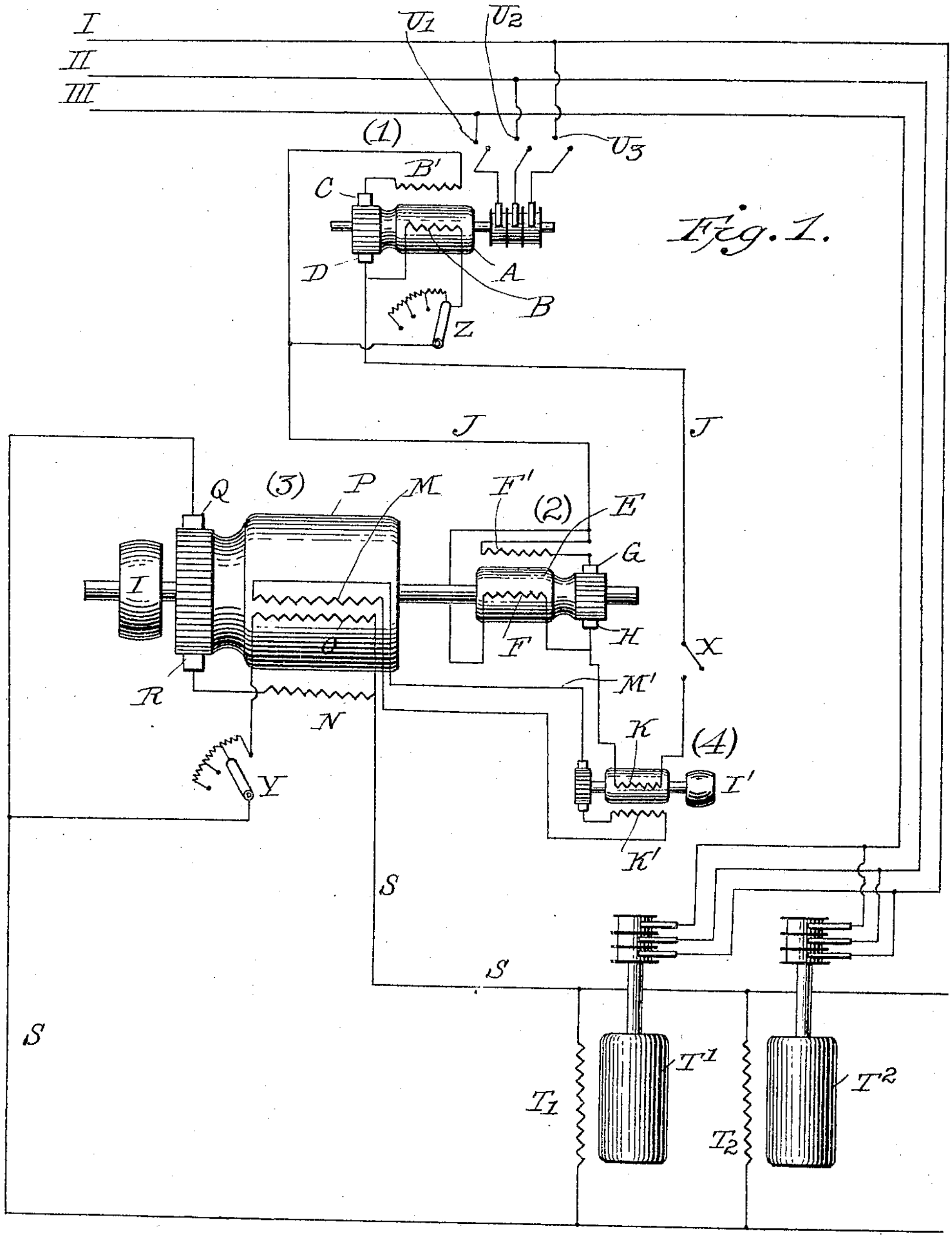
No. 773,508. PATENTED OCT. 25, 1904.

M. LEBLANC.

PROCESS OF REGULATING VOLTAGE.

APPLICATION FILED FEB. 5, 1904.

NO MODEL. 3 SHEETS—SHEET 1.



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NO MODEL. 3 SHEETS—SHEET 2.

Fig. 2.

