(No Model.) 2 Sheets—Sheet 1

A. H. ARMSTRONG.

REGULATING ALTERNATING MOTORS.

No. 562,062. Patented June 16, 1896.

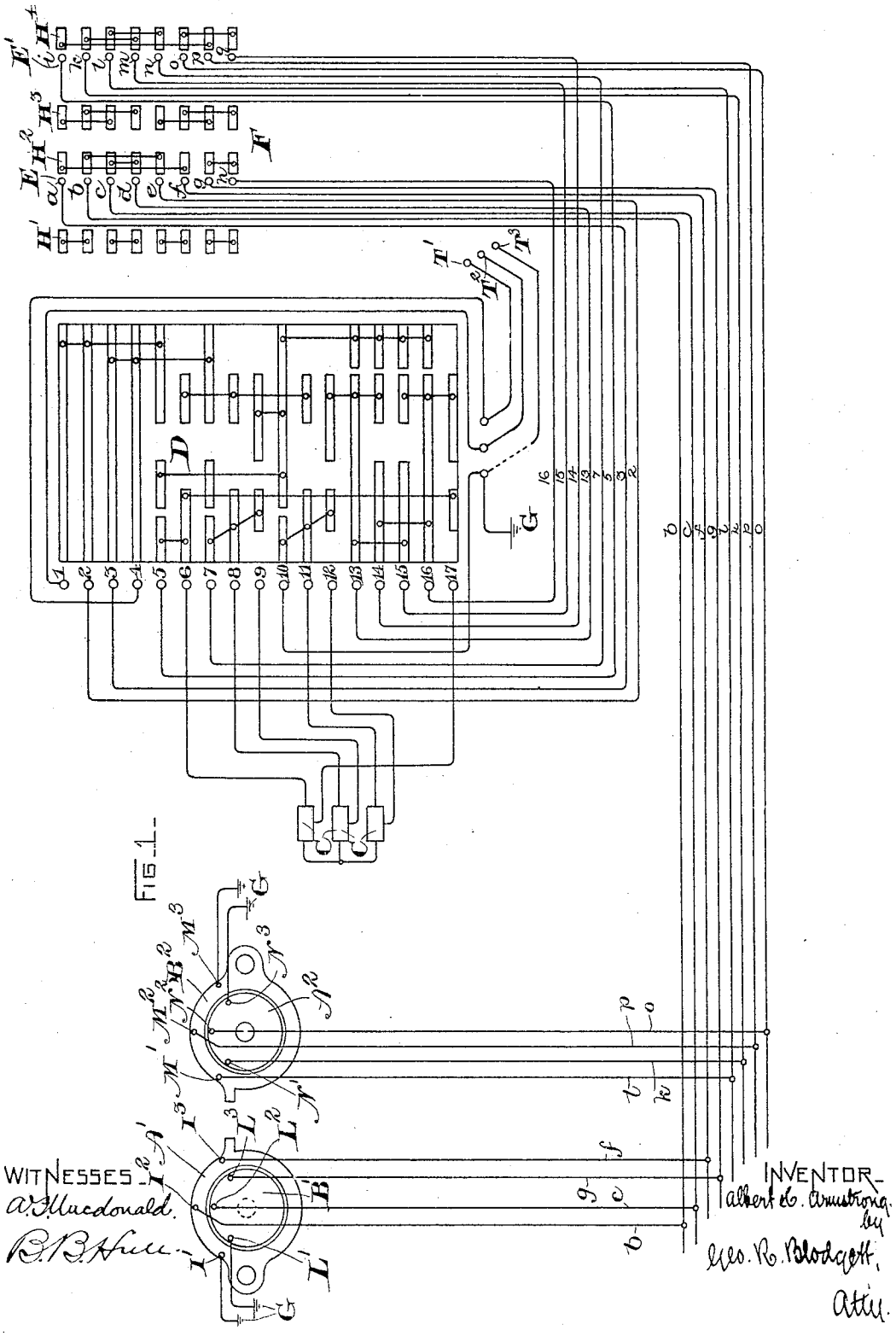

FIG. 1.

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(No Model.) 2 Sheets—Sheet 2.

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FIG. 2.

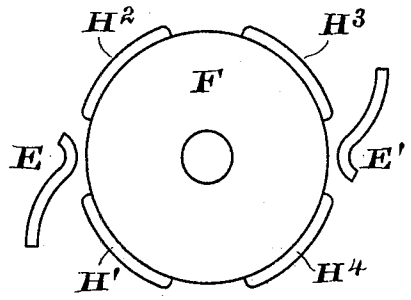


FIG. 3.

