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SELF ACTING RESISTANCE FOR ELECTRIC MOTORS.

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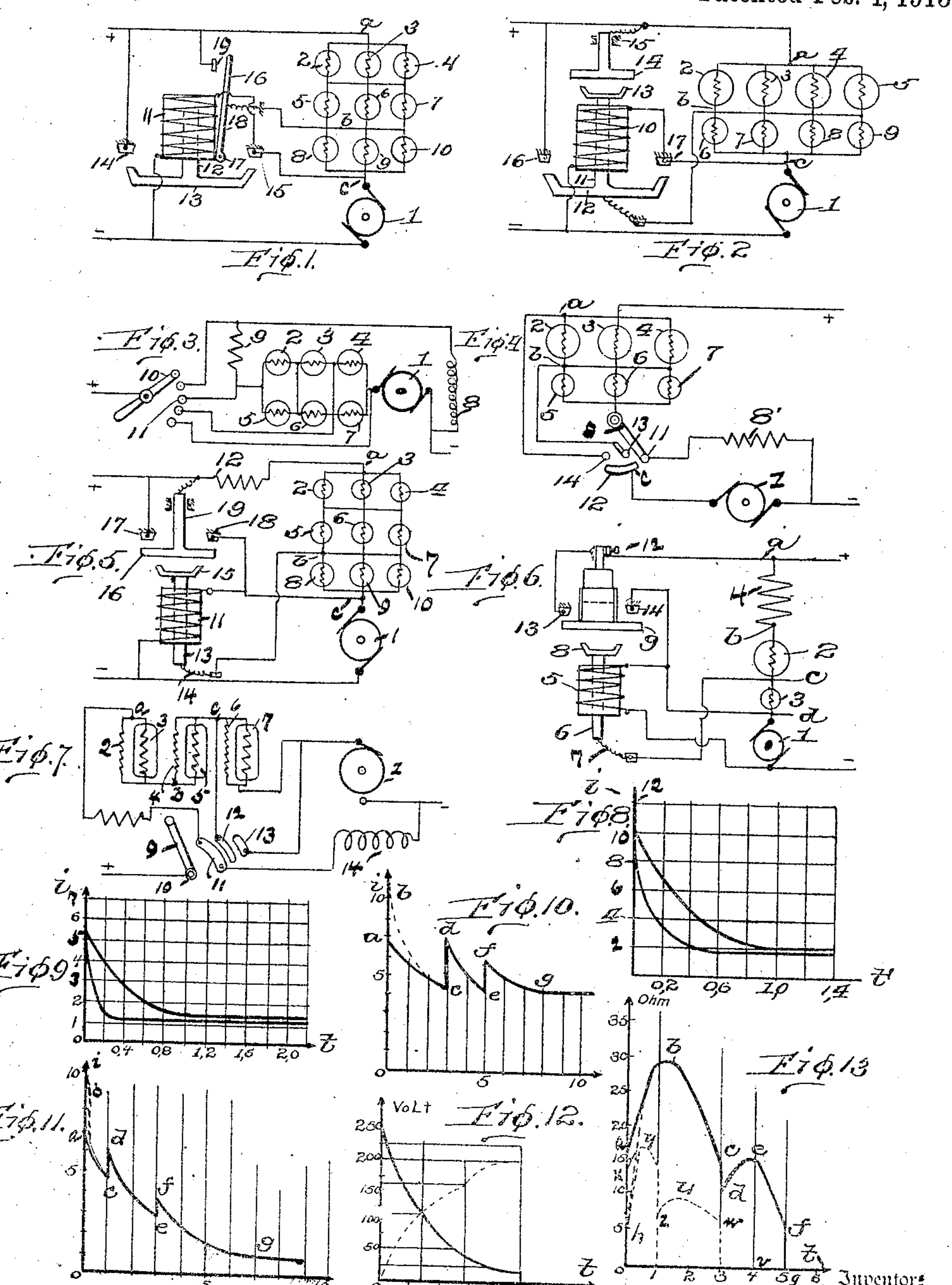

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SELF-ACTING RESISTANCE FOR ELECTRIC MOTORS.

1,052,001. Specification of Letters Patent. Patented Feb. 4, 1913.

