[Third Edition.]

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COMPLETE SPECIFICATION.

[Communicated from abroad by NIKOLA TESLA, of the City and State of New York, United States of America, Electrician.]

Improvements in the Construction and Mode of Operating Alternating Current Motors.

I, HENRY HARRIS LAKE, of the firm of Haseltine, Lake & Co., Patent Agents, Southampton Buildings in the County of Middlesex, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to that form of electro-magnetic motors in which one of the elements, the armature or the field, is provided with coils forming independent energizing circuits, through which from any suitable source or sources, alternating currents differing in phase, are passed for the purpose of producing in the motor a progression or rotation of the points of maximum magnetic attraction.

Motors of this general character are constructed in various ways, the principal forms being, 1st, those in which the independent energizing circuits are connected to independent sources of alternating currents having a definite difference in phase; 2nd, those in which the independent energizing circuits are of different electrical character, or have different degrees of self-induction, and are connected in derivation to the same source or circuit of alternating currents; and 3rd, those having independent energizing circuits in mutually inductive relations whereby alternating currents passed through one circuit will induce similar currents in the other.

This invention relates mainly to the two kinds of motor last named; that is to say, to those which are run by a single source of alternating currents or in which the currents in the two energizing circuits are derived either directly or indirectly from one line or main circuit.

The lag or retardation 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 exist in motors of this kind have led 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 are made of coarse wire, or a conductor of relatively low resistance, and the greatest possible length or number of turns is used.

In the other set of coils are 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, the cores in the self induction circuit are much longer than those in the other or resistance circuit. A motor embodying these features is shown in the accompanying drawing in which

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

In Figure 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. A long length of a large number of turns of coarse wire is therefore used in forming the coils of this circuit.

For the circuit B, a smaller conductor, or a conductor of a higher resistance than copper, such as German silver or iron, is employed, and the coils have fewer turns.

In applying these coils to a motor, a field is built up 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, forming an open space in the center for receiving the armature G.

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 those coils which are designed to have the higher self-induction are almost completely surrounded by iron by which the retardation is considerably increased.

Heretofore in the construction of motors operating according to this principle, it has been customary to wind the armature with coils closed upon themselves, except in some instances in which the energizing circuits are connected to independent sources of alternating currents and the armature coils are also connected to the same sources But for some purposes it is advantageous to include both armature and field circuits in a circuit from a single source of current, as is shown in Figure 3, which is a diagram of the circuit connections.

A, B, in this figure, indicate the two energizing circuits of a motor, and A^1, B^1, two circuits on the armature. Circuit or coil A is connected in series with circuit or coil A^1, and the two circuits B, B^1 are similarly connected.

Between coils A and A^1 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 B^1. 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 there is shown in one of these circuits an artificial resistance R, and in the other a self-induction coil S.

When an alternating current from a generator H 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 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 will close 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*.

The arrangement of the coils with reference to one another may be considerably varied. For example, the two armatures and two field coils instead of being connected together in series in two derived circuits, may be in derivation to themselves and in series with one another as shown in Figure 4. In this figure, A, B, are the field coils, opposite terminals of which are connected to the binding post *h* on one side and binding post *i* on the other through brushes and collecting rings and the armature coils A^1, B^1. These latter are in derived circuits of different self induction which are shown as containing a dead resistance R^1 and a self-induction coil S^1.

Figure 5 shows a further modification, in which the armature has but one coil C^1 in series with the field coils which are in derivation to one another. The winding of the coil C^1 in this case should be such as to maintain effects corresponding to the resultant poles produced by the two field circuits.

In like manner the armature and field coils may all be derived or multiple circuits having the proper relative self-induction, or one of the armature circuits may be closed upon itself and the other connected either in derivation or series with the field coils.

A motor constructed in this way with its field and armature coils connected with the external circuits, exhibits a strong tendency to synchronism, but comparatively little torque on the start. On the other hand, if the armature coils be short circuited, the torque in starting is very greatly increased, but the tendency to run in synchronism with the generator is correspondingly reduced. For the proper operation of these motors, therefore, a shunt K is used around one or both of the armatures coils in which is placed a switch L.

In starting this motor the shunt around the armature coils is closed, so that the latter, therefore, will 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.

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 2000 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. It is therefore preferable 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 2000 revolutions—is reached or passed.

This may be accomplished in various ways, but for all practical purposes the following will suffice. On the armature are wound two sets of coils, on the start one is short-circuited 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.

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.

The method involved in this invention of operating a motor by producing artificially a difference of current phase in its independent energizing circuits, and the broad feature of a motor having energizing circuits of different self induction, are not claimed herein.

Having now particularly described and ascertained the nature of the said invention and in what manner the same is to be performed as communicated to me by my foreign correspondent I declare that 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.

5. 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.

6. 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.

7. 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.

8. 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.

9. 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.

Dated this 3rd day of December 1889.

