C. H. KICKLIGHTER.

VOLTAGE REGULATOR.

APPLICATION FILED SEPT. 29, 1910.

1,222,412.

Patented Apr. 10, 1917.

7 SHEETS—SHEET 1.

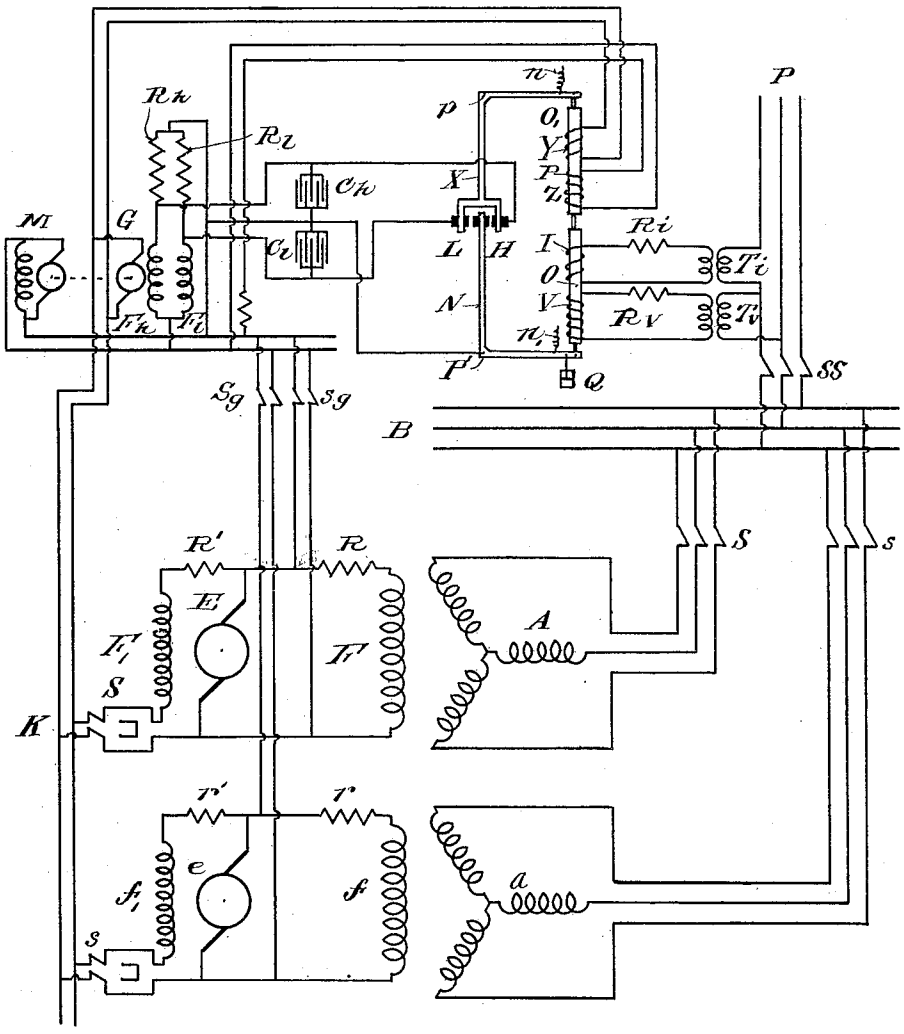


Fig. 1.

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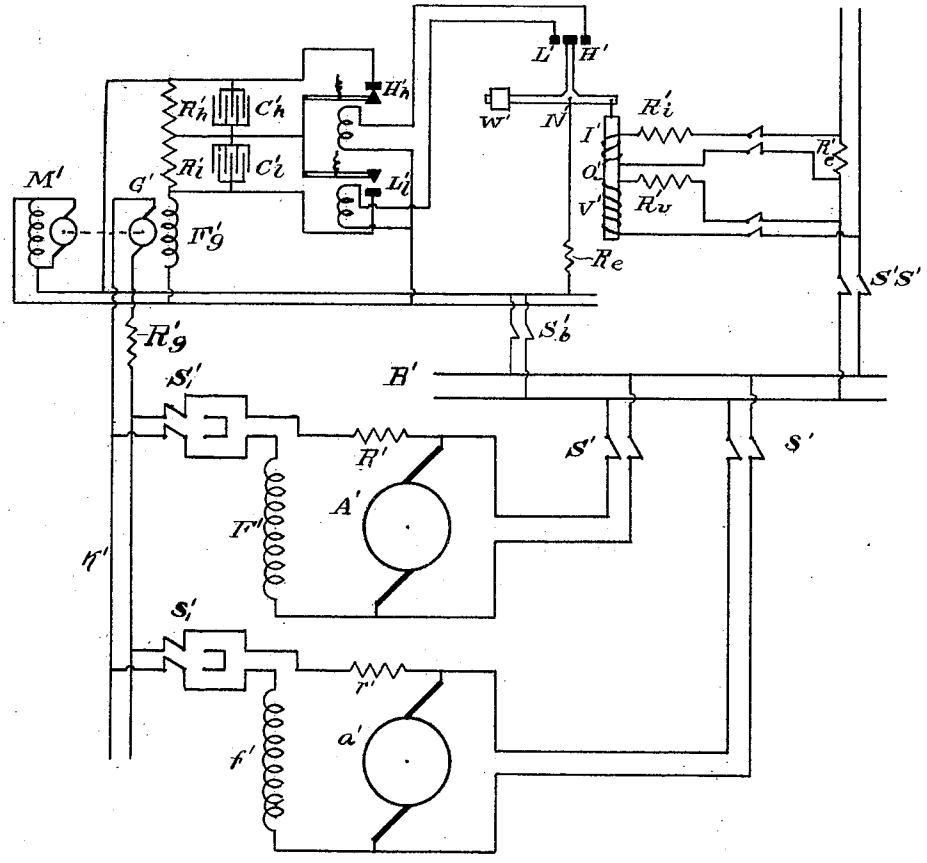


Fig. 2.