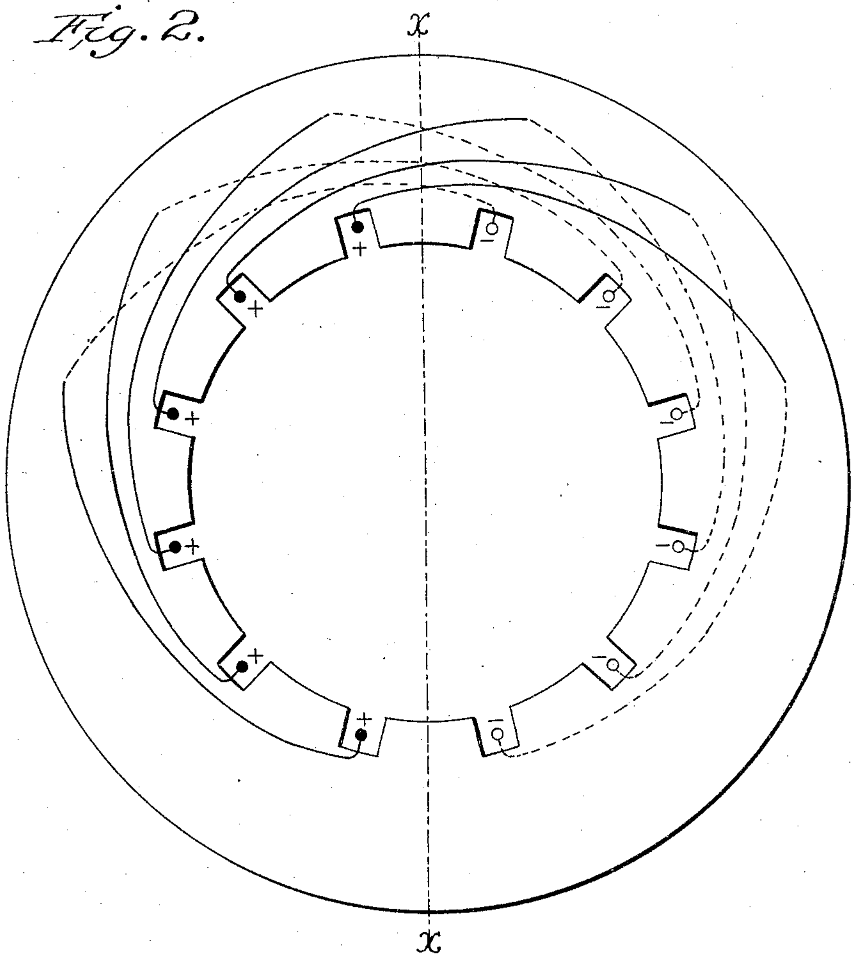


Fig. 3.

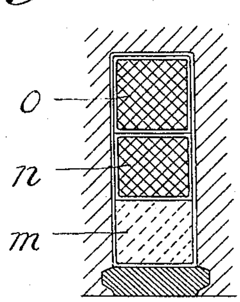
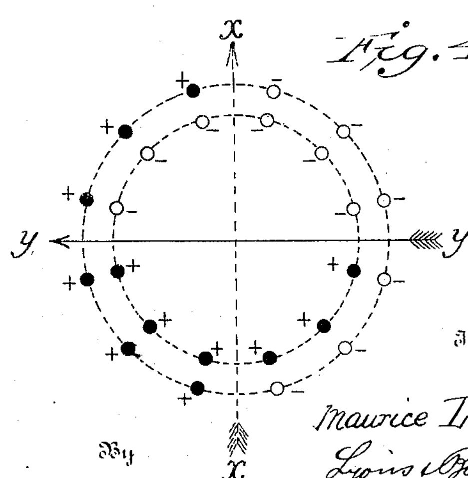


Fig. 4.



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NO MODEL. 3 SHEETS—SHEET 3.

Fig. 5.

