is—

The method herein described of electrically transmitting power, which consists in producing a continuously-progressive shifting of the polarities of either or both elements (the armature or field magnet or magnets) of a motor by developing alternating currents in independent circuits, including the magnetizing-coils of either or both elements, as herein set forth.

NIKOLA TESLA.

Witnesses:
FRANK B. MURPHY,
FRANK E. HARTLEY.

(No Model.) 2 Sheets—Sheet 1.

N. TESLA.

ELECTRICAL TRANSMISSION OF POWER.

No. 382,281. Patented May 1, 1888.

Fig. 1

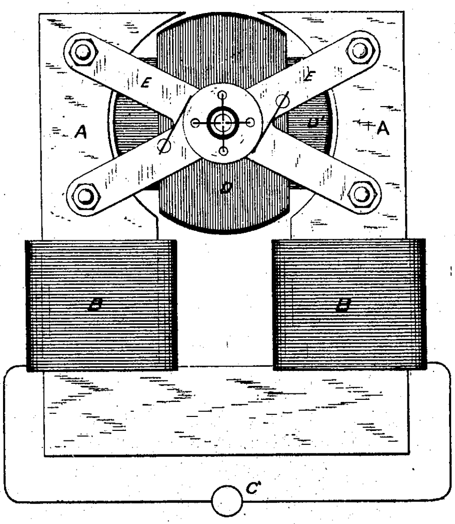
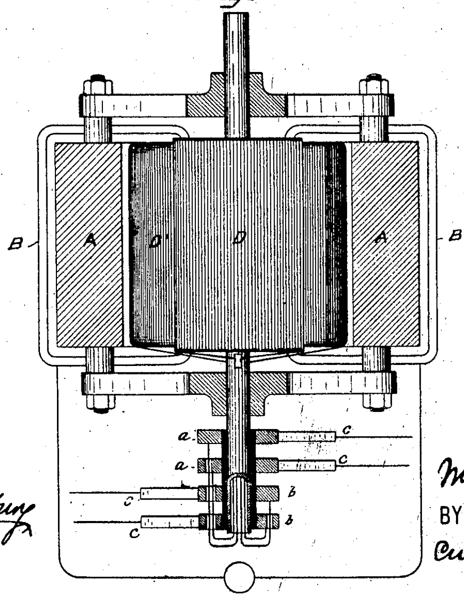


Fig. 2



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INVENTOR.

Nikola Tesla.

BY Duncan, Curtis & Page.

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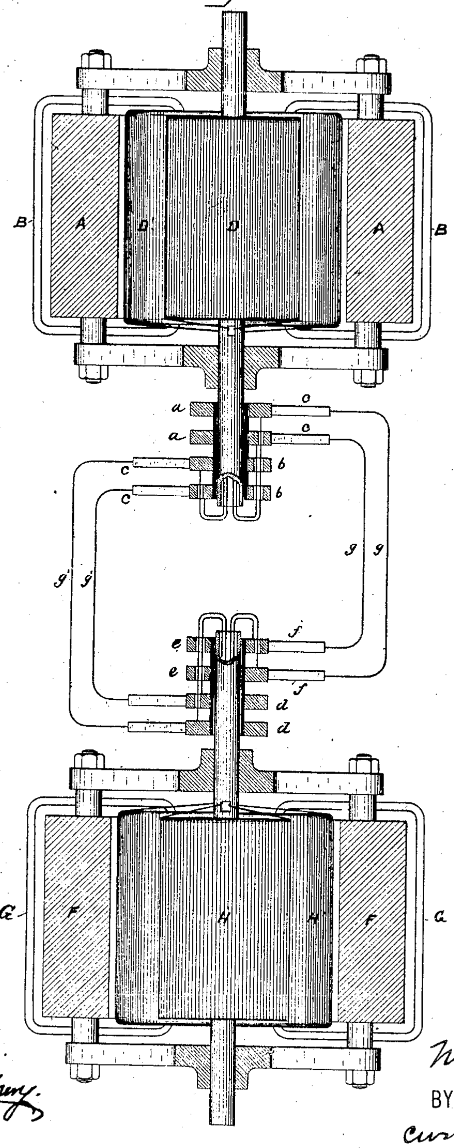
(No Model.) 2 Sheets—Sheet 2.

N. TESLA.

ELECTRICAL TRANSMISSION OF POWER.

No. 382,281. Patented May 1, 1888.

Fig. 3



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INVENTOR.

Nikola Tesla

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ATTORNEYS

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ELECTRICAL TRANSMISSION OF POWER.

SPECIFICATION forming part of Letters Patent No. 382,281, dated May 1, 1888.

Original application filed November 30, 1887, Serial No. 256,562. Divided and this application filed March 9, 1888. Serial No 266,756. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, from Smiljan, Lika, border country of Austria-Hungary, and residing in the city, county, and State of New York, have invented certain new and useful Improvements in the Electric Transmission of Power, of which the following is a specification, this application being a division of an application filed by me November 30, 1887, Serial No. 256,562.

In a previous application filed by me—viz., No. 252,132, filed October 12, 1887—I have set forth an improvement in motors and in the mode or method of operating the same, which, generally stated, consists in progressively and continuously shifting the poles or lines of maximum magnetic effect of either the field-magnets or armature, or both, of a motor, and thereby producing a movement of rotation in the motor. The means which I have shown for effecting this, while varying in detail, are exemplified in the following system, which, for present purposes, it will be sufficient to consider as a typical embodiment of the invention.

The motor is wound with coils forming independent energizing-circuits on the armature, which is a cylinder or disk mounted to rotate between two opposite magnetic poles. These coils are connected up with corresponding induced or current-producing circuits in an alternating-current generator. As a result of this, when the generator is set in motion, currents of alternately-opposite direction are directed through the energizing-coils of the motor in such manner as to produce a progressive shifting or rotation of the magnetic poles of the motor-armature. This movement of the poles of the armature obviously tends to rotate the armature in the opposite direction to that in which the movement of the poles takes place, owing to the attractive force between said poles and the field-magnets, and the speed of rotation increases from the start until it equals that of the generator, supposing both motor and generator to be alike.

As the magnetic poles of the armature are shifted in a direction opposite to that in which the armature rotates, it will be apparent that when the normal speed is attained the poles of the armature will assume a fixed position relatively to the field-magnets, and that in consequence the field-magnets will be energized by magnetic induction, exhibiting two distinct poles, one on each of the pole-pieces. In starting the motor, however, the speed of the armature being comparatively slow, the pole-pieces are subjected to rapid reversals of magnetic polarity; but as the speed increases these reversals become less and less frequent and finally cease, when the movement of the armature becomes synchronous with that of the generator. This being the case, the field-cores or the pole-pieces of the motor become a magnet, but by induction only.

I have found that advantageous results are secured by winding the field-magnets with a coil or coils and passing a continuous current through them, thus maintaining a permanent field, and in this feature my present invention consists.

I shall now describe the apparatus which I have devised for carrying out this invention and explain the mode of using or operating the same.

Figure 1 is an end view in elevation of my improved motor. Fig. 2 is a part horizontal central section, and Fig. 3 is a diagrammatic representation of the motor and generator combined and connected for operation.

Let A A in Fig. 1 represent the legs or pole-pieces of a field-magnet, around which are coils B B, included in the circuit of a continuous-current generator, C, which is adapted to impart magnetism to the said poles in the ordinary manner.

D D' are two independent coils wound upon a suitable cylindrical or equivalent armature-core, which, like all others used in a similar manner, should be split or divided up into alternate magnetic and insulating parts in the usual way. This armature is mounted in non-magnetic cross-bars E E, secured to the poles of the field-magnet. The terminals of the armature-coils D D' are connected to insulated sliding contact-rings *a a b b*, carried by the armature-shaft, and brushes *c c* bear upon these rings to convey to the coils the currents which operate the motor.

The generator for operating this motor is or may be of precisely identical construction, and for convenience of reference I have marked in Fig. 3 its parts, as follows: F F, the field-magnets energized by a continuous current passing in its field-coils G G; H H', the coils carried by the cylindrical armature; *d d e e*, the friction or collecting rings carried by the armature-shaft and forming the terminals of the armature-coils; and *f f* the collecting-brushes which deliver the currents developed in the armature-coils to the two circuits *g g'*, which connect the generator with the motor.

The operation of this system will be understood from the foregoing. The action of the generator by causing a progressive shifting of the poles in the motor-armature sets up in the latter a rotation opposite in direction to that in which the poles move. If, now, the continuous current be directed through the field-coils so as to strongly energize the magnet A A, the speed of the motor, which depends upon that of the generator, will not be increased, but the power which produces its rotation will be increased in proportion to the energy supplied through the coils B B. It is characteristic of this motor that its direction of rotation is not reversed by reversing the direction of the current through its field-coils, for the direction of rotation depends not upon the polarity of the field, but upon the direction in which the poles of the armature are shifted. To reverse the motor the connections of either of the circuits *g g'* must be reversed.

I have found that if the field-magnet of the motor be strongly energized by its coils B B, and the circuits through the armature-coils closed, assuming the generator to be running at a certain speed, the motor will not start; but if the field be but slightly energized, or in general in such condition that the magnetic influence of the armature preponderates in determining its magnetic condition, the motor will start, and with sufficient current will reach its maximum or normal speed. For this reason it is desirable to keep at the start, and until the motor has attained its normal speed, or nearly so, the field-circuit open, or to permit but little current to pass through it. I have found, however, if the fields of both the generator and motor be strongly energized that starting the generator starts the motor, and that the speed of the motor is increased in synchronism with the generator.

Motors constructed and operated on this principle maintain almost absolutely the same speed for all loads within their normal working limits, and in practice I have observed that if the motor be overloaded to such an extent as to check its speed the speed of the generator, if its motive power be not too great, is diminished synchronously with that of the motor.

I have in other applications shown how the construction of these or similar motors may be varied in certain well-known ways—as, for instance, by rotating the field about a stationary armature or rotating conductors within the field—but I do not illustrate these features further herein, as with the illustration which I have given I regard the rest as within the power of a person skilled in the art to construct.

I am aware that a device embodying the characteristics of a motor and having a permanently-magnetized field-magnet has been operated by passing through independent coils on its armature a direct or continuous current in opposite directions. Such a system, however, I do not regard as capable of the practical applications for which my invention is designed, nor is it the same in principle or mode of operation, mainly in that the shifting of the poles is intermittent and not continuous, and that there is necessarily involved a waste of energy.

In my present application I do not limit myself to any special form of motor, nor of the means for producing the alternating currents as distinguished from what are called "reversed currents," and I may excite or energize the field of the motor and of the generator by any source of current which will produce the desired result.

What I claim is—

The method herein described of transmitting power by electro-magnetic motors, which consists in continuously and progressively shifting the poles of one element of the motor by alternating currents and magnetizing the other element by a direct or continuous current, as set forth.

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Witnesses:

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2 Sheets—Sheet 1.

N. TESLA.

METHOD OF CONVERTING AND DISTRIBUTING ELECTRIC CURRENTS.

No. 382,282. Patented May 1, 1888.

Fig. 1

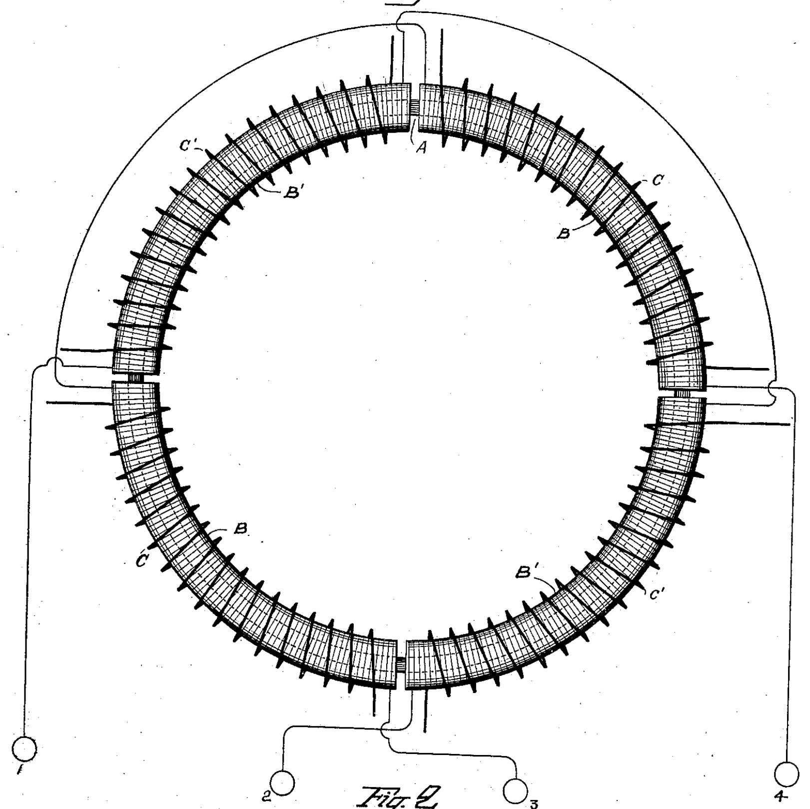
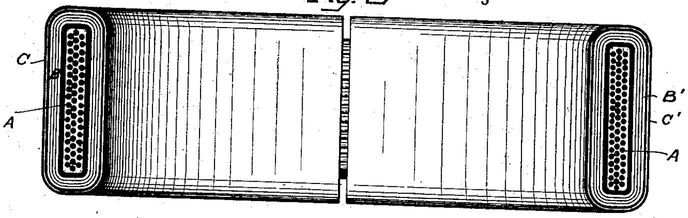


Fig. 2



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(No Model.) 2 Sheets—Sheet 2.

N. TESLA.

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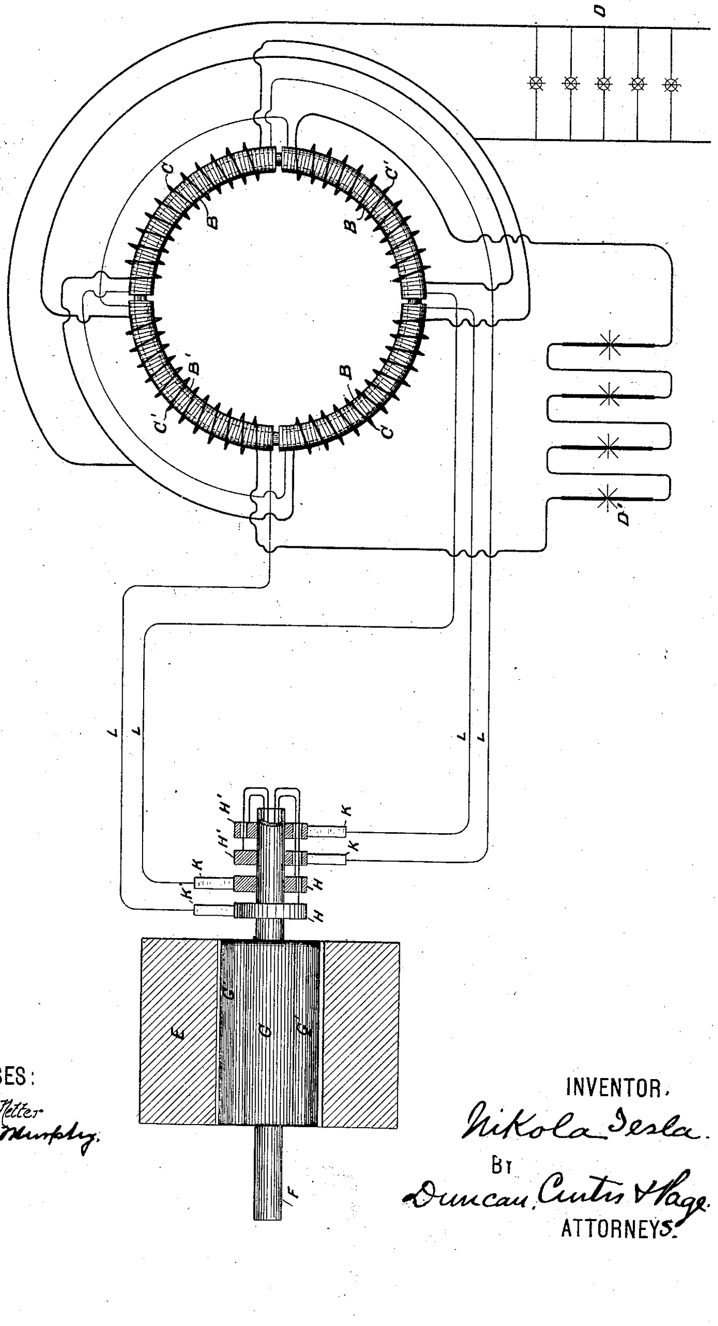

Fig. 3

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UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

METHOD OF CONVERTING AND DISTRIBUTING ELECTRIC CURRENTS.

SPECIFICATION forming part of Letters Patent No. 382,282, dated May 1, 1888.

Original application filed December 23, 1887, Serial No. 258,787. Divided and this application filed March 9, 1888. Serial No. 266,757. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, from Smiljan, Lika, border country of Austria-Hungary, and now residing at New York, in the county and State of New York, have invented certain new and useful Improvements in Methods of Converting and Distributing Electric Currents, of which the following is a specification, this application being a division of an application filed by me December 23, 1887, Serial No. 258,787.

This invention relates to those systems of electrical distribution in which a current from a single source of supply in a main or transmitting circuit is caused to induce, by means of suitable induction apparatus, a current or currents in an independent working circuit or circuits.

The main objects of the invention are the same as have been heretofore obtained by the use of these systems—viz., to divide the current from a single source, whereby a number of lamps, motors, or other translating devices may be independently controlled and operated by the same source of current, and in some cases to reduce a current of high potential in the main circuit to one of greater quantity and lower potential in the independent consumption or working circuit or circuits.

The general character of the devices employed in these systems is now well understood. An alternating-current magneto-machine is used as a source of supply. The current developed thereby is conducted through a transmission-circuit to one or more distant points, at which the transformers are located. These consist of induction-machines of various kinds. In some cases ordinary forms of induction-coil have been used with one coil in the transmitting-circuit and the other in a local or consumption circuit, the coils being differently proportioned, according to the work to be done in the consumption-circuit—that is to say, if the work requires a current of higher potential than that in the transmission-circuit the secondary or induced coil is of greater length and resistance than the primary, while, on the other hand, if a quantity current of lower potential is wanted, the longer coil is made the primary. In lieu of these devices various forms of electro-dynamic induction-machines, including the combined motors and generators, have been devised. For instance, a motor is constructed in accordance with well-understood principles, and on the same armature are wound induced coils which constitute a generator. The motor-coils are generally of fine wire and the generator-coils of coarser wire, so as to produce a current of greater quantity and lower potential than the line-current, which is of relatively high potential to avoid loss in long transmission. A similar arrangement is to wind coils corresponding to those described on a ring or similar core, and by means of a commutator of suitable kind to direct the current through the inducing-coils successively, so as to maintain a movement of the poles of the core or of the lines of force which set up the currents in the induced coils.

Without enumerating the objections to these systems in detail, it will suffice to say that the theory or the principle of the action or operation of these devices has apparently been so little understood that their proper construction and use have, up to the present time, been attended with various difficulties and great expense. The transformers are very liable to be injured and burned out, and the means resorted to for curing this and other defects have invariably been at the expense of efficiency. I have discovered a method of conversion and distribution, however, which is not subject to the defects and objections to which I have alluded, and which is both efficient and safe. I secure by it a conversion by true dynamic induction under highly efficient conditions and without the use of expensive or complicated apparatus or moving devices, which in use wear out and require attention. This method consists in progressively and continuously shifting the line or points of maximum effect in an inductive field across the convolutions of a coil or conductor within the influence of said field and included in or forming part of a secondary or translating circuit.

In carrying out my invention I provide a series of inducing-coils and corresponding induced coils which, by preference, I wind upon a core closed upon itself—such as an annulus or ring—subdivided in the usual manner. The two sets of coils are wound side by side or superposed or otherwise placed in well-known ways to bring them into the most effective relations to one another and to the core. The inducing or primary coils wound on the core are divided into pairs or sets by the proper electrical connections, so that while the coils of one pair or set co-operate in fixing the magnetic poles of the core at two given diametrically-opposite points the coils of the other pair or set—assuming, for the sake of illustration, that there are but two—tend to fix the poles at ninety degrees from such points. With this induction device I use an alternating-current generator with coils or sets of coils to correspond with those of the converter, and by means of suitable conductors I connect up in independent circuits the corresponding coils of the generator and converter. It results from this that the different electrical phases in the generator are attended by corresponding magnetic changes in the converter; or, in other words, that as the generator-coils revolve the points of greatest magnetic intensity in the converter will be progressively shifted or whirled around. This principle I have applied under variously modified conditions to the operation of electro-magnetic motors, and in previous applications—notably in those having serial numbers 252,132 and 256,561—I have described in detail the manner of constructing and using such motors.

In the present application my object is to describe the best and most convenient manner of which I am at present aware of carrying out the invention as applied to a system of electrical distribution; but one skilled in the art will readily understand, from the description of the modifications proposed in said applications, wherein the form of both the generator and converter in the present case may be modified. In illustration, therefore, of the details of construction which my present invention involves, I now refer to the accompanying drawings.

Figure 1 is a diagrammatic illustration of the converter and the electrical connections of the same. Fig. 2 is a horizontal central cross-section of Fig. 1. Fig. 3 is a diagram of the circuits of the entire system, the generator being shown in section.

I use a core, A, which is closed upon itself—that is to say, of an annular, cylindrical, or equivalent form—and as the efficiency of the apparatus is largely increased by the subdivision of this core I make it of thin strips, plates, or wires of soft iron electrically insulated as far as practicable. Upon this core, by any well-known method, I wind, say, four coils, B B B′ B′, which I use as primary coils, and for which I use long lengths of comparatively fine wire. Over these coils I then wind shorter coils of coarser wire, C C C′ C′, to constitute the induced or secondary coils. The construction of this or any equivalent form of converter may be carried farther, as above pointed out, by inclosing these coils with iron—as, for example, by winding over the coils a layer or layers of insulated iron wire.

The device is provided with suitable binding-posts, to which the ends of the coils are led. The diametrically-opposite coils B B and B′ B′ are connected, respectively, in series, and the four terminals are connected to the binding-posts 1 2 3 4. The induced coils are connected together in any desired manner. For example, as shown in Fig. 3, C C may be connected in multiple arc when a quantity current is desired—as for running a group of incandescent lamps, D—while C′ C′ may be independently connected in series in a circuit including arc lamps D′, or the like.

The generator in this system will be adapted to the converter in the manner illustrated. For example, in the present case I employ a pair of ordinary permanent or electromagnets, E E, between which is mounted a cylindrical armature on a shaft, F, and wound with two coils, G G′. The terminals of these coils are connected, respectively, to four insulated contact or collecting rings, H H H′ H′, and the four line-circuit wires L connect the brushes K bearing on these rings to the converter in the order shown. Noting the results of this combination, it will be observed that at a given point of time the coil G is in its neutral position and is generating little or no current, while the other coil, G′, is in a position where it exerts its maximum effect. Assuming coil G to be connected in circuit with coils B B of the converter and coil G′ with coils B′ B′, it is evident that the poles of the ring A will be determined by coils B′ B′ alone; but as the armature of the generator revolves, coil G develops more current and coil G′ less until G reaches its maximum and G′ its neutral position. The obvious result will be to shift the poles of the ring A through one quarter of its periphery. The movement of the coils through the next quarter of a turn, during which coil G′ enters a field of opposite polarity and generates a current of opposite direction and increasing strength, while coil G is passing from its maximum to its neutral position, generates a current of decreasing strength and same direction as before, and causes a further shifting of the poles through the second quarter of the ring. The second half-revolution will obviously be a repetition of the same action. By the shifting of the poles of the ring A a power-dynamic inductive effect on the coils C C′ is produced. Besides the currents generated in the secondary coils by dynamo-magnetic induction, other currents will be set up in the same coils in consequence of any variations in the intensity of the poles in the ring A. This should be avoided by maintaining the intensity of the poles constant, to accomplish which care should be taken in designing and proportioning the generator and in distributing the coils in the ring A and balancing their effect. When this is done, the currents are produced by dynamo-magnetic induction only, the same result being obtained as though the poles were shifted by a commutator with an infinite number of segments.

The apparatus by means of which this method of conversion is or may be carried out may be varied almost indefinitely. The specific form which I have herein shown I regard as the best and most efficient, and in another application I have claimed it; but I do not limit myself herein to the use of any particular form or combination of devices which is or may be capable of effecting the same result in a similar way.

What I claim is—

1. The method of electrical conversion and distribution herein described, which consists in continuously and progressively shifting the points or line of maximum effect in an inductive field, and inducing thereby currents in the coils or convolutions of a circuit located within the inductive influence of said field, as herein set forth.

2. The method of electrical conversion and distribution herein described, which consists in generating in independent circuits producing an inductive field alternating currents in such order or manner as to produce by their conjoint effect a progressive shifting of the points of maximum effect of the field, and inducing thereby currents in the coils or convolutions of a circuit located within the inductive influence of the field, as set forth.

NIKOLA TESLA.

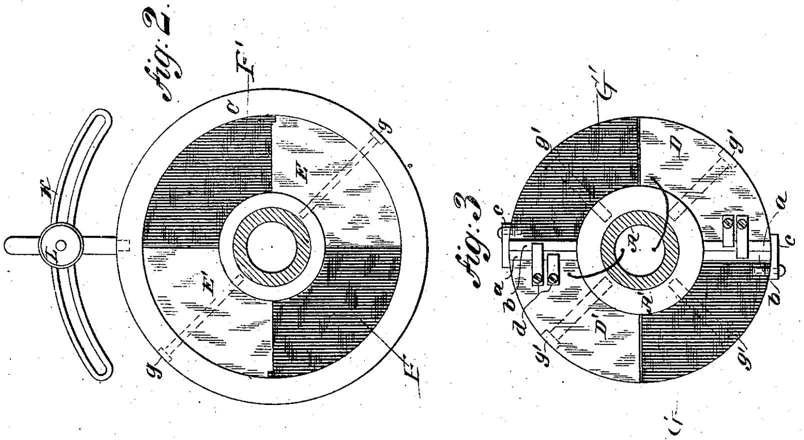
Witnesses:
FRANK B. MURPHY,
FRANK E. HARTLEY.

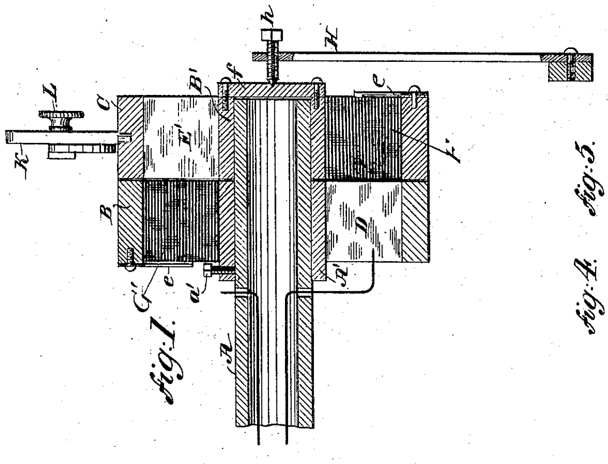
(No Model.) 2 Sheets—Sheet 1.

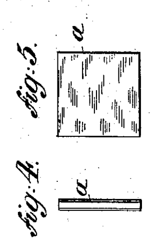
N. TESLA.

COMMUTATOR FOR DYNAMO ELECTRIC MACHINES.

No. 382,845. Patented May 15, 1888.







WITNESSES:

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Robt. P. Harlow

INVENTOR.

Nikola Tesla

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(No Model.) 2 Sheets—Sheet 2.

N. TESLA.

COMMUTATOR FOR DYNAMO ELECTRIC MACHINES.

No. 382,845. Patented May 15, 1888.

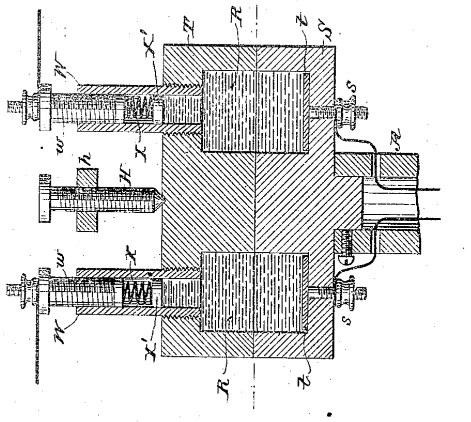

Fig. 6.

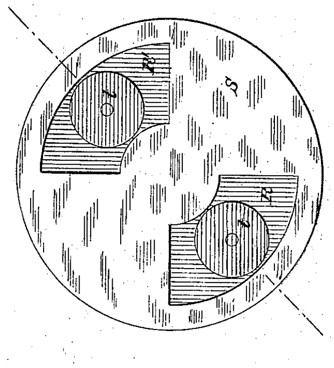

Fig. 7.

WITNESSES:
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Robt. P. Harlow.

INVENTOR.
Nikola Tesla.
BY
Duncan, Curtis & Page.
ATTORNEYS.

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y., ASSIGNOR OF ONE-HALF TO CHARLES F. PECK, OF ENGLEWOOD, NEW JERSEY.

COMMUTATOR FOR DYNAMO-ELECTRIC MACHINES.

SPECIFICATION forming part of Letters Patent No. 382,845, dated May 15, 1888.