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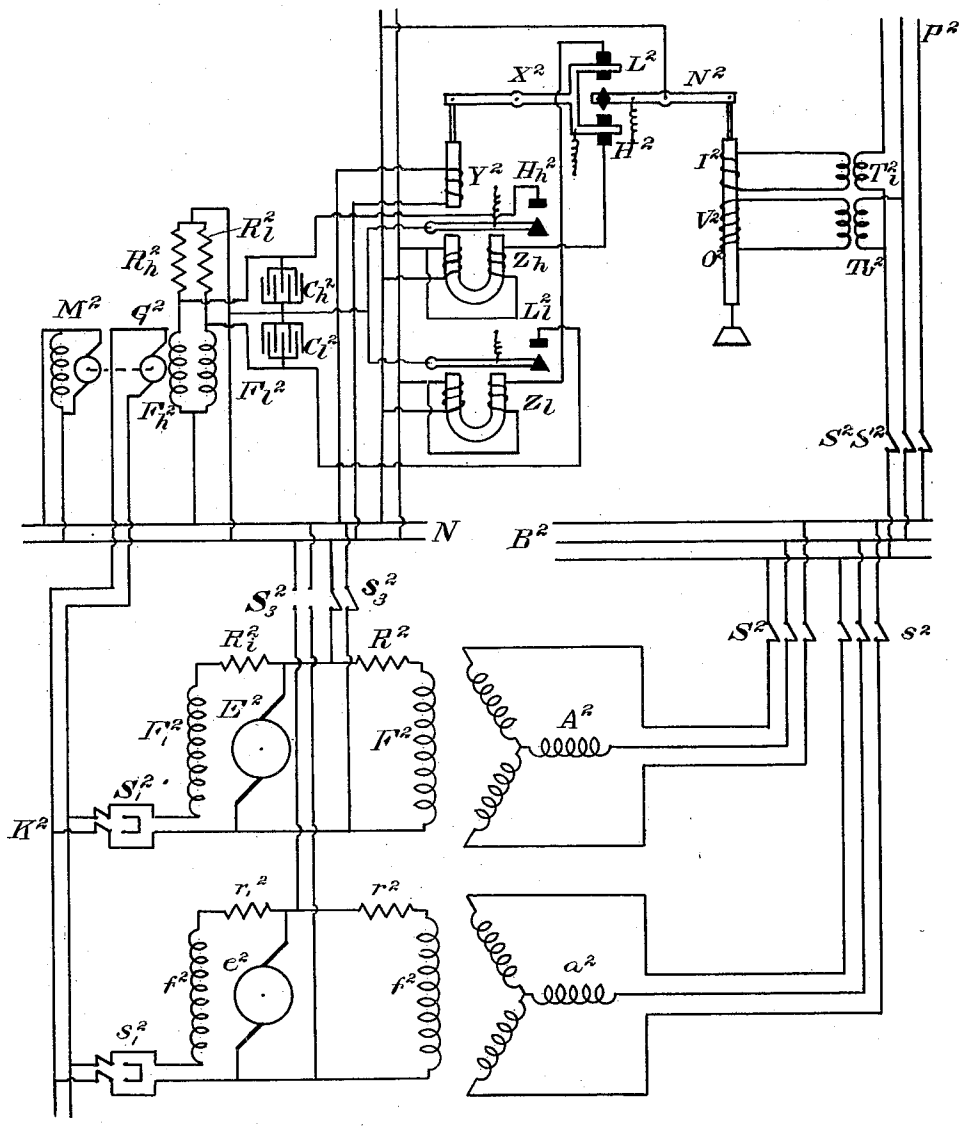


Fig. 3.

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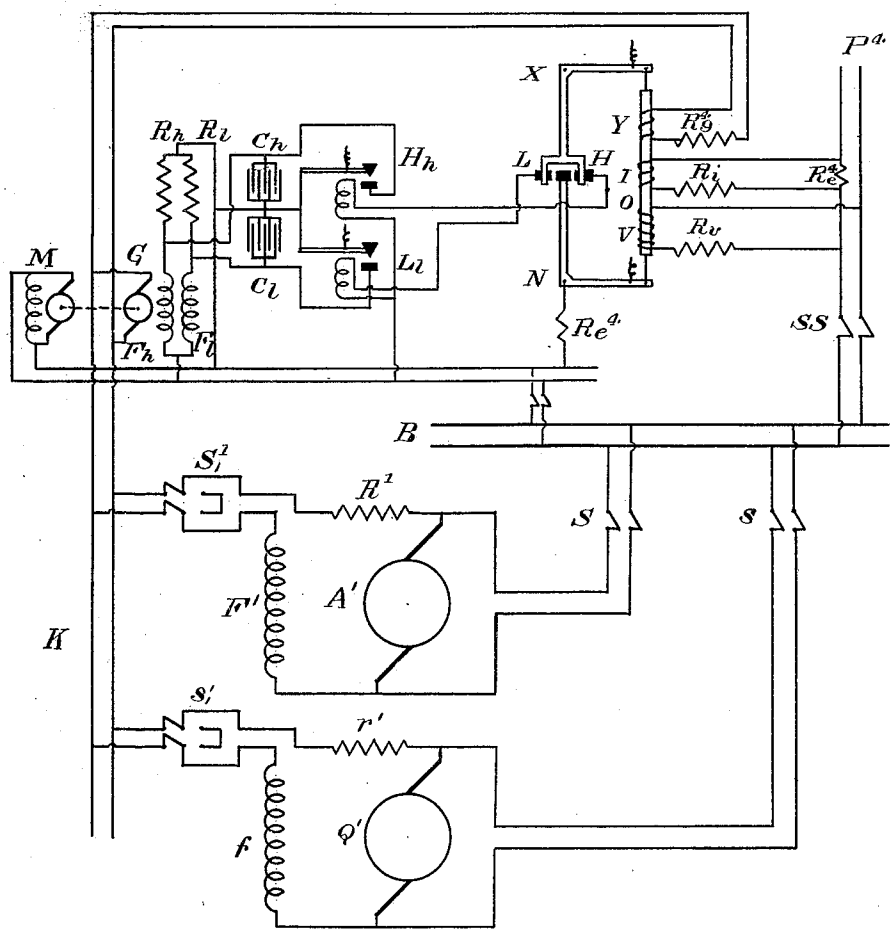


Fig. 4.

