A. S. HUBBARD.

ELECTRICAL SYSTEM OF DISTRIBUTION.

APPLICATION FILED DEC. 17, 1908.

1,160,608.

Patented Nov. 16, 1915.

3 SHEETS—SHEET 1.

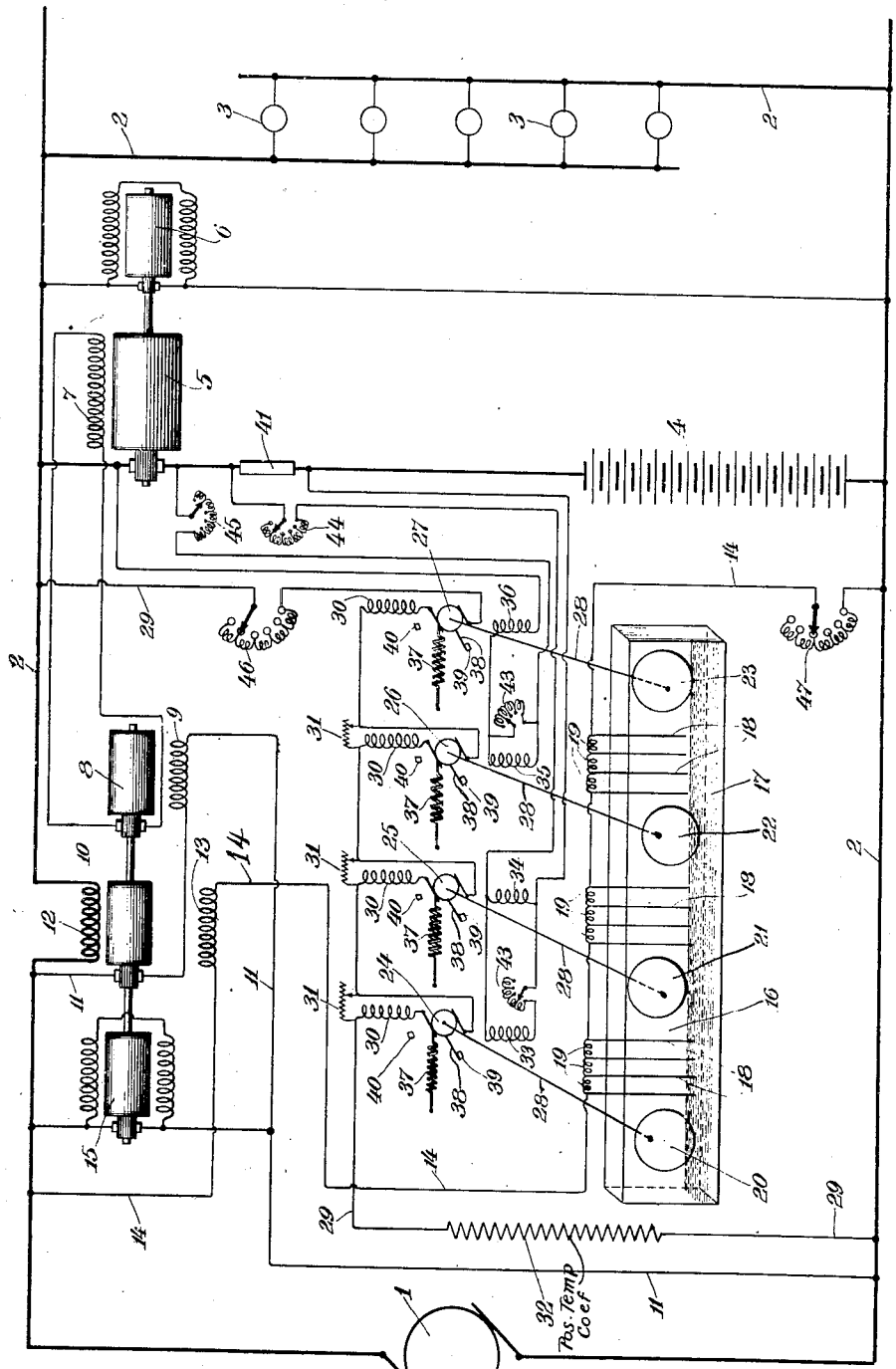


Fig. 1.