Application filed April 30, 1887. Serial No. 236,711. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, from Smiljan, Lika, border country of Austria-Hungary, at present residing in the city, county, and State of New York, have invented certain new and useful Improvements in Commutators for Dynamo-Electric Machines and Motors, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

This invention relates to dynamo-electric machines or motors, and is an improvement in the devices for commutating and collecting the currents.

The objects of the invention are, first, to avoid the sparking and the gradual wearing away or destruction of the commutator-segments and brushes or collectors resulting therefrom; second, to obviate the necessity of readjustment of the commutator or the brushes or collectors and other consequences of the wear of the same; third, to render practicable the construction of very large dynamo-electric machines and motors with the minimum number of commutator-segments, and, fourth, to increase the efficiency and safety and reduce the cost of the machine.

In carrying out my invention in a manner to accomplish these results I construct a commutator and the collectors therefor in two parts mutually adapted to one another, and, so far as the essential features are concerned, alike in mechanical structure. Selecting as an illustration a commutator of two segments adapted for use with an armature the coils or coil of which have but two free ends, connected respectively to the said segments, the bearing-surface is the face of a disk, and is formed of two metallic quadrant-segments and two insulating-segments of the same dimensions, and the face of the disk should be smoothed off, so that the metal and insulating segments are flush. The part which takes the place of the usual brushes, or what I term the "collector," is a disk of the same character as the commutator and having a surface similarly formed with two insulating and two metallic segments. These two parts are mounted with their faces in contact and in such manner that the rotation of the armature causes the commutator to turn upon the collector, whereby the currents induced in the coils are taken off by the collector-segments and thence conveyed off by suitable conductors leading from the collector-segments. This is the general plan of the construction which I have invented. Aside from certain adjuncts, the nature and functions of which will be hereinafter set forth, this means of commutation will be seen to possess many important advantages. In the first place the short-circuiting and breaking of the armature-coil connected to the commutator-segments occur at the same instant, and from the nature of the construction this will be done with the greatest precision; secondly, the duration of both the break and that of the short circuit will be reduced to a minimum. The first results in a reduction which amounts practically to a suppression of the spark, since the break and the short circuit produce opposite effects in the armature-coil. The second has the effect of diminishing the destructive effect of a spark, since this would be in a measure proportioned to the duration of the spark, while lessening the duration of the short circuit obviously increases the efficiency of the machine.

The mechanical advantages will be better understood by referring to the accompanying drawings, in which—

Figure 1 is a central longitudinal section of the end of a shaft with my improved commutator carried thereon. Fig. 2 is a view of the inner or bearing face of the collector. Fig. 3 is an end view from the armature side of a modified form of commutator. Figs. 4 and 5 are views of details of Fig. 3. Fig. 6 is a longitudinal central section of another modification, and Fig. 7 is a sectional view of the same.

A is the end of the armature-shaft of a dynamo-electric machine or motor.

A′ is a sleeve of insulating material around the shaft, secured in place by a screw, a', or by other suitable means.

The commutator proper is in the form of a disk which is made up of four segments, D D′ G G′, similar to those shown in Fig. 3. Two of these segments, as D D′, are of metal and are in electrical connection with the ends of the coils on the armature. The other two segments are of insulating material. The segments are held in place by a band, B, of insulating material. The disk is held in place by friction or by screws, such as g' g', Fig. 3, which secure the disk firmly to the sleeve A'.

The collector is made in the same form as the commutator. It is composed of the two metallic segments E E' and the two insulating-segments F F', bound together by a band, C. The metallic segments E E' are of the same or practically the same width or extent as the insulating segments or spaces of the commutator. The collector is secured to a sleeve, B', by screws g g, and the sleeve is arranged to turn freely on the shaft A. The end of the sleeve B' is closed by a plate, as f, upon which presses a pivot-pointed screw, h, adjustable in a spring, H, which acts to maintain the collector in close contact with the commutator and to compensate for the play of the shaft. Any convenient means is employed to hold the collector so that it may not turn with the shaft. For example, I have shown a slotted plate, K, which is designed to be attached to a stationary support, and an arm extending from the collector and carrying a clamping-screw, L, by which the collector may be adjusted and set to the desired position.

I prefer in the form shown in Figs. 1 and 2 to fit the insulating-segments of both commutator and collector loosely and to provide some means—as, for example, light springs e e, secured to the bands A' B', respectively, and bearing against the segments—to exert a light pressure upon them and keep them in close contact and to compensate for wear. The metal segments of the commutator may be moved forward by loosening the screw a'.

The circuit or line wires are led from the metal segments of the collector, being secured thereto in any convenient manner, the plan of connections being shown as applied to a modified form of the commutator in Fig. 6. The commutator and the collector in thus presenting two flat and smooth bearing-surfaces prevent by mechanical action the occurrence of sparks, and this is more effectively accomplished as is here done—that is to say, by the interposition of an insulating body between the separating plates or segments of the commutator and collector—than by any other mechanical devices of which I am aware.

The insulating-segments are made of some hard material capable of being polished and formed with sharp edges. Such materials as glass, marble, or soapstone may be advantageously used. The metal segments are preferably of copper or brass; but they may have a facing or edge of durable material—such as platinum or the like—where the sparks are liable to occur.

In Fig. 3 a somewhat modified form of my invention is shown, a form designed to facilitate the construction and replacing of the parts. In this form the commutator and collector are made in substantially the same manner as previously described, except that the bands B C may be omitted. The four segments of each part, however, are secured to their respective sleeves by screws g' g', and one edge of each segment is cut away, so that small plates a b may be slipped into the spaces thus formed. Of these plates a a are of metal, and are in contact with the metal segments D D', respectively. The other two, b b, are of glass or marble, and they are all preferably square, as shown in Figs. 4 and 5, so that they may be turned to present new edges should any edge become worn by use. Light springs d bear upon these plates and press those in the commutator toward those in the collector, and insulating-strips c c are secured to the periphery of the disks to prevent the blocks from being thrown out by centrifugal action. These plates are, of course, useful at those edges of the segments only where sparks are liable to occur, and, as they are easily replaced, they are of great advantage. I prefer to coat them with platinum or silver.

In Figs. 6 and 7 is shown the construction which I use when, instead of solid segments, a fluid is employed. In this case the commutator and collector are made of two insulating-disks, S T, and in lieu of the metal segments a space is cut out of each part, as at R R', corresponding in shape and size to a metal segment. The two parts are fitted smoothly and the collector T held by the screw h and spring H against the commutator S. As in the other cases, the commutator revolves while the collector remains stationary. The ends of the coils are connected to binding-posts s s, which are in electrical connection with metal plates t t within the recesses in the two parts S T. These chambers or recesses are filled with mercury, and in the collector part are tubes W W, with screws w w, carrying springs X and pistons X', which compensate for the expansion and contraction of the mercury under varying temperatures, but which are sufficiently strong not to yield to the pressure of the fluid due to centrifugal action, and which serve as binding-posts.

In all the above cases I have described commutators adapted for a single coil, and the device is particularly adapted to such purposes. The number of segments may be increased, however, or more than one commutator used with a single armature, as will be well understood.

Although I have shown the bearing-surfaces as planes at right angles to the shaft or axis, it is evident that in this particular the construction may be very greatly modified without departure from the invention.

Without confining myself, therefore, to the details of construction which I have shown in illustration of the invention, what I claim as new is—

1. In a dynamo-electric machine, the combination, with a commutator formed with conducting terminals or segments with intervening insulating-spaces, of a collector adapted to bear upon the surface of the commutator,

and formed with conducting terminals or segments equal in extent to the insulating-space between the commutator-segments, as set forth.

2. The combination, with a commutator built or formed of alternate blocks or segments of conducting and insulating material, of a collector adapted to bear upon the surface of the commutator and formed of conducting blocks or segments of a width or extent equal to that of the insulating-segments of the commutator and separated by interposed blocks or segments of insulating material, as described.

3. The combination, with a commutator formed as a disk with alternate terminals or segments of conducting and insulating material, of a collector similarly formed and mounted with its face in contact with that of the commutator, as set forth.

4. The combination, with a commutator having a bearing-surface formed of alternate sections of conducting and insulating material, of a collector with a similar and symmetrically-formed bearing-surface and means for applying spring-pressure to force the two bearing-surfaces together, as set forth.

5. The combination, with a commutator and a collector the bearing-surfaces of which are identical in respect to the disposition of the conducting and insulating parts, of means for applying spring-pressure to maintain the two bearing-surfaces in contact and means for holding the collector against rotary movement, as set forth.

Signed this 21st day of April, 1887.

NIKOLA TESLA.

Witnesses:
ROBT. F. GAYLORD,
FRANK E. HARTLEY.

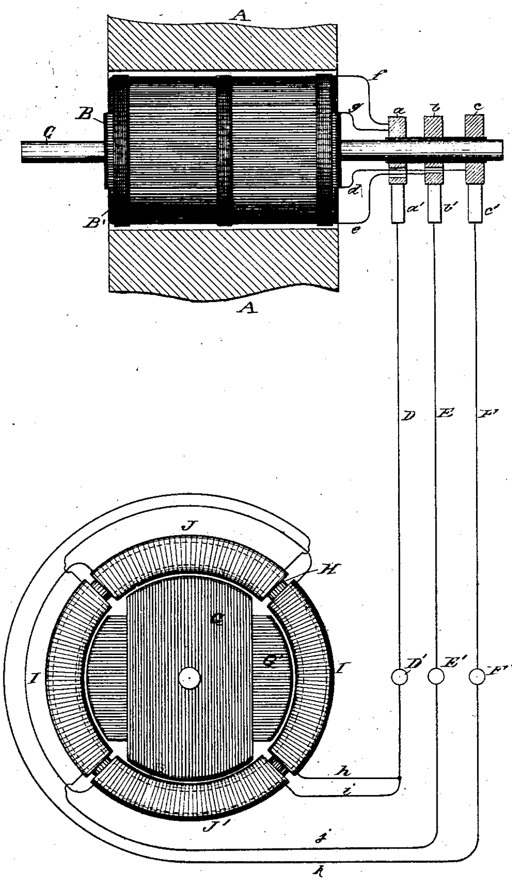
(No Model.) 3 Sheets—Sheet 1.

N. TESLA.

SYSTEM OF ELECTRICAL DISTRIBUTION.

No. 390,413. Patented Oct. 2, 1888.

Fig. 1



WITNESSES:

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INVENTOR

Nikola Tesla

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Duncan, Curtis & Page

ATTORNEY

(No Model.)

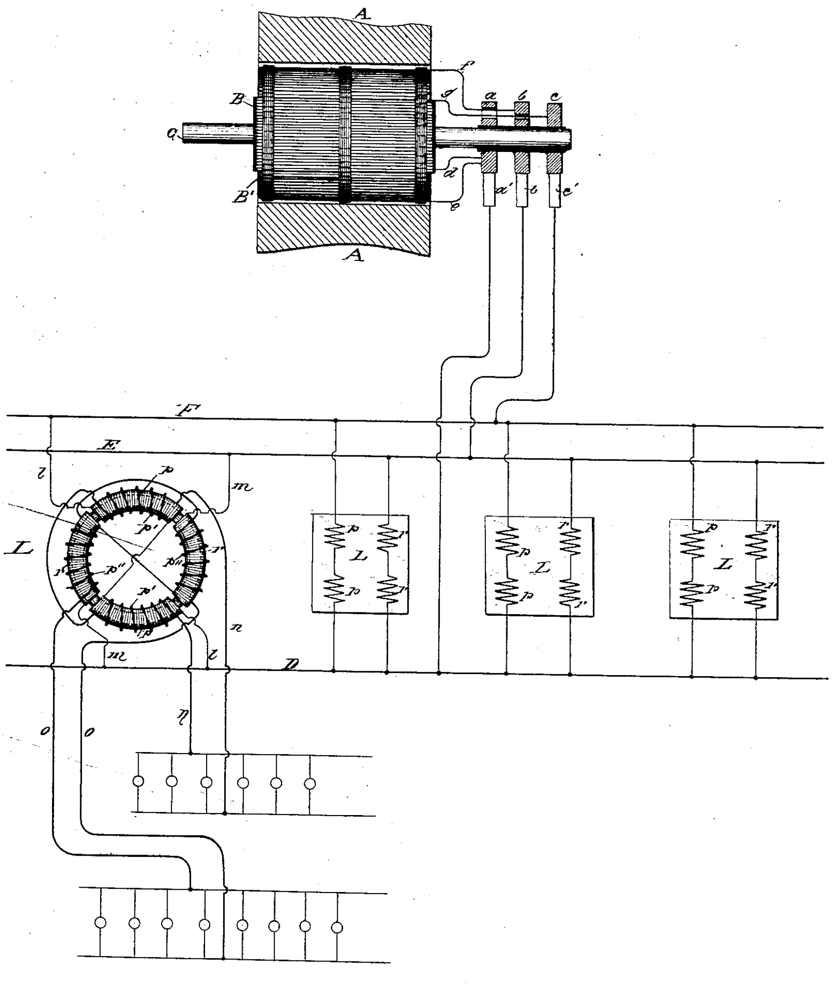
3 Sheets—Sheet 2.

N. TESLA.

SYSTEM OF ELECTRICAL DISTRIBUTION.

No. 390,413. Patented Oct. 2, 1888.

Fig. 2



WITNESSES:

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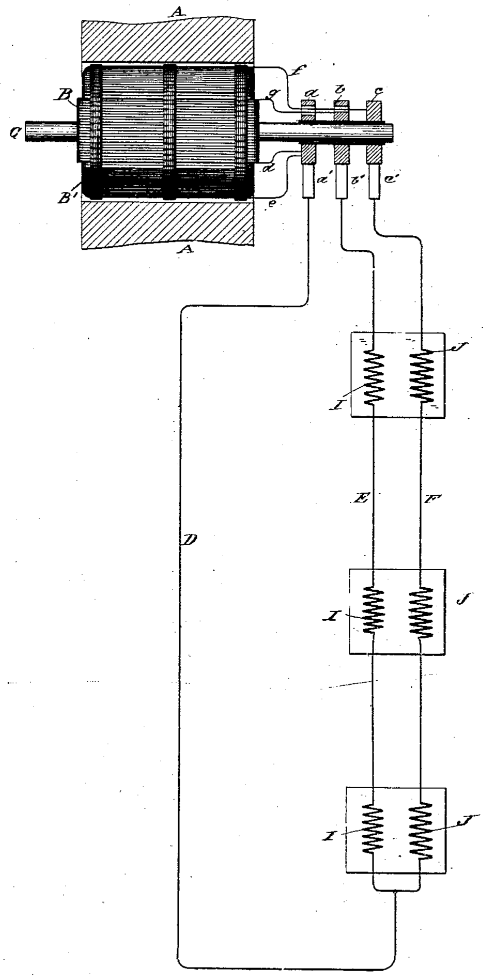
(No Model.) 3 Sheets—Sheet 3.

N. TESLA.

SYSTEM OF ELECTRICAL DISTRIBUTION.

No. 390,413. Patented Oct. 2, 1888.

Fig. 3



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UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y., ASSIGNOR TO THE TESLA ELECTRIC COMPANY, OF SAME PLACE.

SYSTEM OF ELECTRICAL DISTRIBUTION.

SPECIFICATION forming part of Letters Patent No. 390,413, dated October 2, 1888.

Application filed April 10, 1888. Serial No. 270,187. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a subject of the Emperor of Austria, from Smiljan, Lika, border country of Austria-Hungary, residing in the city, county, and State of New York, have invented certain new and useful Improvements in Systems of Electrical Distribution, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

In previous applications for patents made by me I have shown and described electrical systems for the transmission of power and the conversion and distribution of electrical energy, in which the motors and the transformers contain two or more coils or sets of coils, which were connected up in independent circuits with corresponding coils of an alternating-current generator, the operation of the system being brought about by the co-operation of the alternating currents in the independent circuits in progressively moving or shifting the poles or points of maximum magnetic effect of the motors or converters. In these systems, as I have described them, two independent conductors were employed for each of the independent circuits connecting the generator with the devices for converting the transmitted currents into mechanical energy or into electric currents of another character; but I have found that this is not always necessary, and that the two or more circuits may have a single return path or wire in common, with a loss, if any, which is so extremely slight that it may be disregarded entirely. For sake of illustration, if the generator have two independent coils and the motor two coils or two sets of coils in corresponding relations to its operative elements one terminal of each generator-coil is connected to the corresponding terminals of the motor coils through two independent conductors, while the opposite terminals of the respective coils are both connected to one return-wire.

This invention is applicable to my system in various ways, as will be seen by reference to the drawings, in which—

Figure 1 is a diagrammatic illustration of a generator and single motor constructed and electrically connected in accordance with the invention. Fig. 2 is a diagram of the system as it is used in operating motors or converters, or both, in parallel or multiple arc. Fig. 3 illustrates diagrammatically the manner of operating two or more motors or converters, or both, in series.

It is obvious that for purposes of this invention motors or transformers, which may be all designated as "converters," are the same, and that either or both may be operated by the same system or arrangement of circuits.

Referring to Fig. 1, A A designate the poles of the field-magnets of an alternating-current generator, the armature of which, being in this case cylindrical in form and mounted on a shaft, C, is wound longitudinally with coils B B′. The shaft C carries three insulated contact-rings, *a b c*, to two of which, as *b c*, one terminal of each coil, as *e d*, is connected. The remaining terminals, *f g*, are both connected to the third ring, *a*.

A motor in this case is shown as composed of a ring, H, wound with four coils, I I J J, electrically connected, so as to co-operate in pairs, with a tendency to fix the poles of the ring at four points ninety degrees apart. Within the magnetic ring H is a disk or cylindrical core wound with two coils, G G′, which may be connected to form two closed circuits. The terminals *j k* of the two sets or pairs of coils are connected, respectively, to the binding-posts E′ F′, and the other terminals, *h i*, are connected to a single binding-post, D′. To operate the motor, three line-wires are used to connect the terminals of the generator with those of the motor.

So far as the apparent action or mode of operation of this arrangement is concerned, the single wire D, which is, so to speak, a common return-wire for both circuits, may be regarded as two independent wires. In illustration, with the order of connection shown, coil B′ of the generator is producing its maximum current and coil B its minimum; hence the current which passes through wire *e*, ring *b*, brush *b′*, line-wire E, terminal E′, wire *j*, coils I I, wire or terminal D′, line-wire D, brush *a′*, ring *a*, and wire *f*, fixes the polar line of the motor midway between the two coils I I; but as the coil B′ moves from the position indicated it generates less current, while coil B, moving into the field, generates more. The current from coil B passes through the devices and wires designated by the letters *d*, *c*, *c'*, F, F', *k*, J J, *i*, D', D, *a'*, *a*, and *g*, and the position of the poles of the motor will be due to the resultant effect of the currents in the two sets of coils—that is, it will be advanced in proportion to the advance or forward movement of the armature coils. The movement of the generator-armature through one-quarter of a revolution will obviously bring coil B' into its neutral position and coil B into its position of maximum effect, and this shifts the poles ninety degrees, as they are fixed solely by coils B. This action is repeated for each quarter of a complete revolution.

When more than one motor or other device is employed, they may be run either in parallel or series. In Fig. 2 the former arrangement is shown. The electrical device is shown as a converter, L, constructed as I have described in my application Serial No. 258,787, filed December 23, 1887. The two sets of primary coils *p r* are connected, respectively, to the mains F E, which are electrically connected with the two coils of the generator. The cross-circuit wires *l m*, making these connections, are then connected to the common return-wire D. The secondary coils *p' p''* are in circuits *n o*, including, for example, incandescent lamps. Only one converter is shown entire in this figure, the others being illustrated diagrammatically.

When motors or converters are to be run in series, the two wires E F are led from the generator to the coils of the first motor or converter, then continued on to the next, and so on through the whole series, and are then joined to the single wire D, which completes both circuits through the generator. This is shown in Fig. 3, in which J I represent the two coils or sets of coils of the motors.

Obviously it is immaterial to the operation of the motor or equivalent device in Fig. 1 what order of connections is observed between the respective terminals of the generator or motor.

I have described the invention in its best and most practicable form of which I am aware; but there are other conditions under which it may be carried out. For example, in case the motor and generator each has three independent circuits, one terminal of each circuit is connected to a line-wire and the other three terminals to a common return-conductor. This arrangement will secure similar results to those attained with a generator and motor having but two independent circuits, as above described.

When applied to such machines and motors as have three or more induced circuits with a common electrical joint, the three or more terminals of the generator would be simply connected to those of the motor. Such forms of machines, when adapted in this manner to my system, I have, however, found to be less efficient than the others.

The invention is applicable to machines and motors of various types, and according to circumstances and conditions readily understood, with more or less efficient results. I do not therefore limit myself to any of the details of construction of the apparatus herein shown.

What I claim is—

1. The combination, with a generator having independent current-generating circuits and a converter or converters having independent and corresponding circuits, of independent conductors connecting one terminal of each generator-circuit with a corresponding terminal of the motor and a single conductor connecting the remaining generator and converter terminals, as set forth.

2. The combination, with a generator having independent current-generating circuits and a converter or converters having independent and corresponding circuits, of independent line or connecting circuits formed in part through a conductor common to all, as set forth.

3. The system of electrical distribution herein set forth, consisting of the combination, with an alternating-current generator having independent generating-circuits and electro-magnetic motors or converters provided with corresponding energizing-circuits, of line wires or conductors connecting the coils of the motors or converters, respectively, in series with one terminal of each circuit of the generator, and a single return wire or conductor connecting the said conductors with the other terminals of the generator, as set forth.

NIKOLA TESLA.

Witnesses:
ROBT. F. GAYLORD,
FRANK E. HARTLEY.

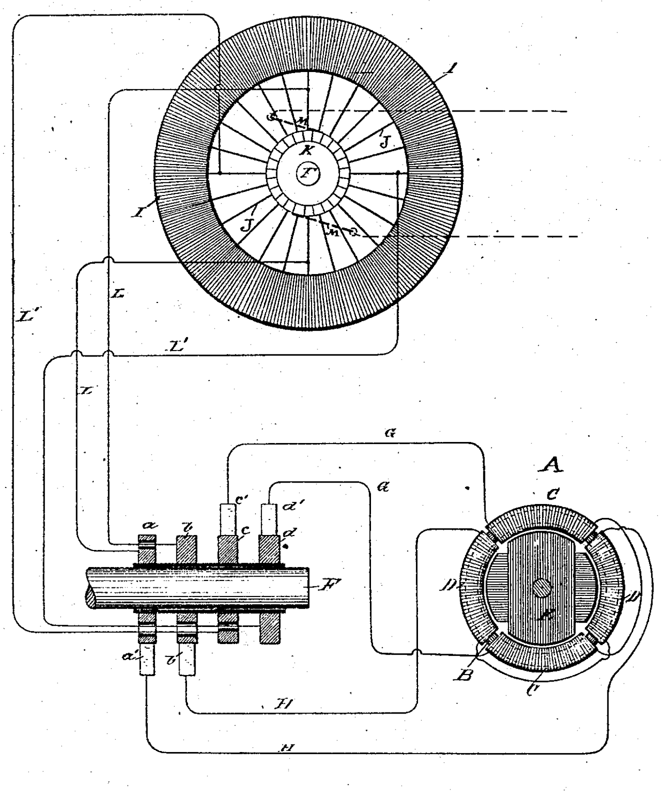
(No Model.) 2 Sheets—Sheet 1.

N. TESLA.

DYNAMO ELECTRIC MACHINE.

No. 390,414. Patented Oct. 2, 1888.

Fig. 1



WITNESSES:
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Frank E. Hartley

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(No Model.) 2 Sheets—Sheet 2.

N. TESLA.

DYNAMO ELECTRIC MACHINE.

No. 390,414. Patented Oct. 2, 1888.

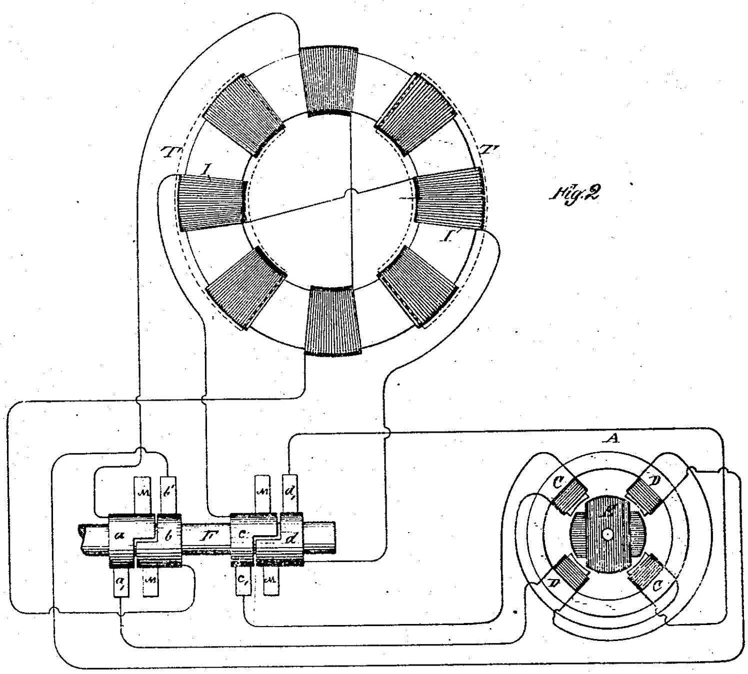

Fig. 2

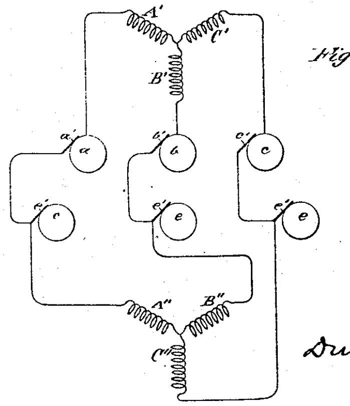

Fig. 3

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Frank B. Hartley

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Nikola Tesla
BY
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NORRIS PETERS, INC., LITHO., WASHINGTON, D. C.

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y., ASSIGNOR TO THE TESLA ELECTRIC COMPANY, OF SAME PLACE.

DYNAMO-ELECTRIC MACHINE.

SPECIFICATION forming part of Letters Patent No. 390,414, dated October 2, 1888.

Application filed April 23, 1888. Serial No. 271,626. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a subject of the Emperor of Austria, from Smiljan, Lika, border country of Austria-Hungary, now residing at New York, in the county and State of New York, have invented certain new and useful Improvements in Dynamo-Electric Machines, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

In certain patents granted to Charles F. Peck and myself—notably in Patents No. 381,968 and No. 382,280, May 1, 1888—I have shown and described a plan of constructing and operating motors, transformers, and the like, by alternating currents conveyed through two or more independent circuits from a generator having such relation to the motors or transformers as to produce therein a progressive movement of the magnetic poles or lines of force. In the said applications the descriptions and illustrations of the generators were confined to those types of alternating current machine in which the current generating coils are independent or separate; but I have found that the ordinary forms of continuous current dynamos now in use may be readily and cheaply adapted to my system, or utilized both as continuous and alternating current generators with but slight changes in their construction. The mode of effecting this forms the substance of my present application.

Generally stated, the plan pursued by me in carrying out this invention is as follows: On the shaft of a given generator, either in place of or in addition to the regular commutator, I secure as many pairs of insulated collecting-rings as there are circuits to be formed. Now, it will be understood that in the operation of any dynamo electric generator the currents in the coils in their movement through the field of force undergo different phases—that is to say, at different positions of the coils the currents have certain directions and certain strengths—and that in my improved motors or transformers it is necessary that the currents in the energizing-coils should undergo a certain order of variations in strength and direction. Hence, the further step—viz, the connection between the induced or generating coils of the machine and the contact-rings from which the currents are to be taken off—will be determined solely by what order of variations of strength and direction in the currents is desired for producing a given result in the electrical translating device. This may be accomplished in various ways; but in the drawings I have given typical instances only of the best and most practicable ways of applying the invention to three of the best-known types of machines, in order to illustrate the principle and to enable any one skilled in the art to apply the invention in any other case or under any modified conditions which the circumstances of particular cases may require.

Figure 1 is a diagram illustrative of the mode of applying the invention to the well-known type of closed or continuous circuit machines. Fig. 2 is a similar diagram containing an armature with separate coils connected diametrically, or what is generally called an "open-circuit" machine. Fig. 3 is a diagram showing the application of the invention to a machine the armature-coils of which have a common joint.

Referring to Fig. 1, let A represent one of my improved motors or transformers, which, for convenience, I shall designate a "converter," which consists of an annular core, B, wound with four independent coils, C and D, those diametrically opposite being connected together so as to co-operate in pairs in establishing free poles in the ring, the tendency of each pair being to fix the poles at ninety degrees from the other. There may be an armature, E, within the ring, which is wound with coils closed upon themselves. The object is to pass through coils C D currents of such relative strength and direction as to produce a progressive shifting or movement of the points of maximum magnetic effect around the ring, and to thereby maintain a rotary movement of the armature. I therefore secure to the shaft F of the generator four insulated contact-rings, *a b c d*, upon which I cause to bear the collecting-brushes *a' b' c' d'*, connected by wires G G H H, respectively, with the terminals of coils C and D.