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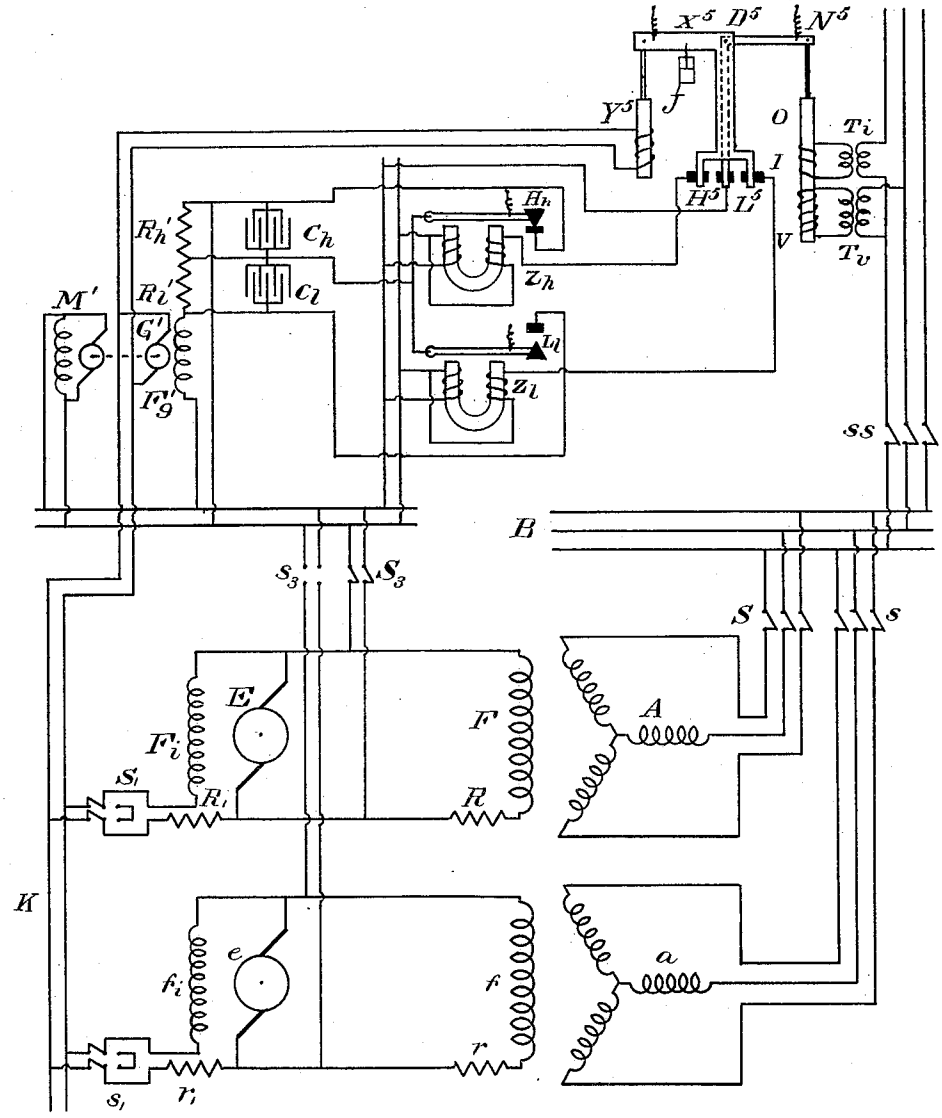


Fig. 5

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7 SHEETS—SHEET 6.

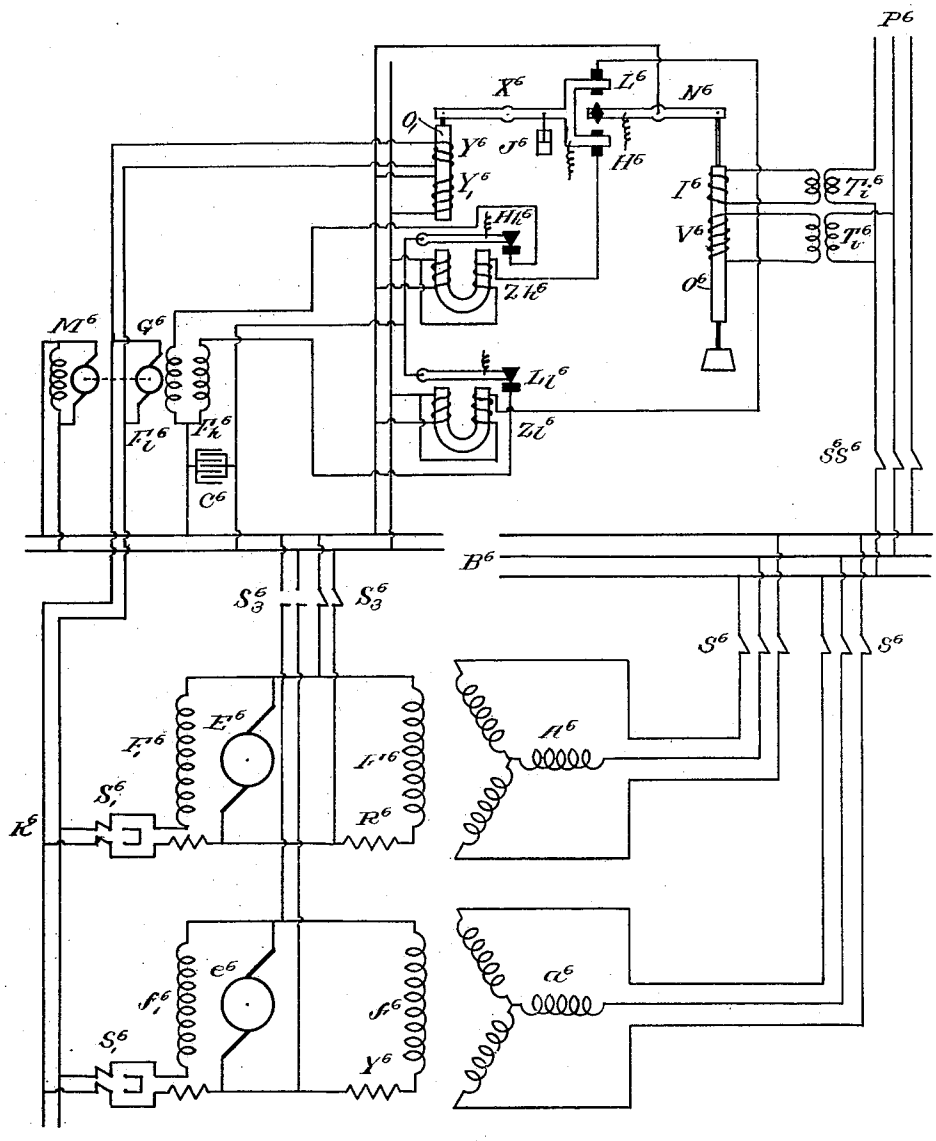


Fig. 6.