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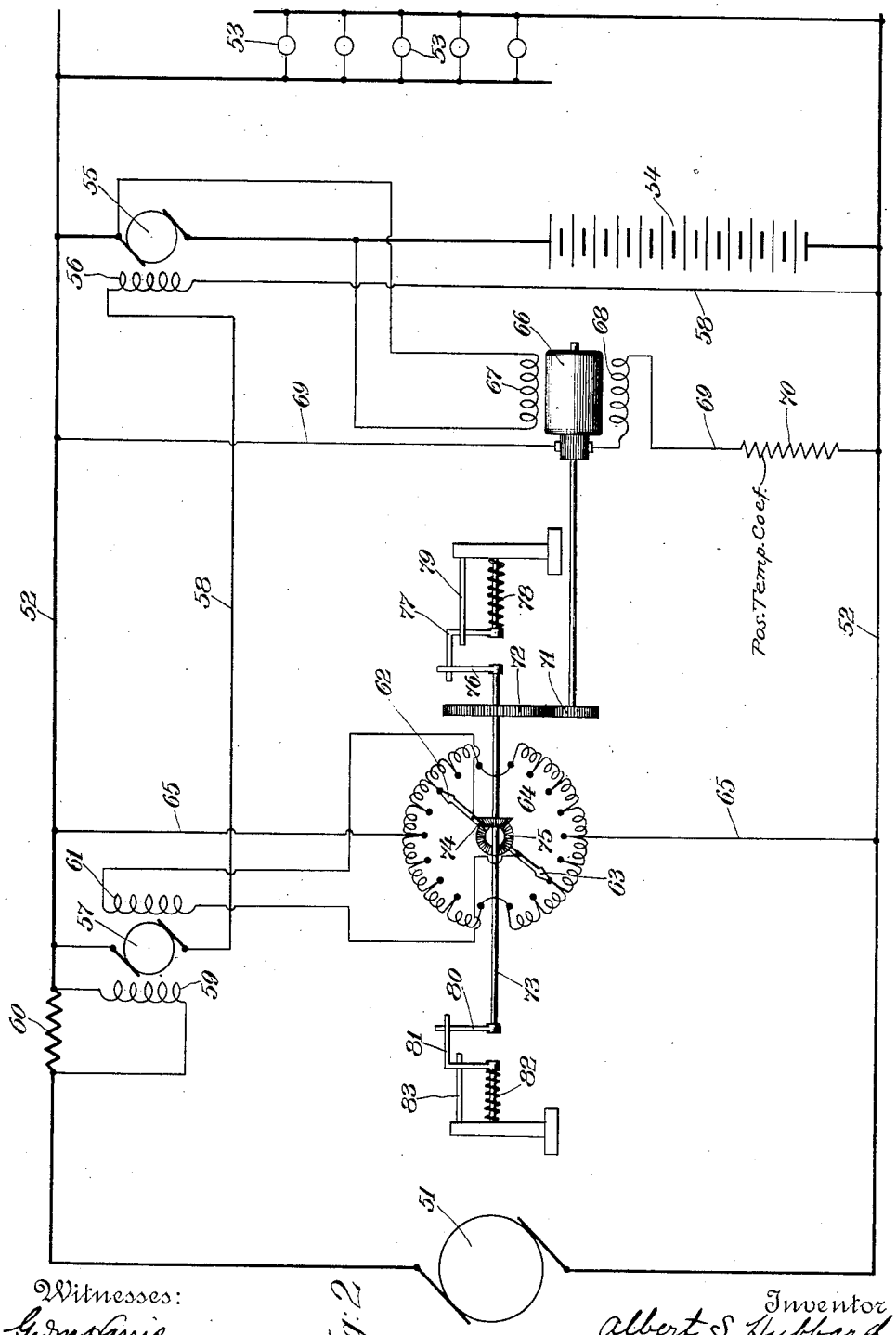
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3 SHEETS—SHEET 2.