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To all whom it may concern:

Be it known that I, MARTIN KALLMANN, a citizen of the Empire of Germany, residing at Berlin, in the Kingdom of Prussia and Empire of Germany, have invented certain new and useful Improvements in Self-Acting Resistances for Electric Motors; and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same.

This invention relates to selfacting starting-resistances for electric motors made of conductors of very high positive temperature-coefficients, preferably of iron, and possessing the property that the iron, or other so-called variation-resistance, at its first insertion before the armature of the motor to be started, becomes very highly heated, eventually up to incandescence, and thereby increases its resisting-value very considerably (even up to ten times) above that of the cold iron resistance. With the increasing armature-speed the tension absorbed by the variation-resistance sinks subsequently, in consequence of the resistance cooling, and decreases, until it finally is, as a rule, cut out in 2 steps by short-circuiting.

In the following will be described special forms of construction of such selfacting variation starting resistances, the object of which is to attain a quiet and steady working of such self-starters on starting the motors, as well as the greatest possible simplicity combined with the smallest cost.

Figures 1–7 show diagrammatically the arrangement of these self-starters, while Figs. 8–13 illustrate graphically the working of the variation resistances during the starting-period.

Similar numerals refer to similar parts throughout the several views.

It has been found that it is possible to regulate the duration of the starting-period as well as the strength of the rushes of current which occur at the first switching on and the subsequent switching off or cutting out of the steps of the resistance by a corresponding division of the variation-resistances into a sufficiently great number of parallel conductors of a very small heat capacity, as well as by a series-connection of the variation-resistances with a constant resistance, and also by a connection in parallel or in multiple of ordinary or constant resistances to the variators (therefore, as a rule, iron resistances). For in this way the duration of the starting of the motor is varied, as the variators, according to their more or less great heat-capacity, are more or less rapidly heated and cooled, on this further depends the strength of the rush or shock of current felt at the switching on and switching off in the net and on the motor, and by a combination of a connection in series or in parallel (or also by both at the same time) of the variators with accurately made constant resistances, it is possible to simplify the construction of the self-regulating starting-resistances within the limits of the rushes of current allowed at the respective works, and thus save expenses, also the load capacity may be increased.

Fig. 1 is a diagrammatic view of the starter having similar variation resistances connected in series and with means to automatically cut out the resistances in sections. Fig. 2 is a diagrammatic view of a starter embodying variators of different resistances connected in multiple and with automatic means for cutting out the variation resistances in sections. Fig. 3 is a diagrammatic view of a starter employing variation resistances connected in series, and means for manually cutting out the variation resistances in sections. Fig. 4 is a diagrammatic view of a starter comprising the features of the invention in simplified embodiment. Fig. 5 is a diagrammatic view of a starter embodying grouped variation resistances and with a solenoid relay adapted to raise and make contact, cutting out a portion of the variation resistance groups and to raise still further and cut out the remaining groups. Fig. 6 shows in diagram a starter employing but two variation resistances and with means to retard the action of the automatic cutout. Fig. 7 is a diagrammatic view of a manually operated starter having variation resistances connected in series with individual constant resistances connected in parallel one with each variation resistance and cut out therewith. Fig. 8 is a diagram illustrating the shock of starting the line A showing the curve of numerous variators while the line B illustrates the use of fewer variators. Fig. 9 is a diagram wherein the upper line illustrates the passage of a current at the start while the lower line illustrates the effect of a reducing resistance in circuit. Fig. 10 is a diagram illustrating the rise and fall of current as the variation resistances are cut out in section. Fig. 11 is a diagram similar to Fig. 10 illustrating a smaller load and consequent shorter starting period. Fig. 12 is a diagram showing in dotted curve the tension absorbed by the motor under normal conditions, the full line representing the resultant curve of absorption by the variation resistance. Fig. 13 is a diagram showing the variation of resistance in the variators during starting, the full line representing a heavy load on the motor, the dotted line a light load.

In Figs. 1–5 the variation-resistances are represented in their subdivision into numerous parallel-groups, while in Figs. 3–5 there have also been added constant series resistances. Figs. 6 and 7 show arrangements without any sub-division of the variation-resistances into parallel and series connections, but on the other hand in series or in parallel connected resistances.