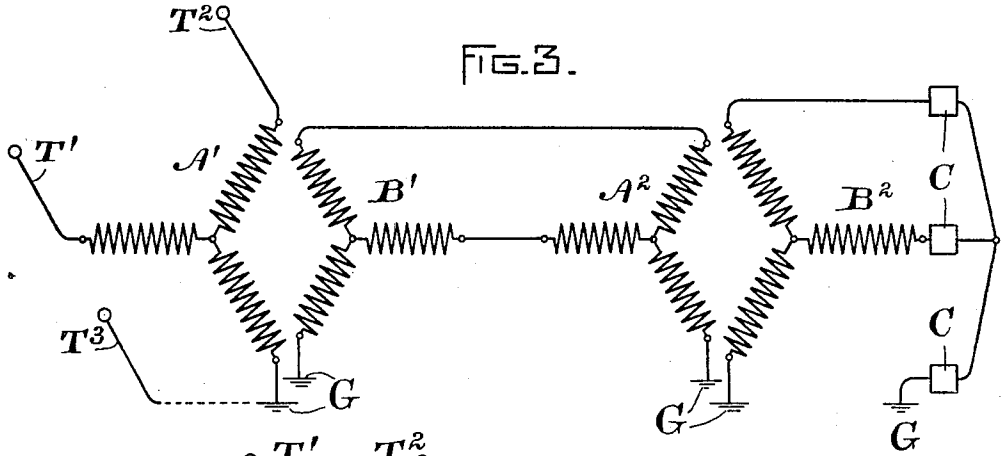
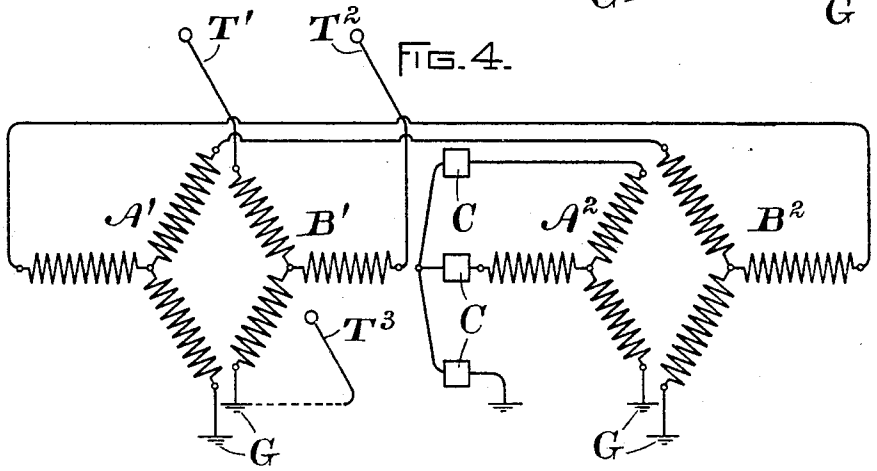


FIG. 4.



WITNESSES.

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A. E. Macdonald.

INVENTOR.

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By his Atty.

UNITED STATES PATENT OFFICE.

ALBERT H. ARMSTRONG, OF SCHENECTADY, NEW YORK, ASSIGNOR TO THE GENERAL ELECTRIC COMPANY, OF NEW YORK.

REGULATING ALTERNATING MOTORS.

SPECIFICATION forming part of Letters Patent No. 562,062, dated June 16, 1896.

Application filed January 11, 1893. Serial No. 575,114. (No model.)

To all whom it may concern:

Be it known that I, ALBERT H. ARMSTRONG, a citizen of the United States, residing at Schenectady, in the county of Schenectady, State of New York, have invented certain new and useful Improvements in Regulating Alternating-Current Motors, (Case No. 283,) of which the following is a specification.

My invention relates to regulating alternating-current motors, and particularly to such motors when applied in railway-work. It is an improvement upon such types of controller as that illustrated in my Patent No. 539,404, granted May 21, 1895, and is designed particularly to overcome a special difficulty arising in the use of alternating-current apparatus, and in dealing with which I avail myself of the fact that the torque of such motors is proportioned to the square of the impressed electromotive forces and not to the current, as is the case with continuous-current machines. In some cases it is desirable to increase the torque of the motors for a short time to an amount which is not best adapted for their constant running. This is effected in one particular class of controllers, such as that in my patent referred to, by the combinations known as "tandem-multiple" arrangements, which, being well known in the art, I will not further describe; but on some occasions the maximum torque developed from the two motors in the tandem position is not sufficient to get the starting effect desired, as when a heavy load is to be started upon a curve or upon an upgrade.

