(No Model.) 2 Sheets—Sheet 1.

J. F. KELLY.

METHOD OF AND APPARATUS FOR TRANSFORMING ALTERNATING INTO CONTINUOUS CURRENTS.

No. 522,988. Patented July 17, 1894.

Fig.1

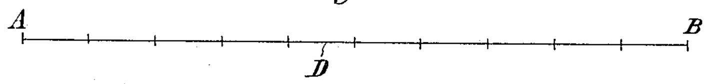


Fig.2

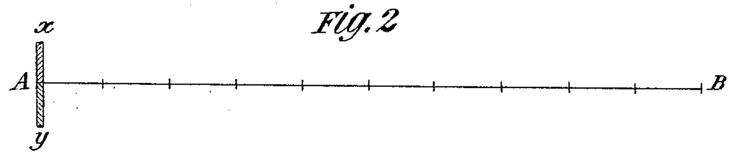


Fig.3

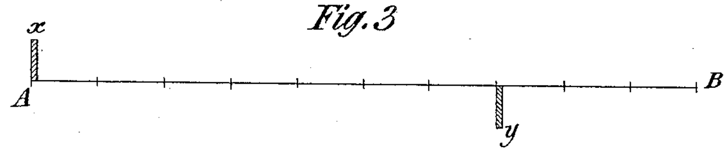


Fig.4

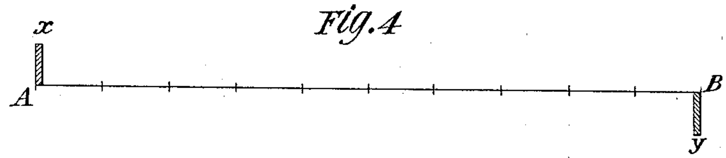


Fig.5

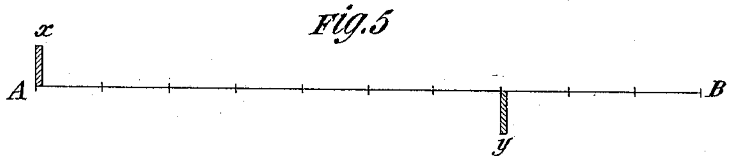


Fig.6

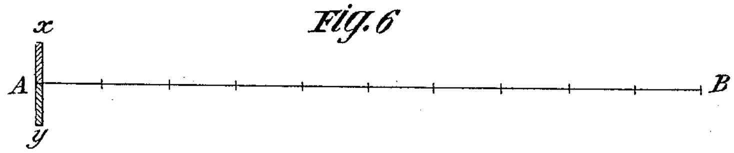


Fig.7

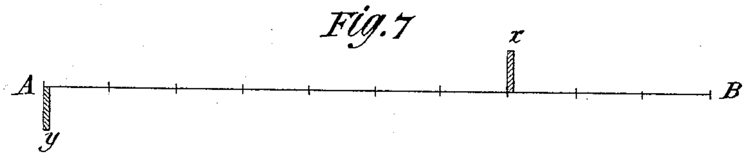


Fig.8

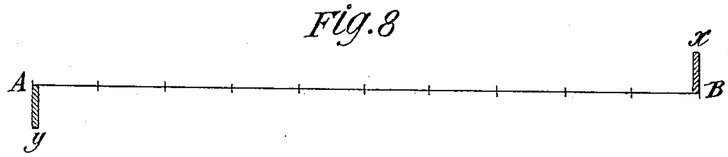
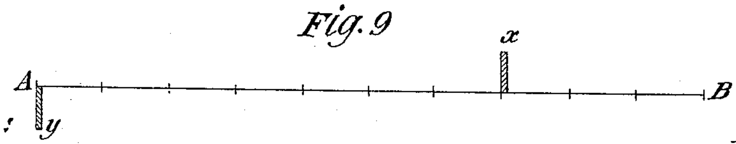


Fig.9



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2 Sheets—Sheet 2.

