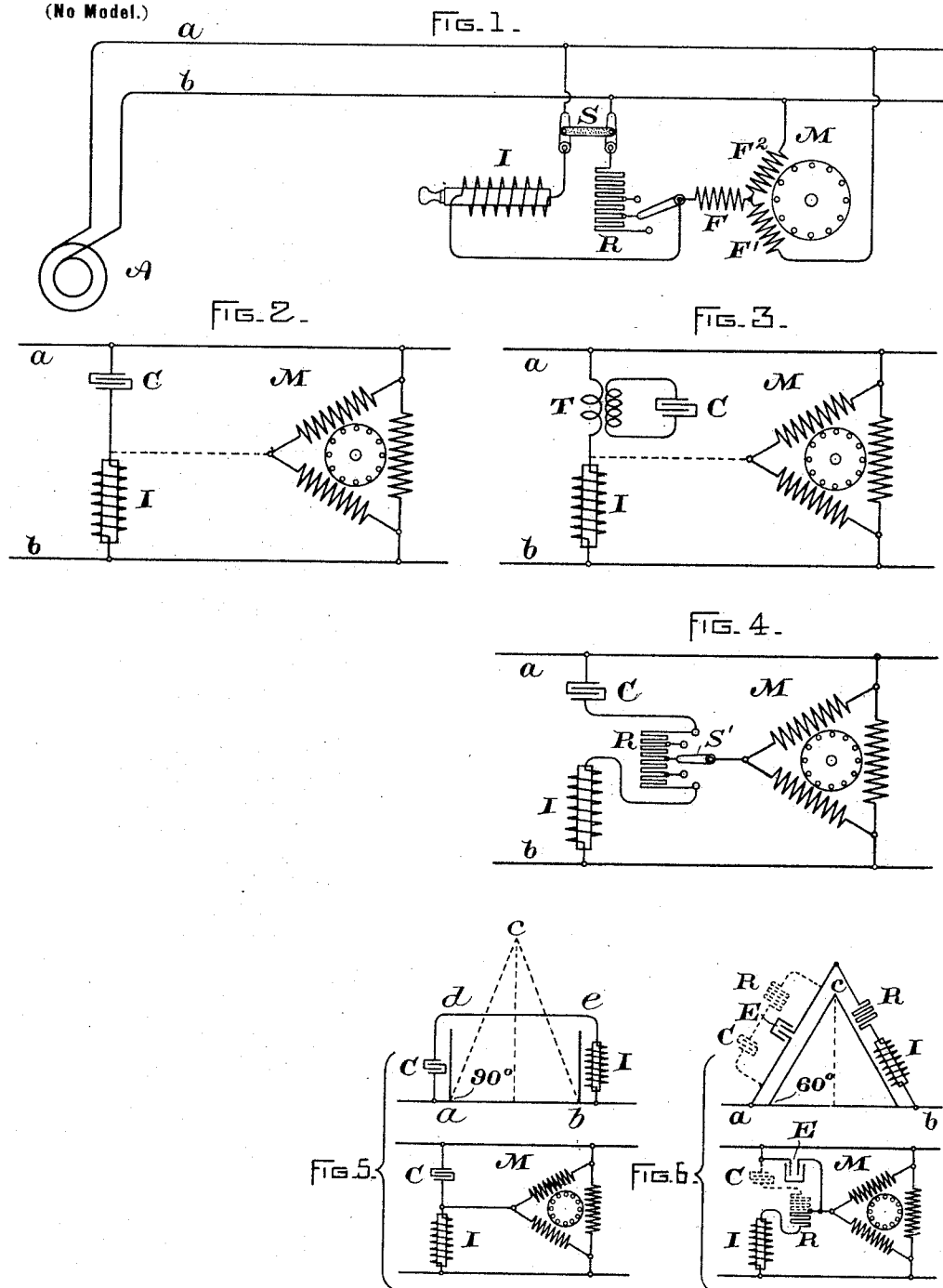


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STARTING DEVICE FOR ELECTRIC MOTORS.

(Application filed Jan. 26, 1897.)

(No Model.)



WITNESSES.

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STARTING DEVICE FOR ELECTRIC MOTORS.

SPECIFICATION forming part of Letters Patent No. 620,989, dated March 14, 1899.

Application filed January 26, 1897. Serial No. 620,741. (No model.)

To all whom it may concern:

Be it known that we, CHARLES P. STEINMETZ, a citizen of the United States, and ERNST J. BERG, a subject of the King of Sweden and Norway, residing at Schenectady, in the county of Schenectady, State of New York, have invented certain new and useful Improvements in Starting Devices, (Case No. 513,) of which the following is a specification.