Assume, for sake of illustration, that the coils D D are to receive the maximum and coils C C at the same instant the minimum current, so that the polar line may be midway between the coils D D, the rings *a b* would therefore be connected to the continuous armature-coil at its neutral points with respect to the field or the point corresponding with that of the ordinary commutator-brushes, and between which exists the greatest difference of potential, while rings *c d* would be connected to two points in the coil, between which exists no difference of potential. The best results will be obtained by making these connections at points equidistant from one another, as shown. These connections are easiest made by using wires L between the rings and the loops or wires J, connecting the coil I to the segments of the commutator K. When the converters are made in this manner, it is evident that the phases of the currents in the sections of the generator-coil will be reproduced in the converter coils. For example, after turning through an arc of ninety degrees the conductors L L, which before conveyed the maximum current, will receive the minimum current by reason of the change in the position of their coils, and it is evident that for the same reason the current in said coils has gradually fallen from the maximum to the minimum in passing through the arc of ninety degrees. In this special plan of connections the rotation of the magnetic poles of the converter will be synchronous with that of the armature-coils of the generator; and the result will be the same, whether the energizing-circuits are derivations from a continuous armature-coil or from independent coils, as in my previous devices.

I have shown in Fig. 1, in dotted lines, the brushes M M in their proper normal position. In practice these brushes may be removed from the commutator and the field of the generator excited by an external source of current; or the brushes may be allowed to remain on the commutator and to take off a converted current to excite the field, or to be used for other purposes.

In a certain well-known class of machines the armature contains a number of coils the terminals of which connect to commutator-segments, the coils being connected across the armature in pairs. This type of machine is represented in Fig. 2. In this machine each pair of coils goes through the same phases as the coils in some of the generators I have shown, and it is obviously only necessary to utilize them in pairs or sets to operate one of my converters by extending the segments of the commutators belonging to each pair of coils and causing a collecting-brush to bear on the continuous portion of each segment. In this way two or more circuits may be taken off from the generator, each including one or more pairs or sets of coils, as may be desired.

In Fig. 2 I I represent the armature-coils, T T the poles of the field-magnet, and F the shaft carrying the commutators, which are extended to form continuous portions *a b c d*. The brushes bearing on the continuous portions for taking off the alternating currents are represented by *a' b' c' d'*. The collecting-brushes, or those which may be used to take off the direct current, are designated by M M. Two pairs of the armature-coils and their commutators are shown in the figure as being utilized; but all may be utilized in a similar manner.

There is another well-known type of machine in which three or more coils, A' B' C', on the armature have a common joint, the free ends being connected to the segments of a commutator. This form of generator is illustrated in Fig. 3. In this case each terminal of the generator is connected directly or in derivation to a continuous ring, *a b c*, and collecting-brushes *a' b' c'*, bearing thereon, take off the alternating currents that operate the motor. It is preferable in this case to employ a motor or transformer with three energizing-coils, A'' B'' C'', placed symmetrically with those of the generator, and the circuits from the latter are connected to the terminals of such coils either directly—as when they are stationary—or by means of brushes *e'* and contact-rings *e*. In this, as in the other cases, the ordinary commutator may be used on the generator, and the current taken from it utilized for exciting the generator field-magnets or for other purposes.

These examples serve to illustrate the principle of the invention. It will be observed that in any case it is necessary only to add the continuous contact or collecting rings and to establish the connections between them and the appropriate coils.

It will be understood that this invention is applicable to other types of machine—as, for example, those by which the induced coils are stationary and the brushes and magnet revolve; but the manner of its application is obvious to one skilled in the art.

Having now described my invention, what I claim is—

1. The combination, with a converter having independent energizing-coils, of a continuous or direct current dynamo or magneto machine, and intermediate circuits permanently connected at suitable points to the induced or generating coils of the generator, as herein set forth.

2. The combination, with a converter provided with independent energizing-circuits, of a continuous or direct current generator provided with continuous collecting-rings connected in derivation to the armature-coils to form the terminals of circuits corresponding to those of the converter, as herein set forth.

NIKOLA TESLA.

Witnesses:

ROBT. F. GAYLORD,

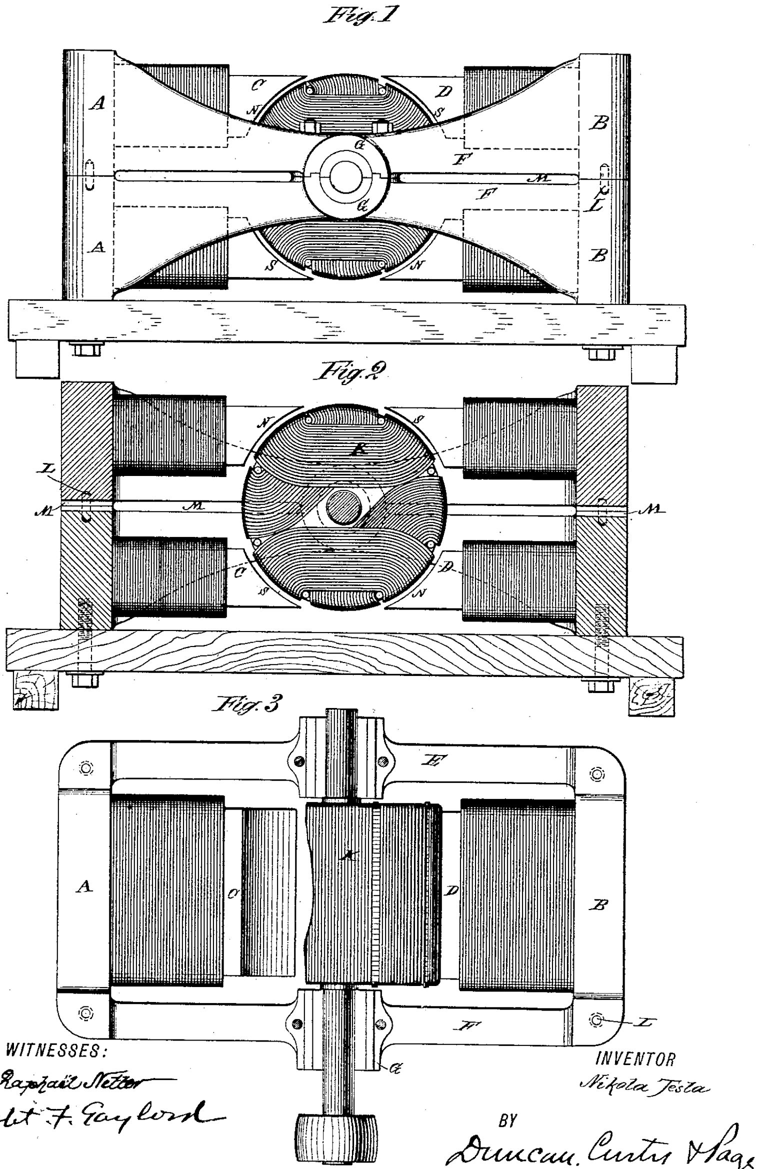
FRANK B. MURPHY.

(No Model.)

N. TESLA.

DYNAMO ELECTRIC MACHINE OR MOTOR.

No. 390,415. Patented Oct. 2, 1888.



WITNESSES:

Raphaël Netter

Robt. F. Gaylord

INVENTOR

Nikola Tesla

BY

Duncan, Curtis & Page

ATTORNEYS

N. PETERS, Photo-Lithographer, Washington, D. C.

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y., ASSIGNOR TO THE TESLA ELECTRIC COMPANY, OF SAME PLACE.

DYNAMO-ELECTRIC MACHINE OR MOTOR.

SPECIFICATION forming part of Letters Patent No. 390,415, dated October 2, 1888.

Application filed May 15, 1888. Serial No. 273,994. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a subject of the Emperor of Austria, from Smiljan, Lika, border country of Austria-Hungary, now residing at New York, in the county and State of New York, have invented certain new and useful Improvements in Dynamo-Electric Machines and Motors, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

This invention is an improvement in the construction of dynamo or magneto electric machines or motors, the improvement consisting in a novel form of frame and field-magnet which renders the machine more solid and compact as a structure, which requires fewer parts, and which involves less trouble and expense in its manufacture.

The invention is applicable to generators and motors generally, not only to those which I have described in former patents, and which have independent circuits adapted for use in my patented alternating current system, but to other continuous or alternating current machines, such as have heretofore been more generally used.

In the drawings hereto annexed, which illustrate my improvements, Figure 1 shows the machine in side elevation. Fig. 2 is a vertical sectional view of the field-magnets and frame and an end view of the armature; and Fig. 3 is a plan view of one of the parts of the frame and the armature, a portion of the latter being cut away.

I cast the field-magnets and frame in two parts. These parts are identical in size and shape, and each consists of the solid plates or ends A B, from which project inwardly the cores C D and the side bars or bridge-pieces, E F. The precise shape of these parts is largely a matter of choice—that is to say, each casting, as shown, forms an approximately-rectangular frame; but it may obviously be more or less oval, round, or square without departure from the invention. I also prefer to reduce the width of the side bars, E F, at the center and to so proportion the parts that when the frame is put together the spaces between the pole-pieces will be practically equal to the arcs which the surfaces of the poles occupy.

The bearings G for the armature-shaft are cast in the side bars, E F. The field-coils are either wound on the pole-pieces or, preferably, wound on a form and then slipped on over the ends of the pole-pieces. The lower part or casting is secured to a suitable base after being finished off. The armature K on its shaft is then mounted in the bearings of the lower casting and the other part of the frame placed in position, dowel-pins L or any other means being used to secure the two parts in proper position.

In order to secure an easier fit I cast the side bars, E F, and end pieces, A B, so that slots M are formed when the two parts are put together.

This machine possesses many advantages. For example, I magnetize the cores alternately, as indicated by the characters N S, and it will be seen that the magnetic circuit between the poles of each part of a casting is completed through the solid iron side bars. The bearings for the shaft are located at the neutral points of the field, so that the armature-core is not affected by the magnetic condition of the field.

My improvement is not restricted to the use of four pole-pieces, as it is evident that each pole-piece could be divided or more than four formed by the shape of the casting.

What I claim is—

1. A dynamo or magneto electric machine or motor the frame of which is built up of two castings, each consisting of end plates with pole-pieces extending inwardly therefrom and connecting side bars, as set forth.

2. A frame for generators or motors built up of two superposed castings, each consisting of a rectangular frame with pole-pieces extending inwardly from its ends, as set forth.

3. A frame and field-magnet for generators and motors built up of two rectangular castings having pole-pieces extending inwardly from their ends, the faces of said pole-pieces being curved to afford clearance for the armature and provided with energizing-coils, as set forth.

NIKOLA TESLA.

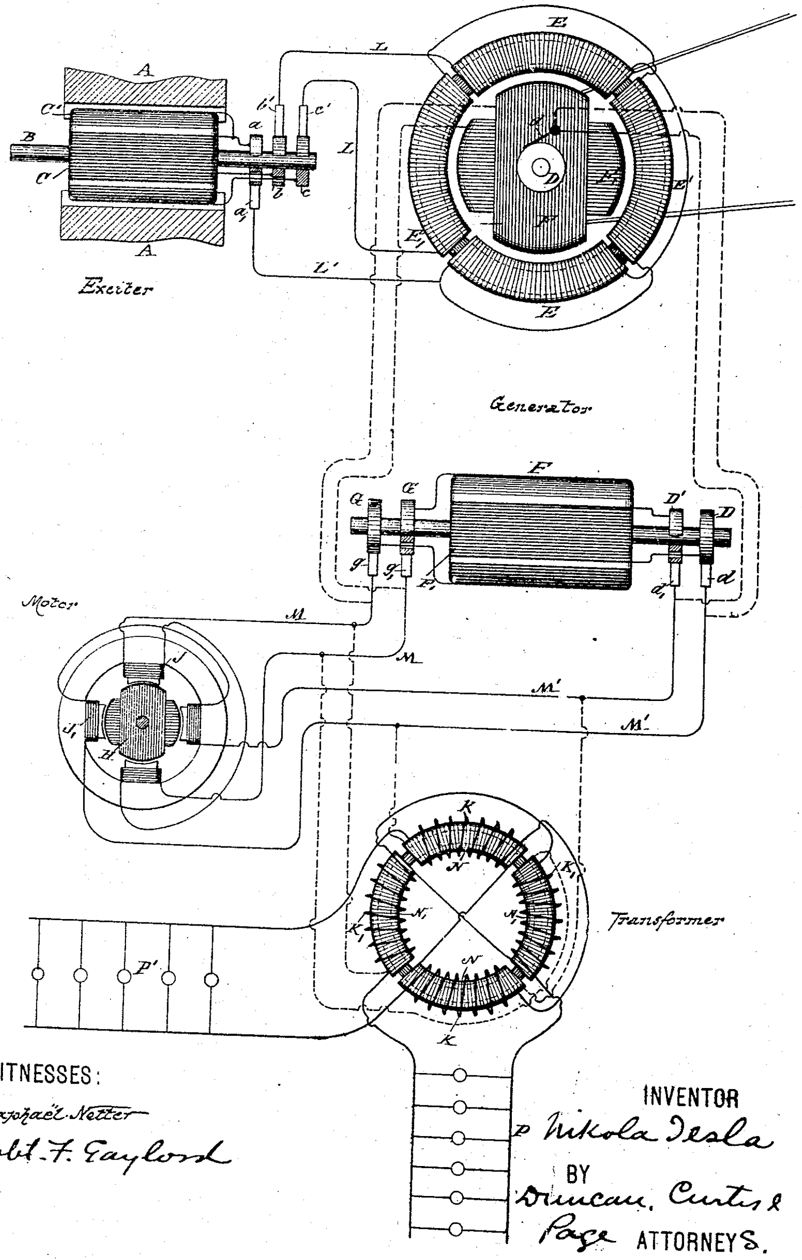
Witnesses:
ROBT. F. GAYLORD,
FRANK E. HARTLEY.

(No Model.)

N. TESLA.

DYNAMO ELECTRIC MACHINE.

No. 390,721. Patented Oct. 9, 1888.



WITNESSES:

Raphaël Netter

Robt. F. Gaylord

INVENTOR

Nikola Tesla

BY

Duncan, Curtis & Page ATTORNEYS.

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y., ASSIGNOR TO THE TESLA ELECTRIC COMPANY, OF SAME PLACE.

DYNAMO-ELECTRIC MACHINE.

SPECIFICATION forming part of Letters Patent No. 390,721, dated October 9, 1888.

Application filed April 28, 1888. Serial No. 272,153. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a subject of the Emperor of Austria, from Smiljan, Lika, border country of Austria-Hungary, now residing at New York, in the county and State of New York, have invented certain new and useful Improvements in Electric Generators, of which the following is a specification, reference being had to the drawing accompanying and forming a part of the same.

My present invention relates, chiefly, to the alternating-current system invented by me and described in prior patents, notably Nos. 381,968 and 382,280, of May 1, 1888, in which the motors or transformers, or generally the converters, are operated by a progressive shifting or movement of their magnetic poles produced by the co-operative action of independent magnetizing-coils through which pass alternating currents in proper order and direction. In my said system, as I have heretofore shown, I employed a generator of alternating currents in which there were independent induced or generating coils corresponding to the energizing-coils of the converter, and the relations of the generator and converters were generally such that the speed of rotation of the magnetic poles of the converter equaled that of the armature of the generator.

To secure the greatest efficiency, it is necessary to run the machines at a high speed, and this is true not only of those generators and motors which are particularly adapted for use in my system, but of others. The practicability of running at very high speeds, however, particularly in the case of large generators, is limited by mechanical conditions, in seeking to avoid which I have devised various plans for operating the system under efficient conditions, although running the generator at a comparatively low rate of speed.

My present invention consists of another way of accomplishing this result, which in certain respects presents many advantages. According to the invention, in lieu of driving the armature of the generator at a high rate of speed, I produce a rotation of the magnetic poles of one element of the generator and drive the other at a different speed, by which similar results are obtained to those secured by a rapid rotation of one of the elements.

I shall describe this invention by reference to the diagram drawing hereto annexed.

The generator which supplies the current for operating the motors or transformers consists in this instance of a subdivided ring or annular core wound with four diametrically-opposite coils, E E'. Within the ring is mounted a cylindrical armature-core wound longitudinally with two independent coils, F F', the ends of which lead, respectively, to two pairs of insulated contact or collecting rings, D D' G G', on the armature-shaft. Collecting-brushes *d d' g g'* bear upon these rings, respectively, and convey the currents through the two independent line-circuits M M'. In the main line there may be included one or more motors or transformers, or both. If motors be used, they are constructed in accordance with my invention with independent coils or sets of coils J J', included, respectively, in the circuits M M'. These energizing-coils are wound on a ring or annular field or on pole-pieces thereon, and produce by the action of the alternating currents passing through them a progressive shifting of the magnetism from pole to pole. The cylindrical armature H of the motor is wound with two coils at right angles, which form independent closed circuits.

If transformers be employed, I connect one set of the primary coils, as N N, wound on a ring or annular core, to one circuit, as M', and the other primary coils, N' N', to the circuit M. The secondary coils K K' may then be utilized for running groups of incandescent lamps P P'.

With the generator I employ an exciter. This consists of two poles, A A, of steel permanently magnetized, or of iron excited by a battery or other generator of continuous currents, and a cylindrical armature-core mounted on a shaft, B, and wound with two longitudinal coils, C C'. One end of each of these coils is connected to the collecting-rings *b c*, respectively, while the other ends are both connected to a ring, *a*. Collecting-brushes *b' c'* bear on the rings *b c*, respectively, and conductors L L convey the currents therefrom through the coils E and E' of the generator. L' is a common return-wire to brush *a'*. Two independent circuits are thus formed, one including coils C of the exciter and E E of the generator, the other coils C' of the exciter and E' E' of the generator. It results from this that the operation of the exciter produces a progressive movement of the magnetic poles of the annular field-core of the generator, the shifting or rotary movement of said poles being synchronous with the rotation of the exciter-armature. Considering the operative conditions of a system thus established, it will be found that when the exciter is driven so as to energize the field of the generator the armature of the latter, if left free to turn, would rotate at a speed practically the same as that of the exciter. If under such conditions the coils F F' of the generator-armature be closed upon themselves or short-circuited, no currents, at least theoretically, will be generated in the said armature-coils. In practice I have observed the presence of slight currents, the existence of which is attributable to more or less pronounced fluctuations in the intensity of the magnetic poles of the generator-ring. So, if the armature-coils F F' be closed through the motor, the latter will not be turned as long as the movement of the generator-armature is synchronous with that of the exciter or of the magnetic poles of its field. If, on the contrary, the speed of the generator-armature be in any way checked, so that the shifting or rotation of the poles of the field becomes relatively more rapid, currents will be induced in the armature-coils. This obviously follows from the passing of the lines of force across the armature-conductors. The greater the speed of rotation of the magnetic poles relatively to that of the armature the more rapidly the currents developed in the coils of the latter will follow one another, and the more rapidly the motor will revolve in response thereto, and this continues until the armature-generator is stopped entirely, as by a brake, when the motor, if properly constructed, runs at the same speed with which the magnetic poles of the generator rotate.

The effective strength of the currents developed in the armature-coils of the generator is dependent upon the strength of the currents energizing the generator and upon the number of rotations per unit of time of the magnetic poles of the generator; hence the speed of the motor-armature will depend in all cases upon the relative speeds of the armature of the generator and of its magnetic poles. For example, if the poles are turned two thousand times per unit of time and the armature is turned eight hundred, the motor will turn twelve hundred times, or nearly so. Very slight differences of speed may be indicated by a delicately-balanced motor.

Let it now be assumed that power is applied to the generator-armature to turn it in a direction opposite to that in which its magnetic poles rotate. In such case the result would be similar to that produced by a generator the armature and field-magnets of which are rotated in opposite directions, and by reason of these conditions the motor-armature will turn at a rate of speed equal to the sum of the speeds of the armature and magnetic poles of the generator, so that a comparatively low speed of the generator-armature will produce a high speed in the motor.

It will be observed in connection with this system that on diminishing the resistance of the external circuit of the generator-armature by checking the speed of the motor or by adding translating devices in multiple arc in the secondary circuit or circuits of the transformer the strength of the current in the armature-circuit is greatly increased. This is due to two causes: first, to the great differences in the speeds of the motor and generator, and, secondly, to the fact that the apparatus follows the analogy of a transformer, for, in proportion as the resistance of the armature or secondary circuits is reduced, the strength of the currents in the field or primary circuits of the generator is increased and the currents in the armature augmented correspondingly. For similar reasons the currents in the armature-coils of the generator increase very rapidly when the speed of the armature is reduced when running in the same direction as the magnetic poles or conversely.

It will be understood from the above description that the generator-armature may be run in the direction of the shifting of the magnetic poles, but more rapidly, and that in such case the speed of the motor will be equal to the difference between the two rates.

In many applications to electrical conversion and distribution this system possesses great advantages both in economy, efficiency, and practicability.

What I claim is—

1. The combination, with an alternating-current generator having independent energizing or field and independent induced or armature coils, of an alternating-current exciter having generating or induced coils corresponding to and connected with the energizing-coils of the generator, as set forth.

2. In an alternating-current generator, the combination of the elements named and co-operatively associated in the following manner: a field-magnet wound with independent coils each connected with a source of alternating currents, whereby the magnetic poles produced by said coils will be progressively shifted or moved through the field, and an armature-core wound with independent coils, each having terminals from which currents are delivered to the independent external circuits.

3. The system of electrical distribution consisting of the combination, with an alternating-current generator having independent energizing-coils and an armature wound with independent induced coils, of an alternating-current exciter having induced coils corresponding to and connected with the energizing-coils of the generator, and one or more electrical converters having independent inducing or energizing coils connected with the corre-

sponding armature coils of the generator, as herein set forth.

4. The combination, with an alternating-current generator having a field-magnet wound with independent energizing-coils and an armature adapted to be rotated within the field produced by said magnet, of an exciter having induced or generating coils corresponding to and connected with the energizing-coils of the generator, as set forth.

NIKOLA TESLA.

Witnesses:
ROBT. F. GAYLORD,
PARKER W. PAGE.

(No Model.)

2 Sheets—Sheet 1.

N. TESLA.

REGULATOR FOR ALTERNATE CURRENT MOTORS.

No. 390,820. Patented Oct. 9, 1888.

Fig. 2

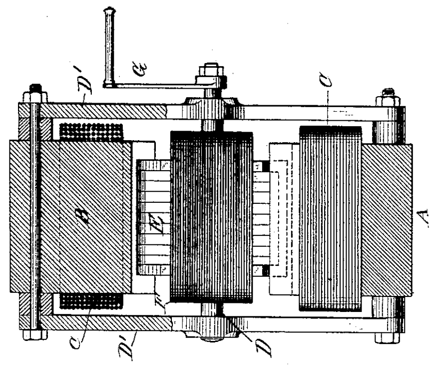
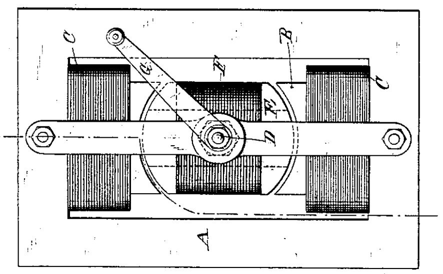


Fig. 1



WITNESSES:

Raphaël Netter,

Robt. F. Gaylord

INVENTOR.

Nikola Tesla

BY

Duncan, Curtis & Page.

ATTORNEYS,

(No Model.)

2 Sheets—Sheet 2.

N. TESLA.

REGULATOR FOR ALTERNATE CURRENT MOTORS.

No. 390,820. Patented Oct. 9, 1888.

Fig. 3

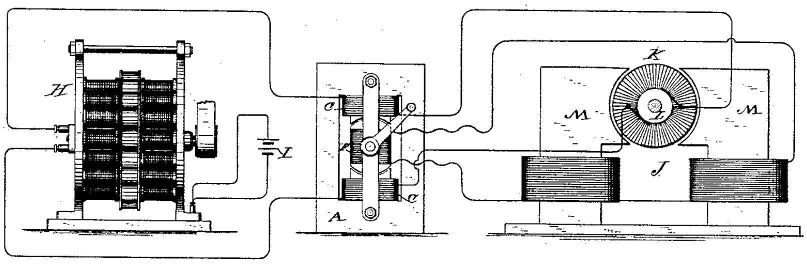
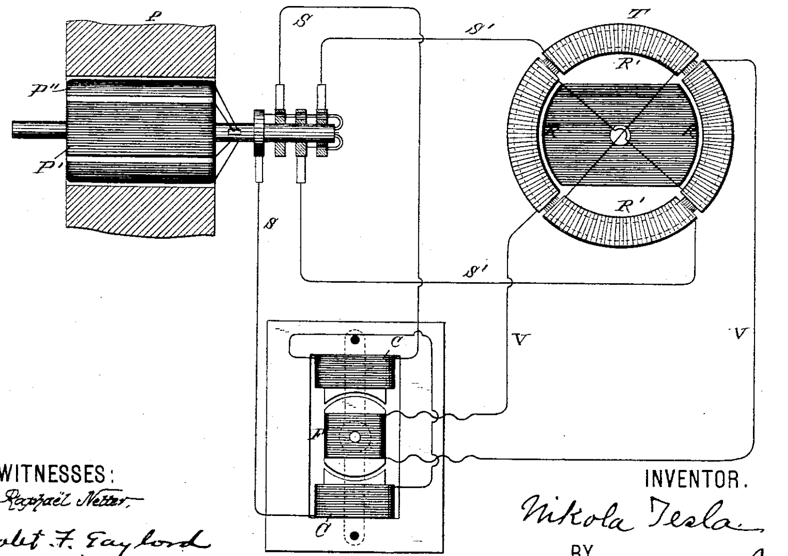


Fig. 4



WITNESSES:

Raphaël Netter.

Robt. F. Gaylord

INVENTOR.

Nikola Tesla

BY

Duncan, Curtis & Page.

ATTORNEYS.

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y., ASSIGNOR TO THE TESLA ELECTRIC COMPANY, OF SAME PLACE.

REGULATOR FOR ALTERNATE-CURRENT MOTORS.

SPECIFICATION forming part of Letters Patent No. 390,820, dated October 9, 1888.

Application filed April 24, 1888. Serial No. 271,682. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a subject of the Emperor of Austria, from Smiljan, Lika, border country of Austria-Hungary, now residing in New York, in the county and State of New York, have invented certain new and useful Improvements in Regulators for Alternating-Current Motors, of which the following is a specification, reference being had to the drawings accompanying and forming part of the same.

My invention is an improvement in systems for the electric transmission of power; and it consists in a means of regulating the speed and power of the motor or motors. The system for use with which the invention is more particularly designed is one in which the motors, or what may be in certain cases their equivalents—the electrical transformers—have two or more independent energizing-circuits, which, receiving current from corresponding sources, act to set up a progressive movement or shifting of the magnetic poles of the motors; but the invention is also applicable to other purposes, as will hereinafter appear. I employ the regulator for the purpose of varying the speed of these motors.

The regulator proper consists of a form of converter or transformer with one element capable of movement with respect to the other, whereby the inductive relations may be altered, either manually or automatically, for the purpose of varying the strength of the induced current. I prefer to construct this device in such manner that the induced or secondary element may be movable with respect to the other; and the improvement, so far as relates merely to the construction of the device itself, consists, essentially, in the combination, with two opposite magnetic poles, of an armature wound with an insulated coil and mounted on a shaft, whereby it may be turned to the desired extent within the field produced by the poles. The normal position of the core of the secondary element is that in which it most completely closes the magnetic circuit between the poles of the primary element, and in this position its coil is in its most effective position for the inductive action upon it of the primary coils; but by turning the movable core to either side the induced currents delivered by its coil become weaker until, by a movement of the said core and coil through ninety degrees, there will be no current delivered.

The construction of this device, broadly, I do not claim as of my invention; but this, together with the manner of applying and using the same, which forms the subject of my invention, I will now explain by reference to the accompanying drawings.

Figure 1 is a view in side elevation of the regulator. Fig. 2 is a broken section on line *x x* of Fig. 1. Fig. 3 is a diagram illustrating the preferred manner of applying the regulator to ordinary forms of motors, and Fig. 4 is a similar diagram illustrating the application of the device to my improved alternating-current motors.

The regulator may be constructed in many ways to secure the desired result; but in the best form of which I am now aware it is shown in Figs. 1 and 2.

A represents a frame of iron, and I would here state that the plan which is now invariably followed of dividing up all iron cores which are subjected to the influence of alternating currents should be adopted in the construction of this device.

B B are the cores of the inducing or primary coils C C, said cores being integral with or bolted to the frame A in any well-known way.

D is a shaft mounted in the side bars, D′, and on which is secured a sectional iron core, E, wound with an induced or secondary coil, F, the convolutions of which are parallel with the axis of the shaft. The ends of the core are rounded off, so as to fit closely in the space between the two poles and permit the core E to be turned. A handle, G, secured to the projecting end of the shaft D, is provided for this purpose.

Any means may be employed for maintaining the core and secondary coil in any given position to which it is turned by the handle.

The operation or effect of the device will be understood by reference to the diagrams illustrating the manner of its application.

In Fig. 3, let H represent an ordinary alternating-current generator, the field-magnets of which are excited by a suitable source of current, I. Let J designate an ordinary form of electro-magnetic motor provided with an armature, K, commutator L, and field-magnets M. It is well known that such a motor, if its field-magnets' cores be divided up into insulated sections, may be practically operated by an alternating current; but in using my regulator with such a motor I include one element of the motor only—say the armature-coils—in the main circuit of the generator, making the connections through the brushes and the commutator in the usual way. I also include one of the elements of the regulator—say the stationary coils—in the same circuit, and in the circuit with the secondary or movable coil of the regulator I connect up the field-coils of the motor. I prefer to use flexible conductors to make the connections from the secondary coil of the regulator, as I thereby avoid the use of sliding contacts or rings without interfering with the requisite movement of the core E.

If the regulator be in its normal position, or that in which its magnetic circuit is most nearly closed, it delivers its maximum induced current, the phases of which so correspond with those of the primary current that the motor will run as though both field and armature were excited by the main current.