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METHOD OF AND APPARATUS FOR TRANSFORMING ALTERNATING INTO CONTINUOUS CURRENTS.

No. 522,988. Patented July 17, 1894.

Fig. 10

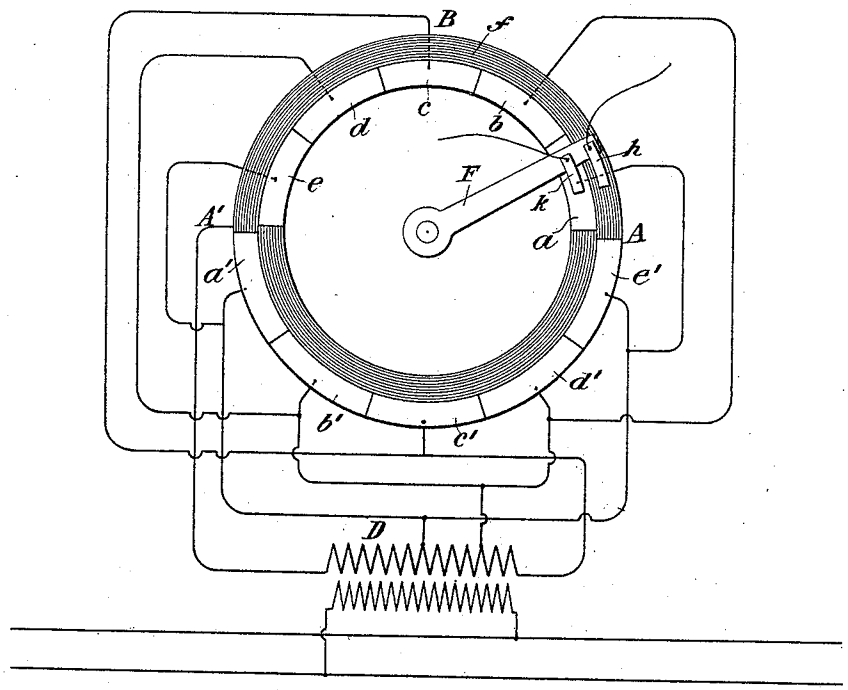
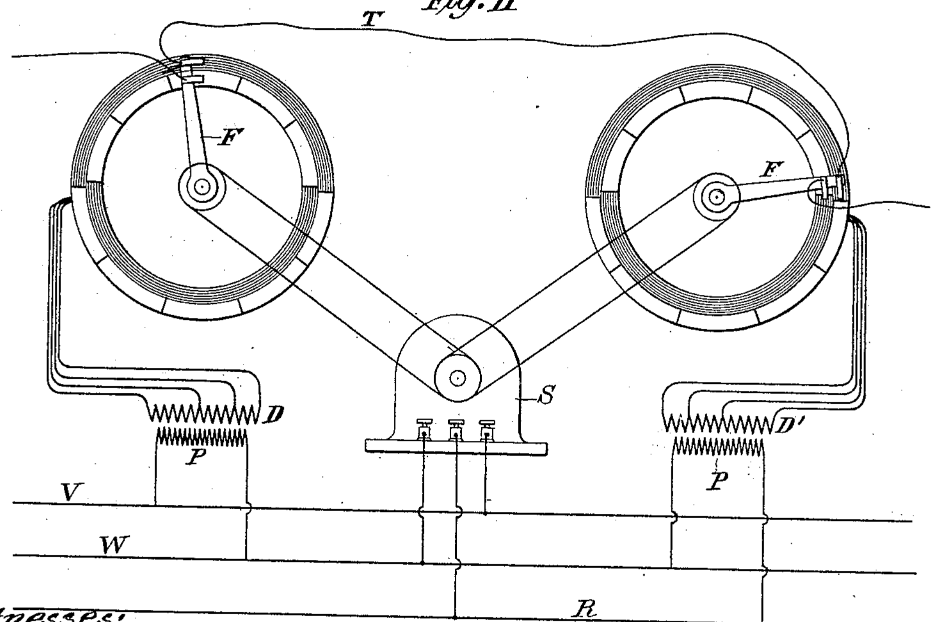


Fig. II



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UNITED STATES PATENT OFFICE.