In Fig. 1 have been switched on in front of the armature 1 of the motor (the magnet-field of the motor has for the sake of simplicity been omitted) between the points a and c, several parallel groups of variation-resistances 2, 3 . . . 10. The variators consist, as a rule, of very thin iron wires of a thickness of from about $\frac{1}{10}$ up to $\frac{5}{10}$ of a millimeter, which are hermetically inclosed in glass boxes filled with hydrogen, and are during the starting temporarily heated, eventually up to incandescence. An electromagnetic relay 11 provided with two armatures 12 and 16, is for instance connected across the motor armature, so that with the increasing speed of the motor its excitation increases until (for instance in 220 volts installations) with a counter electromotive force of about 150 volts, the small armature 16, on one side, which turns on the axle 17 is attracted against the counter-force of the spring 18 and closes a contact at 19. Hereby the part of the variation-resistance lying between the points a and b, thus for instance the group of the variators 2 to 7, is short-circuited after the same has, after the first heating of all the variators, cooled again in the meantime, For at 150 volts counter-pressure all variators together only absorb in the above instance 70 volts and if $\frac{2}{3}$ of the same are now short-circuited the last third, namely the variator-group 8—10 must for a short time absorb this rest of tension of 70 volts. As a result the iron resistances are eventually made incandescent again, if the speed of the motor increases sufficiently slowly, or their inertia is small. But then they cool down again, as for instance at a counter electromotive force of 200 volts they need only absorb 20 volts. The relay 11 has, as a consequence, been excited to such an extent that the armature 12 is drawn into the coil and effects with the contact-arm 13 on the contacts 14 and 15 also the switching off of the last part of the variators, by short-circuiting the whole variation-resistance. The number of the parallelly connected variators depends on the starting-current required for the motor, if for instance at 220 volts there are required 6 amperes for attaining the momentum of starting corresponding with the load on the motor, therefore a power consumption of 6$\times$220=1.32 kilowatts, 6 series of variators are connected in parallel each of which is calculated for 1 ampere and thus brings the same to incandescence at 1 ampere per variator, or 3 series each of 2 amperes are used when a correspondingly stronger iron wire is used in the single variators, which only becomes incandescent at 2 amperes, or else numerous parallel and still thinner iron wires are used in each of the glass boxes. In this way the parallel series are grouped according to the consumption of current and the starting-time will be the shorter the thinner the iron wires are, as the same can then get heated and cool down within a small fraction of a second, as they have a very small heat-capacity. But on the other hand the arrangement is made hereby more complicated and expensive. The thinner the iron wires are, or the smaller their heat-capacity is, the more rapidly take place the fluctuations of current at the first switching on of the whole variation-resistance with the motors and at the switching off of the first part and the last part of the variator groups, so that with a very great subdivision the rushes of current are no longer noticeable and likewise no shocks on the motor.

Fig. 2 shows a similar arrangement as the above described with conductors of a small heat-capacity connected in parallel, in which however, as a variation, instead of, for instance, three variators of the same size connected in series only a large and a small one are connected in series, each of which is again divided into parallel sections. In this way the division, for instance into $\frac{2}{3}$ and $\frac{1}{3}$ of the tension can be made in a more simple way. The relay 10 shows in Fig. 2 one armature, but which has 2 motion steps. It is again connected with the motor 1, between a and c is the above described variation-resistance 2, 3 . . . 9 and the armature 11 of the relay 10 is connected with the point b of the variation-resistance. If the counter electromotive force has for instance in 220 volt motors reached 150 volts, the iron core 11 is drawn into 10 and short-circuits in the first place at 13 and 14 the greater part a, b of the variation-resistance, that is to say, the large variators 2—5, and at an increasing tension the contacts 13 and 14 with the guide-rod 15 are raised by the iron core 11, which has been attracted, higher up, until the contact-arm 12 of the iron armature 11 touches the contacts 16 and 17 and disconnects by short-circuiting the whole or the rest of the variation-resistance. The mode of working is in other respects as illustrated by Fig. 1, the variators of a larger size 2—5 shown as samples are in parallel connection preferably arranged for the same strength of current as the variators of a smaller size 6—9. The number of the variators connected in parallel and the thickness of the iron wires for the same depends, as already remarked, on the heat-capacity desired, the admissible starting duration, the load and the admissible strength of the shocks of current.