To vary the speed of the motor to any rate between the minimum and maximum rates, the core E and coils F are turned in either direction to an extent which produces the desired result, for in its normal position the convolutions of coil F embrace the maximum number of lines of force, all of which act with the same effect upon said coil; hence it will deliver its maximum current; but by turning the coil F out of its position of maximum effect the number of lines of force embraced by it is diminished. The inductive effect is therefore impaired, and the current delivered by coil F will continue to diminish in proportion to the angle at which the coil F is turned until, after passing through an angle of ninety degrees, the convolutions of the coil will be at right angles to those of coils C C, and the inductive effect reduced to a minimum.

Incidentally to certain constructions, other causes may influence the variation in the strength of the induced currents. For example, in the present case it will be observed that by the first movement of coil F a certain portion of its convolutions are carried beyond the line of the direct influence of the lines of force, and that the magnetic path or circuit for said lines is impaired; hence the inductive effect would be reduced. Next, that after moving through a certain angle, which is obviously determined by the relative dimensions of the bobbin or coil F, diagonally-opposite portions of the coil will be simultaneously included in the field, but in such positions that the lines which produce a current-impulse in one portion of the coil in a certain direction will produce in the diagonally-opposite portion a corresponding impulse in the opposite direction; hence portions of the current will neutralize one another.

As before stated, the mechanical construction of the device may be greatly varied; but the essential conditions of the invention will be fulfilled in any apparatus in which the movement of the elements with respect to one another effects the same results by varying the inductive relations of the two elements in a manner similar to that described.

It may also be stated that the core E is not indispensable to the operation of the regulator; but its presence is obviously beneficial. This regulator, however, has another valuable property in its capability of reversing the motor, for if the coil F be turned through a half-revolution the position of its convolutions relatively to the two coils C C and the lines of force is reversed, and consequently the phases of the current will be reversed. This will produce a rotation of the motor in an opposite direction. This form of regulator is also applied with great advantage to my system of utilizing alternating currents, in which the magnetic poles of the field of a motor are progressively shifted by means of the combined effects upon the field of magnetizing-coils included in independent circuits, through which pass alternating currents in proper order and relations to each other.

In illustration, let P represent one of my generators having two independent coils, P′ and P″, on the armature, and T a diagram of a motor having two independent energizing-coils or sets of coils, R R′. One of the circuits from the generator, as S′ S′, includes one set, R′ R′, of the energizing-coils of the motor, while the other circuit, as S S, includes the primary coils of the regulator. The secondary coil of the regulator includes the other coils, R R, of the motor.

While the secondary coil of the regulator is in its normal position it produces its maximum current, and the maximum rotary effect is imparted to the motor; but this effect will be diminished in proportion to the angle at which the coil F of the regulator is turned. The motor will also be reversed by reversing the position of the coil with reference to the coils C C, and thereby reversing the phases of the current produced by the generator. This changes the direction of the movement of the shifting poles which the armature follows.

One of the main advantages of this plan of regulation is its economy of power. When the induced coil is generating its maximum current, the maximum amount of energy in the primary coils is absorbed; but as the induced coil is turned from its normal position the self-induction of the primary coils reduces the expenditure of energy and saves power.

It is obvious that in practice either coils C C or coil F may be used as primary or secondary, and it is well understood that their relative proportions may be varied to produce any desired difference or similarity in the inducing and induced currents.

I am aware that it is not new to vary the secondary current of an induction-coil by moving one coil with respect to the other, and thereby varying the inductive relations normally existing between the two. This I do not claim.

What I claim is—

1. The combination, with a motor having independent energizing-circuits, of an alternating-current regulator, consisting, essentially, of inducing and induced coils movable with respect to one another, whereby the strength of the induced currents may be varied, the induced coils being included in and adapted to supply the current for one of the motor-circuits, as set forth.

2. The combination, with a motor adapted to be run or operated by alternating currents and provided with independent energizing-coils, of a regulator consisting of stationary inducing-coils and an induced coil capable of being rotated, whereby it may be turned to a greater or less angle to the primary coils, or its position with respect thereto reversed, the induced coil or coils being included in and adapted to supply the current for one of the motor-circuits, as set forth.

NIKOLA TESLA.

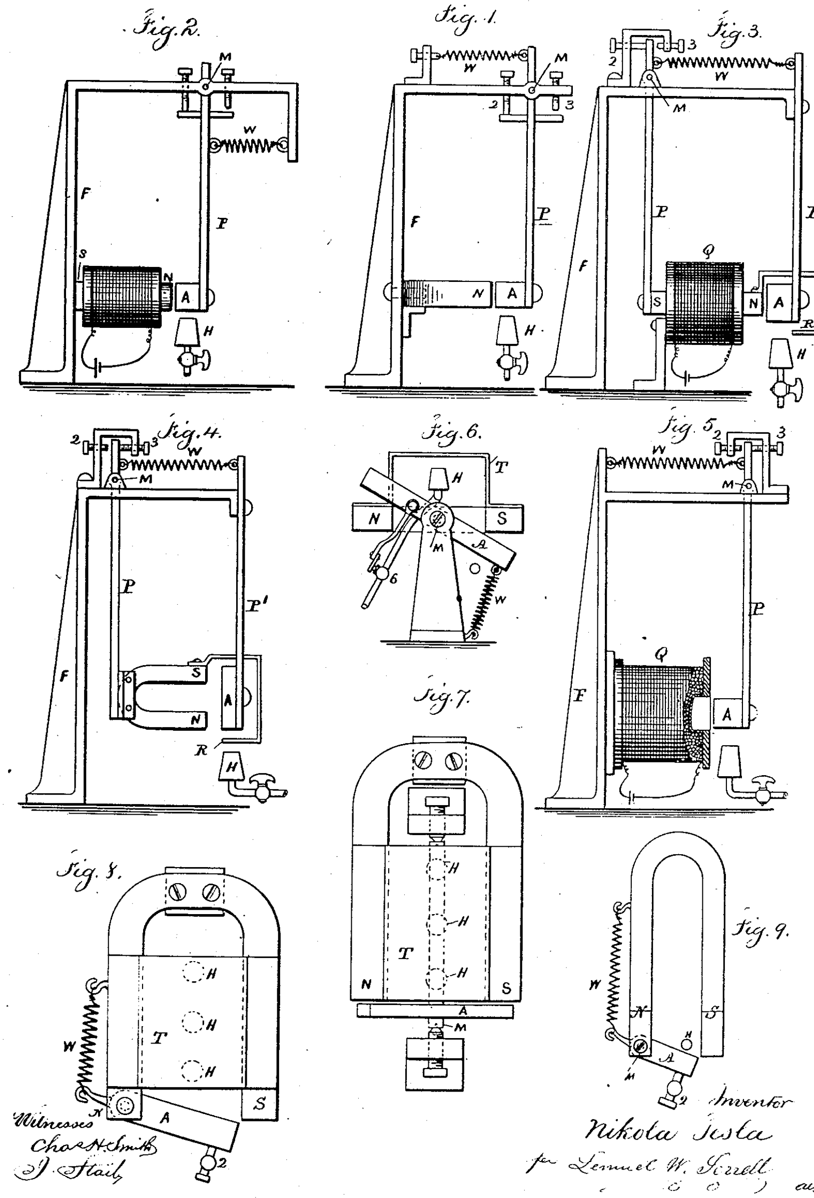
Witnesses:
ROBT. F. GAYLORD,
FRANK B. MURPHY.

(No Model.) BEST AVAILABLE COPY 2 Sheets—Sheet 1.

N. TESLA.

THERMO MAGNETIC MOTOR.

No. 396,121. Patented Jan. 15, 1889.



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(No Model.)

2 Sheets—Sheet 2.

N. TESLA.

THERMO MAGNETIC MOTOR.

No. 396,121. Patented Jan. 15, 1889.

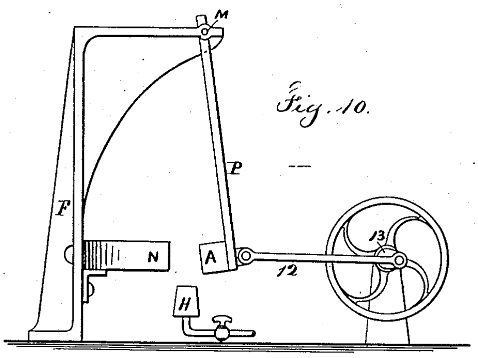


Fig. 10.

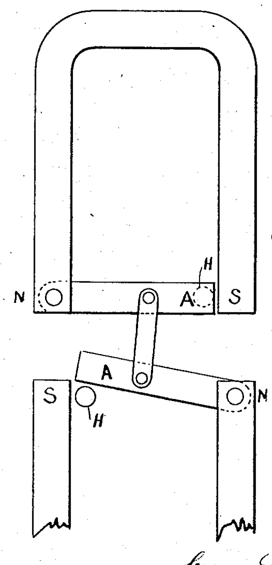


Fig. 11.

Witnesses
Chas H. Smith
J. Staib

Inventor
Nikola Tesla
per Lemuel W. Serrell atty

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF SMILJAN, LIKA, AUSTRIA-HUNGARY.

THERMO-MAGNETIC MOTOR.

SPECIFICATION forming part of Letters Patent No. 396,121, dated January 15, 1889.

Application filed March 30, 1886. Serial No. 197,115. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, of Smiljan, Lika, Border Country of Austria-Hungary, have invented an Improvement in Thermo-Magnetic Motors, of which the following is a specification.

It is well known that heat applied to a magnetized body will lessen the magnetism, and if the temperature is raised sufficiently the magnetism will be neutralized or destroyed.

In my present invention I obtain mechanical power by a reciprocating action resulting from the joint operations of heat, magnetism, and a spring or weight or other force—that is to say, I subject a body magnetized by induction or otherwise to the action of heat until the magnetism is sufficiently neutralized to allow a weight or spring to give motion to the body and lessen the action of the heat, so that the magnetism may be sufficiently restored to move the body in the opposite direction, and again subject the same to the demagnetizing of the heat.

In carrying out my invention I am able to make use of either an electro-magnet or a permanent magnet, and I preferably direct the heat against a body that is magnetized by induction, rather than directly against a permanent magnet, thereby avoiding the loss of magnetism that might result in the permanent magnet by the action of heat. I also provide for lessening the volume of the heat or for intercepting the same during that portion of the reciprocation in which the cooling action takes place.

In the drawings I have represented by diagrams some of the numerous arrangements that may be made use of in carrying out my invention. In all of these figures the magnet-poles are marked N S, the armature A, the Bunsen burner or other source of heat H, the axis of motion M, and the spring or the equivalent thereof—namely, a weight—is marked W.

In Figure 1 the permanent magnet N is connected with a frame, F, supporting the axis M, from which the arm P hangs, and at the lower end of which the armature A is supported. The stops 2 and 3 limit the extent of motion, and the spring W tends to draw the armature A away from the magnet N. It is now to be understood that the magnetism of N is sufficient to overcome the spring W and draw the armature A toward the magnet N. The heat acting upon the armature A neutralizes its induced magnetism sufficiently for the spring W to draw the armature A away from the magnet N and also from the heat at H. The armature now cools, and the attraction of the magnet N overcomes the spring W and draws the armature A back again above the burner H, so that the same is again heated and the operations are repeated. The reciprocating mvements thus obtained are employed as a source of mechanical power in any desired manner. Usually a connecting-rod to a crank upon a fly-wheel shaft will be made use of, as indicated in Fig. 10; but I do not limit myself in this respect.

Fig. 2 represents the same parts as before described; but an electro-magnet is illustrated in place of a permanent magnet. The operations, however, are the same.

In Fig. 3 I have shown the same parts as in Figs. 1 and 2, only they are differently arranged. The armature A, instead of swinging, is stationary and held by an arm, P', and the core N S of the electro-magnet is made to swing within the helix Q, the said core being suspended by the arm P from the pivot M. A shield, R, is connected with the magnet-core and swings therewith, so that after the heat has demagnetized the armature A to such an extent that the spring W draws the core N S away from the armature A the shield R comes between the flame H and armature A, thereby intercepting the action of the heat and allowing the armature to cool, so that the magnetism, again preponderating, causes the movement of the core N S toward the armature A and the removal of the shield R from above the flame, so that the heat again acts to lessen or neutralize the magnetism. A rotary or other movement may be obtained from this reciprocation.

Fig. 4 corresponds in every respect with Fig. 3, except that a permanent horseshoe-magnet, N S, is represented as taking the place of the electro-magnet in said Fig. 3.

In Fig. 5 I have shown a helix, Q, with an armature adapted to swing toward or from the helix. In this case there may be a soft-iron core in the helix, or the armature may assume the form of a solenoid-core, there being no permanent core within the helix.

Fig. 6 is an end view, and Fig. 7 a plan view, illustrating my improvement as applied to a swinging armature, A, and a stationary permanent magnet, N S. In this instance I apply the heat to an auxiliary armature or keeper, T, which is adjacent to and preferably in direct contact with the magnet. This armature T, in the form of a plate of sheet-iron, extends across from one pole to the other and is of sufficient section to practically form a keeper for the magnet, so that when this armature T is cool nearly all the lines of force pass over the same and very little free magnetism is exhibited. Then the armature A, which swings freely on the pivots M in front of the poles N S, is very little attracted and the spring s pulls the same away from the poles into the position indicated in the drawings. The heat is directed upon the iron plate T at some distance from the magnet, so as to allow the magnet to be kept comparatively cool. This heat is applied beneath the plate by means of the burners H, and there is a connection from the armature A or its pivot to the gas-cock 6 or other device for regulating the heat. The heat acting upon the middle portion of the plate T, the magnetic conductivity of the heated portion is diminished or destroyed, and a great number of the lines of force are deflected over the armature A, which is now powerfully attracted and drawn into line, or nearly so, with the poles N S. In so doing the cock 6 is nearly closed and the plate T cools, the lines of force are again deflected over the same, the attraction exerted upon the armature A is diminished, and the spring W pulls the same away from the magnet into the position shown by full lines, and the operations are repeated. The arrangement shown in Fig. 6 has the advantages that the magnet and armature are kept cool and the strength of the permanent magnet is better preserved, as the magnetic circuit is constantly closed.

In the plan view, Fig. 8, I have shown a permanent magnet and keeper-plate, T, similar to those in Figs. 6 and 7, with the burners H for the gas beneath the same; but the armature is pivoted at one end to one pole of the magnet and the other end swings toward and from the other pole of the magnet. The spring W acts against a lever-arm that projects from the armature, and the supply of heat has to be partly cut off by a connection to the swinging armature, so as to lessen the heat acting upon the keeper-plate when the armature A has been attracted.

Fig. 9 is similar to Fig. 8, except that the keeper T is not made use of and the armature itself swings into and out of the range of the intense action of the heat from the burner H.

Fig. 10 is a diagram similar to Fig. 1, except that in place of using a spring and stops the armature is shown as connected by a link, 12, to the crank 13 of a fly-wheel, so that the fly-wheel will be revolved as rapidly as the armature can be heated and cooled to the necessary extent. A spring may be used in addition, as in Fig. 1.

In Fig. 11 the two armatures A A are connected by a link, so that one will be heating while the other is cooling, and the attraction exerted to move the cooled armature is availed of to draw away the heated armature instead of using a spring.

I have shown in the drawings several ways of carrying out my invention; but said invention is not limited by any particular form, arrangement, or construction of devices.

I claim as my invention—

1. The combination, with a swinging body under the influence of magnetism, of a burner or other source of heat acting to vary the magnetism, and a spring or other power to move the swinging body in the opposite direction to the action of the magnetism, substantially as set forth.

2. The combination, with two or more armatures connected to each other, of magnets to influence such armatures, and burners or other sources of heat to vary the magnetic action and cause the armatures to move, substantially as set forth.

Signed by me this 29th day of March, 1886.

NIKOLA TESLA.

Witnesses:

GEO. T. PINCKNEY,

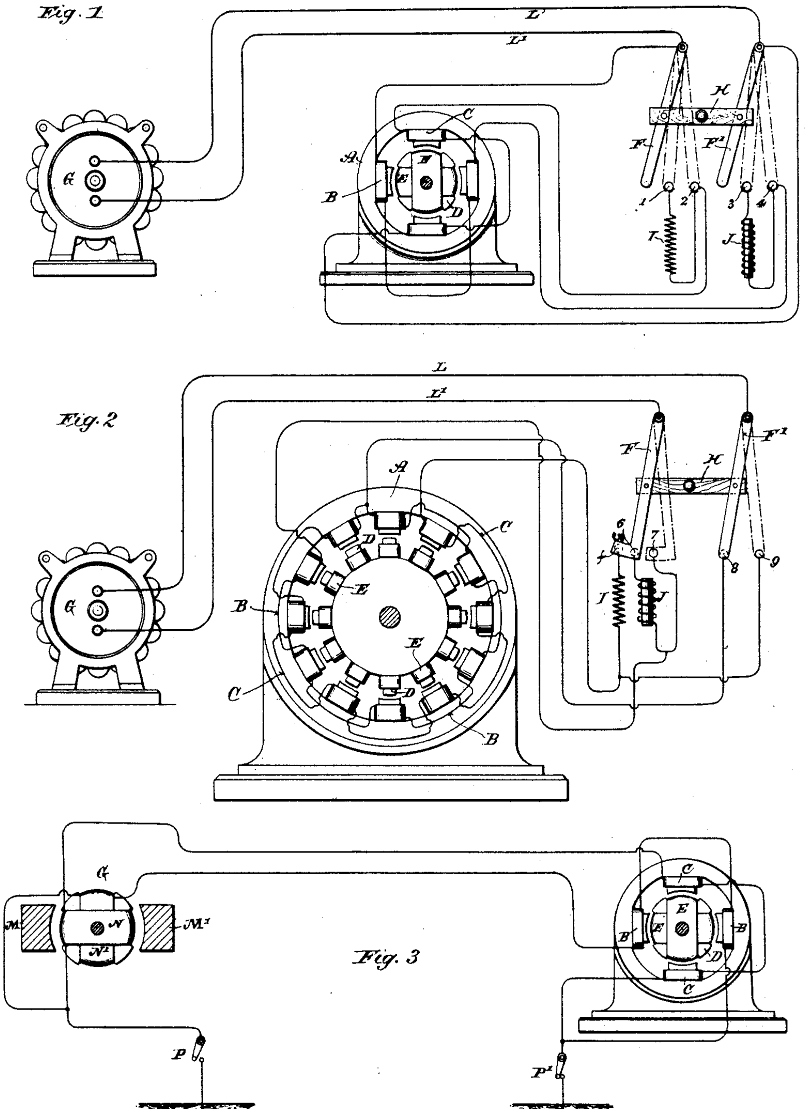
WALLACE L. SERRELL.

(No Model.)

N. TESLA.

METHOD OF OPERATING ELECTRO MAGNETIC MOTORS.

No. 401,520. Patented Apr. 16, 1889.



Witnesses:
Raphael Netter
Ernest Hopkinson

Inventor,
Nikola Tesla
by
Duncan, Curtis & Page.
Attorneys.

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y.

METHOD OF OPERATING ELECTRO-MAGNETIC MOTORS.

SPECIFICATION forming part of Letters Patent No. 401,520, dated April 16, 1889.

Application filed February 18, 1889. Serial No. 300,220. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a subject of the Emperor of Austria, from Smiljan, Lika, border country of Austria-Hungary, and residing at New York, in the county and State of New York, have invented certain new and useful Improvements in Methods of Operating Electro-Magnetic Motors, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

As is well known, certain forms of alternating-current machines have the property, when connected in circuit with an alternating-current generator, of running as a motor in synchronism therewith; but, while the alternating current will run the motor after it has attained a rate of speed synchronous with that of the generator, it will not start it. Hence, in all instances heretofore where these "synchronizing-motors," as they are termed, have been run some means have been adopted to bring the motors up to synchronism with the generator, or approximately so, before the alternating current of the generator is applied to drive them. In some instances mechanical appliances have been utilized for this purpose. In others special and complicated forms of motor have been constructed. I have discovered a much more simple method or plan of operating synchronizing-motors, which requires practically no other apparatus than the motor itself. In other words, by a certain change in the circuit-connections of the motor I convert it at will from a double-circuit motor, or such as I have described in prior patents and applications, and which will start under the action of an alternating current into a synchronizing-motor, or one which will be run by the generator only when it has reached a certain speed of rotation synchronous with that of the generator. In this manner I am enabled to very greatly extend the applications of my system and to secure all the advantages of both forms of alternating-current motor.

The expression "synchronous with that of the generator," is used herein in its ordinary acceptation—that is to say, a motor is said to synchronize with the generator when it preserves a certain relative speed determined by its number of poles and the number of alternations produced per revolution of the generator. Its actual speed, therefore, may be faster or slower than that of the generator; but it is said to be synchronous so long as it preserves the same relative speed.

In carrying out my invention I construct a motor which has a strong tendency to synchronism with the generator. The construction which I prefer for this is that in which the armature is provided with polar projections. The field-magnets are wound with two sets of coils, the terminals of which are connected to a switch mechanism, by means of which the line-current may be carried directly through the said coils or indirectly through paths by which its phases are modified. To start such a motor, the switch is turned onto a set of contacts which includes in one motor-circuit a dead resistance, in the other an inductive resistance, and, the two circuits being in derivation, it is obvious that the difference in phase of the current in such circuits will set up a rotation of the motor. When the speed of the motor has thus been brought to the desired rate, the switch is shifted to throw the main current directly through the motor-circuits, and although the currents in both circuits will now be of the same phase the motor will continue to revolve, becoming a true synchronous motor. To secure greater efficiency, I wind the armature or its polar projections with coils closed on themselves. There are various modifications and important features of this method or plan; but the main principle of the invention will be understood from the foregoing.

In the drawings, to which I now refer, I have illustrated by the diagrams the general features of construction and operation which distinguish my invention, Figure 1 being drawn to illustrate the details of the plan above set forth, and Figs. 2 and 3 modifications of the same.

Referring to Fig. 1, let A designate the field-magnets of a motor, the polar projections of which are wound with coils B C included in independent circuits, and D the armature with polar projections wound with coils E closed upon themselves, the motor in these respects being similar in construction to those described in my patent, No. 382,279, dated May 1, 1888, but having, by reason of the polar projections on the armature-core or other similar and well-known features, the properties of a synchronizing-motor.

L L′ represent the conductors of a line from an alternating-current generator G.

Near the motor is placed a switch the action of which is that of the one shown in the drawings, which is constructed as follows: F F′ are two conducting plates or arms, pivoted at their ends and connected by an insulating cross-bar, H, so as to be shifted in parallelism. In the path of the bars F F′ is the contact 2, which forms one terminal of the circuit through coils C, and the contact 4, which is one terminal of the circuit through coils B. The opposite end of the wire of coils C is connected to the wire L or bar F′, and the corresponding end of coils B is connected to wire L′ and bar F; hence if the bars be shifted so as to bear on contacts 2 and 4 both sets of coils B C will be included in the circuit L L′ in multiple arc or derivation. In the path of the levers F F′ are two other contact-terminals, 1 and 3. The contact 1 is connected to contact 2 through an artificial resistance, I, and contact 3 with contact 4 through a self-induction coil, J, so that when the switch-levers are shifted onto the points 1 and 3 the circuits of coils B and C will be connected in multiple arc or derivation to the circuit L L′, and will include the resistance and self-induction coil, respectively. A third position of the switch is that in which the levers F and F′ are shifted out of contact with both sets of points. In this case the motor is entirely out of circuit.

The purpose and manner of operating the motor by these devices are as follows: The normal position of the switch, the motor being out of circuit, is off the contact-points. Assuming the generator to be running, and that it is desired to start the motor, the switch is shifted until its levers rest upon points 1 and 3. The two motor-circuits are thus connected with the generator-circuit; but by reason of the presence of the resistance I in one and the self-induction coil J in the other the coincidence of the phases of the current is disturbed sufficiently to produce a progression of the poles, which starts the motor in rotation. When the speed of the motor has run up to synchronism with the generator, or approximately so, the switch is shifted over onto the points 2 and 4, thus cutting out the coils I and J, so that the currents in both circuits have the same phase; but the motor now runs as a synchronous motor, which is well known to be a very desirable and efficient means of converting and transmitting power.

It will be understood that when brought up to speed the motor will run with only one of the circuits B or C connected with the main or generator circuit, or the two circuits may be connected in series. This latter plan is preferable when a current having a high number of alternations per unit of time is employed to drive the motor. In such case the starting of the motor is more difficult and the dead and inductive resistances must take up a considerable proportion of the electro-motive force of the circuits. Generally I so adjust the conditions that the electro-motive force used in each of the motor-circuits is that which is required to operate the motor when its circuits are in series. The plan which I follow in this case is illustrated in Fig. 2. In this diagram the motor has twelve poles and the armature has polar projections D wound with closed coils E. The switch used is of substantially the same construction as that shown in the previous figure. There are, however, five contacts, which I have designated by the figures 5, 6, 7, 8, and 9. The motor-circuits B C, which include alternate field-coils, are connected to the terminals in the following order: One end of circuit C is connected to contact 9 and to contact 5 through a dead resistance, I. One terminal of circuit B is connected to contact 7 and to contact 6 through a self-induction coil, J. The opposite terminals of both circuits are connected to contact 8.

One of the levers, as F, of the switch is made with an extension, *f*, or otherwise, so as to cover both contacts 5 and 6 when shifted into the position to start the motor. It will be observed that when in this position and with lever F′ on contact 8 the current divides between the two circuits B C, which from their difference in electrical character produce a progression of the poles that starts the motor in rotation. When the motor has attained the proper speed, the switch is shifted so that the levers cover the contacts 7 and 9, thereby connecting circuits B and C in series. I have found that by this disposition the motor is maintained in rotation in synchronism with the generator. This principle of operation, which consists in converting by a change of connections or otherwise a double-circuit motor or one operating by a progressive shifting of the poles into an ordinary synchronizing-motor may be carried out in many other ways. For instance, instead of using the switch shown in the previous figures, I may use a temporary ground-circuit between the generator and motor, in order to start the motor, in substantially the manner indicated in Fig. 3. Let G in this figure represent an ordinary alternating-current generator with, say, two poles, M M′, and an armature wound with two coils, N N′, at right angles and connected in series. The motor has, for example, four poles wound with coils B C, which are connected in series and an armature with polar projections D wound with closed coils E E. From the common joint or union between the two circuits of both the generator and the motor an earth-connection is established, while the terminals or ends of the said circuits are connected to the line. Assuming that the motor is a synchronizing-motor or one that has the capability of running in synchronism with the generator, but not of starting, it may be started by the above-described apparatus by closing the ground-connection from both generator and motor. The system thus becomes one with a two-circuit generator and motor, the ground forming a common return for the currents in the two circuits L and L'. When by this arrangement of circuits the motor is brought to speed, the ground-connection is broken between the motor or generator, or both, and ground, switches P P' being employed for this purpose. The motor then runs as a synchronizing-motor.

In describing those features which constitute my invention I have omitted illustrations of the appliances used in conjunction with the electrical devices of similar systems—such, for instance, as driving-belts, fixed and loose pulleys for the motor, and the like; but these are matters well understood.

In describing my invention by reference to specific constructions I do not wish to be understood as limiting myself to the constructions shown; and in explanation of my intent in this respect I would say that I may in such forms of apparatus as I have shown in Figs. 1 and 2 include the dead resistance and self-induction coil in either circuit, or use only a dead resistance or a self-induction coil, as in the various ways shown in my application, No. 293,052, filed December 8, 1888. I may also use any form of switch, whether manual or automatic, that will by its manipulation or operation effect the required change of connections, and in order to secure the necessary difference of phase in the two motor-circuits on starting I may employ any of the known means for this purpose.

I believe that I am the first to operate electro-magnetic motors by alternating currents in any of the ways herein suggested or described—that is to say, by producing a progressive movement or rotation of their poles or points of greatest magnetic attraction by the alternating currents until they have reached a given speed, and then by the same currents producing a simple alternation of their poles, or, in other words, by a change in the order or character of the circuit-connections to convert a motor operating on one principle to one operating on another, for the purpose described.

I do not claim herein of itself the method of or apparatus for operating a motor which forms a part of this invention and which involves the principle of varying or modifying the currents passing through the energizing-circuits, so as to produce between such currents a difference of phase, as these matters are described and claimed by me in other applications, but with the object of securing, broadly, the method as a whole which I have herein set forth.

What I claim is—

1. The method of operating an alternating-current motor herein described by first progressively shifting or rotating its poles or points of greatest attraction and then, when the motor has attained a given speed, alternating the said poles, as described.

2. The method of operating an electro-magnetic motor herein described, which consists in passing through independent energizing-circuits of the motor alternating currents differing in phase and then, when the motor has attained a given speed, alternating currents coinciding in phase, as described.

3. The method of operating an electro-magnetic motor herein described, which consists in starting the motor by passing alternating currents differing in phase through independent energizing-circuits and then, when the motor has attained a given speed, joining the energizing-circuits in series and passing an alternating current through the same.

4. The method of operating a synchronizing-motor, which consists in passing an alternating current through independent energizing-circuits of the motor and introducing into such circuits a resistance and self-induction coil, whereby a difference of phase between the currents in the circuits will be obtained, and then, when the speed of the motor synchronizes with that of the generator, withdrawing the resistance and self-induction coil, as set forth.

NIKOLA TESLA.