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7 SHEETS—SHEET 7.

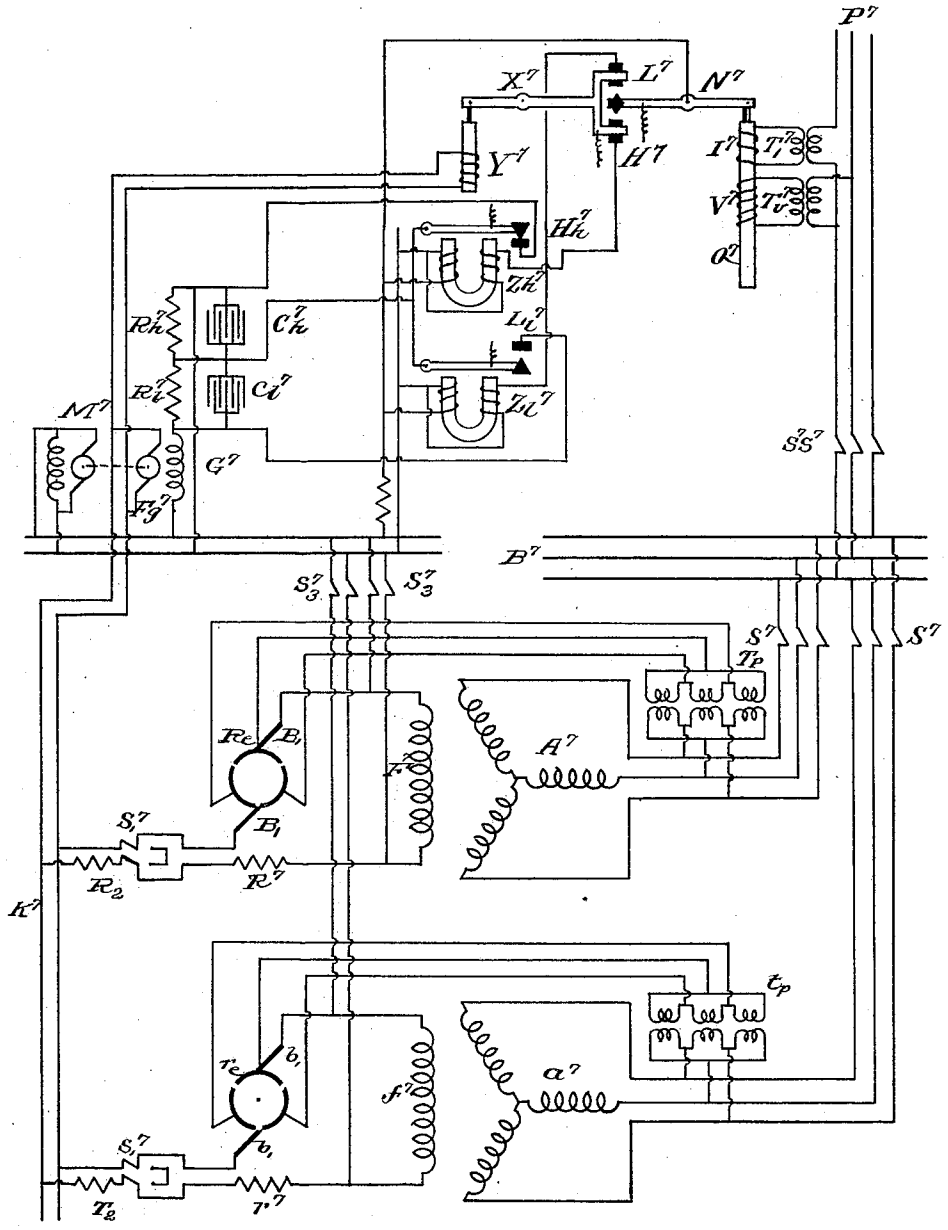


Fig. 7.

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UNITED STATES PATENT OFFICE.

CHARLES H. KICKLIGHTER, OF PASADENA, CALIFORNIA, ASSIGNOR TO WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY, A CORPORATION OF PENNSYLVANIA.

VOLTAGE-REGULATOR.

1,222,412. Specification of Letters Patent. **Patented Apr. 10, 1917.**

Application filed September 29, 1910. Serial No. 584,558.

To all whom it may concern:

Be it known that I, CHARLES H. KICKLIGHTER, a citizen of the United States, and resident of Pasadena, in the county of Los Angeles and State of California, have invented certain new and useful Improvements in Voltage-Regulators, of which the following is a specification.

This invention relates to voltage regulators for dynamo electric machines either alternating or direct, and more particularly to regulators of the make and break type.

One of the objects of the present invention is to provide a system and apparatus whereby many of the objectionable features of existing voltage regulators are eliminated, and whereby the method of regulating several generators, operating in parallel, is greatly simplified, one regulator only being necessary.

One of the objections to voltage regulators of the make and break type is that since the current which is interrupted is necessarily large, sparking necessarily takes place at the contacts, resulting in their wearing down rapidly. Another objection is that the shunt circuit is continually interrupted, the voltage being regulated by the duration of the make or the break.

In accordance with this invention the current in the generator field is controlled by a small auxiliary dynamo electric machine which in turn is controlled by the make and break regulator so that the value of the current interrupted is exceedingly small. The make and break device is so arranged that it can normally float and only comes into play to make or break contact when the voltage varies above and below the normal. At normal voltage it is out of operation.