In a former application, Serial No. 562,037, filed September 10, 1895, we have shown and described improved arrangements for starting alternating-current motors, which improvements constitute what we term the "monocyclic starting device," and have also described certain alternating motors particularly adapted for use therewith. The said monocyclic starting device consists, practically speaking, of two impedances of different power factor connected in series across a pair of single-phase mains, with a connection from the junction of the two impedances to one terminal of a three-terminal motor, whose other two terminals are connected, respectively, to the two single-phase mains. The claims in the said application were directed to covering the use of this device broadly, and also more specifically certain claims were particularly directed to the use of a motor of the Y type. In the present application, which is to be regarded as subordinate to the said former application, we describe and claim certain improvements which we have found useful in various relations.

We have illustrated in the accompanying drawings diagrammatic arrangements which we consider within our invention. Other arrangements may also be made; but the principles herein exemplified will be sufficiently clear from the illustrations afforded.

Figure 1 is a general view of the motor and starting device shown in our above-mentioned former application. Fig. 2 is a diagram of a delta-wound motor constructed in accordance with our present invention. Figs. 3 and 4 show modifications. Figs. 5 and 6 are illustrative diagrams.

The monocyclic starting device shown in Fig. 1 consists of two impedances of different power factor—as, for example, the adjust-

able self-induction I and the adjustable resistance R, connected in series through a switch S, if preferred, across the mains *a b*, which are fed from the source of single-phase current A. The motor M may be of any of the modern types of induction or synchronous motors having windings adapted for use in polyphase systems of distribution. By preference we may employ an ordinary three-phase motor of the induction type, inasmuch as such a motor is particularly adapted for use with our invention. We may, however, substitute a two-phase three-wire motor or a monocyclic motor like that described in the patent to Steinmetz, No. 533,250, and in other patents to the same inventor. Such a motor, whether of the induction or synchronous type, will not start when supplied with single-phase current. This has been one of the great objections to the commercial use of such motors. The particular type of motor illustrated in Fig. 1 is a three-phase Y-wound induction-motor having three inducing-coils $F F' F^2$, connected together at a common point, leaving three free terminals. Two of these terminals are connected to the mains *a b*, while the other terminal is connected to a common point between the two impedances I and R.

In using the monocyclic motor above referred to the third or teaser coil would obviously be connected between the phase-modifying devices in place of the coil F. In any case we have little idle wire and obtain high starting torque in combination with good weight sufficiency and obviate the necessity of running the motors to speed before the load is thrown on. At starting, the switch S is closed, and the three terminals of the motor M are thus all connected to line. Two of the coils are energized by the main electromotive force between the mains *a b*, while the third coil is energized by an electromotive force of displaced phase produced by the inductance I and the resistance R. The motor will have impressed upon it, according to the proportioning of the power factors of the various impedances, either three-phase electromotive force or quarter-phase electromotive force or electromotive force of other desired phase displacement—such, for instance, as that of

the monocyclic system, to which the motor described in the patent to Steinmetz, above referred to, is adapted. Thus energized the motor will start under load and will gradually acquire speed until it runs as an ordinary induction-motor of the single-phase type. At this time the switch *S* may be opened and the motor will derive its entire energy from the mains *a b*.

Having thus explained the nature and object of the monocyclic starting device, we will proceed to describe those improvements within the scope of our present invention.

Fig. 2 shows a motor *M*, which differs from the motor shown in Fig. 1 in that it is of the delta type. One of the energizing-coils is connected directly across the mains *a b*, while the other two energizing-coils are connected together at one end, and the other ends are connected, respectively, to the terminals of the first-named coils. The common point of the two last-named coils is connected, as shown in dotted lines, to the common point of the two impedances *I* and *C*, the condenser *C* being substituted in this case for the resistance *R* in Fig. 1.

Fig. 5 is an illustrative diagram showing the connections and also the electromotive-force relations which exist in the form shown in Fig. 2. The main electromotive force of the system is represented by the line *a b*. The electromotive forces *a c* and *b c* form, with the electromotive force *a b*, a closed triangle. Obviously if the phase-modifying devices *C* and *I* were so arranged as to dephase their respective currents by the theoretical angle of ninety degrees there would be produced an electromotive-force triangle of infinite altitude, as indicated by the lines *a d* and *b e*; but inasmuch as the different reactances cannot be made without resistance there will be a point of convergence, (shown at *c*.) The particular position of this point of intersection, and therefore the particular phase relation of the current in the various coils of the motor, depends on the relation of the three factors—inductance, capacity, and resistance. It is thus easy to secure either three-phase or two-phase electromotive forces in the motor, as may be preferred. In Fig. 3 we show a similar arrangement; but in this case in order to reduce the size of the condenser required we insert a step-up transformer *T*, the primary of which is in series with the inductance *I*, while its secondary, in which high electromotive force and correspondingly small current are obviously developed, is closed through the condenser *C*. With this arrangement a considerably smaller condenser can be used with good results.

In Fig. 4 we show an arrangement embodying a condenser, an adjustable resistance *R*, provided with a switch *S'*, by which different portions of the resistance may be thrown upon either side of the circuit, and an inductance, the three being in series between the lines and the connection of the third coil

of the motor being to the switch *S'*. It is thus possible to adjust the phase displacement in the system with accuracy.