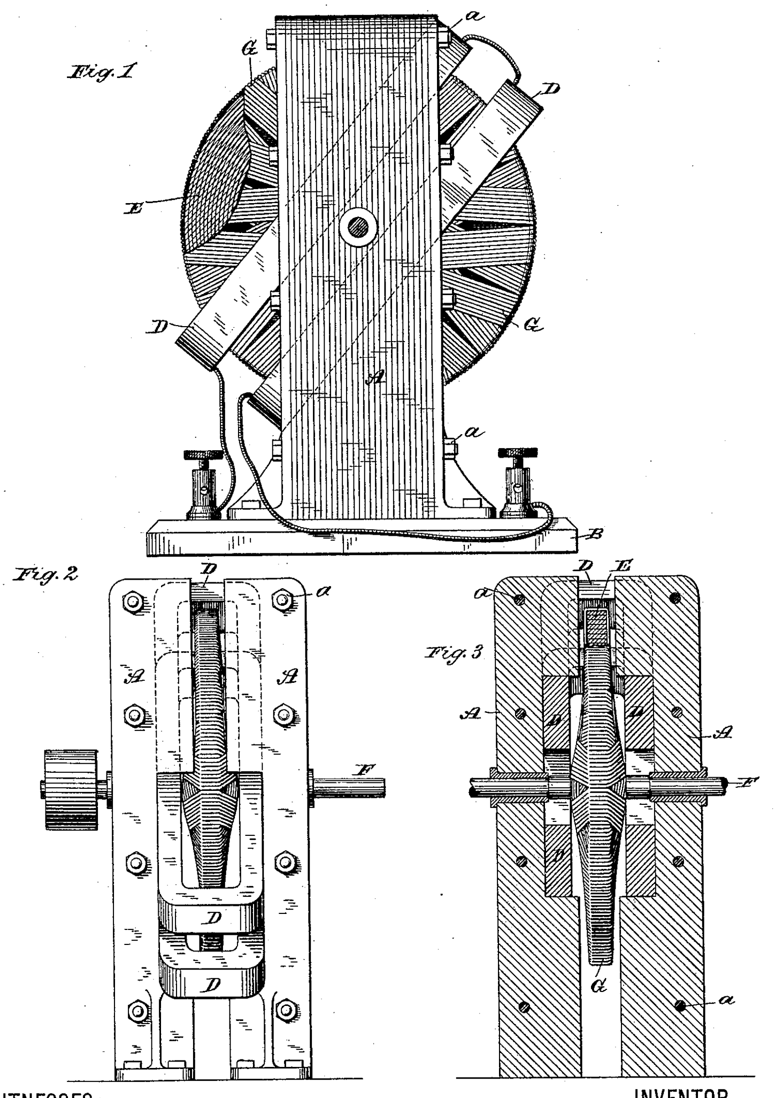
Witnesses:
GEO. M. MONRO,
WM. H. LEMON.

(No Model.)

N. TESLA.

ELECTRO MAGNETIC MOTOR.

No. 405,858. Patented June 25, 1889.



WITNESSES:

Raphael Netter

Robt. F. Gaylord

INVENTOR

Nikola Tesla

BY

Duncan, Curtis & Page

ATTORNEYS.

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y., ASSIGNOR TO THE TESLA ELECTRIC COMPANY, OF SAME PLACE.

ELECTRO-MAGNETIC MOTOR.

SPECIFICATION forming part of Letters Patent No. 405,858, dated June 25, 1889.

Application filed January 8, 1889. Serial No. 295,745. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, from Smiljan, Lika, border country of Austria-Hungary, a subject of the Emperor of Austria, residing at New York, in the county and State of New York, have invented certain new and useful Improvements in Electro-Magnetic Motors, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

In order to define more clearly the relations which the motor forming the subject of my present application bears to others of the class to which it pertains, I will recapitulate briefly the forms of alternating-current motors invented by me and described more in detail in my prior patents and applications. Of these there are two principal types or forms: first, those containing two or more energizing-circuits through which are caused to pass alternating currents differing from one another in phase to an extent sufficient to produce a continuous progression or shifting of the poles or points of greatest magnetic effect, in obedience to which the movable element of the motor is maintained in rotation; second, those containing poles or parts of different magnetic susceptibility, which under the energizing influence of the same current or two currents coinciding in phase will exhibit differences in their magnetic periods or phases. In the first class of motors the torque is due to the magnetism established in different portions of the motor by currents from the same or from independent sources, and exhibiting time differences in phase. In the second class the torque results from the energizing effects of a current upon parts of the motor which differ in magnetic susceptibility—in other words, parts which respond to the same relative degree to the action of a current, not simultaneously, but after different intervals of time. In my present invention, however, the torque, instead of being solely the result of a time difference in the magnetic periods or phases of the poles or attractive parts to whatever cause due, is produced by an angular displacement of the parts which, though movable with respect to one another, are magnetized simultaneously, or approximately so, by the same currents. This principle of operation I have embodied practically in a motor in which I obtain the necessary angular displacement between the points of greatest magnetic attraction in the two elements of the motor—the armature and field—by the direction of the lamination of the magnetic cores of said elements, and the best means of accomplishing this result of which I am at present aware I have shown in the accompanying drawings.

Figure 1 is a side view of the motor with a portion of its armature-core exposed. Fig. 2 is an end or edge view of the same. Fig. 3 is a central cross-section of the same, the armature being shown mainly in elevation.

Let A A designate two plates built up of thin sections or laminæ of soft iron insulated more or less from one another and held together by bolts *a* or any other suitable means and secured to a base B. The inner faces of these plates contain recesses or grooves in which a coil or coils D are secured obliquely to the direction of the laminations. Within the coils D is a disk E, preferably composed of a spirally-wound iron wire or ribbon or a series of concentric rings and mounted on a shaft F, having bearings in the plates A A. Such a device when acted upon by an alternating current is capable of rotation and constitutes a motor, the operation of which I explain in the following manner: A current or current-impulse traversing the coils D tends to magnetize the cores A A and E, all of which are within the influence of the magnetic field of the coils. The poles thus established would naturally lie in the same line at right angles to the coils D, but in the plates A they are deflected by reason of the direction of the laminations and appear at or near the extremities of said plates. In the disk, however, where these conditions are not present, the poles or points of greatest attraction are on a line at right angles to the plane of the coils; hence there will be a torque established by this angular displacement of the poles or magnetic lines, which starts the disk in rotation, the magnetic lines of the armature and field tending toward a position of parallelism. This rotation is continued and maintained by the reversals of the current in coils D D, which change alternately the polarity of the field-cores A A. This rotary tendency or effect will be greatly increased by winding the disk with conductors G, closed upon themselves and having a radial direction, whereby the magnetic intensity of the poles of the disk will be greatly increased by the energizing effect of the currents induced in the coils G by the alternating currents in coils D. The plan of winding and the principle of operation have been fully explained in my patent, No. 382,279, of May 1, 1888.

The cores of the disk and field may or may not be of different magnetic susceptibility—that is to say, they may both be of the same kind of iron, so as to be magnetized at approximately the same instant by the coils D; or one may be of soft iron and the other of hard, in order that a certain time may elapse between the periods of their magnetization. In either case rotation will be produced; but unless the disk is provided with the closed energizing-coils it is desirable that the above-described difference of magnetic susceptibility be utilized to assist in its rotation.

The cores of the field and armature may be made in various ways, as will be well understood, it being only requisite that the laminations in each be in such direction as to secure the necessary angular displacement of the points of greatest attraction. Moreover, since the disk may be considered as made up of an infinite number of radial arms, it is obvious that what is true of a disk holds, under well-understood conditions, for many other forms of armature, and my invention in this respect is in no sense limited to the specific form of armature shown.

It will be understood that the specific ways of carrying out this invention are almost without number, and that, therefore, I do not limit myself to the precise form of motor which I have herein shown.

I believe that I am the first to produce rotation of an armature, at least such as could be utilized for any general or practicable purposes, by means of an alternating current passing through a single coil or several coils acting as one, and which have a direct magnetizing effect upon the cores of both armature and field, and this I claim in its broadest sense.

I further believe that I am the first to impart directly, by means of an alternating current, magnetism to the cores of the two elements of a motor, and by the direction of the lamination of one or both of the same to produce an angular displacement of the poles or lines of magnetic force of the cores, respectively.

What I therefore claim is—

1. An electro-magnetic motor consisting of a field-magnet, a rotary armature, and a single coil adapted to be connected to a source of alternating currents and to impart magnetism to both the armature and the field-magnet with angular displacement of the maximum points, as set forth.

2. In an electro-magnetic motor, the combination, with a coil adapted to be connected with a source of alternating currents, of a field-magnet and rotary armature the cores of which are in such relation to the coil as to be energized thereby and subdivided or laminated in such manner as to produce an angular displacement of their poles or the magnetic lines therein, as set forth.

3. In an electro-magnetic motor, the combination, with a coil adapted to be connected with a source of alternating currents, of field-magnets with laminations lying obliquely to the plane of said coil and a circular or disk armature mounted to rotate between the field-magnets, both field and armature being under the magnetizing influence of the coil, as set forth.

4. In an electro-magnetic motor, the combination, with a coil adapted to be connected with a source of alternating currents, of field-magnets with laminations lying obliquely to the plane of the coil and a circular or disk armature with spiral or concentric laminations mounted between the field-magnets, both field and armature being under the magnetizing influence of the coil, as set forth.

5. In an electro-magnetic motor, the combination, with a coil adapted to be connected to a source of alternating currents, of a field-magnet and a rotary armature with closed coils thereon, both the field and the armature being under the magnetizing influence of said coil and laminated to produce an angular displacement of the poles of the two cores.

NIKOLA TESLA.

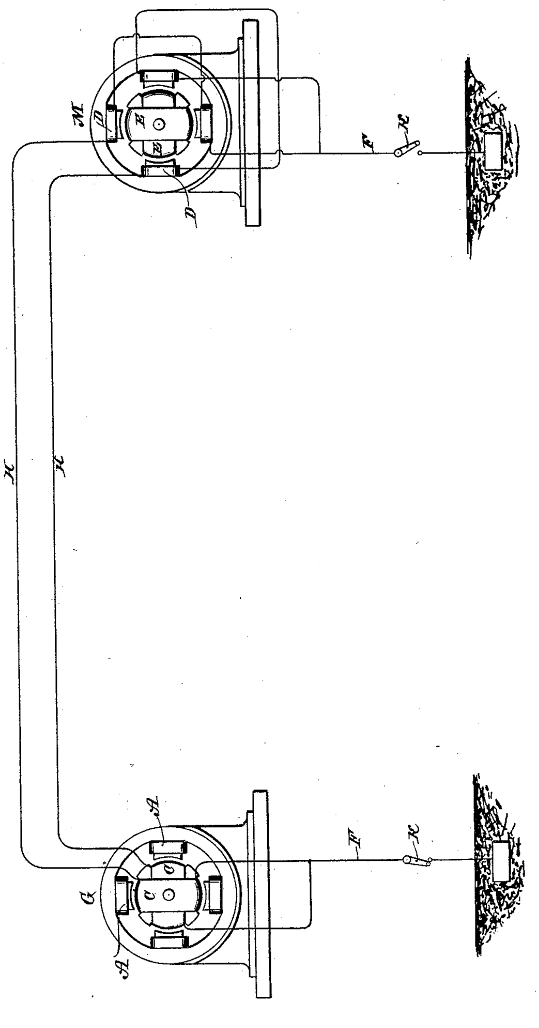
Witnesses:
EDWARD T. EVANS,
GEORGE N. MONRO.

(No Model.)

N. TESLA.

METHOD OF ELECTRICAL POWER TRANSMISSION.

No. 405,859. Patented June 25, 1889.



Witnesses:
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UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y., ASSIGNOR TO THE TESLA ELECTRIC COMPANY, OF SAME PLACE.

METHOD OF ELECTRICAL POWER TRANSMISSION.

SPECIFICATION forming part of Letters Patent No. 405,859, dated June 25, 1889.

Application filed March 14, 1889. Serial No. 303,251. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a subject of the Emperor of Austria, from Smiljan, Lika, border country of Austria-Hungary, residing at New York, in the county and State of New York, have invented certain new and useful Improvements in Methods of Electrical Power Transmission, of which the following is a specification, reference being had to the drawing accompanying and forming a part of the same.

This application is for a specific method of transmitting power electrically, shown and described in, and covered broadly by the claims of, an application filed by me February 18, 1889, No. 300,220.

As is well known, certain forms of alternating-current machines have the property, when connected in circuit with an alternating-current generator, of running as a motor in synchronism therewith; but, while the alternating current will run the motor after it has attained a rate of speed synchronous with that of the generator, it will not start it; hence, in all instances heretofore where these "synchronizing motors," as they are termed, have been run, some means have been employed to bring the motors up to synchronism with the generator, or approximately so, before the alternating current of the generator is applied to drive them. In some instances mechanical appliances have been utilized for this purpose. In others special and complicated forms of motor have been constructed.

My present invention is an improvement in methods of operating these motors and involves a new and improved plan of bringing the motor up to the proper rate of speed, that it may be run in synchronism with the generator.

The expression "synchronism with the generator" is used herein in its ordinary acceptation—that is to say, a motor is said to synchronize with the generator when it preserves a certain relative speed determined by its number of poles and the number of alternations produced per revolution of the generator. Its actual speed, therefore, may be faster or slower than that of the generator, but it is said to be synchronous so long as it preserves the same relative speed.

In carrying out my present invention I construct a generator with two coils or sets of coils and a motor with corresponding energizing coils or sets of coils. By means of two line-wires one terminal of each generator-coil or set of coils is connected to one terminal of its corresponding motor-coil or set of coils, while the opposite terminals of the generator-coils are joined together and likewise those of the motor.

To start the motor I establish temporarily an electrical connection between the points of connection between the coils in the generator and those in the motor, so that the system becomes an ordinary double-circuit system identical with that described in my patent, No. 390,413, of October 2, 1888, except that the generator and motor are constructed in any well-known way with a strong tendency to synchronize. When by this plan of connection the motor has attained the desired speed, the earth-connection is severed, by which means the system becomes an ordinary single-circuit synchronizing system.

In the drawing I have illustrated this method by a diagram.

Let G represent an ordinary alternating-current generator having four field-poles A, permanently or artificially magnetized, and an armature wound with two coils C connected together in series.

Let M represent an alternating-current motor with, say, four poles D, the coils on which are connected in pairs and the pairs connected in series. The motor-armature should have polar projections and closed coils E.

From the common joint or union between the two coils or sets of coils of both the generator and motor an earth-connection F is established, while the terminals or ends of the said coils or circuits which they form are connected to the line-conductors H H.

Assuming that the motor is a synchronizing motor, or one that has the capability of running in synchronism with the generator, but not of starting, it may be started by the above-described plan by closing the ground-connection from both generator and motor. The system thus becomes one with a two-circuit generator and motor, the ground forming a common return for the currents in the two wires H H. When by this arrangement of circuits the motor is brought to speed, the ground-connection is broken between the generator or motor or both and ground, switches K K being employed for this purpose. The motor then runs as a synchronizing motor.

This system is capable of various useful applications which it is not necessary to describe in detail; but it will be enough to say that the convertibility of the system from double circuit to single circuit is a feature in itself of great value and utility.

I do not wish to be understood as confining myself to the precise arrangement or order of connections herein set forth, as these may be obviously varied in many respects.

What I claim is—

1. The method of operating synchronizing motors herein described, which consists in electrically connecting intermediate points of the inducing-circuit of the generator and the energizing-circuit of the motor until the motor has reached a desired speed and then interrupting such connection, as set forth.

2. The method herein described of starting or operating synchronizing motors, which consists in electrically connecting intermediate points of the inducing-circuit of the generator and the energizing-circuit of the motor to earth until the motor has reached the desired speed and then interrupting either or both of the ground-connections, as set forth.

NIKOLA TESLA.

Witnesses:

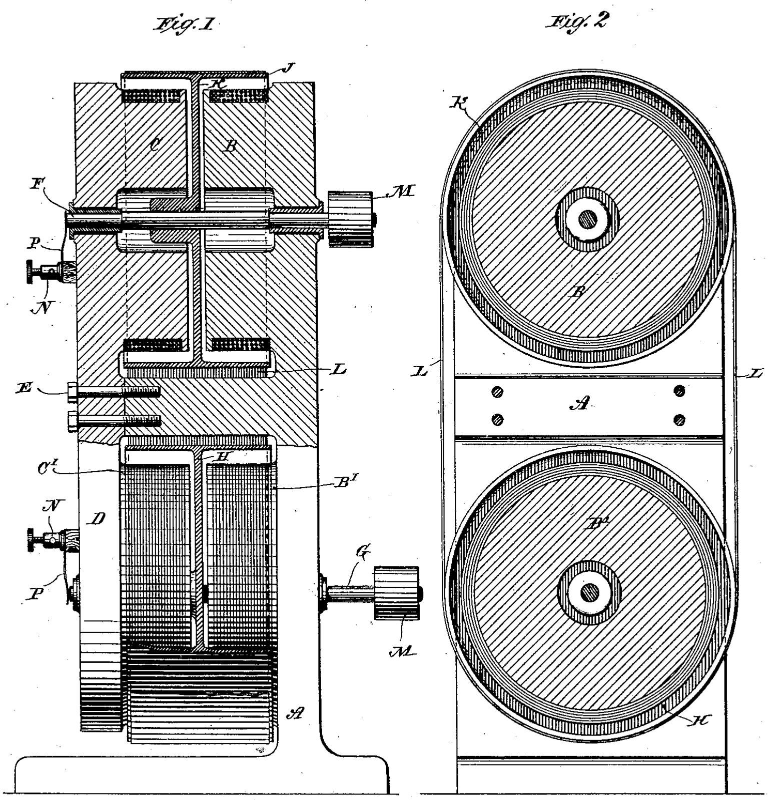
EDWARD T. EVANS,
E. C. UPSTILL.

(No Model.)

N. TESLA.

DYNAMO ELECTRIC MACHINE.

No. 406,968. Patented July 16, 1889.



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N. PETERS, Photo-Lithographer, Washington, D. C.

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y., ASSIGNOR OF TWO-THIRDS TO CHARLES F. PECK, OF ENGLEWOOD, NEW JERSEY, AND ALFRED S. BROWN, OF NEW YORK, N. Y.

DYNAMO-ELECTRIC MACHINE.

SPECIFICATION forming part of Letters Patent No. 406,968, dated July 16, 1889.

Application filed March 23, 1889. Serial No. 304,498. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, from Smiljan, Lika, border country of Austria-Hungary, a subject of the Emperor of Austria, and a resident of New York, in the county and State of New York, have invented certain new and useful Improvements in Dynamo or Magneto Electric Machines, of which the following is a specification, reference being had to the accompanying drawings.

This invention relates to that class of electrical generators known as "unipolar," in which a disk or cylindrical conductor is mounted between magnetic poles adapted to produce an approximately-uniform field. In the first-named or disk armature machines the currents induced in the rotating conductor flow from the center to periphery, or conversely, according to the direction of rotation or the lines of force as determined by the signs of the magnetic poles, and these currents are taken off usually by connections or brushes applied to the disk at points on its periphery and near its center. In the case of the cylindrical armature-machine the currents developed in the cylinder are taken off by brushes applied to the sides of the cylinder at its ends.

In order to develop economically an electromotive force available for practicable purposes, it is necessary either to rotate the conductor at a very high rate of speed or to use a disk of large diameter or cylinder of great length; but in either case it becomes difficult to secure and maintain a good electrical connection between the collecting-brushes and the conductor, owing to the high peripheral speed.

It has been proposed to couple two or more disks together in series with the object of obtaining a higher electro-motive force; but with the connections heretofore used and using other conditions of speed and dimension of disk necessary to securing good practicable results this difficulty is still felt to be a serious obstacle to the use of this kind of generator. These objections I have sought to avoid; and for this purpose I construct a machine with two fields, each having a rotary conductor mounted between its poles, but the same principle is involved in the case of both forms of machine above described, and as I prefer to use the disk form I shall confine the description herein to that machine. The disks are formed with flanges, after the manner of pulleys, and are connected together by flexible conducting bands or belts.

I prefer to construct the machine in such manner that the direction of magnetism or order of the poles in one field of force is opposite to that in the other, so that rotation of the disks in the same direction develops a current in one from center to circumference and in the other from circumference to center. Contacts applied therefore to the shafts upon which the disks are mounted form the terminals of a circuit the electro-motive force in which is the sum of the electro-motive forces of the two disks.

I would call attention to the obvious fact that if the direction of magnetism in both fields be the same the same result as above will be obtained by driving the disks in opposite directions and crossing the connecting-belts. In this way the difficulty of securing and maintaining good contact with the peripheries of the disks is avoided and a cheap and durable machine made which is useful for many purposes—such as for an exciter for alternating-current generators, for a motor, and for any other purpose for which dynamo-machines are used.

The specific construction of the machine which I have just generally described I have illustrated in the accompanying drawings, in which—

Figure 1 is a side view, partly in section, of my improved machine. Fig. 2 is a vertical section of the same at right angles to the shafts.

In order to form a frame with two fields of force, I cast a support A with two pole-pieces B B′ integral with it. To this I join by bolts E a casting D, with two similar and corresponding pole-pieces C C′. The pole-pieces B B′ are wound or connected to produce a field of force of given polarity, and the pole-pieces C C′ are wound or connected to produce a field of opposite polarity. The driving-shafts F G pass through the poles and are journaled in insulating-bearings in the casting A D, as shown.

H K are the disks or generating-conductors. They are composed of copper, brass, or iron and are keyed or secured to their respective shafts. They are provided with broad peripheral flanges J. It is of course obvious that the disks may be insulated from their shafts, if so desired. A flexible metallic belt L is passed over the flanges of the two disks, and, if desired, may be used to drive one of the disks. I prefer, however, to use this belt merely as a conductor, and for this purpose may use sheet steel, copper, or other suitable metal. Each shaft is provided with a driving-pulley M, by which power is imparted from a counter-shaft.

N N are the terminals. For sake of clearness they are shown as provided with springs P, that bear upon the ends of the shafts. This machine, if self-exciting, would have copper bands around its poles, or conductors of any kind—such as the wires shown in the drawings—may be used.

I do not limit my invention to the special construction herein shown. For example, it is not necessary that the parts be constructed in one machine or that the materials and proportions herein given be strictly followed. Furthermore, it is evident that the conducting belt or band may be composed of several smaller bands and that the principle of connection herein described may be applied to more than two machines.

What I claim is—

1. An electrical generator consisting of the combination, with two rotary conductors mounted in unipolar fields, of a flexible conductor or belt passing around the peripheries of said conductors, as herein set forth.

2. The combination, with two rotary conducting-disks having peripheral flanges and mounted in unipolar fields, of a flexible conducting belt or band passing around the flanges of both disks, as set forth.

3. The combination of independent sets of field-magnets adapted to maintain unipolar fields, conducting-disks mounted to rotate in said fields, independent driving mechanism for each disk, and a flexible conducting belt or band passing around the peripheries of the disks, as set forth.

NIKOLA TESLA.

Witnesses:
PARKER W. PAGE,
ROBT. F. GAYLORD.

(No Model.)

3 Sheets—Sheet 1.

N. TESLA.

METHOD OF OBTAINING DIRECT FROM ALTERNATING CURRENTS.

No. 413,353. Patented Oct. 22, 1889.

Fig. 1

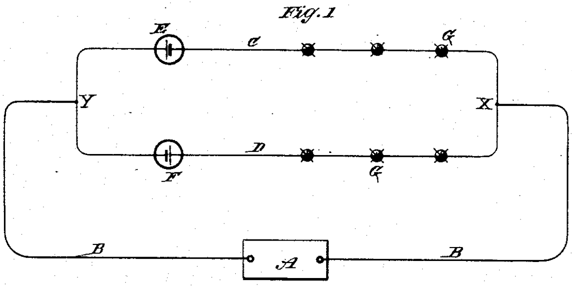


Fig. 2

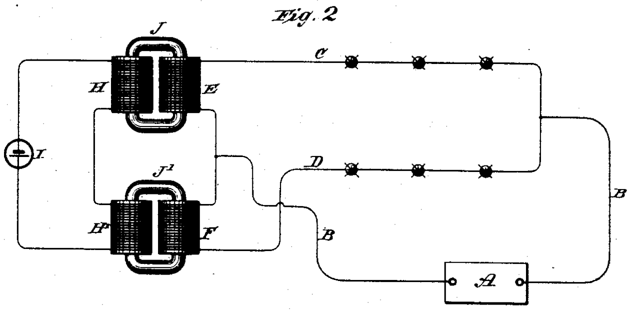
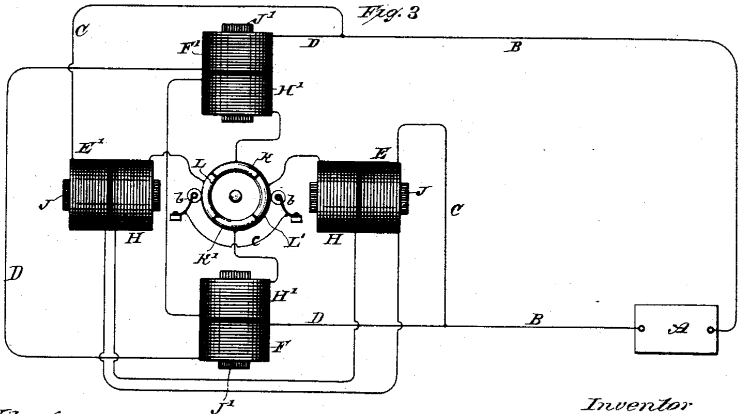


Fig. 3



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(No Model.) 3 Sheets—Sheet 2.

N. TESLA.

METHOD OF OBTAINING DIRECT FROM ALTERNATING CURRENTS.

No. 413,353. Patented Oct. 22, 1889.

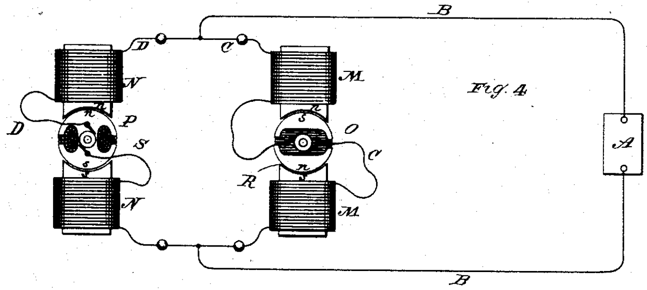


Fig. 5

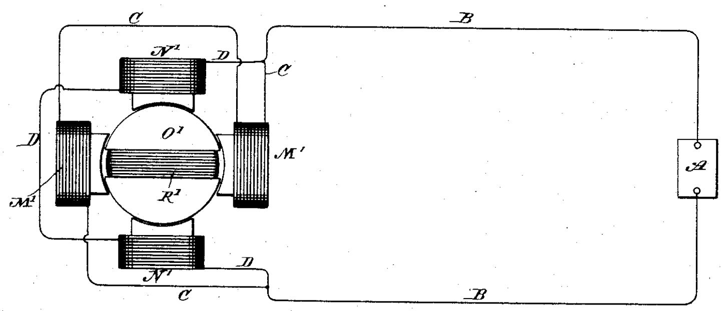
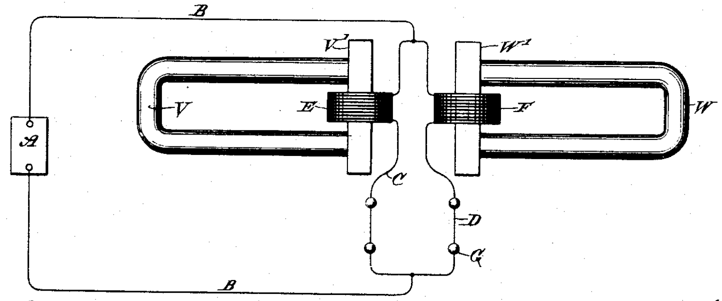


Fig. 6



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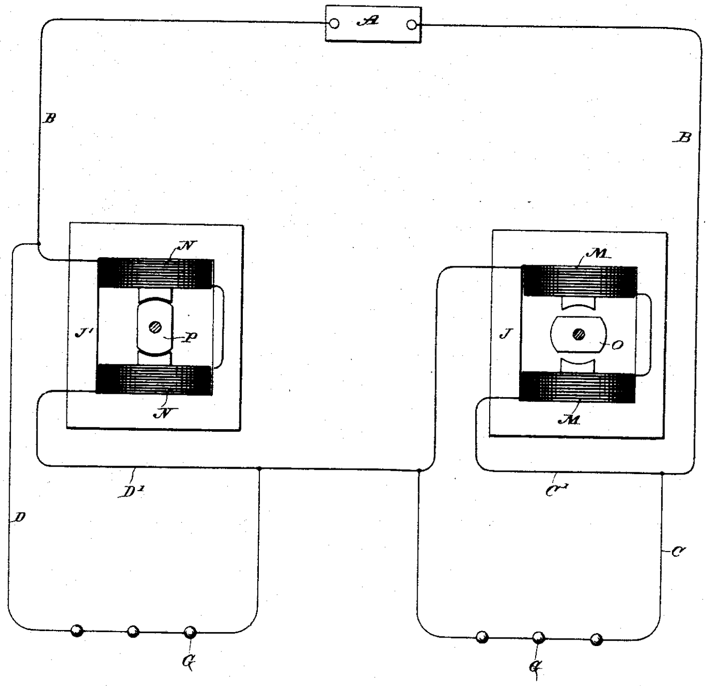
3 Sheets—Sheet 3.

N. TESLA.

METHOD OF OBTAINING DIRECT FROM ALTERNATING CURRENTS.

No. 413,353. Patented Oct. 22, 1889.