To accomplish the ends thus briefly indicated, I prefer to have the motors wound with a different number of turns in their inducing and induced members, which, as is well known in the art, may be interchanged in their relation to the supply-circuit. As an illustrative proportion I may assume that the stationary and rotating parts, or, as the motor is commonly used, the inducing and induced members, are wound in the proportion of five to four.

With the parts of the motor connected to line as just described—that is, with the inducing member having the higher number of turns—the torque would be sixteen twenty-fifths of that obtained from the second connection, in which the part of the motor having the less number of turns would be connected to line. In this latter case the torque would obviously be the reciprocal or twenty-five sixteenths of that formerly obtained. If the torque of the first connection be x, that of the second would be $1.56 + x$. The motor acting as a transformer thus impresses upon its secondary or induced member an electromotive force corresponding to the line-voltage into the ratio of the primary and secondary turns, omitting minor modifying factors, which in these constructions are practically negligible. The torque of the motor, as a whole, is in direct proportion to the square of the electromotive force impressed upon the inducing member and directly as the electromotive force in its induced member. Inasmuch as the torque is equal to the ampere turns of the secondary member into the flux, a rise in the impressed electromotive force raising both the flux and the current in the secondary, the resultant rise in torque would be as the product of these quantities or square of the electromotive force. It is to take advantage of this fact that I have devised my present invention, which consists in adapting to a controller of the general type above described an "emergency-switch," so called, by which when increase of torque is desired the switch may be thrown, (the controller being of course at the off position,) and the leads of the rotating and stationary parts may be respectively interchanged, so that the line-current passes to the part with the greater number of turns, which may be provided for this purpose with collector-rings and brushes, while in the ordinary operation of the motors the line-current would pass to the part with less turns, and the brushes would be closed-circuited, the motor acting, of course, in both cases as an induction-motor.

As a specific aspect of the invention thus briefly pointed out I combine this emergency-switch with the ordinary reversing-switch of the controller and preferably adapt suitable interlocking mechanism to the two. This latter feature, however, I do not claim, inasmuch as it is old in the art.

The combined reversing and emergency switch consists, briefly, in four series of contacts upon a single cylinder having coöperat-

ing therewith two sets of fixed contacts or brushes, one set for each motor. The direction of revolution of the motors is determined by the first and second rows of contacts, respectively—that is to say, in the middle position of the reversing-switch the brushes are out of contact and the circuit is opened, as is ordinarily the case. In its first position forward the motors run forward with the current supplied to the stationary member of the motor or motors. In its second position forward the motors still run forward; but the current is supplied to what was before the induced or rotating member of the motor, and the reversed ratio of transformation referred to in my statement of invention above is brought into play. In the first backward position of the switch the motors run backward with the same ratio as in the first forward position, while in the last or second backward position the reversed ratio is brought into effect with the motors running backward.

The particular combinations just pointed out are additional and auxiliary to those commonly employed in a tandem-multiple controller of the general type sketched above, and the switch which I have devised is in one sense simply a torque-regulating switch. The various combinations of speed and torque necessary for the commercial operation of a tram-car are supplied by the ordinary controller-cylinder and its connections.

The accompanying drawings show diagrammatic embodiments of my invention, which may of course be arranged in a great many different ways; but in its broadest aspect I consider any combination, in an induction-motor, of a revolving and stationary part having different numbers of turns or ratio of transformation, or, to speak more broadly, a ratio of transformation other than one to one, and a switch adapted to interchange the terminals of the revolving and stationary parts, within my invention. The more specific aspects of the invention will be pointed out fully in the specification and in the claims annexed.

Referring now to the drawings more particularly, Figure 1 is a general diagram of the circuits, showing a controlling-switch of the type referred to in my patent developed, and also a development of my combined reversing and emergency switch. Fig. 2 is a plan of the cylindrical switch shown on the right in Fig. 1, and Figs. 3 and 4 are diagrams illustrative of the particular combinations of motors effected by the reversing and emergency switch.

Referring now to Fig. 1, I shall not trace the connections from the controller proper in detail, inasmuch as they are fully discussed and the various combinations of motors effected thereby are described in my patent referred to. I will, however, describe Figs. 3 and 4, and afterward trace the combinations of circuits by which the motor combinations of these latter figures are produced.