The invention can be best set forth in connection with the accompanying drawings, in which:

Figure 1 is a diagram showing the electrical connections of the apparatus as applied to the voltage regulation of an alternating current generating system;

Fig. 2 is a diagram showing the electrical connections of the apparatus as applied to the voltage regulation of a direct current generating system;

Fig. 3 is a diagram showing another form of this invention as applied to an alternating current system;

Fig. 4 is a diagram showing still another form of this invention as applied to a direct current system; and

Fig. 5 is a diagram showing still another form of this invention as applied to an alternating current system.

Fig. 6 is a diagram showing still another form of this invention as applied to an alternating current system.

Fig. 7 is a diagram showing still another form of this invention as applied to an alternating current system.

Referring to the drawings, and first to Fig. 1, the system to be controlled consists in this case of two alternators feeding a single main. The armatures A, *a*, are connected to the alternating bus bars B by means of switches S, *s*. The field windings F, *f* are excited by means of exciters E, *e*, which are the usual direct current machines and provided with shunt field windings F_r, f_r. The current in the field windings F, *f*, is controlled by the usual regulating resistances R, *r*, and the current in the exciting fields is controlled by the usual regulating resistances R′, *r*′. The alternating current mains, the voltage of which is to be regulated, are designated by P, and the line switch by SS.

An auxiliary direct current machine G is arranged to be driven at a uniform speed by means of any suitable motor, in this particular instance a shunt wound direct current motor M which is arranged to be connected across the brushes of either of the exciters E, *e*, by means of switches S_g or s_g. The motor M and machine G are preferably a motor generator set of small capacity so that the set can be mounted directly on the switch board. The auxiliary machine G is a direct current machine and is provided with a differential field winding F_h, F_l, which is connected across a source of direct current. In this particular instance the current is supplied by means of one of the exciters E, *e*. Each one of the windings F_h, F_l has in series with it a resistance R_h, R_l, respectively. The machine G is provided with

bus bars K, and a pair of double throw switches $S_,$ $s_,$ are arranged to connect either or both of the field windings $F_,$ $f_,$ in series with the auxiliary machine G. Either of the exciters may be cut off from the machine G by throwing the switch to the right which will also close the field circuit for that machine.

The make and break regulator comprises a pair of levers X, N, pivoted at p, p', respectively. The lever X is forked as shown and provided with contacts L, H, which are connected to resistances R_l, R_h, respectively. The lever N is connected to the junction of the resistances and is provided with a contact which is arranged to normally float between the contacts H and L and to cooperate with one or the other. The other arms of the levers X, N are connected together and to cores O, and $O_,$ the weight of the cores being balanced by means of springs n, $n_,$. A dash pot Q is provided to steady the movements of the levers. The solenoid core O is arranged to be controlled by a potential coil V and by a current coil I. The coils V and I are supplied with current from the potential and current transformers T_v, T_i, respectively, and the current is arranged to be regulated by means of regulating resistances R_v, R_i. The coils V and I are in opposition so that the current coil will compensate for a drop in voltage if so desired. Where however the voltage at the bus-bars is to be kept constant then the current coil can be dispensed with. A third coil Y may control the core $O_,$ and is connected across the brushes of the auxiliary machine G. The coil Y is here mounted on the same core $O_,$ with coil Z, which latter is connected to any source furnishing a continuous current, in this case to one of the exciters E, e. The current in coil Y either increases or decreases the normal excitation in core $O_,$ according to the direction of its flow. The resistances R_h, R_l will normally prevent sparking at the contacts of the regulator, but for additional insurance against sparking the condensers C_h and C_l may be connected across the contacts. The auxiliary machine G preferably has its field magnets constructed of soft iron so that hysteresis will not interfere with or delay its action. The levers X and N are preferably both movable, but either lever can be stationary if so desired. The action however is more sensitive if both are movable and there is no disadvantage in this case in view of the fact that both levers are moved in unison by means of a single core.

The operation of the apparatus will now be described. If the terminal or feeder pressure tends to rise, magnet core O is drawn down, due to the increased excitation of pressure coil V; contact is made between levers N and X at H; resistance R_h is short circuited; the current in F_h exceeds that in F_l, the machine G generates a pressure opposed to the exciter field currents in $F_,$ and $f_,$ the exciter pressures drop; the main generator field currents decrease, and bus-bar pressure is lowered. Simultaneously with the decreased flow of current through the exciter fields, current flows through coil Y, tending to open the regulator contacts at H. Due to the delaying action of hysteresis in the exciter and generator fields contact at H is broken before the feeder pressure drops too much and hunting is prevented.

Conversely, if the terminal or feeder pressure tends to become too low, magnet core O rises, due to the decreased excitation of coil V, contact is made between levers N and X at L; resistance R_l is short circuited; the current in F_l exceeds that in F_h, the machine G generates a pressure in the same direction with the field currents in $F_,$ and $f_,$; the exciter pressures rise; the main generator field currents increase and the bus-bar pressure is increased. The current in Y flows now in the opposite direction from above and assists in breaking contact at L before bus-bar pressure rises too high.

If resistances R, R′, r and r' are adjusted so as to give the correct alternator pressure for the usual load and conditions without the regulator, then when voltage regulator is thrown into service by switches $S_,$ $s_,$ the main controlling magnet O should hold the arm N so as to make contact with neither points H or L. Thus the controlling arm for usual conditions will float and constant making and breaking of contacts will not occur. But should conditions tend to cause the pressure to rise above normal, the making and breaking of contact between arm N and point H will hold the voltage constant. Should conditions tend to cause the pressure to fall below normal, the making and breaking of contact between arm N and point L will hold the voltage constant. In either of these cases the vibrations of arm N are not so frequent as in other regulators where the field regulated under all conditions gives too high an excitation and a constant make and break is necessary to hold it down.

The coils Y and Z may be dispensed with if so desired. In this case after the regulator has been set in operation on a rise of voltage to lower the excitation of the generator, the drop of voltage resulting from this decrease of excitation will cause a decrease in the strength of the coil V and thus will permit the springs n $n_,$ to raise the core and break the contact between N and H. The operation will be similar when the voltage drops below normal. It is of course more advantageous to add the additional coil

Y which acts as an anticipator and thereby prevents hunting, but a suitable dashpot Q will steady the movements of the levers X and N even if the coil Y is not used.