HASELTINE, LAKE & Co.,
45, Southampton Buildings, London, Agents for the Applicant.

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Fig. 1

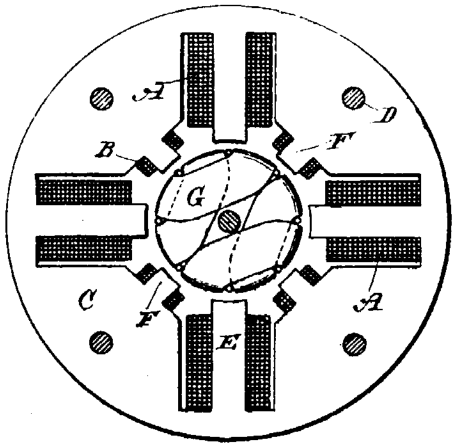


Fig. 2

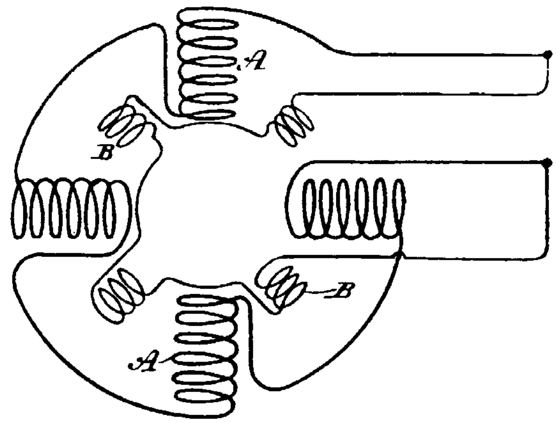


Fig. 3

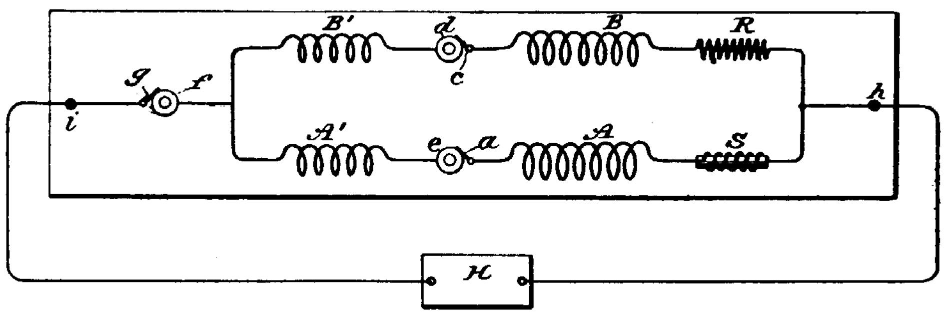


Fig. 4

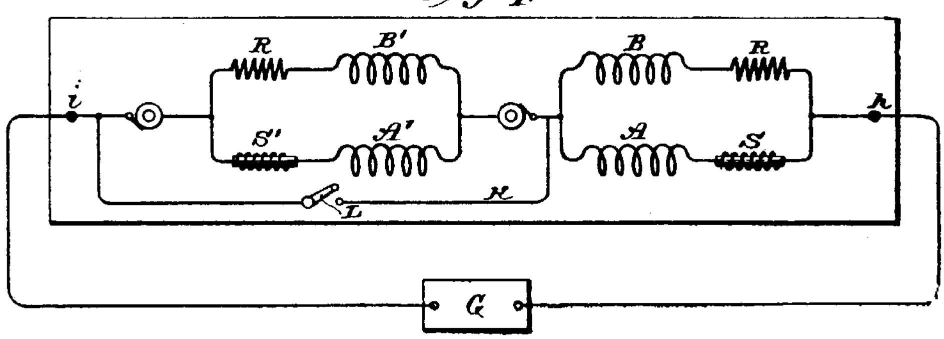
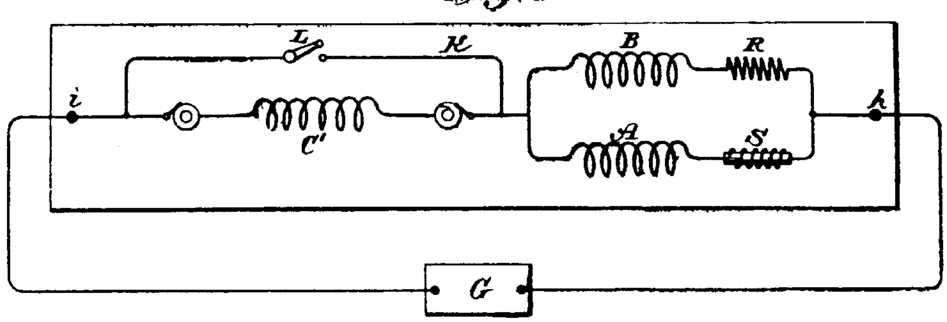


Fig. 5



[This Drawing is a reproduction of the Original on a reduced scale.]