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Fig. 2

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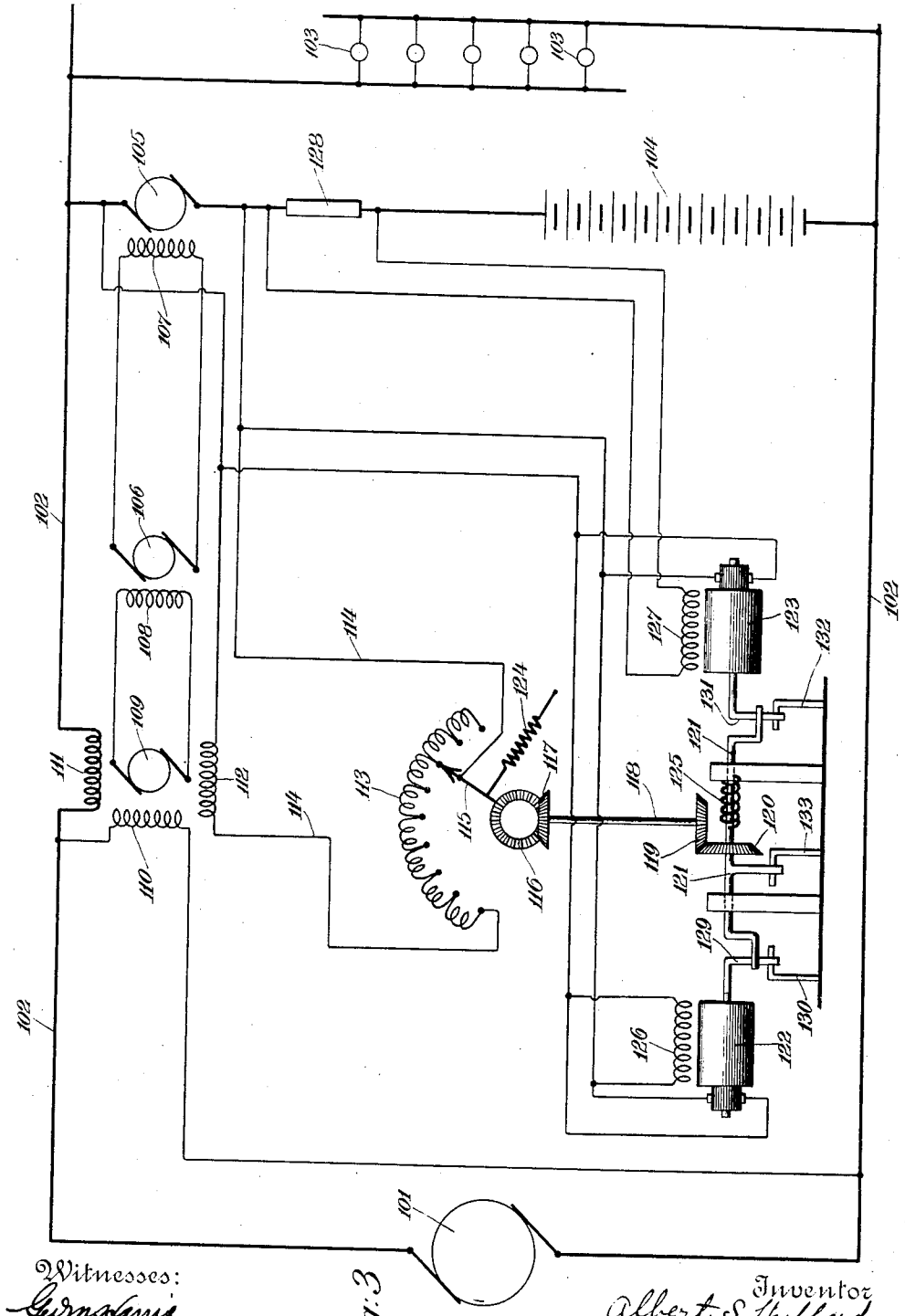
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3 SHEETS—SHEET 3.