Referring now to Fig. 2, the diagram illustrates the invention applied to a direct current system consisting of one or several direct current dynamos operating in parallel.

The armatures A', a' of the direct current generators are connected to the direct current bus-bars B', by means of the generator switches S', s'. The shunt field windings F', f', are provided with the usual regulating resistances R', r', and connected by means of the switches S', s', across the bus-bars K' of the small direct current auxiliary machine G' which is driven by a suitable motor M' connected across the direct current bus-bars B' and adapted to boost the current in F' and f'. The machine G is provided with a single field winding F'_g, which is connected across a suitable source of direct current and has connected in series therewith a pair of resistances R'_h, R'_l. This machine always therefore acts as a booster.

The regulator comprises a pair of stationary contacts H', L', and a movable arm or needle N' which is provided with a contact adapted to engage either H' or L', but adapted to normally float between these two contacts. One arm of this lever has secured to it a solenoid core O' which is energized by a potential coil V' connected across the line B' and by a current coil I' connected across a low resistance shunt R'_e. The coils V' and I' are in opposition and the current is regulated by means of regulating resistances R'_v and R'_i, respectively. The contacts H', L' control the magnets for a pair of switches H'_h and L'_l, the former being normally held closed and the latter being normally held open. These contacts are arranged to short circuit the resistances R'_h and R'_l, respectively, and the sparking is prevented by means of suitable condensers C'_h, C'_l. The current in the magnet coils for the switches H'_h and L'_l is controlled by a regulating resistance R_c. The solenoid core is balanced so as to maintain the lever N in position between the contact H' and L' by means of a weight w' which may be adjusted on the arm of the lever.

The operation of the apparatus will now be apparent. If the terminal or feeder pressure tends to rise, arm N' makes contact with point H', the relay switch H'_h is opened, the resistance R'_h is thrown into the field circuit, the field F'_g is weakened, the pressure generated by booster G' is lowered, the fields F' and f' are weakened, and the bus-bar pressure drops.

Conversely, if the terminal or feeder pressure tends to become too low, arm N' makes contact with point L', the relay switch L'_l is closed, the resistance R'_l is short circuited, the field F'_g is strengthened, the pressure generated by booster G' is increased, the fields F' and f' are strengthened, and the bus-bar pressure rises.

If the dynamo field resistances R' and r' are adjusted so as to give the correct bus-bar pressure for the usual load and usual conditions without the regulator, then when the voltage regulator is thrown into service, the booster G' will increase the excitation of fields F' and f' above normal. Sufficient resistance R'_g should then be inserted to reduce the field currents back to their normal value with the needle N' in the floating position and with usual load conditions prevailing. The drop through R'_g will then exactly equal the pressure generated by the booster G' when the needle N' is floating. As in Fig. 1, this apparatus after adjustment will float and will not operate so long as the usual load conditions prevail. Should conditions tend to cause the pressure to increase, needle N' will make and break contact with H' and relay key H'_h will hold the pressure down. Should conditions tend to cause the pressure to decrease, needle N' will make and break contact with L' and relay L'_l will hold the pressure up. In either of the latter cases the vibrations will not be so frequent as in the ordinary make and break regulator.

It is obvious that the same arrangement may be used for regulating an alternating current circuit. Since the auxiliary generator generates a current which is in the same direction as the current passing through the windings F', f', this machine may furnish the entire exciting current for the generators. In this case however the current interrupted at the contacts of the regulator will be very much greater than where the generator merely furnishes just enough current for regulating purposes.

Fig. 3 shows a refinement and a slight modification of the embodiment shown in Fig. 1. The construction and arrangement of the exciters and the auxiliary machine are the same as shown in Fig. 1 and therefore similar parts will be designated by the same reference characters with the exponent 2 added.

The regulator consists of two levers X^2 and N^2, the lever X^2 being provided with contacts H^2 and L^2, each of which coöperates with a contact on lever N^2 to control one leg of a pair of differential magnets or relays Z_h and Z_l respectively. The relay Z_h controls the switch H^2_h which is arranged to short circuit the resistance R^2_h and the relay Z_l controls the switch L^2_l which is arranged to short circuit the resistance R^2_l. The lever N^2 is provided with a solenoid core O^2 which is controlled by potential and current coils V^2 and I^2, respectively, which

receive current from the mains P^2 through the potential and current transformers T^2_v and T^2_i. The lever X^2 is provided with a solenoid core, the exciting coil Y^2 of which is connected in this case across the exciter bus-bars N.

The operation of the apparatus will now be apparent. If the terminal or feeder pressure tends to rise, magnet core O^2 is lifted; contact is made between lever N^2 and contact piece H^2; the core Z_h is demagnetized and is drawn up by its spring; the resistance R^2_h is shunted; the current in F^2_h exceeds that in F^2_l; the generator G^2 gives a pressure opposing that impressed upon the field winding F^2 and f^2 of the exciters; the exciter pressure drops; the field excitation of F^2 and f^2 is decreased, and the alternator voltage is lowered. Simultaneously with the decrease of exciter pressure, the current in winding Y^2 decreases and lever X^2 breaks the contact at H^2 before the alternator voltage drops too low. Conversely, if the terminal or feeder pressure tends to fall, magnet O^2 is drawn down; contact is made between lever N^2 and contact piece L^2; the core Z_l is demagnetized and is drawn up by its opposing spring; the resistance R^2_l is shunted; the current in F^2_l exceeds that in F^2_h; the generator G^2 gives a pressure assisting that impressed upon the field windings F^2 and f^2 of the exciters; the exciter pressure rises; the field excitation at F^2 and f^2 is increased, and the alternator voltage is raised. Simultaneously with the increase of exciter pressure, the current in winding Y^2 increases and lever X^2 breaks the contact at L^2 before the alternator voltage rises too much.

In this case the regulator is controlled and actuated in response to the voltage of the regulated point, that is the line, and of the voltage of the exciter.