Fig. 7



Witnesses:
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UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y., ASSIGNOR OF TWO-THIRDS TO ALFRED S. BROWN, OF SAME PLACE, AND CHARLES F. PECK, OF ENGLEWOOD, NEW JERSEY.

METHOD OF OBTAINING DIRECT FROM ALTERNATING CURRENTS.

SPECIFICATION forming part of Letters Patent No. 413,353, dated October 22, 1889.

Application filed June 12, 1889. Serial No. 314,069. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a subject of the Emperor of Austria, from Smiljan, Lika, border country of Austria-Hungary, temporarily residing in New York city, in the State of New York, have invented a certain new and useful Improvement in Methods of Obtaining Direct from Alternating Currents, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

In nearly all the more important industrial applications of electricity the current is produced by dynamo-electric machines driven by power, in the coils of which the currents developed are primarily in reverse directions or alternating; but as very many electrical devices and systems require direct currents, it has been usual to correct the current alternations by means of a commutator, instead of taking them off directly from the generating-coils.

The superiority of alternating-current machines in all cases where their currents can be used to advantage renders their employment very desirable, as they may be much more economically constructed and operated; and the object of this my present invention is to provide means for directing or converting at will at one or more points in a circuit alternating into direct currents.

Stated as broadly as I am able to express it, my invention consists in obtaining direct from alternating currents, or in directing the waves of an alternating current so as to produce direct or substantially direct currents by developing or producing in the branches of a circuit including a source of alternating currents, either permanently or periodically, and by electric, electro-magnetic, or magnetic agencies, manifestations of energy, or what may be termed active resistances of opposite electrical character, whereby the currents or current-waves of opposite sign will be diverted through different circuits, those of one sign passing over one branch and those of opposite sign over another.

I may consider herein only the case of a circuit divided into two paths, inasmuch as any further subdivision involves merely an extension of the general principle. Selecting, then, any circuit through which is flowing an alternating current, I divide such circuit at any desired point into two branches or paths. In one of these paths I insert some device to create an electro-motive force counter to the waves or impulses of current of one sign and a similar device in the other branch which opposes the waves of opposite sign. Assume, for example, that these devices are batteries, primary or secondary, or continuous-current dynamo-machines. The waves or impulses of opposite direction composing the main current have a natural tendency to divide between the two branches; but by reason of the opposite electrical character or effect of the two branches one will offer an easy passage to a current of a certain direction, while the other will offer a relatively high resistance to the passage of the same current. The result of this disposition is, that the waves of current of one sign will, partly or wholly, pass over one of the paths or branches, while those of the opposite sign pass over the other. There may thus be obtained from an alternating current two or more direct currents without the employment of any commutator such as it has been heretofore regarded as necessary to use. The current in either branch may be used in the same way and for the same purposes as any other direct current—that is, it may be made to charge secondary batteries, energize electro-magnets, or for any other analogous purpose.

In the drawings I have illustrated some of the various ways in which I may carry out this invention.

The several figures are diagrammatic in character, and will be described in detail in their order.

Figure 1 represents a plan of directing the alternating currents by means of devices purely electrical in character. Figs. 2, 3, 4, 5, 6, and 7 are diagrams illustrative of other ways of carrying out the invention, which will be hereinafter more particularly described.

In Fig. 1, A designates a generator of alternating currents, and B B the main or line circuit therefrom. At any given point in this circuit at or near which it is desired to obtain direct currents I divide the circuit B into two paths or branches C D. In each of these branches I place an electrical generator, which for the present we will assume produces direct or continuous currents. The direction of the current thus produced is opposite in one branch to that of the current in the other branch, or, considering the two branches as forming a closed circuit, the generators E F are connected up in series therein, one generator in each part or half of the circuit. The electro-motive force of the current sources E and F may be equal to or higher or lower than the electro-motive forces in the branches C D or between the points X and Y of the circuit B B. If equal, it is evident that current-waves of one sign will be opposed in one branch and assisted in the other to such an extent that all the waves of one sign will pass over one branch and those of opposite sign over the other. If, on the other hand, the electro-motive force of the sources E F be lower than that between X and Y, the currents in both branches will be alternating, but the waves of one sign will preponderate. One of the generators or sources of current E or F may be dispensed with; but it is preferable to employ both, if they offer an appreciable resistance, as the two branches will be thereby better balanced. The translating or other devices to be acted upon by the current are designated by the letters G, and they are inserted in the branches C D in any desired manner; but in order to better preserve an even balance between the branches due regard should be had to the number and character of the devices, as will be well understood.

Figs. 2, 3, 4, and 5 illustrate what may be termed "electro-magnetic" devices for accomplishing a similar result—that is to say, instead of producing directly by a generator an electro-motive force in each branch of the circuit, I may establish a field or fields of force and lead the branches through the same in such manner that an active opposition of opposite effect or direction will be developed therein by the passage or tendency to pass of the alternations of current. In Fig. 2, for example, A is the generator of alternating currents, B B the line-circuit, and C D the branches over which the alternating currents are directed. In each branch I include the secondary of a transformer or induction-coil, which, since they correspond in their functions to the batteries of the previous figure, I have designated by the letters E F. The primaries H H′ of the induction-coils or transformers are connected either in parallel or series with a source of direct or continuous currents I, and the number of convolutions is so calculated for the strength of the current from I that the cores J J′ will be saturated. The connections are such that the conditions in the two transformers are of opposite character—that is to say, the arrangement is such that a current wave or impulse corresponding in direction with that of the direct current in one primary, as H, is of opposite direction to that in the other primary H′; hence it results that while one secondary offers a resistance or opposition to the passage through it of a wave of one sign the other secondary similarly opposes a wave of opposite sign. In consequence the waves of one sign will, to a greater or less extent, pass by way of one branch, while those of opposite sign in like manner pass over the other branch.

In lieu of saturating the primaries by a source of continuous current, I may include the primaries in the branches C D, respectively, and periodically short-circuit by any suitable mechanical devices—such as an ordinary revolving commutator—their secondaries. It will be understood of course that the rotation and action of the commutator must be in synchronism or in proper accord with the periods of the alternations in order to secure the desired results. Such a disposition I have represented diagrammatically in Fig. 3. Corresponding to the previous figures, A is the generator of alternating currents, B B the line, and C D the two branches for the direct currents. In branch C are included two primary coils E E′, and in branch D are two similar primaries F F′. The corresponding secondaries for these coils and which are on the same subdivided cores J or J′ are in circuits the terminals of which connect to opposite segments K K′ and L L′, respectively, of a commutator. Brushes *b b* bear upon the commutator and alternately short-circuit the plates K and K′ and L and L′ through a connection *c*. It is obvious that either the magnets and commutator or the brushes may revolve.

The operation will be understood from a consideration of the effects of closing or short-circuiting the secondaries. For example, if at the instant when a given wave of current passes one set of secondaries be short-circuited, nearly all the current flows through the corresponding primaries; but the secondaries of the other branch being open-circuited the self-induction in the primaries is highest, and hence little or no current will pass through that branch. If, as the current alternates, the secondaries of the two branches are alternately short-circuited, the result will be that the currents of one sign pass over one branch and those of the opposite sign over the other. The disadvantages of this arrangement, which would seem to result from the employment of sliding contacts, are in reality very slight, inasmuch as the electro-motive force of the secondaries may be made exceedingly low, so that sparking at the brushes is avoided.

Fig. 4 is a diagram, partly in section, of another plan of carrying out the invention. The circuit B in this case is divided, as before, and each branch includes the coils of both the field and revolving armatures of two induction devices. The armatures O P are preferably mounted on the same shaft, and are adjusted relatively to one another in such manner that when the self-induction in one branch, as C, is maximum in the other branch D it is minimum. The armatures are rotated in synchronism with the alternations from the source A. The winding or position of the armature-coils is such that a current in a given direction passed through both armatures would establish in one poles similar to those in the adjacent poles of the field and in the other poles unlike the adjacent field-poles, as indicated by *n n s s* in the drawings. If the like poles are presented, as shown in circuit D, the condition is that of a closed secondary upon a primary, or the position of least inductive resistance; hence a given alternation of current will pass mainly through D. A half-revolution of the armatures produces an opposite effect, and the succeeding current impulse passes through C. Using this figure as an illustration, it is evident that the fields N M may be permanent magnets or independently excited and the armatures O P driven, as in the present case, so as to produce alternate currents, which will set up alternately impulses of opposite direction in the two branches D C, which in such case would include the armature-circuits and translating devices only.

In Fig. 5 a plan alternative with that shown in Fig. 3 is illustrated. In the previous case illustrated each branch C and D contained one or more primary coils, the secondaries of which were periodically short-circuited in synchronism with the alternations of current from the main source A, and for this purpose a commutator was employed. The latter may, however, be dispensed with and an armature with a closed coil substituted.

Referring to Fig. 5, in one of the branches, as C, are two coils M′, wound on laminated cores, and in the other branches D are similar coils N′. A subdivided or laminated armature O′, carrying a closed coil R′, is rotatably supported between the coils M′ N′, as shown. In the position shown—that is, with the coil R′ parallel with the convolutions of the primaries N′ M′—practically the whole current will pass through branch D, because the self-induction in coils M′ M′ is maximum. If, therefore, the armature and coil be rotated at a proper speed relatively to the periods or alternations of the source A, the same results are obtained as in the case of Fig. 3.

Fig. 6 is an instance of what may be called, in distinction to the others, a "magnetic" means of securing the results arrived at in this invention. V and W are two strong permanent magnets provided with armatures V′ W′, respectively. The armatures are made of thin laminæ of soft iron or steel, and the amount of magnetic metal which they contain is so calculated that they will be fully or nearly saturated by the magnets. Around the armatures are coils E F, contained, respectively, in the circuits C and D. The connections and electrical conditions in this case are similar to those in Fig. 2, except that the current source I of Fig. 2 is dispensed with and the saturation of the core of coils E F obtained from the permanent magnets.

In the illustrations heretofore given I have in each instance shown the two branches or paths containing the translating or induction devices as in derivation one to the other; but this is not always necessary. For example, in Fig. 7, A is an alternating-current generator; B B, the line wires or circuit. At any given point in the circuit I form two paths, as D D′, and at another point two paths, as C C′. Either pair or group of paths is similar to the previous dispositions with the electrical source or induction device in one branch only, while the two groups taken together form the obvious equivalent of the cases in which an induction device or generator is included in both branches. In one of the paths, as D, are included the devices to be operated by the current. In the other branch, as D′, is an induction device that opposes the current impulses of one direction and directs them through the branch D. So, also, in branch C are translating devices G, and in branch C′ an induction device or its equivalent that diverts through C impulses of opposite direction to those diverted by the device in branch D′. I have also shown a special form of induction device for this purpose. J J′ are the cores, formed with pole-pieces, upon which are wound the coils M N. Between these pole-pieces are mounted at right angles to one another the magnetic armatures O P, preferably mounted on the same shaft and designed to be rotated in synchronism with the alternations of current. When one of the armatures is in line with the poles or in the position occupied by armature P, the magnetic circuit of the induction device is practically closed; hence there will be the greatest opposition to the passage of a current through coils N N. The alternation will therefore pass by way of branch D. At the same time, the magnetic circuit of the other induction device being broken by the position of the armature O, there will be less opposition to the current in coils M, which will shunt the current from branch C. A reversal of the current being attended by a shifting of the armatures, the opposite effect is produced.

There are many other modifications of the means or methods of carrying out my invention; but I have not deemed it necessary herein to specifically refer to more than those described, as they involve the chief modifications of the plan. In all of these it will be observed that there is developed in one or all of the branches of a circuit from a source of alternating currents an active (as distinguished from a dead) resistance or opposition to the currents of one sign, for the purpose of diverting the currents of that sign through the other or another path, but permitting the currents of opposite sign to pass without substantial opposition.

Whether the division of the currents or waves of current of opposite sign be effected with absolute precision or not is immaterial to my invention, since it will be sufficient if the waves are only partially diverted or directed, for in such case the preponderating influence in each branch of the circuit of the waves of one sign secures the same practical results in many if not all respects as though the current were direct and continuous.

An alternating and direct current have been combined so that the waves of one direction or sign were partially or wholly overcome by the direct current; but by this plan only one set of alternations are utilized, whereas by my system the entire current is rendered available. By obvious applications of this discovery I am enabled to produce a self-exciting alternating dynamo, or to operate direct-current meters on alternating-current circuit, or to run various devices—such as arc lamps—by direct currents in the same circuit with incandescent lamps or other devices run by alternating currents.

It will be observed that if an intermittent counter or opposing force be developed in the branches of the circuit and of higher electromotive force than that of the generator an alternating current will result in each branch, with the waves of one sign preponderating, while a constantly or uniformly acting opposition in the branches of higher electro-motive force than the generator would produce a pulsating current, which conditions would be under some circumstances the equivalent to those I have previously described.

What I claim as my invention is—

1. The method herein set forth of obtaining direct from alternating currents, which consists in developing or producing in one branch of a circuit from an alternating-current source an active resistance to the current impulses of one direction, whereby the said currents or waves of current will be diverted or directed through another branch.

2. The method of obtaining direct from alternating currents, which consists in dividing the path of an alternating current into branches, and developing in one of said branches, either permanently or periodically, an electrical force or active resistance counter to or opposing the currents or current-waves of one sign, and in the other branch a force counter to or opposing the currents or current-waves of opposite sign, as set forth.

3. The method of obtaining direct from alternating currents, which consists in dividing the path of an alternating current into branches, establishing fields of force and leading the said branches through the said fields of force in such relation to the lines of force therein that the impulses of current of one direction will be opposed in one branch and those of opposite direction in the other, as set forth.

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Witnesses:
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(No Model.)

2 Sheets—Sheet 1.

N. TESLA.

ELECTRO MAGNETIC MOTOR.

No. 416,191.

Patented Dec. 3, 1889.

Fig. 1

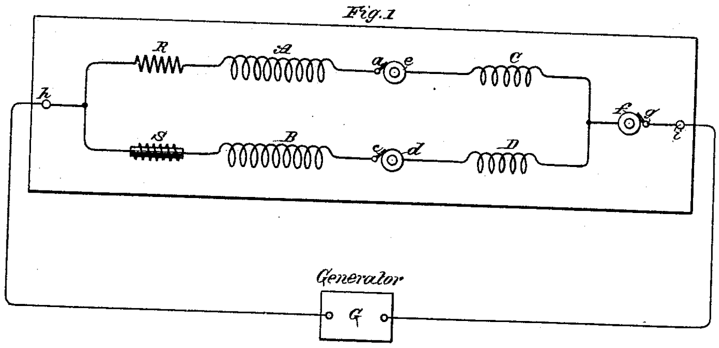


Fig. 2

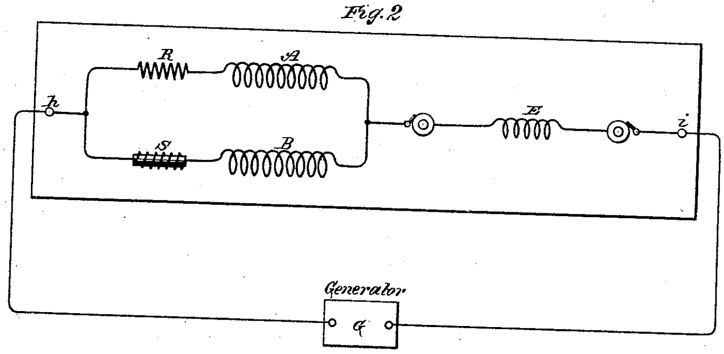
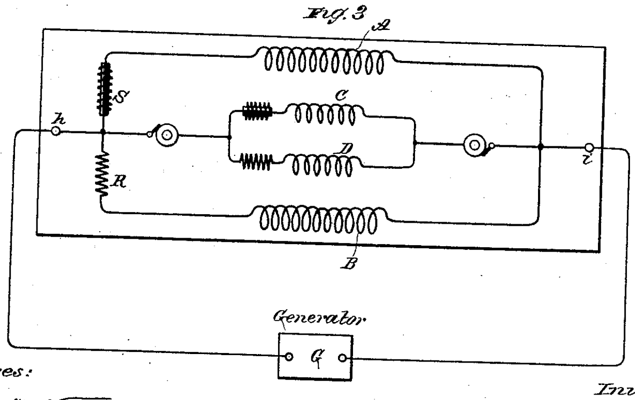


Fig. 3



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(No Model.) 2 Sheets—Sheet 2.

N. TESLA.

ELECTRO MAGNETIC MOTOR.

No. 416,191. Patented Dec. 3, 1889.

Fig. 4.

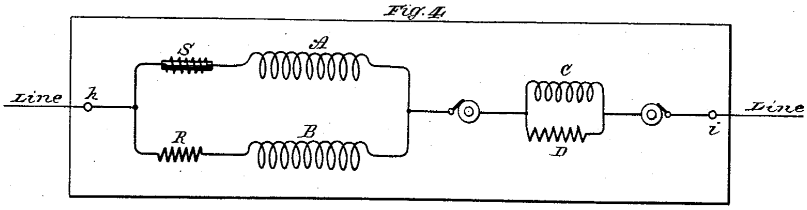


Fig. 5

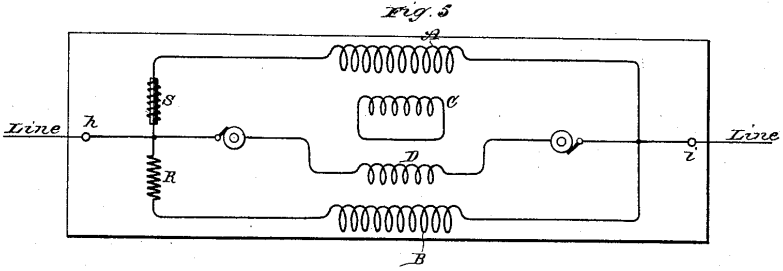


Fig. 6

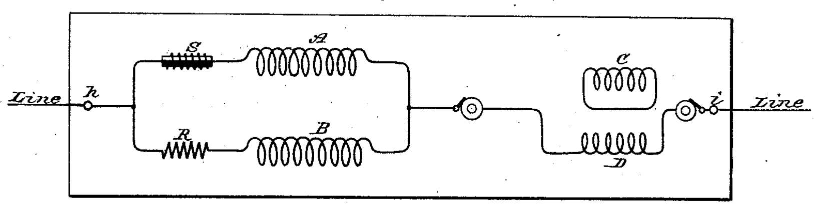
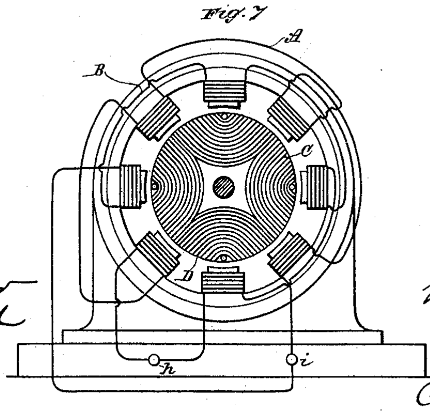


Fig. 7



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N. PETERS, Photo-Lithographer, Washington, D. C.

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y., ASSIGNOR TO THE TESLA ELECTRIC COMPANY, OF SAME PLACE.

ELECTRO-MAGNETIC MOTOR.

SPECIFICATION forming part of Letters Patent No. 416,191, dated December 3, 1889.

Application filed May 20, 1889. Serial No. 311,413. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a subject of the Emperor of Austria, from Smiljan, Lika, border country of Austria-Hungary, residing at New York, in the county and State of New York, have invented certain new and useful Improvements in Electro-Magnetic Motors, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

This invention pertains to that class of electro-magnetic motors invented by me in which two or more independent energizing-circuits are employed, and through whicha lternating currents differing in phase are passed to produce the operation or rotation of the motor.

One of the general ways which I have followed in carrying out this invention is to produce practically independent currents differing primarily in phase and pass these through the motor-circuits. Another way is to produce a single alternating current, to divide it between the motor-circuits, and to effect artificially a lag in one of the said circuits or branches, as by giving to the circuits different self-inductive capacity, and in other ways. In the former case, in which the necessary difference of phase is primarily effected in the generation of currents, I have, in some instances, passed the currents through the energizing-coils of both elements of the motor—the field and armature; but I have made the discovery that a new and useful result is or may be obtained by doing this under the conditions hereinafter specified in the case of motors in which the lag, as above stated, is artificially secured. In this my present invention resides.

In illustration of the nature of this invention I shall refer to the accompanying drawings, in which—

Figures 1 to 6, inclusive, are diagrams of different ways in which the invention is or may be carried out; and Fig. 7, a side view of a form of motor which I have used for this purpose.

The diagrams in detail will be described separately.

A B in Fig. 1 indicate the two energizing-circuits of a motor, and C D two circuits on the armature. Circuit or coil A is connected in series with circuit or coil C, and the two circuits B D are similarly connected. Between coils A and C is a contact-ring *e*, forming one terminal of the latter, and a brush *a*, forming one terminal of the former. A ring *d* and brush *c* similarly connect coils B and D. The opposite terminals of the field-coils connect to one binding-post *h* of the motor, and those of the armature-coils are similarly connected to the opposite binding-post *i* through a contact-ring *f* and brush *g*. Thus each motor-circuit while in derivation to the other includes one armature and one field-coil. These circuits are of different self-induction, and may be made so in various ways. For the sake of clearness I have shown in one of these circuits an artificial resistance R and in the other a self-induction coil S. When an alternating current is passed through this motor it divides between its two energizing-circuits. The higher self-induction of one circuit produces a greater retardation or lag in the current therein than in the other. The difference of phase between the two currents effects the rotation or shifting of the points of maximum magnetic effect that secures the rotation of the armature. In certain respects this plan of including both armature and field coils in circuit is a marked improvement. Such a motor has a good torque at starting; yet it has also considerable tendency to synchronism, owing to the fact that when properly constructed the maximum magnetic effects in both armature and field coincide—a condition which in the usual construction of these motors with closed armature-coils is not readily attained. The motor thus constructed exhibits, too, a better regulation of current from no load to load, and there is less difference between the apparent and real energy expended in running it. The true synchronous speed of this form of motor is that of the generator when both are alike—that is to say, if the number of the coils on the armature and on the field is *x*, the motor will run normally at the same speed as a generator driving it if the number of field-magnets or poles of the same be also *x*.

Fig. 2 shows a somewhat modified arrangement of circuits. There is in this case but one armature-coil E, the winding of which maintains effects corresponding to the resultant poles produced by the two field-circuits.

Fig. 3 represents a disposition in which both armature and field are wound with two sets of coils, all in multiple arc to the line or main circuit. The armature-coils are wound to correspond with the field-coils with respect to their self-induction. A modification of this plan is shown in Fig. 4—that is to say, the two field-coils and two armature-coils are in derivation to themselves and in series with one another. The armature-coils in this case, as in the previous figure, are wound for different self-induction to correspond with the field-coils.

Another modification is shown in Fig. 5. In this case only one armature-coil, as D, is included in the line-circuit, while the other, as C, is short-circuited.

In such a disposition as that shown in Fig. 2, or where only one armature-coil is employed, the torque on the start is somewhat reduced, while the tendency to synchronism is somewhat increased. In such a disposition, as shown in Fig. 5, the opposite conditions would exist. In both instances, however, there is the advantage of dispensing with one contact-ring.

In Fig. 5 the two field-coils and the armature-coil D are in multiple arc. In Fig. 6 this disposition is modified, coil D being shown in series with the two field-coils.

Fig. 7 is an outline of the general form of motor in which I have embodied this improvement. The circuit-connections between the armature and field coils are made, as indicated in the previous figures, through brushes and rings, which are not shown.

In the above description I have made use of the terms "armature" and "field;" but it will be understood that these are in this case convertible terms, for what is true of the field is equally so of the armature, except that one is stationary, the other capable of rotation.

I do not claim in this application the method or means of operating a double-circuit motor by making its circuits of different self-induction or in any way retarding the phases of current in one circuit more than in another, having made these features subject of other applications; but

What I claim is—

1. In an alternating-current motor, the combination, with field-circuits of different self-inductive capacity, of corresponding armature-circuits electrically connected therewith, as set forth.

2. In an alternating-current motor, the combination, with independent field-coils of different self-induction, of independent armature-coils, one or more in circuit with the field-coils and the others short-circuited, as set forth.

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(No Model.) 2 Sheets—Sheet 1.

N. TESLA.

METHOD OF OPERATING ELECTRO MAGNETIC MOTORS.

No. 416,192. Patented Dec. 3, 1889.

Fig. 1

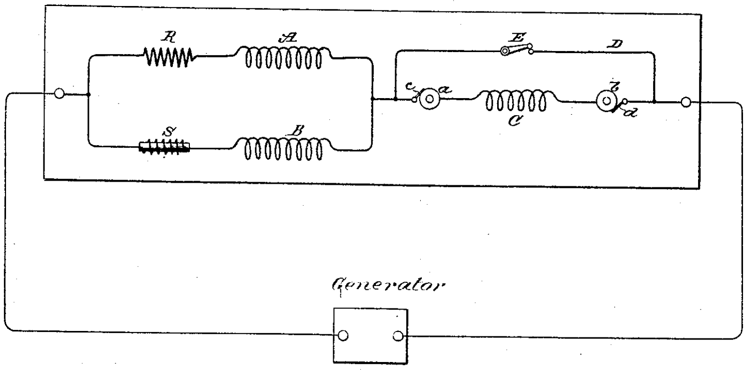


Fig. 2

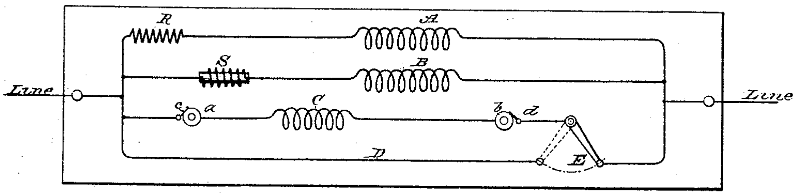
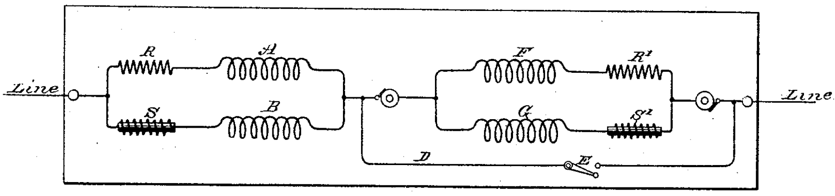


Fig. 3



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2 Sheets—Sheet 2.

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METHOD OF OPERATING ELECTRO MAGNETIC MOTORS.

No. 416,192. Patented Dec. 3, 1889.

Fig. 4

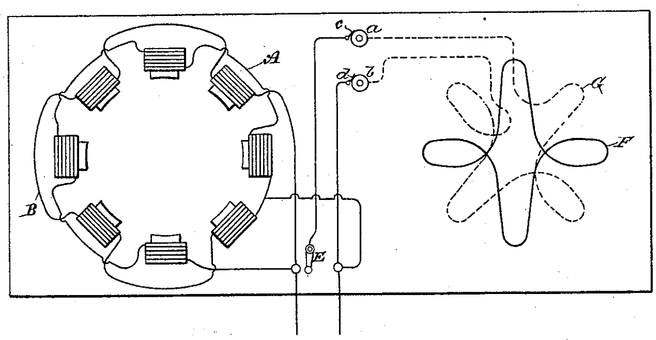
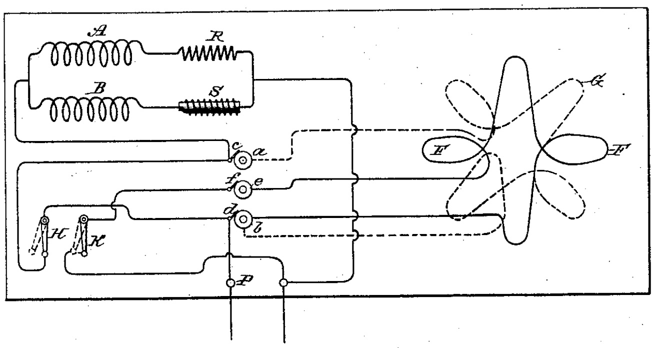


Fig. 5



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UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y., ASSIGNOR TO THE TESLA ELECTRIC COMPANY, OF SAME PLACE.

METHOD OF OPERATING ELECTRO-MAGNETIC MOTORS.

SPECIFICATION forming part of Letters Patent No. 416,192, dated December 3, 1889.

Application filed May 20, 1889. Serial No. 311,414. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a subject of the Emperor of Austria, from Smiljan, Lika, border country of Austria-Hungary, and a resident of New York, in the county and State of New York, have invented certain new and useful Improvements in Methods of Operating Electro-Magnetic Motors, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

In a patent granted to me April 16, 1889, No. 401,520, I have shown and described a method of starting and operating synchronizing motors which involved the transformation of the motor from a torque to a synchronizing motor. This I have heretofore done by a change of the circuit-connections, whereby on the start the poles or resultant attraction of the field-magnets of the motor were shifted or rotated by the action of the current until the motor reached synchronous speed, after which the poles were merely alternated. The present application is based upon another way of accomplishing this result, the main features being as follows: If an alternating current be passed through the field-coils only of a motor having two energizing-circuits of different self-induction and the armature-coils be short-circuited, the motor will have a strong torque, but little or no tendency to synchronism with the generator; but if the same current which energizes the field be passed also through the armature-coils the tendency to remain in synchronism is very considerably increased. This is due to the fact that the maximum magnetic effects produced in the field and armature more nearly coincide. This principle discovered by me I have utilized in the operation of motors. In other words, I construct a motor having independent field-circuits of different self-induction, which are joined in derivation to a source of alternating currents. The armature I wind with one or more coils, which are connected with the field-coils through contact rings and brushes, and around the armature-coils I arrange a shunt with means for opening or closing the same. In starting this motor I close the shunt around the armature-coils, which will therefore be in closed circuit. When the current is directed through the motor, it divides between the two circuits, (it is not necessary to consider any case where there are more than two circuits used,) which, by reason of their different self-induction, secure a difference of phase between the two currents in the two branches that produces a shifting or rotation of the poles. By the alternations of current other currents are induced in the closed—or short-circuited—armature-coils and the motor has a strong torque. When the desired speed is reached, the shunt around the armature-coils is opened and the current directed through both armature and field coils. Under these conditions the motor has a strong tendency to synchronism.