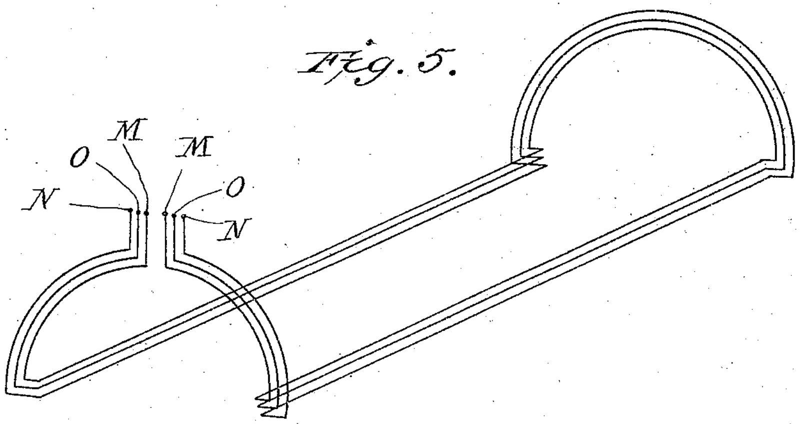
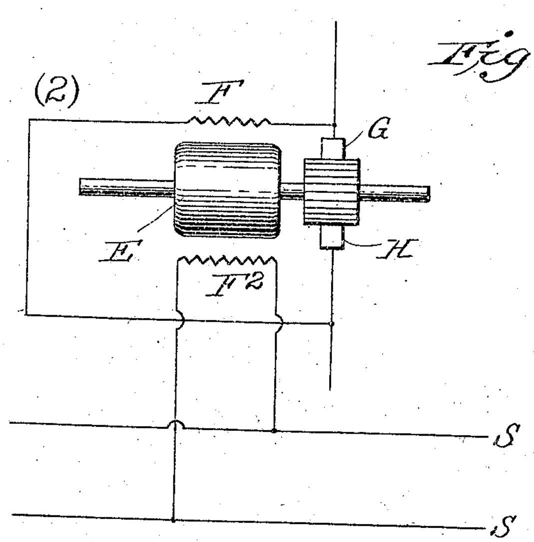


Fig. 6.



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UNITED STATES PATENT OFFICE.

MAURICE LEBLANC, OF PARIS, FRANCE, ASSIGNOR TO WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY, A CORPORATION OF PENNSYLVANIA.

PROCESS OF REGULATING VOLTAGE.

SPECIFICATION forming part of Letters Patent No. 773,508, dated October 25, 1904.

Application filed February 5, 1904. Serial No. 192,225. (No model.)

To all whom it may concern:

Be it known that I, MAURICE LEBLANC, a citizen of the Republic of France, residing at Paris, France, have invented a new and useful Process of Regulating Voltage, of which the following is a specification.

My process is designed to automatically regulate the voltages of electrical apparatus, more particularly the voltage of alternators or induction machines when used as generators. In this case the strength of the exciting-current of the generators is varied from moment to moment in such a manner as to secure a constant voltage or a voltage of predetermined or desired value whatever be the causes which tend to vary this voltage and whether this tendency to variation of voltage is due to a variation of output or to a variation of speed of the alternators. This automatic regulation I obtain in accordance with my process by purely electrical means and by a system of excitation which permits the use of alternators or of induction-machines having a great reactance; but despite the reactance the variations of the exciting-current may be large and are obtained almost instantaneously. In fact, my process of voltage regulation may be applied to alternators which are supplied with the customary deadening-circuits for forcibly deadening the oscillatory movements known as "hunting." To this end I employ a source of voltage varying with the voltage of the line and a source of voltage opposed thereto which may have a uniformly-constant value or, more broadly stated, some predetermined or desired value. Those opposing voltages give rise to a regulating-current which may change its direction under a variation of the main-line voltage, and this current is used either directly or through the intervention of a relay to control the strength of the field of the generator to maintain the voltage supplied by the alternator at the desired value.

In order to fix ideas, I will show my process as applied to regulation of a generator of alternating currents, and more particularly to a three-phase alternator. It will be understood, however, that my process is equally applicable to other types of electrical generators and motors.

In the drawings, Figure 1 shows in diagram a system in which my process is executed. Fig. 2 shows the field-magnet of one of my regulating-machines. Figs. 3, 4, and 5 show the field-windings of this regulating-machine, and Fig. 6 shows a modification.