In Fig. 3 there is connected with the variators 2, 3 . . . 7 switched in parallel a constant resistance 9, for instance of nickelin. Behind the same is the armature 1 of the motor, whose shunt field is marked with 8. For the sake of distinctness the switching off of the steps is shown as being done by means of a crank, but it can also be effected quite automatically, for instance by the above described relays. On putting the crank 10 on the first contact the motor is started, while the reducing-resistance 9 and the groups of variators 2—7 (in series parallel) and the armature 1 are connected in series. If the speed of the armature has increased to such an extent that the variators have cooled down sufficiently (for instance if only 70 volts are absorbed by the reducing- and variation-resistance) the crank is put on the second contact and thereby the constant reducing resistance 9 is switched off, the variators 2 to 7 receive for a short time the rest of the tension and become heated, at the further increase of the speed they cool down again, the crank is put on the next contact and 2, 3, 5, 6 switched off, the rest of the tension is absorbed now by 4 and 7, which become heated again, and if they have cooled down again, which will be the case at a tension of the armature of about 200 volts, the crank is put on the last contact and the starting-period terminated thereby. The field takes current through the resistances.

In the construction shown in Fig. 4 resistances 2 to 7 and resistance 8 are at first connected with the armature. Upon moving arm 9 to contact 13, resistances 5 to 7 are short circuited and resistance 8′ is eliminated or cut out, and upon a further movement of arm 9 to contact 14 resistances 2, 3, and 4 are short circuited. In Fig. 5 this arrangement is represented in combination with an automatic relay, switched off, for instance in 2 steps. Also here are used, as shown by the parallel switching, variators of a small heat-capacity 2, 3, 4, 5 . . . 10 connected in front of the armature 1 of the motor, moreover the constant resistance 12 is connected to this series, in order to reduce the initial shock of the current, as the variators offer otherwise in their first cold state too little resistance. The relay 11 is connected to the poles of the armature of the motor; at a corresponding increased speed the iron core 13 with the contact 15 is raised up to the contact-piece 16, and as 13 is connected through the lead 14 with the point b of the variation-resistance there takes place, as 16 is connected through the guide-rod 19, with the positive pole of the net, and over 12 with the point of the variators, a short-circuiting of the variators 2 to 7 and of the reducing-resistance 12, by the touching of 15 and 16. There remain only connected 8, 9, 10 which absorb, while becoming heated again, the rest of the tension at a further increase in the speed of the motor the iron core 13 is further raised, together with 15, 16 and 19, until 16 is in contact with 17 and 18, and as 18 is connected to point c of the variators, the fixed resistance 12, as well as the whole variation-resistance, is switched off. By using a suitable fixed resistance, for instance of nickelin, it is possible, even in spite of the use of relatively inert iron resistances of a thicker wire, or the like, as variators to sufficiently reduce the shock of the current at the switching on and switching off, and the construction may be greatly simplified by reducing the number of parallel switched variators.

In Fig. 6 is only used a single series, for instance of two variators 2 and 3, the same are connected to the armature 1 of the motor, moreover the fixed reducing resistance 4, between the points a and b, is connected to the variators and the armature. When the speed of the motor increases, the iron core 6 is attracted by the coil 5, and as 6 through the lead 7 is connected with the point c of the variators, the reducing-resistance 4 and the largest of the variators, 2, are switched off by the contact 8 on 6 through its touching the bar g. Now 3, while becoming heated again, absorbs the rest of the tension, until finally, at the further increase of the electromotive counter-force, the iron armature 6 carrying the bar g is further raised. But this raising is retarded as by a dash pot or other brake, whose stamper is fixed at 12. The contact rod g with the cylinder of the dash pot or other impediment is thus raised very slowly, until it forms a contact with 13 and 14 and hereby switches off the remainder or the whole variation- and reducing-resistance, as 14 is connected with point d of the variation-resistance. This brake may be timed as desired, for instance for the duration of

3 seconds. In this way there is attained that the switching off of the remaining variation-resistance 3 does not take place too rapidly, in order that the same, if it possesses a greater inertia in consequence of a thicker wire and larger size, can, at least for the greater part, cool down again, after having absorbed the rest of the tension, for which, as a rule, about 3 seconds are sufficient. In consequence of this also more inert resistances of a greater heat capacity may be used in this step without any danger of too great shocks or rushes of current by such an artificial damping even if it is intended to set in the last step the relay 5 to work in the case of a proportionately low electromotive counter-force, or speed of the motor, in order to be able to work the automatic starter even with a low net tension.