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Fig. 3

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UNITED STATES PATENT OFFICE.

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ELECTRICAL SYSTEM OF DISTRIBUTION.

1,160,608. Specification of Letters Patent. Patented Nov. 16, 1915.

Application filed December 17, 1908. Serial No. 467,943.

To all whom it may concern:

Be it known that I, ALBERT S. HUBBARD, a citizen of the United States, and a resident of Belleville, Essex county, and State of New Jersey, have invented certain new and useful Improvements in Electrical Systems of Distribution, of which the following is a specification.

My invention relates to electrical systems of distribution and apparatus therefor and more especially to systems in which a source of electromotive force feeds a consumption or work circuit and a storage apparatus is operatively arranged to take portions of the load at certain periods. Generally, in such systems, there is provided regulating means for causing the storage apparatus to receive and give energy from and to the consumption circuit according to whether the load on the consumption circuit is less or more than a predetermined average.

One object of my invention is to provide an arrangement and apparatus whereby the division of load on the main source and upon the storage apparatus may be varied in accordance with certain desired results. More particularly I provide an arrangement whereby the storage apparatus may take certain fluctuations of load up to a certain point whereupon the main source will assume further increases in the load or parts of further increases of load. If the load still further increases beyond the limits desired to be placed upon the main source the storage apparatus will again be called upon to take more of the load. With my improved arrangement the load due to the storage apparatus when it is receiving energy may also be varied much in the same way as pointed out above. These features may be widely varied to suit particular conditions which may arise with respect to systems of this kind or with respect to similar systems.

Various other objects, features and advantages will more clearly appear from the detailed description given below taken in connection with the accompanying drawings which form a part of this specification.

In the drawings Figure 1 represents, diagrammatically, a system embodying one form of various of my improvements. Fig. 2 represents a similar system but showing a somewhat more simple arrangement and in which only certain of my improvements are shown, and certain arrangements of which are shown as modifications of those in Fig. 1. Fig. 3 is another modification in which only certain of my improvements are shown and in which still other arrangements are diagrammatically disclosed.

Referring to the drawings 1 represents a main generator feeding the consumption or work circuit 2, 2, which has connected thereto lamps or other translating devices 3. Connected across the circuit 2, 2 is a storage battery 4 and in series therewith the armature 5 of the booster. The booster is driven by a shunt motor 6 connected across the busses or circuit 2, 2. The field windings 7 of the booster 5 are supplied by an exciter 8. The exciter 8 is provided with field windings 9 connected in series with the counter-electromotive force machine 10, the two being connected in a circuit 11 across the busses or circuit 2, 2. The counter-electromotive force machine 10 is provided with two sets of field windings, one set of which, 12, is connected in series in the main circuit 2, 2. The other set of field windings, 13, is connected in series in the circuit 14 which is connected across the busses or mains 2, 2. The counter machine 10 and exciter 8 are driven at a substantially constant speed by means of the shunt motor 15 connected across the mains 2, 2.