I have shown two three-phase alternators having their field-windings T_1 and T_2 coupled in parallel and having their armatures T' and T^2 supplying electrical energy in the shape of triphase currents to the main lines I, II, and III. Connected to this main line, through the switches U_1 U_2 U_3, is the commutating-machine or rotary converter 1, caused in any desired way to run at a constant speed and impressing upon the circuit J, connected to its brushes C D, a voltage which is strictly proportional to the voltage of the main line. This commutating-machine has an armature A and a shunt field-winding B. There is also a series field-winding B′ displaced ninety degrees, magnetically considered, from the shunt field-winding, as indicated in Fig. 1. This series field-winding B′ is designed to overcome the effect of armature reaction, as will more fully appear. It is to be understood then that this rotary converter has been shown as a source of electromotive force proportional to the electromotive force of the line such as I may employ. Opposed to this source of electromotive force, which is proportional to the electromotive force of the line, is any source of electromotive force of constant value. In the present case I have shown for such source of constant electromotive force a direct-current dynamo 2, having an armature E, a shunt field-winding F, brushes G H, and a series field-winding F′ displaced ninety degrees from the shunt field-winding F, so as to overcome the effect of armature reaction. The magnitude of the voltage furnished by the source of constant voltage 2 is preferably so chosen that when the voltage of the line is normal the voltage furnished by the source 2 will be equal and opposite to the voltage furnished by the source 1, so that under these conditions no current flows in the circuit J. When the line-voltage falls below normal, the voltage furnished by the source 2 will be greater than the voltage furnished by the source 1, so that a current will traverse the circuit J in a given direction. When the line-voltage increases above normal, the voltage furnished by the source 2 will be less than the voltage furnished by the source 1, so that a current will now traverse the circuit J in the opposite direction. The regulating-current in the circuit J thus produced is utilized to vary the excitation of the alternator to bring the voltage supplied by it to the line back to normal. There are manifestly numerous ways in which this regulating-current in the circuit J can be utilized to keep the alternator-voltage normal, all of which would fall within the scope of my process, broadly considered; but since it is desirable that a small variation of the regulating-current shall produce a considerable variation in the field excitation of the alternator I prefer to employ a relay-dynamo 4, which has a field-winding K in the regulating-circuit J, so that when the regulating-current is zero the field strength of this dynamo 4 and the current supplied by its brushes are both zero. When the regulating-current is in a given direction, the current supplied by the brushes of the dynamo 4 will also be in a given direction, and vice versa. The current supplied by the brushes of the dynamo 4 will thus change in direction in accordance with the changes in direction of the regulating-current in the circuit J; but the magnitude of the relay-dynamo current will be proportionately much greater than that of the regulating-current.

The dynamo 4 is driven at a constant velocity in any suitable manner—as, for instance, by pulley I′—and in order to overcome the effect of armature reaction I preferably again employ a series field-winding K′, which is displaced ninety degrees from the field-winding K.

The exciter 3 has a field-winding M in circuit with the armature of the dynamo 4. It has a shunt field-winding O, which coöperates with the field-winding M. Finally, it has a series field-winding N displaced ninety degrees from the field-windings M O for the purpose of overcoming armature reaction. The armature P, the commutator, the brushes Q R, and the pulley I, which drives the armature P, (and may also drive the armature E,) are all of the usual type. It need merely be added that the brushes Q R of the exciter 3 are in circuit with the field-windings T_1 T_2 of the alternators whose voltages are to be regulated.

The process executed by the system as thus far described will now be clear. When the voltage in the line is normal, the regulating-current in the circuit J is zero, which means that my regulating devices are, in effect, out of action. This is as it should be; but when the voltage in the line falls, and with it the voltage supplied by the source I, a regulating-current will flow in a given direction. This will cause a current to flow in a given direction in the winding M of the exciter 3, and the direction of this winding is so chosen that the current in the direction just specified will add to the magnetizing effect produced by the shunt-winding O. The excitation of the exciter being thus increased, its armature-circuits furnish a stronger current to the field-windings T_1 T_2 of the alternators, which alternators thereupon furnish an increased voltage to the line, so as to restore the line-voltage to normal. Should the line-voltage at any time rise above normal, a regulating-current will flow in the circuit J in a direction contrary to that just referred to. This will have for its result that a current will flow in the winding M of the exciter 3 in a direction to subtract from the effect of the shunt-winding O. The excitation of the exciter having thus been decreased, the amount of current which its armature supplies to the alternator-field will be correspondingly decreased, so that the voltage which the alternator supplies to the line will be decreased until this last-mentioned voltage has regained its normal value.