In Fig. 7 there is finally shown how the power of the variation-starter can still be further increased by a simple and strong construction for working it by hand, which however, quite similar to the one shown in Fig. 6, can be made automatic by working it with relays. Constant resistances 2, 4 and 6 of nickelin or the like are connected to the variators 3, 5 and 7, each of the former being in parallel with one of the latter and each parallel group being in series respectively between *a* and *b*, *b* and *c*, *c* and *d*. The shunt field 14 of the motor 1 is already excited at the first position of the crank 10, on the sliding-piece 11, and hereby the fixed resistance, for instance the nickelin resistance 8, and the series of the variators 3, 5 and 7 with their parallel resistances 2, 4, and 6 are connected to the armature 1. After the motor has attained a sufficient speed, and if the crank 10 is on the sliding-piece 12, which is connected with point *c* of the variators, the fixed resistance 8, together with the two variators 3 and 5 and their parallel resistances 2 and 4, are switched off as soon as the same have sufficiently cooled down, and if, for instance, altogether only 70 volts of 8, 3, 5 and 7 with 220 volt-motors are absorbed. These 70 volts are now absorbed by the last group 7 and 6, in consequence of which 7 becomes hot again and increases its resistance, and after the speed of the motor has further increased and in consequence of the cooling of 7 only, say, 15 volts are absorbed, the remaining resistance is short circuited off, and the starting-period ends. A remarkable fact in this connection is that though it is true that the "elasticity" of the variation-resistance 3, 5, 7 is slightly lessened by this parallel switching of 2, 4, 6, a greater load capacity of the variation-starter is attained, for instance if the variators are brought to incandescence already at 5 amperes, and can only overcome say 5 amperes×220 volts=1.1 kilowatt of motor-power on the starting, by the parallel switching of a constant resistance 2, 4, 6, which absorbs in the heated state of the variators, in consequence of the current-branching in this state only perhaps 2 amperes, the load-capacity could be increased to a starting power of 7 amperes×220 volts=1.54 kilowatts. The variation-capacity of the starter sinks, it is true, by this parallel switching, but the slightly greater shock caused by this, by switching off the steps, is frequently still admissible. If therefore the greater leading is for the sake of economy not to be effected by increasing the number of the variators then the addition of a constant resistance offers within certain limits a means for a better utilization of the variation starters.

Figs. 8–13 show the working of the different forms of construction. In Fig. 8 the curve A shows that, for instance, by the use of numerous variators of a slight heat-capacity the shock of the current sinks at the beginning exceedingly rapidly from over 12 amperes almost momentarily to about 8 amperes, and is after 0.5 seconds about 2 amperes, while when using fewer but inert variators, according to the curve B, the current sinks much slower and is after 0.59 seconds still nearly 5 amperes. But it is possible, as Fig. 9 shows, by switching on a constant resistance to sufficiently reduce the initial shock of the current even with variators of a great heat-capacity, so that the fluctuation does no longer disturb the net. The upper curve in Fig. 9 shows the passage of the current during the first seconds without the switching on of a reducing resistance; the lower curve shows it with a reducing-resistance switched on.

Figs. 10–13 show how the variation-resistances act when being switched on to the motor.

Fig. 10 shows in the dotted curve the magnitude of the initial shock of the current, if no constant resistance is switched on to weaken it; the current then rises at the beginning over the point *b*, whereas for instance with a fixed reducing resistance the current is reduced down to the point *a*. The current then sinks gradually, while the motor is working with its full power, in about 3 seconds, according to the cooling of the resistance and the increase of the speed of the motor down to the point *c*. Here the greater part of the variation-resistance, as well as the constant reducing-resistance, is short-circuited, while the current for a short moment rises up to the point *d*, in order to sink then, according to the reheating of the rest of the variators and the further increase of the speed, rapidly down to the point *e*. Now there takes place, after about 5 seconds, the short-circuiting of the rest of the variators, while the current increases a little (point f) until, with the increasing speed of the motor, at the point g the permanence is reached. With "t" there is indicated in all curves on the abscissa the duration in seconds.

Fig. 11 is exactly similar to Fig. 10 with only the difference that the power of the motor is smaller here, that is to say the load. In consequence of this the whole starting-period is much shorter and lasts only about 3 seconds; also here point b indicates again the shock of the current, at first without, and point a with the switching on of a constant resistance; c, d, indicates again the shock of the current at the first, e f that at the second step of switching off, and g the permanence.