JOHN F. KELLY, OF PITTSFIELD, MASSACHUSETTS, ASSIGNOR TO THE STANLEY LABORATORY COMPANY, OF SAME PLACE.

METHOD OF AND APPARATUS FOR TRANSFORMING ALTERNATING INTO CONTINUOUS CURRENTS.

SPECIFICATION forming part of Letters Patent No. 522,988, dated July 17, 1894.

Application filed January 6, 1894. Serial No. 495,930. (No model.)

To all whom it may concern:

Be it known that I, JOHN F. KELLY, a citizen of the United States, residing at Pittsfield, in the county of Berkshire and State of Massachusetts, have invented certain new and useful Improvements in Methods of and Apparatus for Transforming Alternating into Continuous Currents, of which the following is a specification, reference being had to the drawings accompanying and forming a part of the same.

The alternating electro-motive force produced by such generators as are commonly used, varies as the sine of the angle traversed, that is to say, it is proportionate at any given instant to the sine of the angle through which the induced coil has passed from the zero or starting point, the angle between two similar poles being considered as equal to four right angles, or 2π and corresponds in form to the curve expressed by the value E sin $2\pi nt$, in which E is the maximum electro-motive force, n the number of complete cycles, or revolutions of the coil per second, t the time at any instant required by the coil to reach a given point, measured from the beginning of a cycle and hence variable, and π the symbol for the ratio between diameter and circumference. Of two such electro-motive forces, therefore, in quadrature, or which have a fixed displacement of ninety degrees, one will vary as the sine and the other as the cosine of the angle $2\pi nt$ for all its values. Various methods and appliances have been proposed for commuting and adding together two such electro-motive forces to produce a unidirectional current, but the resulting current will of necessity undergo a very considerable variation in electro-motive force, since it may be readily shown that if the two added electro-motive forces vary respectively as the sine and cosine of the same angles, at times their sum exceeds the maximum value of either. If, however, they be compelled to vary respectively as the sine squared and cosine squared of the angle traversed, their sum will always be constant, and the object of my invention is to effect this result in a novel and simple manner.

As I may illustrate most readily the nature of my invention by a diagram, I now refer to the accompanying drawings.

Figures 1 to 9 are diagrams illustrative of the principle of the invention. Fig. 10 is a diagrammatic illustration of a device forming a part of the mechanism for practically carrying out the invention. Fig. 11 is a similar illustration of a complete combination of devices of the invention.

Let it be assumed that two points, A, B, Figs. 1 to 9, are connected by a uniform conductor D and that an alternating electro-motive force is maintained between them which varies as the sine of the angle traversed, or is of the form E sin $2\pi nt$. Let X Y represent two brushes in contact with such conductor and assume that at the instant when E sin $2\pi nt = O$, both brushes are at the point A, with brush Y just about to start toward B at a velocity = A B cos $2\pi nt$, or in other words, so that the distance between the brushes at any instant of time will be proportionate to the sine of the angle $2\pi nt$. If now we assume that the electro-motive force between the brushes will be to the distance between them as this distance is to the distance A B, which would be the case if we assume that the current drawn off by the brushes is not sufficient to disturb the distribution of the electro-motive forces, it is obvious that the electro-motive force between the brushes will be equal at any instant—until B is reached—to that at the terminals A B multiplied by the ratio of the distance between the brushes and the distance A B, that is, it will be equal to E $\sin^2 2\pi nt$.

Under the conditions assumed, the position of the brush Y at the end of the first eighth of a period would be at a point about seven-tenths of the total distance from A to B, as shown in Fig. 3, so that it would be receiving only a fractional part of the electro-motive force at that point, while at the end of the first quarter of a period it will have reached the point B. The curve of the current which the brushes have thus drawn off will rise as the sine squared of the angle traversed.