I need hardly remark that since the only effect of the relay-dynamo 4 is to cause a greater current to flow in the winding M of the exciter 3 than flows in the winding K it will be possible to omit this relay-dynamo and to use the winding K directly on the exciter 3.

In the above description I have assumed that it is desired to maintain the line-voltage at a constant fixed value; but in certain cases it is of advantage that the line-voltage should increase in a predetermined manner with the output. Under this aspect of my invention the invariably-constant line-voltage, the production of which I have specifically described in the preceding paragraphs, is a specific case of a line-voltage of predetermined value when that predeterined value becomes constant.

It will be clear from what precedes that the source of constant voltage 2 determines the voltage of the line. If the voltage furnished by this source 2 is constant, the line-voltage is constant. If the voltage of the source 2 has some predetermined value, the line-voltage will have the same predetermined value. To have the line-voltage vary with the output, it is then merely necessary to have the voltage of the source 2 vary with the output. To accomplish this result, I add to the field-winding F of the dynamo 2 a second field-winding F^2, tapped from the circuit S (see Fig. 6) in such a manner that these two field-windings conspire in their effects. When the output of the alternators increases, the intensity of the exciting-currents in the alternators has increased proportionately, so that the strength of the current flowing in the winding F^2 is caused to increase in proportion to the output; but this means that the voltage furnished by the dynamo 2 will increase with the output or that the line-voltage will increase with the output.

When I use the dynamo 2 as a source of constant electromotive force for the regulating-circuit J, it is manifestly desirable to strongly saturate its field; but when it is desired to have the dynamo 2 furnish to the regulating-circuit a voltage which varies with the output of the alternators the magnetic circuits of the machine 2 should not be completely saturated by the action of the shunt-coil F, so as to leave room for the additional effect of the field-coil F^2.

In constructing the machines 3 and 4 several considerations are to be borne in mind. For instance, the magnetic fluxes therein should vary rapidly and be always practically proportional to the intensity of the currents which produce them. This requires that the iron of their structure should be well laminated. Again, it is desirable that the potential energy stored in the machines 3 and 4 should be as small as possible. This requires the magnetic leakage to be reduced to a minimum, so that we are led to use a stator like those of induction-machines. It is furthermore desirable that the requisite number of ampere-turns for producing a given flux should be as small as possible. This means that we must employ small air-gaps and that we must work below magnetic saturation at all points. In addition to all this it is desirable to avoid the effect of armature reactions, and this is the purpose of the series windings N and K′, as has been pointed out above. Taking the field-coil N, for instance, I wind it, in fact, in such a manner that it develops upon the stator along the surface of the air-gap as many ampere-turns as are developed by the rotor, but having their magnetizing force acting in a contrary direction. The same remark applies to the field-coil K′.