The operation of the system thus far described is as follows: When the load upon the generator has reached a predetermined value the current caused thereby in the field coil 12 causes this field coil to preponderate over the field coil 13 and thereby causes the counter-machine 10 to produce a voltage exactly equal and in opposite direction to that applied to the circuit 11 by the generator 1. Therefore no current flows in the circuit 11 and the field coil 9 in the exciter 8 is not energized. If, however, an increase of load takes place upon the circuit 2, 2 the current in the field coil 12 increases, thereby causing the voltage produced by the counter-machine 10 to increase above that applied by the generator 1, so that a current flows in the circuit 11, thereby energizing the field windings 9 of the exciter 8. The exciter 8 thereupon produces an electromotive force which produces current and excitation for the field coil 7 of the booster 5 in such a manner that the booster 5 produces an electromotive force in the proper direction to cause the battery 4 to discharge onto the line

and take part of the load, thereby maintaining the load on the main generator substantially constant. If the load of the translating devices decreases below normal the regulating apparatus above described operates in a reverse manner and the voltage applied by the generator 1 overcomes that produced by the counter-machine 10, so that the exciter 8 furnishes a current to the field winding 7 in the opposite direction thereby causing the booster to produce an electromotive force in opposition to the battery, thereby causing it to receive energy and be charged from the circuit 2, 2.

When considering the above operation it was assumed that the field coil 13 of the counter-machine 10 produced a constant excitation. It will be apparent, however, that if the magnetomotive force produced by this coil is increased in opposition to that produced by the field windings 12 the average normal load required by the system will thereby be increased. That is, a much larger current will be required in the field windings 12 in order to cause the counter-machine 10 to produce an electromotive force equal to that applied by the main generator 1. It will therefore be apparent that, to increase the portion of the load taken by the main generator 1 it is only necessary to increase the opposing action of the field coil 13 upon the counter-machine 10. For thus regulating the action of the field coil 13 I provide in series therewith in the circuit 14 a variable resistance or rheostatic device 16. The rheostatic device 16 consists of a mercury bath 17 which has, dipping into it at different depths, a plurality of terminals 18 connected by resistances 19. The surface of the mercury of the bath 17 is raised and lowered to short-circuit various of the resistances 19 in order to vary the resistance in the circuit 14. This raising and lowering of the mercury is caused by the rotation therein of eccentrically mounted circular bodies 20, 21, 22 and 23 which when rotated enter the mercury to a greater or less depth, thereby causing the rise and fall of the surface of the mercury. The eccentrically mounted bodies 20, 21, 22 and 23 are rotated by means of dynamometers or motors 24, 25, 26 and 27, and shafts 28. Each of the dynamometers or motors 24, 25, 26 and 27 is connected in series in a circuit 29 and is provided with a series field coil 30. The voltage applied to the dynamometers may be varied by means of shunt resistances 31. I also provide in series in the circuit 29 a high temperature co-efficient resistance 32 to prevent excessive fluctuations of current in the circuit 29. Each of the dynamometers or motors 24, 25, 26 and 27 is made responsive to certain electrical fluctuations or variations by means of field coils 33, 34, 35 and 36 which preponderate over the series field coils 30 respectively when the dynamometers operate. Each of the dynamometers 24, 25, 26 and 27 is also provided with a spring 37 to maintain the dynamometer in an inactive position by causing a projection 38 thereon to be rotated against, or brought up to, a stop 39. Stops 40 are also provided to limit the rotation of each dynamometer or motor in the opposite direction.

The field coil 33 of dynamometer 24 is connected across a shunt 41 in series with the battery 4, so that it is responsive to variations in the battery current. The field windings 34 of dynamometer 25 are connected in parallel with the field windings 33 and are also therefore responsive to fluctuations of battery current. The field windings 35 and 36 are connected in series with each other across the terminals of the booster 5 and are therefore responsive to variations or fluctuations in the booster voltage. The dynamometers or motors 24, 25, 26 and 27 are so connected and arranged and the field windings thereon are so disposed that when the current in the battery circuit is flowing into the battery and the booster is producing a corresponding voltage, the field coil 33 will so energize the dynamometer 24 in opposition to its series field coil 30 against the spring 37 that its member 38 will tend to rotate away from the stop 39 and will accordingly tend to rotate the member 20 out of the bath 17 to cause the surface of the mercury to be lowered and so increase the resistance in series with the coil 13 and weaken it, so that the booster voltage is weakened and consequently the generator output is decreased so as to maintain only that maximum value of battery charging current desirable for the battery. Under these same conditions the field coil 34 produces a magnetomotive force in a direction which tends to cause the dynamometer 25 to rotate the member 38 against its top 39 which prevents any further rotation of the member 21. The spring 37 of the dynamometer 25 also tends to bring it to its retracted position by causing its member 38 to rotate against the stop 39. Also, under the same conditions, the field coil 35 of dynamometer 26 sets up a magnetomotive force responsive to the booster voltage and in opposition to field coil 30 and tends to cause the dynamometer to rotate its member 38 away from the stop 39 and against the action of its spring 37 to cause the body 22 to be withdrawn from the mercury bath 17 and weaken coil 13 with a consequent reduction in booster voltage and battery current. This will occur especially when the battery voltage is high due to its being fully or nearly fully charged. Under these same conditions the field coil 36 acts with the field coil 30 of the dynamometer 27 to cause it to rotate its member 38 against its stop 39.