In the drawings hereto annexed I have illustrated several modifications of the plan above set forth for operating motors. The figures are diagrams, and will be explained in their order.

Figure 1: A and B designate the field-coils of the motor. As the circuits including these coils are of different self-induction, I have represented this by a resistance-coil R in circuit with A, and a self-induction coil S in circuit with B. The same result may of course be secured by the winding of the coils. C is the armature-circuit, the terminals of which are rings *a b*. Brushes *c d* bear on these rings and connect with the line and field circuits. D is the shunt or short circuit around the armature. E is the switch therein. The operation of these devices I have stated above.

It will be observed that in such a disposition as is illustrated in Fig. 1, the field-circuits A and B being of different self-induction, there will always be a greater lag of the current in one than the other, and that, generally, the armature phases will not correspond with either, but with the resultant of both. It is therefore important to observe the proper rule in winding the armature. For instance, if the motor have eight poles—four in each circuit—there will be four resultant poles, and hence the armature-winding should be such as to produce four poles, in order to constitute a true synchronizing motor.

Fig 2: This diagram differs from the previous one only in respect to the order of connections. In the present case the armature-coil, instead of being in series with the field-coils, is in multiple arc therewith. The armature-winding may be similar to that of the field—that is to say, the armature may have two or more coils wound or adapted for different self-induction and adapted, preferably, to produce the same difference of phase as the field-coils. On starting the motor the shunt is closed around both coils. This is shown in Fig. 3, in which the armature-coils are F G. To indicate their different electrical character, I have shown in circuit with them, respectively, the resistance R′ and the self-induction coil S′. The two armature coils are in series with the field-coils and the same disposition of the shunt or short circuit D is used. It is of advantage in the operation of motors of this kind to construct or wind the armature in such manner that when short-circuited on the start it will have a tendency to reach a higher speed than that which synchronizes with the generator. For example, a given motor having, say, eight poles should run, with the armature-coil short-circuited, at two thousand revolutions per minute to bring it up to synchronism. It will generally happen, however, that this speed is not reached, owing to the fact that the armature and field currents do not properly correspond, so that when the current is passed through the armature (the motor not being quite up to synchronism) there is a liability that it would not "hold on," as it is termed. I therefore prefer to so wind or construct the motor that on the start, when the armature-coils are short-circuited, the motor will tend to reach a speed higher than the synchronous—as, for instance, double the latter. In such case the difficulty above alluded to is not felt, for the motor will always hold up to synchronism if the synchronous speed—in the case supposed of two thousand revolutions—is reached or passed. This may be accomplished in various ways; but for all practical purposes the following will suffice: I wind on the armature two sets of coils. On the start I short-circuit one only, thereby producing a number of poles on the armature, which will tend to run the speed up above the synchronous limit. When such limit is reached or passed, the current is directed through the other coil, which, by increasing the number of armature-poles, tends to maintain synchronism. In Fig. 4 such a disposition is shown. The motor having, say, eight poles contains two field-circuits A and B, of different self-induction. The armature has two coils F and G. The former is closed upon itself, the latter connected with the field and line through contact-rings *a b*, brushes *c d*, and a switch E. On the start the coil F alone is active and the motor tends to run at a speed above the synchronous; but when the coil G is connected to the circuit the number of armature-poles is increased, while the motor is made a true synchronous motor. This disposition has the advantage that the closed armature-circuit imparts to the motor torque when the speed falls off, but at the same time the conditions are such that the motor comes out of synchronism more readily. To increase the tendency to synchronism, two circuits may be used on the armature, one of which is short-circuited on the start and both connected with the external circuit after the synchronous speed is reached or passed. This disposition is shown in Fig. 5. There are three contact-rings *a b e* and three brushes *c d f*, which connect the armature-circuits with the external circuit. On starting, the switch H is turned to complete the connection between one binding-post P and the field-coils. This short-circuits one of the armature-coils, as G. The other coil F is out of circuit and open. When the motor is up to speed, the switch H is turned back, so that the connection from binding-post P to the field-coils is through the coil G, and switch K is closed, thereby including coil F in multiple arc with the field-coils. Both armature-coils are thus active.

From the above-described instances it is evident that many other dispositions for carrying out the invention are possible.

I do not claim herein the method and means described and shown for operating a motor by producing artificially a difference of current phase in its independent energizing-circuits; nor do I claim, broadly, a motor having independent energizing-circuits of different self-induction and armature-circuits connected therewith, as these features are made subjects of other applications which I have filed.

What I claim is—

1. The method herein described of operating alternating-current motors having independent energizing-circuits, which consists in short-circuiting the armature circuit or circuits until the motor has reached or passed a synchronizing speed and then connecting said armature-circuits with the external circuit, as set forth.

2. The method of operating alternating-current motors having field-coils of different self-induction, which consists in directing alternating currents from an external source through the field-circuits only until the motor has reached a given speed and then directing said currents through both the field-circuits and one or more of the armature-circuits, as set forth.

3. The method of operating alternating-current motors having field-coils of different self-induction, which consists in directing alternating currents from an external source through the field-circuits and short-circuiting a part of the armature-circuits, and then when the motor has attained a given speed directing the alternating currents through both the field and one or more of the armature-circuits, as set forth.

NIKOLA TESLA.

Witnesses:
ROBT. F. GAYLORD,
FRANK E. HARTLEY.

(No Model.)

N. TESLA.

ELECTRO MAGNETIC MOTOR.

No. 416,193. Patented Dec. 3, 1889.

Fig. 1

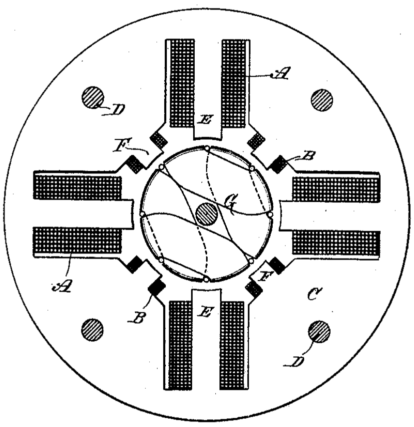
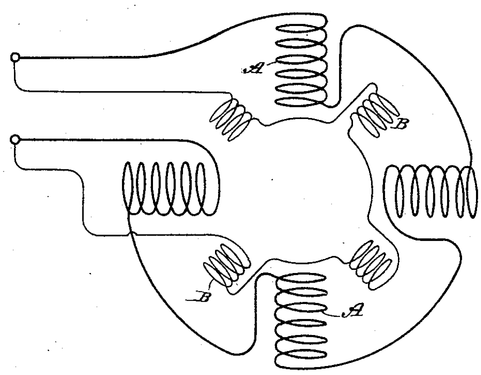


Fig. 2



Witnesses:
Raphaël Netter
Robt. F. Gaylord

Inventor
Nikola Tesla
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Duncan, Curtis & Page
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N. PETERS, Photo-Lithographer, Washington, D. C.

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y., ASSIGNOR TO THE TESLA ELECTRIC COMPANY, OF SAME PLACE.

ELECTRO-MAGNETIC MOTOR.

SPECIFICATION forming part of Letters Patent No. 416,193, dated December 3, 1889.

Application filed May 20, 1889. Serial No. 311,415. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a subject of the Emperor of Austria, from Smiljan, Lika, border country of Austria-Hungary, residing at New York, in the county and State of New York, have invented certain new and useful Improvements in Electro-Magnetic Motors, of which the following is a specification, reference being had to the accompanying drawings.

This invention relates to alternating-current motors of the general description invented by me, and in which two or more energizing-circuits are employed, through which alternating currents differing in phase are passed, with the result of producing a progressive shifting or rotation of the poles or points of maximum attractive effect.

In prior patents and applications I have shown and described various forms of motors of this kind. Among them are motors in which both energizing-circuits are electrically alike—that is to say, both have the same or approximately the same electrical resistance and self-induction—in the operation of which the alternating currents used are primarily of different phase. In others the difference of phase is artificially produced—as, for instance, in cases where the motor-circuits are of different resistance and self-induction, so that the same current divided between them will be retarded in one to a greater extent than in the other, and the requisite phase difference secured in this way. To this latter class generally my present invention relates.

The lag or rotation of the phases of an alternating current is directly proportional to the self-induction and inversely proportional to the resistance of the circuit through which the current flows. Hence, in order to secure the proper difference of phase between the two motor-circuits, it is desirable to make the self-induction in one much higher and the resistance much lower than the self-induction and resistance, respectively, in the other. At the same time the magnetic quantities of the two poles or sets of poles which the two circuits produce should be approximately equal. These requirements, which I have found to exist in motors of this kind, have led me to the invention of a motor having the following general characteristics: The coils which are included in that energizing-circuit which is to have the higher self-induction I make of coarse wire, or a conductor of relatively low resistance, and I use the greatest possible length or number of turns. In the other set of coils I use a comparatively few turns of finer wire or a wire of higher resistance. Furthermore, in order to approximate the magnetic quantities of the poles excited by these coils, I use in the self-induction circuit cores much longer than those in the other or resistance circuit. I have shown in the drawings a motor embodying these features.

Figure 1 is a part-sectional view of the motor at right angles to the shaft. Fig. 2 is a diagram of the field-circuits.

In Fig. 2, let A represent the coils in one motor-circuit, and B those in the other. The circuit A is to have the higher self-induction. I therefore use a long length or a large number of turns of coarse wire in forming the coils of this circuit. For the circuit B, I use a smaller conductor, or a conductor of a higher resistance than copper, such as German silver or iron, and wind the coils with fewer turns. In applying these coils to a motor I build up a field-magnet of plates C, of iron or steel, secured together in the usual manner by bolts D. Each plate is formed with four (more or less) long cores E, around which is a space to receive the coil and an equal number of short projections F to receive the coils of the resistance-circuit. The plates are generally annular in shape, having an open space in the center for receiving the armature G, which I prefer to wind with closed coils. An alternating current divided between the two circuits is retarded as to its phases in the circuit A to a much greater extent than in the circuit B. By reason of the relative sizes and disposition of the cores and coils the magnetic effect of the poles E and F upon the armature closely approximate. These conditions are well understood and readily secured by one skilled in the art.

An important result secured by the construction herein shown of the motor is, that these coils which are designed to have the higher self-induction are almost completely surrounded by iron, by which the retardation is considerably increased.

I do not claim herein, broadly, the method and means of securing rotation by artificially producing a greater lag of the current in one motor-circuit than in the other, nor the use of poles or cores of different magnetic susceptibility, as these are features which I have specially claimed in other applications filed by me.

What I claim is—

1. An alternating-current motor having two or more energizing-circuits, the coils of one circuit being composed of conductors of large size or low resistance and those of the other of fewer turns of wire of smaller size or higher resistance, as set forth.

2. In an alternating-current motor, the combination, with long and short field-cores, of energizing-coils included in independent circuits, the coils on the longer cores containing an excess of copper or conductor over that in the others, as set forth.

3. The combination, with a field-magnet composed of magnetic plates having an open center and pole-pieces or cores of different length, of coils surrounding said cores and included in independent circuits, the coils on the longer cores containing an excess of copper over that in the others, as set forth.

4. The combination, with a field-magnet composed of magnetic plates having an open center and pole-pieces or cores of different length, of coils surrounding said cores and included in independent circuits, the coils on the longer cores containing an excess of copper over that in the others and being set in recesses in the iron core formed by the plates, as set forth.

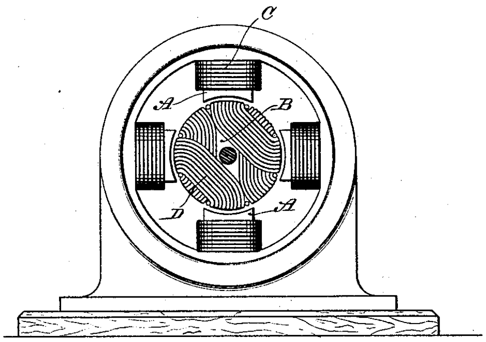
NIKOLA TESLA.

Witnesses:
ROBT. F. GAYLORD,
FRANK E. HARTLEY.

(No Model.)

N. TESLA.
ELECTRIC MOTOR.

No. 416,194. Patented Dec. 3, 1889.



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Inventor
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UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y., ASSIGNOR TO THE TESLA ELECTRIC COMPANY, OF SAME PLACE.

ELECTRIC MOTOR.

SPECIFICATION forming part of Letters Patent No. 416,194, dated December 3, 1889.

Application filed May 20, 1889. Serial No. 311,418. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a subject of the Emperor of Austria, from Smiljan, Lika, border country of Austria-Hungary, residing at New York, in the county and State of New York, have invented certain new and useful Improvements in Electro-Magnetic Motors, of which the following is a specification.

This invention relates to the alternating-current electro-magnetic motors invented by me, in which a progressive shifting or rotation of the poles or points of maximum magnetic effect is produced by the action of the alternating currents. These motors I have constructed in a great variety of ways. As instances, I have built motors with two or more energizing-circuits, which I connected up with corresponding circuits of a generator so that the motor will be energized by alternating currents differing primarily in phase. I have also built motors with independent energizing-circuits of different electrical character or self-induction, through which I have passed an alternating current the phases of which were artificially distorted by the greater retarding effect of one circuit over another. I have also constructed other forms of motor operating by magnetic or electric lag, which it is not necessary to describe herein in detail. although my present invention is applicable thereto. In such motors I use an armature wound with a coil or coils, which is sometimes connected with the external circuit and sometimes closed upon itself, and to both forms the present invention applies. In these motors the total energy supplied to effect their operation is equal to the sum of the energies expended in the armature and the field. The power developed, however, is proportionate to the product of these quantities. This product will be greatest when these quantities are equal; hence in constructing a motor I determine the mass of the armature and field cores and the windings of both and adapt the two so as to equalize as nearly as possible the magnetic quantities of both. In motors which have closed armature-coils this is only approximately possible, as the energy manifested in the armature is the result of inductive action from the other element; but in motors in which the coils of both armature and field are connected with the external circuit the result can be much more perfectly obtained.

In further explanation of my object let it be assumed that the energy as represented in the magnetism in the field of a given motor is ninety and that of the armature ten. The sum of these quantities, which represents the total energy expended in driving the motor, is one hundred; but, assuming that the motor be so constructed that the energy in the field is represented by fifty and that in the armature by fifty, the sum is still one hundred; but while in the first instance the product is nine hundred, in the second it is two thousand five hundred, and as the energy developed is in proportion to these products it is clear that those motors are the most efficient—other things being equal—in which the magnetic energies developed in the armature and field are equal. These results I obtain by using the same amount of copper or ampère turns in both elements when the cores of both are equal, or approximately so, and the same current energizes both; or in cases where the currents in one element are induced to those of the other I use in the induced coils an excess of copper over that in the primary element or conductor.

While I know of no way of illustrating this invention by a drawing such as will meet the formal requirements of an application for patent, I have appended for convenience a conventional figure of a motor such as I employ. I would state, however, that I believe that with the problem before him which I have herein stated, and the solution which I have proposed, any one skilled in the art will be able to carry out and apply this invention without difficulty.

Generally speaking, if the mass of the cores of armature and field be equal, the amount of copper or ampère turns of the energizing-coils on both should also be equal; but these conditions will be modified in well-understood ways in different forms of machine. It will be understood that these results are most advantageous when existing under the conditions presented when the motor is running with its normal load, and in carrying out the invention this fact should be taken into consideration.

Referring to the drawing, A is the field-magnet, B the armature, C the field-coils, and D the armature-coils, of the motor.

The motors described in this application, except as to the features specifically pointed out in the claims, are described and claimed in prior patents granted to and applications filed by me, and are not herein claimed.

What I claim is—

1. An electro-magnetic motor having field and armature magnets of equal strength or magnetic quantity when energized by a given current, as set forth.

2. In an alternating-current motor, the combination, with field and armature cores of equal mass, of energizing-coils containing equal amounts of copper, as herein set forth.

NIKOLA TESLA.

Witnesses:
ROBT. F. GAYLORD,
FRANK E. HARTLEY.

(No Model.)

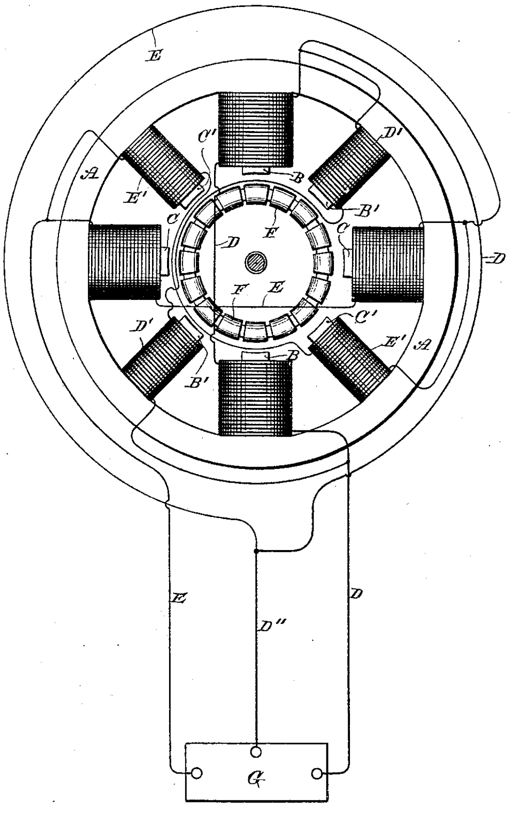
3 Sheets—Sheet 1.

N. TESLA.

ELECTRO MAGNETIC MOTOR.

No. 416,195. Patented Dec. 3, 1889.

Fig. 1



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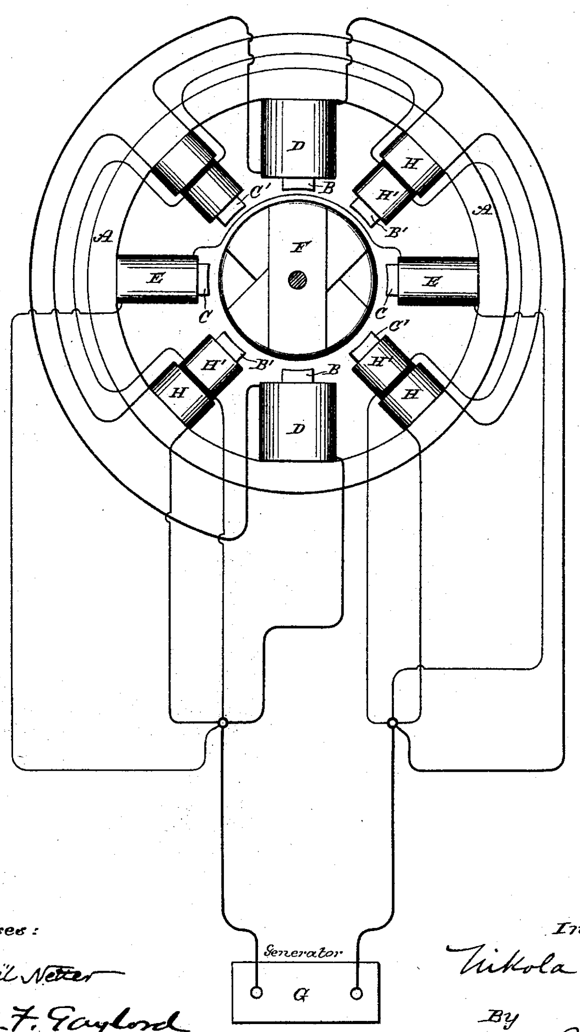
(No Model.) 3 Sheets—Sheet 2.

N. TESLA.

ELECTRO MAGNETIC MOTOR.

No. 416,195. Patented Dec. 3, 1889.

Fig. 2



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(No Model.)

3 Sheets—Sheet 3.

N. TESLA.

ELECTRO MAGNETIC MOTOR.

No. 416,195.

Patented Dec. 3, 1889.

Fig. 3

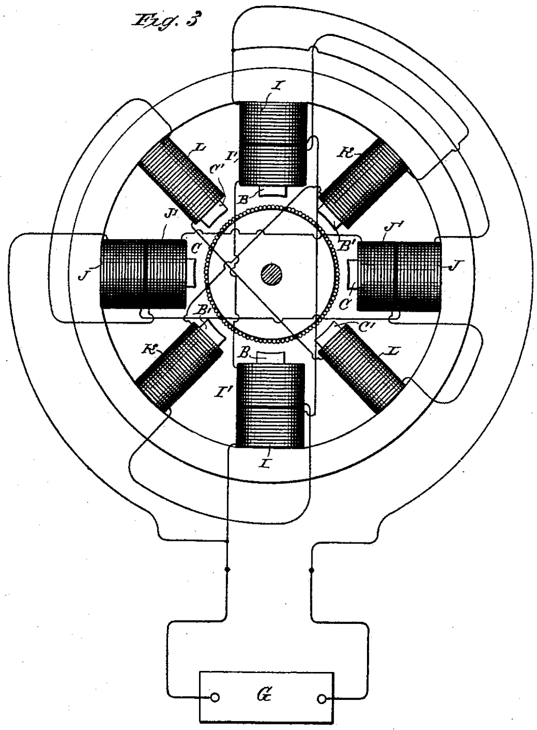
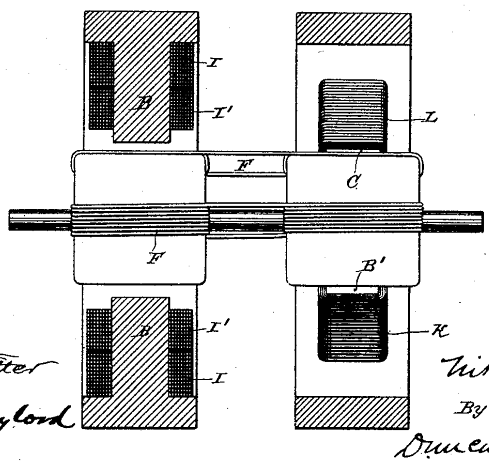


Fig. 4



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UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y., ASSIGNOR TO THE TESLA ELECTRIC COMPANY, OF SAME PLACE.

ELECTRO-MAGNETIC MOTOR.

SPECIFICATION forming part of Letters Patent No. 416,195, dated December 3, 1889.

Application filed May 20, 1889. Serial No. 311,419. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a subject of the Emperor of Austria, from Smiljan, Lika, border country of Austria-Hungary, residing at New York, in the county and State of New York, have invented certain new and useful Improvements in Electro-Magnetic Motors, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

This invention relates to that form of alternating-current motor invented by me, in which there are two or more energizing-circuits through which alternating currents differing in phase are caused to pass. I have in prior patents and applications shown various forms or types of this motor—first, motors having two or more energizing-circuits of the same electrical character, and in the operation of which the currents used differ primarily in phase; second, motors with a plurality of energizing-circuits of different electrical character, in or by means of which the difference of phase is produced artificially, and, third, motors with a plurality of energizing-circuits, the currents in one being induced from currents in another. I shall hereinafter show the application of my present invention to these several types. Considering the structural and operative conditions of any one of them—as, for example, that first-named—the armature which is mounted to rotate in obedience to the co-operative influence or action of the energizing-circuits has coils wound upon it which are closed upon themselves and in which currents are induced by the energizing-currents with the object and result of energizing the armature-core; but under any such conditions as must exist in these motors it is obvious that a certain time must elapse between the manifestations of an energizing-current impulse in the field-coils, and the corresponding magnetic state or phase in the armature established by the current induced thereby; consequently a given magnetic influence or effect in the field which is the direct result of a primary-current impulse will have become more or less weakened or lost before the corresponding effect in the armature indirectly produced has reached its maximum. This is a condition unfavorable to efficient working in certain cases—as, for instance, when the progress of the resultant poles or points of maximum attraction is very great, or when a very high number of alternations is employed—for it is apparent that a stronger tendency to rotation will be maintained if the maximum magnetic attractions or conditions in both armature and field coincide, the energy developed by a motor being measured by the product of the magnetic quantities of the armature and field.

The object, therefore, in this invention is to so construct or organize these motors that the maxima of the magnetic effects of the two elements—the armature and field—shall more nearly coincide. This I accomplish in various ways, which I may best explain by reference to the drawings, in which various plans for accomplishing the desired results are illustrated.

Figure 1: This is a diagrammatic illustration of a motor system such as I have described in my prior patents, and in which the alternating currents proceed from independent sources and differ primarily in phase.

A designates the field-magnet or magnetic frame of the motor; B B, oppositely-located pole-pieces adapted to receive the coils of one energizing-circuit; and C C, similar pole-pieces for the coils of the other energizing-circuit. These circuits are designated, respectively, by D E, the conductor D″ forming a common return to the generator G. Between these poles is mounted an armature—for example, a ring or annular armature, wound with a series of coils F, forming a closed circuit or circuits. The action or operation of a motor thus constructed is now well understood. It will be observed, however, that the magnetism of poles B, for example, established by a current-impulse in the coils thereon, precedes the magnetic effect set up in the armature by the induced current in coils F. Consequently the mutual attraction between the armature and field-poles is considerably reduced. The same conditions will be found to exist if, instead of assuming the poles B or C as acting independently, we regard the ideal resultant of both acting together, which is the real condition. To remedy this, I construct the motor-field with secondary poles B′ C′, which are situated between the others. These pole-pieces I wind with coils D′ E′, the former in derivation to the coils D, the latter to coils E. The main or primary coils D and E are wound for a different sef-induction from that of the coils D′ and E′, the relations being so fixed that if the currents in D and E differ, for example, by a quarter-phase, the currents in each secondary coil, as D′ E′, will differ from those in its appropriate primary D or E by, say, forty-five degrees, or one-eighth of a period.

I explain the action of this motor as follows: Assuming that an impulse or alternation in circuit or branch E is just beginning while in the branch D it is just falling from maximum, the conditions of a quarter-phase difference. The ideal resultant of the attractive forces of the two sets of poles B C therefore may be considered as progressing from poles B to poles C while the impulse in E is rising to maximum and that in D is falling to zero or minimum. The polarity set up in the armature, however, lags behind the manifestations of field magnetism, and hence the maximum points of attraction in armature and field, instead of coinciding, are angularly displaced. This effect is counteracted by the supplemental poles B′ C′. The magnetic phases of these poles succeed those of poles B C by the same, or nearly the same, period of time as elapses between the effect of the poles B C and the corresponding induced effect in the armature; hence the magnetic conditions of poles B′ C′ and of the armature more nearly coincide and a better result is obtained. As poles B′ C′ act in conjunction with the poles in the armature established by poles B C, so in turn poles C B act similarly with the poles set up by B′ C′, respectively. Under such conditions the retardation of the magnetic effect of the armature and that of the secondary poles will bring the maximum of the two more nearly into coincidence and a correspondingly-stronger torque or magnetic attraction secured.

In such a disposition as is shown in Fig. 1 it will be observed that as the adjacent pole-pieces of either circuit are of like polarity they will have a certain weakening effect upon one another. I therefore prefer to remove the secondary poles from the direct influence of the others. This I may do by constructing a motor with two independent sets of fields, and with either one or two armatures electrically connected, or by using two armatures and one field. These modifications will be illustrated hereinafter.

Fig. 2 is a diagrammatic illustration of a motor and system in which the difference of phase is artificially produced. There are two coils D D in one branch and two coils E E in the other branch of the main circuit from the generator G. These two circuits or branches are of different self-induction, one, as D, being higher than the other. For convenience I have indicated this by making coils D much larger than coils E. By reason of this difference in the electrical character of the two circuits the phases of current in one are retarded to a greater extent than the other. Let this difference be thirty degrees. A motor thus constructed will rotate under the action of an alternating current; but as happens in the case previously described the corresponding magnetic effects of the armature and field do not coincide owing to the time that elapses between a given magnetic effect in the armature and the condition of the field that produces it. I therefore employ the secondary or supplemental poles B′ C′. There being thirty degrees difference of phase between the currents in coils D E, the magnetic effects of poles B′ C′ should correspond to that produced by a current differing from the current in coils D or E by fifteen degrees. This I may accomplish by winding each supplemental pole B′ C′ with two coils H H′. The coils H are included in a derived circuit having the same self-induction as circuit D, and coils H′ in a circuit having the same self-induction as circuit E, so that if these circuits differ by thirty degrees the magnetism of poles B′ C′ will correspond to that produced by a current differing from that in either D or E by fifteen degrees. This is true in all other cases. For example, if in Fig. 1 the coils D′ E′ be replaced by the coils H H′ included in derived circuits, the magnetism of the poles B′ C′ will correspond in effect or phase, if it may be so termed, to that produced by a current differing from that in either circuit D or E by forty-five degrees, or one-eighth of a period.