Fig. 4 shows the regulating means of Fig. 1 applied to a direct current system. The construction of the auxiliary machine is very similar to that shown in Fig. 1 and therefore the parts thereof are indicated by the same reference characters. The connection between the auxiliary machine and the field circuits of the direct current machines is the same as shown in Fig. 2. In this case however coil Z is unnecessary since coil Y is mounted on the same core O with coil V. Here also contacts H and L control the magnets of switches H_h and L_l which in turn shunt or short circuit the resistances R_h and R_l. The current through the magnets for these switches is controlled by a resistance $R_e{}^4$. The coil Y is controlled by regulating resistance R^4_g. The potential and current coils V and I are connected across the line P^4 and across a shunt R^4_e, respectively.

If the terminal or feeder pressure tends to rise, magnet core I is drawn down; contact is made between lever N and H; key H is closed; resistance R_h is shunted; the current in F_h exceeds that in F_l; the auxiliary generator G generates a pressure opposed to the field currents in F and f, and terminal pressure is held down. As the auxiliary generator pressure rises, current flows in coil Y, weakening magnet O and contact at H is broken before the feeder pressure drops too low.

Conversely, if the terminal or feeder pressure tends to drop, magnet core O is raised, contact is made between lever N and L; key L_l is closed; resistance R_l is shunted; the current in F_l exceeds that in F_h; the auxiliary generator G generates a pressure in the same direction with the field currents in F and f, and the terminal pressure is held up. As the auxiliary generator pressure rises, current flows in coil Y, strengthening magnet O, and contact at L is broken before feeder pressure rises too high.

Fig. 5 shows one embodiment of this invention applied to an alternating current system in which the auxiliary machine is of the same construction as that shown in Fig. 2, and therefore similar parts are indicated by similar reference characters. The regulator in this case consists of two levers X^5 and N^5 which are pivoted one behind the other at D^5. The lever N^5 is controlled by the voltage and current coils V and I and the lever X^5 is controlled by coil Y^5 which is connected across the brushes of the auxiliary machine G′. A dashpot J of any suitable construction is provided to steady the movements of the lever X^5. The contacts H^5 and L^5 on the lever X^5 control the differential relays Z_h and Z_l, which in turn control a pair of switches H_h and L_l which are adapted to short circuit the resistances R'_h and R'_l.

If the terminal or feeder pressure tends to rise, magnet core O is drawn down; contact is made between lever N^5 and H^5; magnet Z_h is demagnetized; key H_h is opened; resistance R_h' is inserted in field F_g'; the current in F_g' decreases; the auxiliary generator G generates a lower pressure; the exciter field currents in F and f, decrease; the exciter pressures drop; the generator field currents decrease and the terminal pressure is held down. As auxiliary generator pressure drops, the magnet Y^5 is weakened and contact at H^5 is broken before feeder pressure drops too low.

Conversely, if the terminal or feeder pressure tends to fall, magnet core O rises; contact is made between lever N^5 and L^5; magnet Z_l is demagnetized; key L_l is closed; resistance R_l' is shunted; the current in F_g' increases; the auxiliary generator G′ generates a higher pressure; the exciter field

currents in F′ and f, increase; the exciter pressures rise; the generator field currents increase, and the terminal pressure is held up. As the auxiliary generator pressure rises, the magnet Y^5 is strengthened and contact at L^5 is broken before the feeder pressure rises too high.

Fig. 6 shows still another embodiment of this invention applied to an alternating current system in which the construction of the regulator is similar to that shown in Fig. 3, and therefore similar parts are indicated by similar reference characters with the exponent 6 added. In this case, however, the magnet which controls lever X^6 has two coils,—one Y^6, is connected to some source of substantially constant supply, in this case to one of the exciters E^6, e^6. The other coil Y^6 is connected across the brushes of the auxiliary machine G^6. The current in coil Y^6 increases or decreases the magnetism in core O, according as its direction of flow is in the same or opposite direction to the current in Y^6,. A dash pot J^6 is provided to steady the movement of lever X^6. The contacts H^6 and L^6 on the lever X^6 control the differential relays $Z^6{}_h$ and $Z^6{}_l$ which in turn control a pair of switches $H^6{}_h$ and $L^6{}_l$. These switches are adapted to open circuit the fields $F^6{}_l$ and $F^6{}_h$. The auxiliary generator G^6, in this case, is provided with differential field windings $F^6{}_l$ and $F^6{}_h$ which are connected through switches $H^6{}_h$ and $L^6{}_l$ respectively, across a source of direct current. Normally the current through the two windings mutually neutralize each other's effects and the auxiliary machine G generates no pressure. When one of the windings is open circuited, the other determines the direction of the pressure generated by auxiliary generator G.

The operation will now be apparent. If the terminal or feeder pressure tends to rise, magnet core O^6 is lifted; contact is made between lever N^6 and contact piece H^6; the core $Z^6{}_h$ is demagnetized and is drawn up by its spring; the field $F^6{}_l$ is opened; the generator G^6 gives a pressure opposing that impressed upon the field windings $F,^6$ and $f,^6$, of the exciters; the exciter pressure drops; the field excitation of F^6 and f^6 is decreased, and the alternator voltage is lowered. Simultaneously with the decreased flow of current through the exciter fields, current flows through coil Y^6 so as to weaken the magnetism in the core and the contact at H^6 is broken before the alternator voltage drops too low.

Conversely, if the terminal or feeder pressure tends to fall, magnet O^6 is drawn down; contact is made between lever N^6 and contact piece L^6; the core Z^6 is demagnetized and is drawn up by its opposing spring; field $F^6{}_h$ is opened; the machine G^6 generates a pressure in the same direction with the field currents in $F,^6$ and $f,^6$; the exciter pressure rises; the field excitation at F^6 and f^6 is increased, and the alternator voltage is raised. Simultaneously with the increase of exciter pressure, current flows through coil Y^6 so as to strengthen the magnetism in the core and the contact at L^6 is broken before the alternator voltage rises too high.

Fig. 7 shows still another modification of this invention applied to an alternating current system in which the construction of the regulator is the same as that shown in Fig. 5; the regulator levers X^7 and N^7, in this case, being straight instead of bent. Similar parts of the regulator and auxiliary generator are indicated by similar reference characters with the exponent 7 added.