When the current in the battery circuit flows in the opposite direction on discharge and the booster voltage is in the opposite direction the dynamometers 24 and 26 are retracted since the current in the field coils 33 and 35 is in the opposite direction and aids the field coils 30 of these dynamometers so that the members 38 are brought against the stops 39 and no motion is imparted to the members 20 and 22. Under these conditions one or both the dynamometers 25 and 27 may be brought into operation since their field coils 34 and 36, responsive respectively to the battery current and the booster voltage, will not act with the field coils 30 of these dynamometers to produce a magnetomotive force which will tend to cause the members 38 of these dynamometers to rotate away from the stops 39 against the action of their springs 37 and thereby cause the members or bodies 21 and 23 to dip within the mercury bath 17 to cause its surface to rise and vary the number of resistances 19 which are short-circuited. This strengthens coils 13, thereby decreasing the booster voltage (the coil 12 preponderating when the battery is on discharge) so that a greater proportion of the load is thrown on the generator. This may occur due to the excessive current taken by the translating devices in which case dynamometer 25 would act or it may be due to a highly discharged battery, resulting in the requirement of an excessive booster voltage, in which case the dynamometer 27 would act.

From the above it will be apparent that before any of the dynamometers or motors will act or operate upon the circular members in the mercury bath its field coil 33, 34, 35 or 36 as the case may be must produce a sufficient field strength to overcome both the action of its series field coil 30 and the opposing tension of its spring 37. Therefore the dynamometers do not begin to operate immediately a current flows in the battery circuit or immediately there is a difference of potential across the terminals of the booster, but only when the battery current has reached a certain predetermined value or when the booster voltage has reached a certain predetermined value, sufficient to cause the field coil 33, 34, 35 or 36 as the case may be to produce the proper excitation of the dynamometer to cause it to rotate against its opposing force. It will therefore be apparent that when the discharge load on the battery circuit reaches a certain predetermined value or when the booster output with the battery discharging reaches a certain predetermined value the dynamometers 25, 27 will operate to increase the strength of the field coil 13 of the counter-machine 10, thereby cutting down or eliminating its regulating action and causing the generator to assume further increases of load and causing the load upon the battery circuit to remain substantially constant or be decreased.

By my improvements one of the dynamometers or motors may be responsive to fluctuations of battery current when the battery is charging; another will be responsive only to fluctuations of battery current when the battery is discharging; another will be responsive only to fluctuations of booster voltage when the battery is charging and the fourth will be responsive only to fluctuations of booster voltage when the battery is discharging. Therefore, the rheostatic device 16 may be made to operate to maintain the battery current at a certain predetermined value when the battery current is in one direction and at an entirely different and independent value when the battery current is in the other direction. In the same manner the booster voltage may be limited to a certain predetermined value when in one direction and to a different and independent value when in the other direction. It will also be apparent that the regulation due to differences in booster voltage may be different and is entirely independent of the regulation due to fluctuations in the battery current.