A' A^2 are the inducing members of the motors; B' B^2, their induced members; T' T^2, the trolleys; C C C, the resistances, the motors being shown in Fig. 3 connected in tandem. The ground at G takes the place of one of the connections, nothing in my invention, however, limiting me to the use of ground-circuits, as I may use another trolley T^3, (shown in dotted lines,) and all the connections may be metallic. The alternating electromotive forces are furnished to the inducing member A' from the trolleys. The member B' has alternating electromotive forces induced in it from the field A', which send current over the lines connecting B' to the inducing member A^2. Corresponding forces are induced in the member B^2, the circuits of which are closed through the resistances C C C in ways well understood.

In Fig. 4 the same parts have like letters of reference; but in this the leads have been interchanged by the action of the switch, and energy is now furnished from the trolleys to the member B', acting to induce forces in the member A', connected directly to the field B^2, which acts upon the member A^2, the circuits of which are now closed through the resistances C C C, as was before the case with the member B^2. It will be seen that the relation of the stationary and revolving members is thus interchanged, and the increase of torque referred to in my statement of invention is obtained. Referring now to Fig. 1, the results thus pointed out are obtained by means of the switch F on the right of that figure, in which four series of movable contacts are illustrated in conventional ways, and the two sets E E' of brushes *a* to *h* and *i* to *q* are illustrated out of contact for the sake of clearness. Fig. 2 also illustrates the construction of this switch F, it showing the switch in plan, and the two series of fixed contacts are respectively lettered E E', the rows of movable contacts being lettered H' to H^4, respectively. It is to be understood that the brushes can stand upon any of the diametrically opposite contacts in any desired order. Stated in tabular form, the combinations of this switch are as follows:

E H^2 / E' H^4	Forward.
E H' / E' H^3	Reverse.
E H^3 / E' H'	Emergency forward.
E H^4 / E' H^2	Emergency reverse.

The circuits in Fig. 1 are as follows: Starting with the trolley T', the circuit leads to contact 4 upon the controlling-cylinder D, by cross connection to contact 3, by the lead 3 to contact *a* on the switch F, by cross connection to contact *f*, by the lead *f* to terminal I^3 upon the inducing member A' of the first motor. Passing through the coils of this member there

are two paths, the first leaving at the terminal I′, passing to the ground-wire or to the trolley T^3, according to whether a grounded circuit or metallic circuit is used. The other path is from the terminal I^2 by the lead *b* to contact *b* upon the switch *f*, by cross connection to contact *e*, and by the lead 2 to contact 2 upon the controller D, by cross connection to contact 1, and thence to trolley T^2. Electromotive forces, being induced in the secondary B′ of the motor, send current to the primary B^2 of the second motor, as follows: Starting with the terminal L′, direct connection is made to the terminal N^3 by the ground-wire. From the terminal L^2 the circuit is by the lead *c* to contact *c* upon the switch F, by cross connection to contact *d*, by the lead 13 to the controller, by cross connection to the lead 15, to contact *m* upon the switch F, by cross connection to contact *k*, and by the lead K to the terminal N′. Starting again from the terminal L^3, pass by the lead *g* to the contact *g* on the switch F, by cross connection to contact *h*, by the lead 16 to the controller, by cross connection to the lead 14, contact Q upon the switch, by cross connection to contact *o*, and by the lead *o* to the terminal M^2. From the primary B^2 electromotive forces are induced in the secondary A^2 of the second motor, the circuit of which secondary is closed through the resistances C C C, as follows: Starting with the terminal M′, the circuit is by the lead *l* to contact *l* upon the switch F, to contact *n*, by the lead 7 to the controller, thence by lead 8 to the middle resistance C. Thence passing through that resistance the circuit divides, passing first through the upper resistance C to the contact 6 upon the controller, by cross connection to contact 5, by the lead 5 to contact *i*, by cross connection to contact *p*, by the lead *p* to the terminal M^2. Returning to the resistance as the dividing-point of the circuit, the other branch passes through the lower resistance C to contact 11 upon the controller, then to contact 10, to the ground-wire, and by the ground-wire to the terminal M^3. The other steps in the regulation of the motors are described and fully pointed out in my patent above referred to.

The circuit just traced is, as will be observed, with the row of brushes E, comprising those lettered *a* to *h*, upon the row of contacts H^2, and the brushes E′, comprising those lettered *i* to *q*, upon the row of contacts H^4, and is that established when the switch F is thrown to the first or forward position, which would be by the rotation of the cylinder (see Fig. 2) from the neutral position in which it is illustrated to make the contacts just described.

When the rows of brushes E E′ are upon the contacts H′ H^3, respectively, the circuits are in the same condition substantially, except that the first pair of terminals are reversed, and of course the motors run in the opposite direction. These circuits will not be particularly described. Each of these running positions is forty-five degrees from the neutral position in which the brushes are illustrated in Fig. 2. At the next step, however, the switch rotates ninety degrees in whichever direction it may be thrown, and thus the total revolution of the cylinder is two hundred and seventy degrees.