In this case however the sources, from which the fields F^7 f^7 of the alternators A^7 a^7 are supplied, are the rectifiers R_e r_e. These rectifiers are mounted on the shafts with the rotating members of the alternators, and they may be any of the types known to the art. In this case however they are shown in their simplest form,—each consisting of three segments, which are connected to the secondary leads of a bank of transformers T_p t_p. The brushes B, B, b, b,, which bear on the rectifiers R_e r_e are connected in series with the alternator fields F^7 f^7 and with the auxiliary generator G^7. When the switches S,^{7} $s,^7$ are thrown to the right, the strengths of fields F^7 f^7 may be adjusted by resistances R^7 r^7. The switches may now be thrown to the left connecting to the auxiliary generator leads K^7.

If the terminal or feeder pressure tends to rise, magnet core O^7 is lifted; contact is made between lever N^7 and contact piece H^7; the core $Z^7{}_h$ is demagnetized; key $H^7{}_h$ is opened; resistance $R^7{}_h$ is inserted in field $F^7{}_g$, the current in $F^7{}_g$ decreases; the auxiliary generator G^7 generates a lower pressure, the alternator field currents in F^7 and f^7 decrease, and the alternator voltage is held down. As auxiliary generator pressure drops, the magnet Y^7 is weakened and contact at H^7 is broken by the opposing spring before the voltage drops too low.

Conversely, if the terminal or feeder pressure tends to fall, magnet O^7 descends due to its weight; contact is made between lever N^7 and contact piece L^7; the core $Z^7{}_l$ is demagnetized; key $L^7{}_l$ is drawn up by the opposing spring; resistance $R^7{}_l$ is short circuited; the machine G^7 generates a higher pressure, the generator field currents in F^7 and f^7 increase, and the terminal pressure is held up. As the auxiliary generator pressure rises, the magnet Y^7 is strengthened and contact at L^7 is broken before the feeder pressure rises too high.

It will therefore be seen that the inven-

tion attains the objects aimed at. The current which is actually interrupted is exceedingly small since the field circuit of the machine which furnishes the actual regulating current is the only one which is made or broken and in addition the circuit is only made or broken when the voltage varies. When the voltage is constant the movable member of the regulator floats so as to be normally out of operation, as distinguished from the ordinary make and break regulator in which the value of the current is varied by the duration of the make and break.

With the regulating system of this invention the voltage can be closely regulated for all conditions, namely, change of load, power factor, speed of primer mover and temperature of generator or exciter. The regulator can be easily thrown into and out of operation at any time without interruption of service. The regulator can be adjusted so that under usual load condition it is inactive and the movable member floats between contacts, and under abnormal conditions the frequency of vibration is a minimum.

A number of generators can be readily controlled and regulated by a single regulator and there is a positive load division among the several generators since the pressure on each generator field is altered the same amount and in the same ratio. The errors due to differences in sensitiveness or adjustment and lack of simultaneous action incident to the use of a plurality of regulators is therefore avoided.

The currents interrupted are small thereby minimizing the trouble due to the burning of the contacts and permitting the use of small condensers, field resistances, and other parts. The pressure delivered by the auxiliary generator is small so that the energy consumed is small and this generator and its motor may be combined as a small motor generator set and mounted on the switch board where it will run silently with little attention. The regulator is easy to keep in adjustment and can be handled by any ordinary switch board attendant and it can be easily adjusted for change of conditions by means of the different regulating resistances shown in the drawings.

It is obvious that various changes may be made in the details of construction without departing from this invention, and it is therefore to be understood that this invention is not to be limited to the specific construction shown and described, but only by the appended claims:

1. The combination with a generator having an exciting field winding and means for supplying current to said winding, of an auxiliary dynamo electric machine connected therewith and adapted by virtue of its relation thereto to control the strength of the field set up by said exciting field winding, a differential winding for said auxiliary machine, and means to cause either of said differential windings to preponderate, said means being normally disposed in neutral position to cause said differential windings to normally neutralize each other.

2. The combination with a generator having an exciting field winding and means for supplying current to said winding of an auxiliary dynamo electric machine connected thereto and adapted by virtue of its relation therewith to control the strength of the field set up by said exciting field winding, a differential winding for said auxiliary machine having regulating resistances, and contact devices normally disposed in neutral or out of contact position and arranged to control either of said resistances.

3. A regulator for a dynamo electric machine having a plurality of regulating resistances, comprising in combination, a pivoted member carrying a pair of contacts one connected to each resistance, and a second pivoted member carrying another contact and movable relatively to the first member to control said resistances, said members being mechanically connected.

4. A regulator for a dynamo electric machine having a plurality of regulating resistances, comprising in combination, a movable fork provided with a pair of contacts, and a second member mechanically connected with said fork and provided with a cooperating contact movable between the contacts of said fork, said contacts being connected to and controlling said resistances.

5. The combination with a plurality of generators, of a set of mains to which said generators are connected, exciting field windings for said generators, electric machines for supplying current to said field windings, each machine having a field winding, a single auxiliary electric machine, each of the field windings for said electric machines being connected in series with said auxiliary electric machine, and means for automatically controlling the auxiliary electric machine whereby the latter simultaneously controls the strength of field set up in all of said exciting field windings.

6. The combination with a generator, of an exciter therefor, a field winding for the exciter, a dynamo electric machine arranged to furnish current to said winding and to thus control the strength of the field set up by the exciter, a field winding for said machine having a regulating resistance, and means controlled by the generator, exciter and electric machine for cutting in or out said resistance.

7. The combination with a generator of an exciter therefor, a field winding for the

exciter, a dynamo electric machine arranged to furnish current to said winding and to thus control the strength of the field set up by the exciter, a field winding for said machine having a regulating resistance, and means controlled by the generator and exciter for cutting in or out said resistance.

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

CHARLES H. KICKLIGHTER.

Witnesses:
WILLIAM H. VEDDER,
W. L. WATKYM, Jr.

Copies of this patent may be obtained for five cents each, by addressing the "Commissioner of Patents, Washington, D. C."