In Fig. 12 the voltage at the resistance is shown by a full line curve and the voltage at the motor by a dotted line. The amount of tension absorbed by the starting-resistance is for instance at the beginning fully 220 volts, the same as the tension of the net, it sinks within about 3 seconds to 50 volts, which are absorbed by the constant and the variation-resistance, which has cooled down in the meantime. Then takes place a short-circuiting of the first step, and after a further 2 seconds, during which the amount of tension absorbed by the rest of the variators has sunk down to about 15 volts, takes place the full switching off, so that then the full tension of for instance 220 volts can act in the armature of the motor. The curve of the tension on the armature of the motor represents the counter-piece of the curve showing the tension of the resistance.

Fig. 13 shows the variations of the resistance undergone by the variation starting-resistance during the starting-period in the curve a, b, c, d, e, f, g, drawn in full lines, at the full working of the motor, therefore with a great strain on the resistance, and the dotted curve x, y, z, u w v shows the same with a slight load on the motor, therefore with a weak current. Point h shows the small initial resistance which the variation-resistance would show in a cold state. By the switching on of a constant additional resistance this initial value is increased to the point x or a, and hereby, as explained, the shock of the current is considerably reduced.

The different strengths of the current are easily found by dividing the amounts of the absorbed tensions and the resistances. The period of the heating of the variators is marked with h, b and h, v, the period of the cooling with b, c and so on, the renewed reheating of the rest of the variators is shown by d e, and z u and the renewed cooling by e f and u, w the short-circuitings are shown by c, d, and f, g; respectively w, v and so on.

The above described apparatus show the working of the variation-resistances under different loads, during the different steps of switching, with different amounts of the heat-capacity and inertia of the variators, with and without any addition of a constant resistance, and these properties of the variations of the amounts of the resistances of conductors with high temperature-coefficients, especially of iron, make it possible to work with one, two or several steps of switching-off for the different purposes of self-starters, either with the hand or automatically.

The same as for direct current and shunt motors, which were selected on account of the simplicity of the example, these variation self-starters can also be used for series or compound motors, and consequently also for alternating current or three-phase motors.

What I claim as my invention and desire to secure by United States Letters Patent is—

1. In a device of the class described, a motor circuit, a self regulating resistance consisting of a plurality of resistance elements having a high positive temperature coefficient connected in series parallel and arranged to be included in the motor circuit, a substantially constant resistance connected with the resistances first mentioned, a solenoid, a contact member, a conductor connecting the latter with the motor circuit between one of the brushes and the self regulating resistance and also connected with the solenoid, a contact member connected with the positive lead of the circuit, an armature adjacent to the solenoid, connected with the positive lead and arranged to connect the contact members upon movement of the core of the solenoid, a conductor connecting the core of the solenoid with certain of the resistances for short circuiting a portion of the latter, and means for connecting the solenoid with the negative lead of the circuit.

2. A device of the character described comprising a constant resistance and a plurality of groups of self-regulating resistances formed with conductors of high temperature coefficients, said constant resistance, all of said groups and an armature connected in series.

3. A starting resistance for electro-motors comprising a substantially constant resistance and a plurality of thin iron resistances connected in parallel with each other, said constant resistance and said iron resistances being connected in series with each other and with the armature of said motor.

4. In a motor starter, a group of resistances comprising independent sections, each comprising a coil, an electro-magnetic device for cutting out one of the sections, said

device being automatically operated by an increase in voltage, the resistance of the remaining section increasing at the moment of cutting out in a degree and for a period substantially corresponding with the increase of voltage resulting from such operation and a constant resistance connected with the group of resistances first mentioned.

5. In a motor starter, a group of resistances comprising independent sections, each consisting of parallel connected coils constituting units of a predetermined value, the units of the respective sections being connected in series, an electro-magnetic device for cutting out one of the sections, said device being automatically operated by an increase of voltage, the resistance of the remaining section increasing at the moment of cutting out in a degree and for a period substantially corresponding with the increase of voltage resulting from such operation and a constant resistance connected with the group of resistances first mentioned.

In testimony whereof I affix my signature in presence of two witnesses.

MARTIN KALLMANN.

Witnesses:

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