If when brush Y reaches B it be caused to return over the same path at the same rate, we shall have the same law for the electro-motive force in the second quadrant, the current drawn off falling to zero, when the two brushes are again at A, and the electro-motive force between A and B being zero and about to become negative. Let us now start brush X over the path toward B at the same rate as before. The electro-motive force between the brushes will evidently follow the same law as to magnitude as before, and the position of the brushes with respect to A, B, having changed when the electro-motive force between A and B changed sign, it is evident that the electro-motive force between the brushes will be of the same sign as before. When X reaches B it stops and then returns, following the same law as to velocity. If now we assume another similar conductor between the terminals of which is maintained an electro-motive force of the form E cos $2\pi nt$, and along which the brushes are similarly moved with the velocity A B sin $2\pi nt$, or so that, as before, the distance between the brushes at any instant of time will be proportionate to the cosine of the angle $2\pi nt$, the brushes being at opposite ends of the conductor at starting, it is obvious that we will have between this second pair of brushes an electro-motive force which will vary as the cosine squared of the angle traversed. If therefore, we connect the two sets of brushes together so as to superimpose the two electro-motive forces, we shall have a resultant electro-motive force of the form E $(\sin^2 2\pi nt+\cos^2 2\pi nt)$, which for all values of t is constant and equal to E, or unity.

Since the rectilinear movement of the brushes in the illustrative case above is not uniform, it would be difficult in practice to secure it properly, but the same result may be attained in a simple and practicable way by means of such a mechanism as I have illustrated in Figs. 10 and 11.

The conductor D, Fig. 10, is in the form of a coil, such as the secondary of a transformer, a self-induction coil, the induced coil of a dynamo or the like. If this conductor be divided up into a certain number of sections of proper lengths and a brush caused to travel at a uniform rate in contact with the terminals of such sections, it is evident that the proportionate part of such conductor included between such brush and a stationary brush connected with one end of the conductor will depend upon the relative lengths of the sections. I therefore proportion these sections in the following manner: Suppose that there are M sections in the conductor, and that the whole number of turns or length of the conductor which we will represent by L be taken as corresponding to the $\sin\frac{1}{2}\pi$ or ninety degress. Then the number of turns included in the first section beginning with the largest will be $\sin\frac{\pi}{2M}L$ the number included in the first two sections, $\sin\frac{2\pi}{2M}L$, in the first three $\sin\frac{3\pi}{2M}L$, and so on up to M−1 sections, $\sin\frac{(M-1)\pi}{2M}L$.

I provide a series of insulated contact plates which are designated by the letters a, b, c, d, e and a', b', c', d', e', and a continuous plate f so arranged that two brushes h, k may be caused to sweep over them, the disposition of the plates being such that during one half of the cycle of movement one brush, as h, will remain in contact with f, while brush k passes successively over plates a, b, c, d, e, and during the remaining time the brush k remains in contact with f while brush h passes successively over plates a', b', c', d', e'.

Any well known disposition or arrangement of parts may be followed in securing the result, but for simplicity, I have shown the plates as secured to a flat surface in two concentric circles, one half of each being composed of the plates a, b, c, d, e and a', b', c', d', e' respectively and the other half by the plate f, the two parts of which are electrically connected.

F is an arm carrying the two brushes h, k and motion is imparted to it so that the brushes make one complete revolution in the time occupied by a complete cycle of the current to be transformed.