This invention as applied to a derived-circuit motor is illustrated in Figs. 3 and 4. The former is an end view of the motor with the armature in section and a diagram of connections, and Fig. 4 a vertical section through the field. These figures are also drawn to show one of the dispositions of two fields that may be adopted in carrying out the invention. The poles B B C C are in one field, the remaining poles in the other. The former are wound with primary coils I J and secondary coils I′ J′, the latter with coils K L. The primary coils I J are in derived circuits, between which, by reason of their different self-induction, there is a difference of phase, say, of thirty degrees. The coils I′ K are in circuit with one another, as also are coils J′ L, and there should be a difference of phase between the currents in coils K and L and their corresponding primaries of, say, fifteen degrees. If the poles B C are at right angles, the armature-coils should be connected directly across, or a single armature-core wound from end to end may be used; but if the poles B C be in line there should be an angular displacement of the armature-coils, as will be well understood.

The operation will be understood from the foregoing. The maximum magnetic condition of a pair of poles, as B′ B′, coincides closely with the maximum effect in the armature, which lags behind the corresponding condition in poles B B.

There are many other ways of carrying out this invention, but they all involve the same broad principle of construction and operation.

In using expressions herein to indicate a coincidence of the magnetic phases or effects in one set of field-magnets with those set up in the armature by the other I refer only to approximate results; but this of course will be understood.

What I claim is—

1. In an alternating-current motor, the combination, with an armature wound with closed coils, of main and supplemental field magnets or poles, one set of which is adapted to exhibit their maximum magnetic effect simultaneously with that set up in the armature by the action of the other, as set forth.

2. In an electro-magnetic motor, the combination, with an armature, of a plurality of field or energizing coils included, respectively, in main circuits adapted to produce a given difference of phase and supplemental or secondary circuits adapted to produce an intermediate difference of phase, as set forth.

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Witnesses:

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JOHN GILLESPIE.

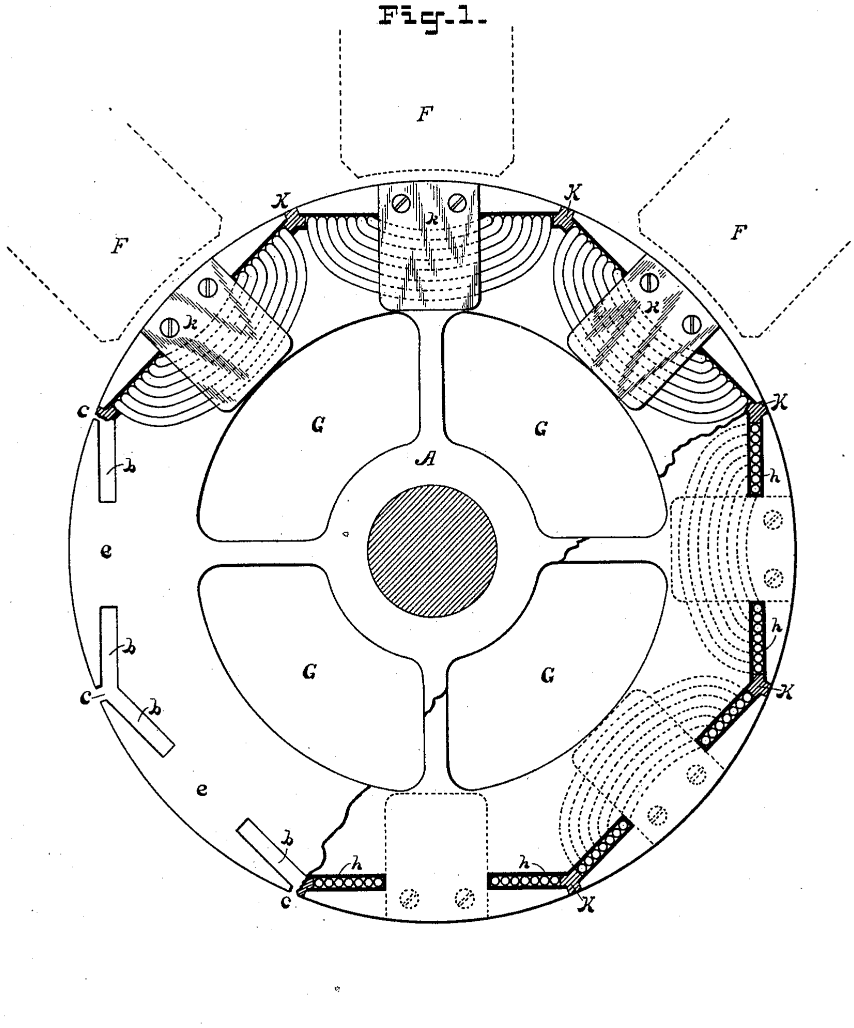
(No Model.) 2 Sheets—Sheet 1.

A. SCHMID & N. TESLA.

ARMATURE FOR ELECTRIC MACHINES.

No. 417,794. Patented Dec. 24, 1889.

Fig. 1.



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Wm. Smith.

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Charles A. Terry

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N. PETERS, Photo-Lithographer, Washington, D. C.

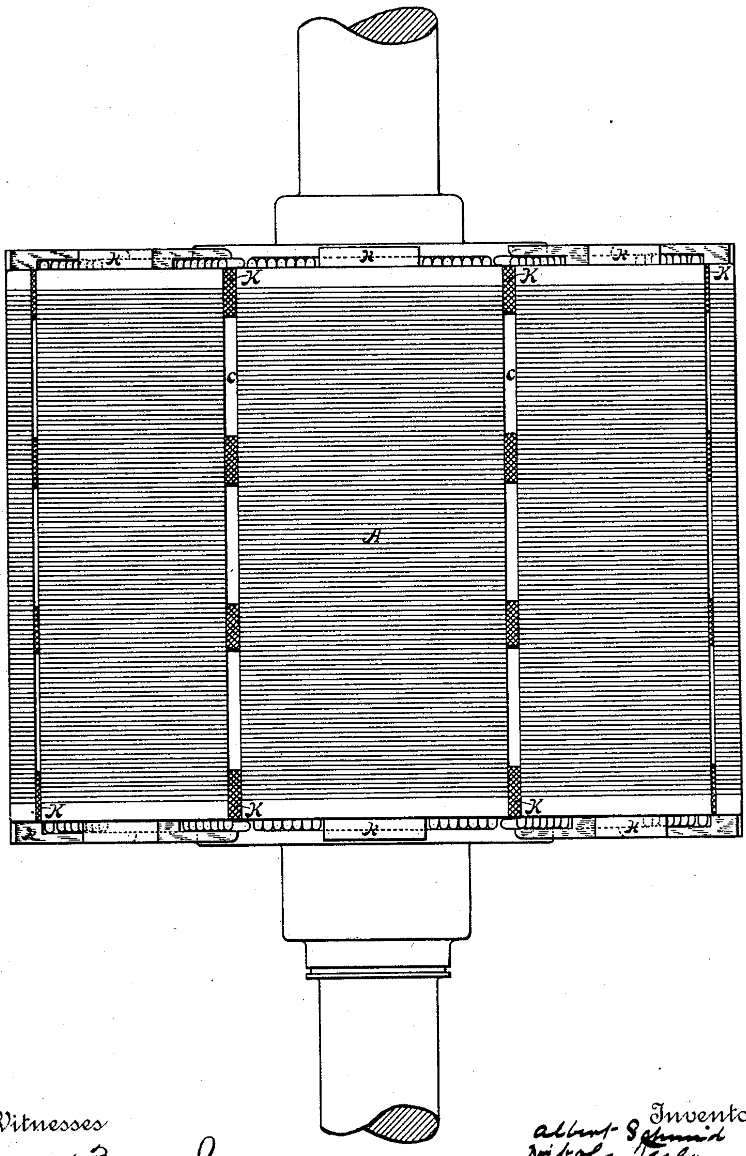
(No Model.) 2 Sheets—Sheet 2.

A. SCHMID & N. TESLA.

ARMATURE FOR ELECTRIC MACHINES.

No. 417,794. Patented Dec. 24, 1889.

Fig. 2.



Witnesses
George Brown Jr.
J. Wm. Smith

Inventor
Albert Schmid
Nikola Tesla
By their Attorney
Charles A. Terry

N. PETERS, Photo-Lithographer, Washington, D. C.

UNITED STATES PATENT OFFICE.

ALBERT SCHMID, OF ALLEGHENY, AND NIKOLA TESLA, OF PITTSBURG, ASSIGNORS TO THE WESTINGHOUSE ELECTRIC COMPANY, OF PITTSBURG, PENNSYLVANIA.

ARMATURE FOR ELECTRIC MACHINES.

SPECIFICATION forming part of Letters Patent No. 417,794, dated December 24, 1889.

Application filed June 28, 1889. Serial No. 315,937. (No model.)

To all whom it may concern:

Be it known that we, ALBERT SCHMID and NIKOLA TESLA, citizens, respectively, of the Republic of Switzerland and Smiljan, Lika, border country of Austria-Hungary, now residing in Allegheny and Pittsburg, both in the county of Allegheny and State of Pennsylvania, have invented a certain new and useful Improvement in Armatures for Electric Machines, (Case No. 310,) of which the following is a specification.

The invention relates to the construction of armatures for electric generators and motors, and the object is to provide an electrically-efficient armature, the construction of which is simple and economical, and in which the coils of insulated conducting wire or ribbon may be conveniently wound or formed into bobbins so located with reference to the body of the armature as to afford as good results as possible.

For certain purposes it is desirable to construct the armatures of electric generators and motors with their cores of magnetizable material projecting through the coils into close proximity to the field-magnet poles. When armatures are constructed in this manner, some means are necessary for holding the coils in position and preventing them from being thrown out by centrifugal force.

This invention aims to provide such means in an armature having polar projections, and also to form an armature in such manner as to expose a large area of core-surface to the field-magnet poles.

The invention consists, in general terms, in forming an armature-core which is preferably built up of laminæ of magnetizable material insulated from each other, with diverging slots or openings for receiving the armature wire or ribbon, which slots are connected with the exterior of the armature by openings through which the wire may be laid in the slots, and in placing the wire in such slots in the proper manner.

We are aware of the United States Patents No. 327,797, granted to Immisch, and No. 292,077, granted to Wenstrom, and the British patent of Coerper, No. 9,013 of 1887, and do not claim the constructions shown and described therein.

The invention will be described more particularly in connection with the accompanying drawings, in which—

Figure 1 is an end view, partly in section, of an armature embodying the features of the invention, and Fig. 2 is a plan of the armature.

Referring to the figures, F F indicate field-magnet poles, and A represents the body or core of an armature composed, in this instance, of laminæ of magnetizable material built up in any suitable manner, the laminæ being preferably separated by intervening strata of insulating material. The individual plates or laminæ are constructed with radial openings *c*, extending a short distance from the surface, and with slots or openings *b*, which extend in different directions from the openings *c*. The slots diverge from each other at such angles as to cause the two slots upon the opposite sides of each web *e* thus formed to lie in the same chord of the circle of the armature. The plates may also be stamped or formed with openings G to remove the unnecessary metal. After the plates are formed they are laid up in the proper manner to form the entire armatur-core, the slots *b* being placed opposite each other to form continuous openings through the entire length of the armature. These openings may be lined by pockets *h* of insulating material—such, for instance, as vulcanized fiber—and the wires are then wound into the slots from the openings *c* and around the respective webs *e*. Winding-clips *k* may be placed at the respective ends of the armature opposite each web *e* to hold the wires in the proper positions as they are wound in the slots and down upon the armature ends.

The wires having been wound into their proper positions, they may be held more securely in position by means of blocks K of non-magnetic material, placed at intervals or extending through the entire slots or openings *c* and projecting into the slots *b*.

An armature constructed in the manner

described is found to be very efficient in its operations and at the same time simple in its construction.

The connections between the armature-coils and the conductors or collecting-plates may be made in any usual well-known manner, according to the purposes desired to be served.

We claim as our invention—

1. A core for electrical machines, composed of plates of magnetizable material separated by insulation, said plates having diverging slots for receiving the armature-conductors and an opening to the exterior of the plate at the origin of the diverging slots.

2. A core-plate for electrical machines, stamped with diverging slots at intervals near its periphery and an opening to the periphery at the angle formed by each two diverging slots.

3. A core for electrical machines, composed of plates of magnetizable material separated by insulation, said plates having diverging slots for receiving the armature-conductors and an opening to the exterior of the plate at the origin of the diverging slots, the width of such openings being approximately equal to the width of the slot.

4. An armature-core for electric machines, consisting of plates of magnetizable material separated by insulation, having radial openings at intervals, slots diverging from said openings for receiving armature-coils, and winding blocks or clips at the ends of the core.

5. An armature-core for electrical apparatus, composed of plates of magnetizable material separated by insulation and having radial openings at intervals, slots extending in opposite directions from said openings for receiving wires, and insulating-linings for said slots.

6. An armature for electric machines, consisting of a laminated core formed with diverging slots for receiving the wires, said slots leaving intervening webs, and coils of wire wound in said slots.

7. An armature for electric machines, consisting of a laminated core formed with diverging slots for receiving the wires, said slots leaving intervening webs, coils of wire wound in said slots, and non-magnetizable material closing the openings of the adjacent slots outside the wires, substantially as described.

8. An armature for electric machines, consisting of a core having its outer surface continuous except for narrow longitudinal openings at intervals and having slots diverging from said openings, armature-coils wound in said slots, and blocks or strips of non-magnetizable material closing the openings and forming with the metal of the armature a practically continuous surface.

In testimony whereof we have hereunto subscribed our names this 25th day of June, A. D. 1889.

ALBERT SCHMID.
NIKOLA TESLA.

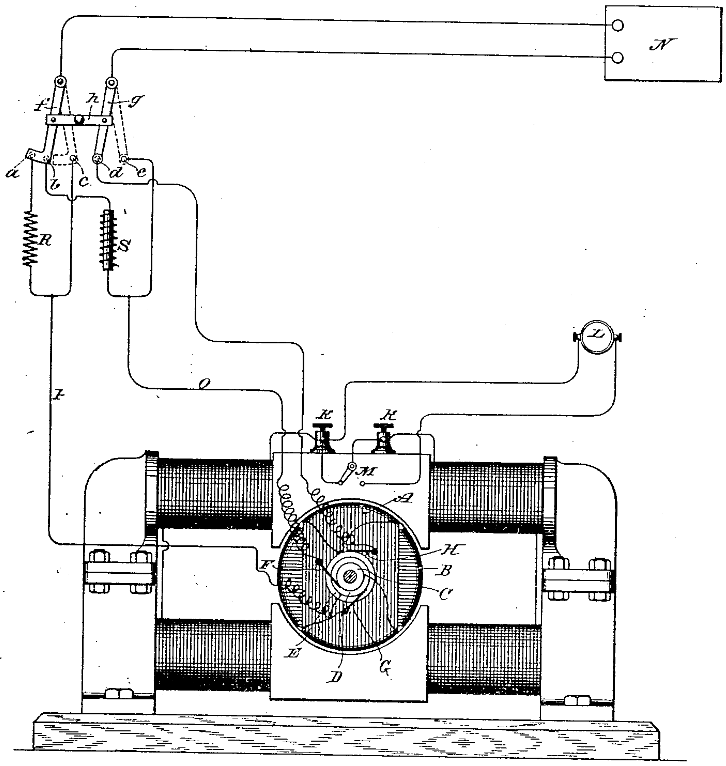
Witnesses:
W. D. UPTEGRAFF,
CHARLES A. TERRY.

(No Model.)

N. TESLA.

ELECTRO MAGNETIC MOTOR.

No. 418,248. Patented Dec. 31, 1889.



Witnesses:
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Robt. F. Gaylord

Inventor
Nikola Tesla
By
Duncan, Curtis & Page
Attorneys.

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UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y., ASSIGNOR TO THE TESLA ELECTRIC COMPANY, OF SAME PLACE.

ELECTRO-MAGNETIC MOTOR.

SPECIFICATION forming part of Letters Patent No. 418,248, dated December 31, 1889.

Application filed May 20, 1889. Serial No. 311,420. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a subject of the Emperor of Austria-Hungary, formerly of Smiljan, Lika, border country of Austria-Hungary, but now residing at New York, in the county and State of New York, have invented certain new and useful Improvements in Methods of Operating Electro-Magnetic Motors, of which the following is a specification, reference being had to the drawing accompanying and forming a part of the same.

In a patent granted to me April 16, 1889, No. 401,520, I have shown and described a method of operating alternating-current motors by first shifting or rotating their magnetic poles until they had reached or passed a synchronous speed and then alternating the poles, or, in other words, by transforming the motor by a change of circuit-connections from one operated by the action of two or more independent energizing-currents to a motor operated by a single current or several acting as one.

The present invention is a specific way of carrying out the same invention; and it consists in the following method: On the start I progressively shift the magnetic poles of one element or field of the motor by alternating currents differing in phase as passed through independent energizing-circuits and short-circuit the coils of the other element. When the motor thus started reaches or passes the limit of speed synchronous with the generator, I connect up the coils previously short-circuited with a source of direct current and by a change of the circuit-connections produce a simple alternation of the poles. The motor then continues to run in synchronism with the generator. There are many specifically-different ways in which this may be carried out; but I have selected one for illustrating the principle. This is illustrated in the annexed drawing, which is a side view of a motor with a diagram of the circuits and devices used in the system.

The motor shown is one of the ordinary forms, with field-cores either laminated or solid and with a cylindrical laminated armature wound, for example, with the coils A B at right angles. The shaft of the armature carries three collecting or contact rings C D E. (Shown, for better illustration, as of different diameters.)

One end of coil A connects to one ring, as C, and one end of coil B connects with ring D. The remaining ends are connected to ring E. Collecting springs or brushes F G H bear upon the rings and lead to the contacts of a switch, to be hereinafter described. The field-coils have their terminals in binding-posts K K, and may be either closed upon themselves or connected with a source of direct current L by means of a switch M. The main or controlling switch has five contacts *a b c d e* and two levers *f g*, pivoted and connected by an insulating cross-bar *h*, so as to move in parallelism. These levers are connected to the line-wires from a source of alternating currents N. Contact *a* is connected to brush G and coil B through a dead-resistance R and wire P. Contact *b* is connected with brush F and coil A through a self-induction-coil S and wire O. Contacts *c* and *e* are connected to brushes G F, respectively, through the wires P O, and contact *d* is directly connected with brush H. The lever *f* has a widened end, which may span the contacts *a b*. When in such position and with lever *g* on contact *d*, the alternating currents divide between the two motor-coils, and by reason of their different self-induction a difference of current-phase is obtained that starts the motor in rotation. In starting, as I have above stated, the field-coils are short-circuited.

When the motor has attained the desired speed, the switch is shifted to the position shown in dotted lines—that is to say, with the levers *f g* resting on points *c e*. This connects up the two armature-coils in series, and the motor will then run as a synchronous motor. The field-coils are thrown into circuit with the direct-current source when the main switch is shifted.

What I claim herein as my invention is—

1. The method of operating electro-magnetic motors, which consists in first progressively shifting or rotating the magnetic poles of one element until it has reached a synchronous speed and then alternating said poles and passing a direct current through the coils of the other element, as herein set forth.

2. The method of operating electro-mag-

netic motors, which consists in short-circuiting the coils of one element, as the field-magnet, and passing through the energizing-coils of the other element, as the armature, alternating currents differing in phase, and then, when the motor has attained a given speed, passing through the field-coils a direct current and through the armature-coils alternating currents coinciding in phase.

NIKOLA TESLA.

Witnesses:
R. J. STONEY, Jr.,
E. P. COFFIN.

(No Model.)

2 Sheets—Sheet 1.

N. TESLA.

ELECTRO MAGNETIC MOTOR.

No. 424,036. Patented Mar. 25, 1890.

Fig. 1

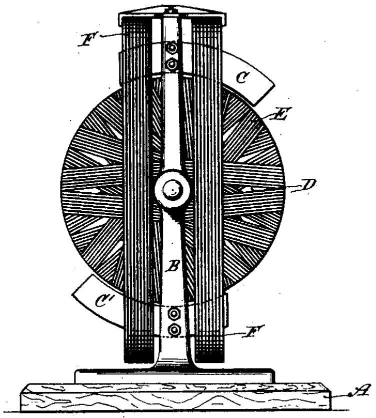
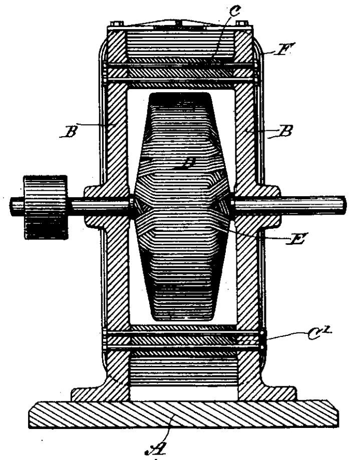


Fig. 2



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N. PETERS, Photo-Lithographer, Washington, D. C.

(No Model.)

2 Sheets—Sheet 2.

N. TESLA.

ELECTRO MAGNETIC MOTOR.

No. 424,036.

Patented Mar. 25, 1890.

Fig. 3

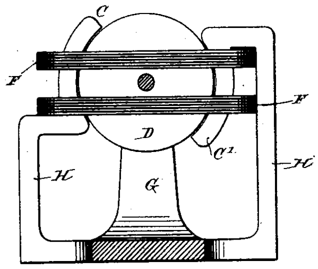
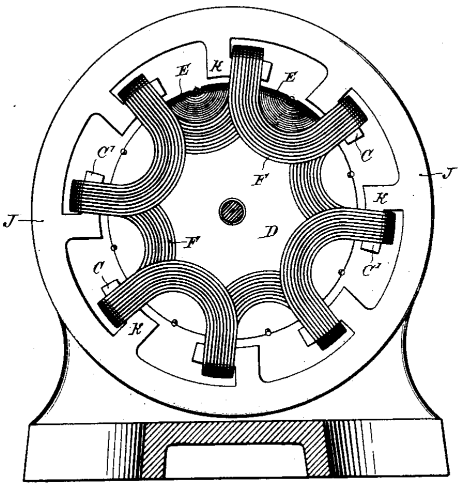


Fig. 4



Witnesses:
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Duncan, Curtis & Page
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N. PETERS, Photo-Lithographer, Washington, D. C.

UNITED STATES PATENT OFFICE.

NIKOLA TESLA, OF NEW YORK, N. Y., ASSIGNOR TO THE TESLA ELECTRIC COMPANY, OF SAME PLACE.

ELECTRO-MAGNETIC MOTOR.

SPECIFICATION forming part of Letters Patent No. 424,036, dated March 25, 1890.

Application filed May 20, 1889. Serial No. 311,416. (No model.)

To all whom it may concern:

Be it known that I, NIKOLA TESLA, a subject of the Emperor of Austria-Hungary, from Smiljan, Lika, border country of Austria-Hungary, residing at New York, in the county and State of New York, have invented certain new and useful Improvements in Electro-Magnetic Motors, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

I have invented and elsewhere described an electro-magnetic motor operated or adapted to be operated by an alternating electric current, and which is now commonly designated, whether correctly or not, a "magnetic-lag" motor. The main distinguishing features of this motor are the following: An armature is mounted within the magnetizing influence of a certain number of field magnets or poles of different magnetic susceptibility—that is to say, poles of unequal length, mass, or composition—and wound with coils adapted in the operation of the motor to be connected to a source of alternating currents. When an alternating current is passed through the coils of such a motor, the field magnets or poles do not appear to manifest their attractive effect upon the armature simultaneously, the magnetic attraction of some appearing to lag behind that of others, with the result of producing a torque and rotation of the motor. Generally I have made such motors with closed armature-coils.

I have invented another form of motor, which, for similar reasons, may be called a "magnetic-lag" motor; but in operation it differs from that which I have above described in that the attractive effects or phases of the poles, while lagging behind the phases of current which produce them, are manifested simultaneously and not successively.

To carry out this invention I employ a motor embodying the principle of construction of a motor described and claimed in an application filed by me January 8, 1889, No. 295,745, to the extent that both the armature and field receive their magnetism from a single energizing-coil or a plurality of coils acting as one.

A motor which embodies my invention, with certain modifications thereof, is illustrated in the accompanying drawings.

Figure 1 is a side view of the motor in elevation. Fig. 2 is a part-sectional view at right angles to Fig. 1. Fig. 3 is an end view in elevation and part section of a modification, and Fig. 4 is a similar view of another modification.

In Figs. 1 and 2, A designates a base or stand, and B B the supporting-frame of the motor. Bolted to the said supporting-frame are two magnetic cores or pole-pieces C C′, of iron or soft steel. These may be subdivided or laminated, in which case hard iron or steel plates or bars should be used, or they should be wound with closed coils. D is a circular disk-armature built up of sections or plates of iron and mounted in the frame between the pole-pieces C C′, which latter are preferably curved to conform to the circular shape thereof. I may wind this disk with a number of closed coils E. F F are the main energizing-coils, supported in any convenient manner by the supporting-frame, or otherwise, but so as to include within their magnetizing influence both the pole-pieces C C′ and the armature D. The pole-pieces C C′ project out beyond the coils F F on opposite sides, as indicated in the drawings. If an alternating current be passed through the coils F F, rotation of the armature will be produced, and this rotation I explain by the following apparent action or mode of operation: An impulse of current in the coils F F establishes two polarities in the motor. The protruding end of pole-piece C, for instance, will be of one sign, and the corresponding end of pole-piece C′ will be of the opposite sign. The armature also exhibits two poles at right angles to the coils F F, like poles to those in the pole-pieces being on the same side of the coils. While the current is flowing there is no appreciable tendency to rotation developed; but after each current impulse ceases or begins to fall the magnetism in the armature and in the ends of the pole-pieces C C′ lags or continues to manifest itself, which produces a rotation of the armature by the repellent force between the more closely approximating points of maximum magnetic effect. This effect is continued by the reversal of current, the polarities of field and armature being simply reversed. One or both of the elements—the armature or field—may be wound with closed induced coils to intensify this effect, although in the drawings I have shown but one of the fields, each element of the motor really constitutes a field, wound with the closed coils, the currents being induced mainly in those convolutions or coils which are parallel to the coils F F. A modified form of this motor is shown in Fig. 3. In this form G is one of two standards that support the bearings for the armature-shaft. H H are uprights or sides of a frame, preferably magnetic, the ends C C′ of which are bent, substantially as shown, to conform to the shape of the armature D and form field-magnet poles. The construction of the armature may be the same as in the previous figure, or it may be simply a magnetic disk or cylinder, as shown, and a coil or coils F F are secured in position to surround both the armature and the poles C C′. The armature is detachable from its shaft, the latter being passed through the armature after it has been inserted in position. The operation of this form of motor is the same in principle as that previously described and needs no further explanation.

One of the most important features in alternating-current motors is that they should be adapted to and capable of running efficiently in the alternating systems in present use, in which almost without exception the generators yield a very high number of alternations. Such a motor I have designed by a development of the principle of the motor shown in Fig. 3, making a multipolar motor, which is illustrated in Fig. 4. In the construction of this motor I employ an annular magnetic frame J, with inwardly-extending ribs or projections K, the ends of which all bend or turn in one direction and are generally shaped to conform to the curved surface of the armature. Coils F F are wound from one part K to the one next adjacent, the ends or loops of each coil or group of wires being carried over toward the shaft, so as to form U-shaped groups of convolutions at each end of the armature. The pole-pieces C C′, being substantially concentric with the armature, form ledges, along which the coils are laid and should project to some extent beyond the coils, as shown. The cylindrical or drum armature D is of the same construction as in the other motors described, and is mounted to rotate within the annular frame J and between the U-shaped ends or bends of the coils F. The coils F are connected in multiple or in series with a source of alternating currents, and are so wound that with a current or current impulse of given direction they will make the alternate pole-pieces C of one polarity and the other pole-pieces C′ of the opposite polarity. The principle of the operation of this motor is the same as the other herein described, for, considering any two pole-pieces C C′, a current impulse passing in the coil which bridges them or is wound over both tends to establish polarities in their ends of opposite sign and to set up in the armature-core between them a polarity of the same sign as that of the nearest pole-piece C. Upon the fall or cessation of the current impulse that established these polarities the magnetism which lags behind the current phase, and which continues to manifest itself in the polar projections C C′ and the armature, produces by repulsion a rotation of the armature. The effect is continued by each reversal of the current. What occurs in the case of one pair of pole-pieces occurs simultaneously in all, so that the tendency to rotation of the armature is measured by the sum of all the forces exerted by the pole-pieces, as above described. In this motor also the magnetic lag or effect is intensified by winding one or both cores with closed induced coils. The armature-core is shown as thus wound. When closed coils are used, the cores should be laminated.

It is evident that a pulsatory as well as an alternating current might be used to drive or operate the motors herein described; but I prefer to use alternating currents.

It will be understood that the degree of subdivision, the mass of the iron in the cores, their size, and the number of alternations in the current employed to run the motor must be taken into consideration in order to properly construct this motor. In other words, in all such motors the proper relations between the number of alternations and the mass, size, or quality of the iron must be preserved in order to secure the best results. These are matters, however, that are well understood by those skilled in the art.

What I claim is—

1. In an alternating-current motor, the combination, with the armature and field-cores, of stationary energizing-coils enveloping the said cores and adapted to produce polarities or poles in both, the field-cores extending out from the coils and constructed so as to exhibit the magnetic effect imparted to them after the fall or cessation of current impulse producing such effect, as set forth.

2. In an alternating-current motor, the combination, with an armature-core circular in configuration, of a supporting-frame, field-cores extending therefrom over portions of the periphery of the armature, and energizing-coils surrounding said armature and parts of the field-cores, as set forth.

3. The combination, with the rotatably-mounted armature, of the circular frame J, the ribs K, with polar extensions extending over portions of the armature, and the energizing-coils F, wound over portions of the pole-pieces and carried in loops over the ends of the armature, as herein set forth.

NIKOLA TESLA.

Witnesses:

R. J. STONEY, Jr.,
E. P. COFFIN.