The further running positions of the controller D, being fully described in my patent above referred to, will not be traced in detail. It is sufficient to say that they combine the motors in tandem and multiple and close the circuit of the armature or armatures through resistances, which is not broadly new with me.

Referring now to the emergency positions of the switch, it will be sufficient to describe what I may call the "emergency-forward" combination. In this the row of brushes E is upon the contacts H^3, and E′ is upon the contacts H′, as will be apparent from Fig. 2. The circuits, as traced in Fig. 1, are as follows: Starting from the trolley T′, it passes to the contact 4, by cross connection to contact 3, by the lead 3 to contact *a*, thence by cross connection upon the row of contacts H^3 to contact *c*, thence by the lead *c* to the terminal L^2 upon the member B′ of the first motor, thence from the terminal L′ to the ground-wire or trolley T^3, and from the terminal L^3 by the lead *g* to contact *g* upon the switch F, thence by cross connection to contact *e*, thence by the lead 2 to contact 2 upon the controller, by cross connection to contact 1, and to the trolley T^2. Electromotive forces, being induced in the member A′ of the first motor, send current from the terminal I^2 by the lead *b* to contact *b* upon the switch F, by cross connection to contact *d*, by lead 13 to the controller, by cross connection to lead 15, thence to contact *m*, by cross connection upon the row of contacts H′, to contact *l*, by the lead *l* to the terminal M′ of the second motor. Starting again from the terminal I^3, by the lead *f* to contact *f* upon the switch F, by cross connection to contact L, by the lead 16 to the controller, by cross connection to the lead 14, to contact *q*, by cross connection to contact *p*, and to the terminal M^2 of the second motor. The terminal I′ of the first motor is connected to the terminal M^3 of the second motor through the ground-wire. The induced electromotive forces set up in the member B^2 of the second motor send current through circuits closed through the resistances C C C. These circuits are as follows: Starting from the terminal N^2, pass by the lead *o* to contact *o* upon the switch F, thence by cross connection to contact *n*, by the lead 7 to the controller, by cross connection to the lead 8, and to the middle resistance C. There, as before, the circuit divides, passing through the upper resistance C, to contact 6, by cross connection to contact 5, by the lead 5 to contact *i*, by cross connection to contact *a*, by the lead

k to the terminal N′, returning to the middle resistance as the dividing-point, passing through the lower resistance, pass to contact 11 upon the controller, thence to contact 10, by the ground-wire back to terminal N^3.

In the position of the switch in which the brushes E are upon the contact-plates H^4, and the brushes E′ upon the contacts H^2, the circuits are made for the "emergency-reverse" position. These are the same as those already described in connection with the emergency-forward position, except that the first two terminals of the first motor are reversed, so that the motors run in a backward position, with the increase of torque already referred to in my statement of invention.

It is of course manifest that the usual changes, with which those skilled in the art are conversant, may be made in the arrangements I have pointed out as the best adapted to my invention without affecting its essence. The use of the invention necessarily extends to either one or a plurality of motors, and where I use the term "a number" in the claims I mean to include either one or any other larger number of motors.

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

1. In combination, an induction-motor having a revolving and stationary part with a ratio of transformation other than one to one, and a switch adapted to interchange the terminals of the revolving and stationary parts.

2. In combination, a number of induction-motors having a ratio of transformation other than one to one between their stationary and revolving parts, and a switch adapted to interchange the terminals of such stationary and revolving parts.

3. In combination, a tandem-multiple controller, a number of motors having revolving and stationary parts with a relation other than one to one, and a switch adapted to interchange the terminals of the revolving and stationary parts respectively.

4. In combination, a tandem-multiple controller, a number of induction-motors operated thereby having revolving and stationary parts with a relation other than one to one, and a combined emergency and reversing switch adapted to determine by some of its positions the direction of rotation of the motors, and by its other positions to interchange the terminals of the revolving and stationary parts of the motors, in whichever direction they may rotate.

5. A combined emergency and reversing switch for a number of induction-motors having revolving and stationary parts, with a ratio of transformation other than one to one, such switch composed of four sets of movable contacts and two sets of fixed contacts or brushes, and having four operative positions, two of which determine the direction of rotation of the motors and the other two of which interchange the terminals of the revolving and stationary parts respectively.

In witness whereof I have hereunto set my hand this 8th day of January, 1896.

ALBERT H. ARMSTRONG.

Witnesses:
B. B. HULL,
M. H. EMERSON.