One terminal of the conductor D is connected with plate f and the terminals of the several sections are connected in order to plates a, b, and c. If, therefore, the brush k be caused to traverse in succession the contacts a, b, c in a quarter period, brush h meanwhile remaining on plate f, all of the conductor D will have been traversed in that time, the number of turns included in the circuit varying as above described so that the electro-motive force between the brushes h and k will be equal, at any instant, to E $\sin^2 2\pi nt$. If the brushes be then moved back the sections of conductor D will be cut out in reverse order, but this is more readily accomplished by causing the brushes to continue their motion so that brush k passes over plates c, d, e while brush h remains on plate f, said plates d and e being connected with the sections of D but in the opposite order to a and b, so that a forward motion of brush k from c to e is equivalent to a backward motion from c to a. The two brushes being carried around together one in contact with the continuous plate f, pass from the point A, when they include no section to B, where they include all the sections of conductor D, and thence to A′, where they again include no section.

At A′, the continuous plate and the sections change places with reference to the brushes, so that the brushes in traveling onward reverse the connections of the conductor with respect to the external circuit.

The order of the plates a', b', c' is also reversed again in the third quadrant so that the last section of D cut out in the second quadrant is the first brought in in the third, and it will be understood that the plates in the third quadrant are connected in the same order as those in the first, while those in the fourth quadrant are connected in the same order as those in the second.

As the pair of brushes are rotated synchronously with the impressed frequency, they will include between them a number of turns substantially proportioned to the sine of the angle of rotation, and as the electro-motive force at the terminals of the conductor D is also varying as the sine of the same angle, the electro-motive force between the brushes will be substantially proportional to the square of the sine.

A similar conductor D′ and a commutator such as described, but with the phase of the electro-motive force shifted ninety degrees, will give an electro-motive force substantially proportional to the square of the cosine, and if we connect the two sets of brushes so as to superimpose the two electro-motive forces their sum will be constant. This is illustrated in Fig. 11, where V, W, indicate the leads from a source of two alternating currents in quadrature and R the common return. P and P′ are the primaries of transformers included in the two circuits respectively and D, D′ the secondaries, connected with the commutators as above described.

I have shown a small synchronous motor S for rotating the brushes and have indicated the external circuit into which the corrected currents are delivered by T.

It will be understood from the nature of the case that the conductor D should have a high self-induction in order to avoid loss of energy.

The mechanical construction and arrangement of the mechanism for carrying out my invention may be greatly modified. In this, as in analogous classes of mechanism, it is immaterial to the character of the ultimate result, for example, whether the commutator or the brushes revolve, or whether the commutator be arranged on a flat or on a cylindrical surface. My invention is not, however, limited to the specific devices herein described. It will also be understood that the number of sections into which the conductor D is divided should in general be greater than shown herein for purposes of illustration.

In illustration of the invention and the way in which the same is or may be carried into effect, I have confined the description to the case of two alternating currents in quadrature, but the same principles apply to the transformation of any number of currents between which there exists a uniform difference in phase. For if we represent the difference in phase by a, we may write for a multiphase system of electro-motive forces, E sin $(2\pi nt)$, E sin $(2\pi nt+a)$, E sin $(2\pi nt+2a)$ — E sin $(2\pi nt+(n-1)\,a)$, and then the length of conductor or number of turns included in each coil of the device described will vary as sin $(2\pi nt)$, sin $(2\pi nt+a)$, &c., respectively, or what is the same thing, the rate of motion of the brushes will vary as the cosines of the said angles. The electromotive forces between the various pairs of brushes will then be respectively E $\sin^2 2\pi nt$; E $\sin^2 (2\pi nt+a)$; E $\sin^2 (2\pi nt+2a)$ — E $\sin^2 (2\pi nt+(n-1)\,a)$. The sum of this series is independent of t whatever the value of n.

When there are only two currents in quadrature, we have for the electro-motive forces E sin $(2\pi nt)$, and E sin $(2\pi nt+a)$ and a being now equal to ninety degrees or $\frac{1\pi}{2}$, these expressions are equivalent to E sin $2\pi nt$ and E cos $2\pi nt$, the number of turns being similarly proportional to sin $2\pi nt$ and cos $2\pi nt$, and the rate of motion of the brushes to cos $2\pi nt$ and sin $2\pi nt$. Therefore for the particular case of two phase currents everything may be expressed as functions of either the sine or cosine of one variable angle; but in general the electro-motive forces and number of turns in circuit must be expressed as functions of the sines of the several variable angles, and the rate of motion of the brushes as functions of the cosines of the same angles respectively.