If the stator structure which I prefer to employ were of the type ordinarily used in continuous-current dynamos, it would manifestly be sufficient to wind the coils K′ on auxiliary poles in line with the armature-brushes, the coils K being wound on poles at right angles to the line of the armature-brushes; but as the stator structures which I prefer to employ in the machines 3 and 4 are of the type used in induction-machines a little further description of the method of applying the field-coils to the field structure will be necessary. Since the dynamo 4 has two field-windings and the dynamo 3 has three such windings, it will be sufficient to describe the manner of applying the three field-windings M N O to the stator structure of the dynamo 3, when the method of applying the two field-windings K K′ to the stator structure of the dynamo 4 will have become plain without further description. Let us suppose, to fix ideas, that the machine 3 is bipolar and that the magnetic frame of its stator is built up of sheets, such as shown in Fig. 2, with twelve interior longitudinal grooves parallel to the axis of the machine. If it were a question of applying a single-turn winding to such a stator to produce a magnetic axis along the lines *x x*, we should manifestly lodge a single wire in each longitudinal groove and we should so interconnect them that the current would flow in one direction in all the wires marked "plus" on the left in Fig. 2 and would flow in the opposite direction in all the wires marked "minus" on the right of Fig. 2; but we must wind in each groove three sets of wires M N O, any or all of which may consist of a multiplicity of turns. To this end we may proceed as follows: We may take a mandrel of proper shape and wind upon it a conductor in the shape of the conductor N of Fig. 5, and we may give to this conductor N one turn or a number of superposed turns. Similarly we wind upon the same mandrel the conductors O and M, each of as many turns as may be necessary. These three sets of conductors N M O we may secure together mechanically by a wrapping of tape. Having built one set of conductors, such as is indicated in Fig. 5, we remove it from the mandrel and build five other similar sets of conductors. We thereupon place one of the sets of conductors of Fig. 5 inside the stator structure of Fig. 2 with one straight portion in one groove and the other parallel straight portion in the diametrically opposite groove. We similarly insert the five other conducting sets of Fig. 5 into the five other parts of diametrically opposite grooves of Fig. 2. Each conducting set has one wire of entry and one wire of exit for each circuit M N O. These wires of entry and wires of exit of the six conducting sets of the circuit M are thereupon interconnected, so that current will traverse each of the branches M in one direction to the left of *x x* in Fig. 4 and in the opposite direction to the right of *x x* in Fig. 4. A similar remark applies to the circuit O; but the wires of entry and exit of the circuits N are so interconnected that those portions of these circuits which lie above the line *y y* of Fig. 4 will be traversed by currents in one direction and the portions of those circuits which lie below the line *y y* will be traversed by currents in the opposite direction. It is thus seen that the windings O and M each tend to produce a magnetic axis along the line *x x*, which is taken at right angles to the brushes. It is further evident that the winding N tends to produce a magnetic axis along the line *y y* in the direction of the brushes—that is to say, a magnetization of a kind proper to annul the effect of the armature-magnetization. In the case of the dynamo 4 we should only have two circuits K K′, as has previously been remarked, instead of the three circuits M N O. To properly represent this in the drawings would mean that but two circuits should be shown in Fig. 5 and but two sections of circuits in Fig. 3. Furthermore, the outer circle of Fig. 4 would now represent but a single circuit K instead of two circuits M O, each tending to produce a magnetic axis along *x x*.

I may say that I have shown but a single exciter 3, since the circuit connections would be precisely the same for a number of exciters coupled in parallel. I may, furthermore, say that the total power consumed by the machines 1, 2, and 4, which comprise my regulating system when used in its most perfected form, is quite small with reference to the maximum power of the exciter. In fact, it is safe to say that if the exciter is of one-hundred-kilowatt capacity the machines 1 and 2 need only be of five-kilowatt capacity each, whereas the machine 4 need only be of one-kilowatt capacity. The proof of this it is unnecessary to give.

In what I have said above the regulating devices have been assumed as operating at a normal speed. A few words will be necessary to show how these regulating devices may be started to bring them up to speed. At the moment of starting the regulating system the switches U_1 U_2 U_3 and the switch X are put on open circuit. The continuous-current machines 2, 3, and 4 are then brought up to their normal speed by power applied to their pulleys. The exciter 3 behaves like a compound machine, building up automatically and exciting the field-circuits of the alternator. These alternator-fields are brought up to the desired voltage by manipulating a rheostat Y in the shunt field-circuits O of the exciter 3. The switch X being closed, the commutating-machine 1 is driven as a motor by current furnished by the cuntinuous-current machine 2, and the commutating-machine is brought up to synchronism by manipulating the field-rheostat Z. The switches U_1 U_2 U_3 being now closed and the field-rheostats Y and Z being cut out, the regulating system is in operation.

I may say that my voltage-regulator is particularly applicable to the alternators shown and described in my application Serial No. 140,933, filed January 28, 1902.

I claim—

1. The process of exciting a current-generator, which consists in varying the electrical energy furnished by the exciter to keep the voltage of the current fed by the generator to the main line at a predetermined value, by supplying to the exciter-field a current which changes its direction under a variation of the main-line voltage, substantially as described.

2. The process of exciting a current-generator, which consists in varying the electrical energy furnished by the exciter to keep the voltage of the current fed by the generator to the main line normally constant, by supplying to the exciter-field a current which has one direction when the main-current voltage is above normal and an opposite direction when the main-current voltage is below normal, substantially as described.

3. The process of exciting a current-generator which consists in varying the electrical energy furnished by the exciter to keep the voltage of the current fed by the generator to the main line of predetermined value, by supplying to the exciter-field a current which is determined by a voltage of predetermined value and an opposing voltage which varies with the main-line voltage, substantially as described.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses.

MAURICE LEBLANC.

Witnesses:
HANSON C. COXE,
JEAN COTTIER.