The diagram shown in Fig. 6 is similar to the form shown in Fig. 4; but we have indicated at *E* an electrolytic cell substituted for the condenser *C* of Fig. 4. It will be seen that an electrolytic cell or a suitable number of electrolytic cells suitably connected will form at once a true equivalent of the condenser and of that portion of the ohmic resistance of Fig. 4 above the switch *S'*. The upper part of Fig. 6 shows the phase relations of the electromotive forces which might be made to exist in such a system. *a b* represent, as in Fig. 5, the electromotive force impressed upon the system, while *a c* and *b c* are the two auxiliary electromotive forces forming in the particular case shown a symmetrical system of three-phase electromotive forces.

It will be obvious that any of the various forms shown may be connected with the switch *S*, &c., as shown in Fig. 1.

In all of the diagrams illustrating the proper displacement of phase the torque is proportional to the perpendicular from the point *c* to the base *a b*, as shown in dotted lines. It is therefore of advantage to have the displacement of the phase as great as possible, limited only by the danger of having excessive electromotive forces at the terminals when the motor is not running. The different reactances would therefore be so proportioned as to bring the point *c* higher at starting than was desired for normal running, the effect of connecting in the motor being to bring this point down to the proper displacement of phase. The proportions of the different devices may be arranged by following the principles pointed out, so that any desired displacement of phase and starting torque may within reasonable limits be obtained, either an exact sixty-degree relation or any other necessary, though in general the three-phase relation is a desirable one.

Ordinarily the switch *S* would be opened as soon as the motor was at speed; but if the phase-modifying devices be of such a character as to be capable of remaining in circuit without injury the switch may be left closed and the motor operated as a multiphase motor. The phase displacement being external to and independent of the motor, any desired type of armature may be used and resistance in its circuit to enable it to start may be dispensed with.

By our invention we are enabled to start motors provided with squirrel-cage armatures even when of low resistance, whereas other devices, such as that of the shaded pole, work best when the armature has a large resistance. We thus dispense with sliding contacts leading to an external resistance and obtain the efficiency of a low-resistance armature.

As already pointed out, since the phase displacement is independent of and external to the motor the particular type of the latter is

unimportant, and we may use a three-phase, a monocyclic, a quarter-phase, or other poly-phase machine, or we may employ any desired winding in the motor selected.

5 We prefer to call our improved apparatus a "monocyclic starting device," because as we have employed it in practice it resembles in principle the monocyclic system exemplified in the patents to Charles P. Steinmetz,
10 No. 533,244, and others.

It is manifest that uses of the displaced phase other than simply to start a single motor might be made; but all such applications of our invention as would be apparent to an
15 electrical engineer we aim to cover by the claims.

What we claim as new, and desire to secure by Letters Patent of the United States, is—

1. In a single-phase alternating-current
20 system of distribution, an alternating-current motor having main and supplemental inducing-windings, the main windings being directly connected to the supply-lines of the system, phase-modifying devices connected
25 to the lines in parallel with the main inducing-windings and connecting the supplemental inducing-windings to the supply-lines, one of the phase-modifying devices consisting of a phase-advancing device in the secondary circuit of a step-up transformer.

2. The combination of a single-phase supply-circuit and a third conductor between which and the mains a displaced electromotive force is to be maintained, with phase-modifying devices connected in series across
35 the main circuit, such devices consisting of an inductive resistance, a capacity reactance, and an intermediate resistance to a point in which the third conductor is connected.

3. The combination of a single-phase supply-circuit and a third conductor between which and the mains a displaced electromotive force is to be maintained, with phase-modifying devices connected in series across

the main circuit, such devices consisting of an
45 inductive resistance, a capacity reactance, and an intermediate resistance to a point in which the conductor is connected, and means for varying the point of connection between the intermediate resistance and the third
50 conductor.

4. In an alternating-current electric motor the combination, with an induced member, of an inducing-coil connected across a pair of
55 single-phase mains, two impedances of different power factor also connected across the mains, and two additional inducing-coils, joined at one end to each other and to a point between the two impedances, and at the other
60 ends respectively to the ends of the first-named inducing-coil.

5. The combination with a motor having two terminals connected to a source of single-phase current, of two dissimilar impedances
65 connected across the said source, with a connection from a third terminal of the motor to a point between the said impedances, the two impedances being so adjusted and proportioned as to cause the potential difference
70 across their terminals to be large while the motor is at rest, and to become less as the motor attains speed.

6. The method of starting and running an alternating-current motor fed from a single-phase system, which consists in supplying
75 certain coils of said motor with current from the single-phase system, through phase-modifying devices adjusted to cause a rise of potential, and reducing said rise of potential by the reaction of the motor as the motor attains
80 speed.

In witness whereof we have hereunto set our hands this 8th day of January, 1897.

CHARLES P. STEINMETZ.
ERNST J. BERG.

Witnesses:

B. B. HULL,
M. H. EMERSON.