It will be observed that if a unidirectional current be supplied to the rotating brushes that the converse of the operation takes place and that multi-phase currents would be produced in the conductors.

Having now described my invention, what I claim is—

1. The method of transforming a plurality of alternating currents of the same frequency and uniform phase difference into a unidirectional current of substantially constant electro-motive force, which consists in collecting such fractional portions of the electro-motive forces as shall vary as the sines squared of the current phases and superimposing the same as herein set forth.

2. The electrical transformer herein described comprising in combination a conductor adapted for connection with a source of alternating current which varies as the sine of the angle traversed by its inducing conductor, collecting brushes movable along said conductor in alternately opposite directions and means for moving said brushes in synchronism with the frequency of the current and at a rate proportionate to the cosine of the angle traversed by its inducing conductor, as set forth.

3. The combination with a conductor traversed by or adapted to carry an alternating current which varies as the sine of the angle traversed by its inducing conductor of the following devices, viz: a circular series of contact plates, comprising four groups, the plates of each group being connected in alternately reversed order to the conductor at such distances apart that the amount of said conductor included in any number of sections taken from the end next the largest is to the whole conductor as the sine of 3.1416 times the number of sections considered divided by twice the total number of sections is to unity, a continuous contact connected with one terminal of the conductor, a pair of rotary brushes alternately bearing on the continuous and sectional contacts during each successive half revolution, and means for rotating said

brushes synchronously with the frequency of the current, as herein described.

4. The electrical transformer herein described comprising in combination two conductors adapted for connection with sources of alternating currents which vary as the sine and cosine of the same angles, collecting brushes movable along said conductors in alternately opposite directions and means for moving said brushes in synchronism with the frequency of the currents and at a rate proportionate respectively to the cosine and sine of the angles traversed by the inducing coils of the generator and connections between the brushes whereby the currents collected and commuted by them will be superimposed, as set forth.

5. The combination with each of two conductors traversed by or adapted to carry two alternating currents which vary as the sine and cosine of the same angles, of the following devices, viz., a circular series of contact plates, comprising four groups, the plates of each group being connected in alternately reversed order to the conductor at such distances apart that the amount included in any number of sections counting from the end next the largest is to the whole conductor as the sine of 3.1416 times the number of sections considered divided by twice the whole number of sections is to unity, a continuous contact connected with one terminal of the conductor, a pair of rotating brushes alternately bearing on the continuous and sectional contacts during each successive half revolution, means for rotating such brushes synchronously with the frequency of the current and connections between the brushes whereby the currents collected and commuted by the same will be superimposed, as set forth.

6. The combination with an alternate current coil D, divided into sections, the number of turns of each being such that the amount included in any number of sections counting from the end next the largest is to the whole conductor as the sine of 3.1416 times the number of sections considered divided by twice the whole number of sections is to unity, of a series of contact plates forming the terminals of said sections, a continuous contact plate f, brushes h, k, means for moving said brushes over said plates so as to collect a uni-directional current varying as the sine squared of the angle traversed by the inducing coil of the generator, a second conductor, and commutator similar to the first but delivering an electro-motive force varying as the cosine squared of the angle, traversed by the said inducing coil and connections between the two sets of brushes whereby the two currents are superimposed, as set forth.

7. The combination with two sources of alternating currents which vary respectively as the sine and cosine of the same angles, of two conductors or coils connected to the said sources, means for collecting from said coils alternating electro-motive forces varying as the sine squared and cosine squared of the same angles, commutators for correcting or straightening such currents and electrical connections for combining them into a single current, as set forth.

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