If the load on the system should increase so much above that at which the dynamometers operate that altogether too much load is falling upon the main generator 1 and it is desired that the battery again take a certain portion of the increased load the dynamometers will rotate their arms 39 against the stops 40 whereupon they will stop and the magnetomotive force produced by the field coil 13 of the counter-machine 10 will increase no further, whereupon the field windings 12 will again assume their full regulating action and cause the battery to take a certain portion of the increased load by means of the action of the booster 5.

Various regulating rheostatic devices 43, 44 and 45 are included in the regulating circuits in order that their action may be varied to suit the various conditions under which the system may be operating. A variable resistance 46 is also connected in the circuit 29 and another variable resistance 47 is included in the circuit 14.

It will be noted that as the load on the system increases or decreases, as the case may be, beyond that sufficient to cause one of the dynamometers to act, and if the increase or decrease, as the case may be, be more than sufficient to cause the dynamometer to rotate its arm 38 against its stop 40, then the load on the battery circuit or the booster voltage will again be increased. If the increase in load on the system is sudden rather than gradual the battery may take a certain excess of load over the predetermined value at which one or the other of

the dynamometers 24 or 25 is designed to operate. That is, the dynamometers may be so constructed that it will take a measurable amount of time for any of the dynamometers to operate through their range of movement and it will be, therefore, a measurable length of time before the effect of the variations in the field coil 13 is felt.

From the above it will be clear that I have provided a system with regulating devices by means of which the load or current in the battery circuit may be limited in almost any way desired. The load upon charging of the battery may be limited to a value entirely independent of that load to which it is limited when discharging and the booster voltage, and consequently its output, may be limited to certain values which are entirely independent on charge and on discharge.

Referring to Fig. 2 the main generator 51 feeds a consumption or work circuit 52 which supplies lamps or other translating devices 53. Across the circuit 52 is connected a battery 54 and in series therewith the usual booster 55. The booster is provided with a field 56 which is energized by means of the counter machine 57 connected in series therewith in the circuit 58 across the busses or mains 52. The counter machine 57 is provided with a regulating field coil 59 in parallel with a shunt 60 in the main circuit 52. The field windings 59, therefore, energize the counter machine 57 responsive to load or current fluctuations upon the system. The counter machine 57 is also provided with a field coil 61 which opposes the field windings 59 and which is connected to contacts 62 and 63 of a rheostatic device 64. The rheostatic device 64 is connected across the mains 52 by means of a circuit 65.

Assuming the excitation due to the winding 61 is substantially constant and that the load of the system is normal the field windings 59 produce sufficient excitation preponderating the coil 61 to cause the counter machine 57 to produce an electromotive force equal to and exactly opposite in direction to that applied by the main generator 51. No current, therefore, flows in the circuit 58, the booster is not excited, and the battery will float across the mains. When an increase in load occurs on the system the excitation of the counter machine 57 is increased thereby exciting the booster and causing it to produce an electromotive force in the proper direction to cause the battery to discharge. When the load on the system decreases below normal the booster is operated in the reverse manner and the battery is caused to receive energy and be charged from the circuit 52.

In this system I also provide means for limiting the load on the battery circuit to a certain predetermined value. In this case, however, I only provide one dynamometer or motor, 66, which has a field coil 67 connected across the terminals of the booster, and therefore responsive to changes in the booster voltage. The dynamometer or motor 66 is provided with a series field coil 68 of constant excitation and is connected across the mains 52 in a circuit 69. A high temperature coefficient resistance 70 is also provided in the circuit to prevent an excessive fluctuation of current flowing into the dynamometer. The dynamometer is connected to operate the rheostatic device 64 by means of gears 71, 72, which operate a shaft 73. Shaft 73 is provided with a beveled gear 74 which meshes with a beveled gear 75 connected to an arm carrying the contacts 62 and 63. As this arm rotates the contacts 62 and 63 connect the field windings 61 to points of varying difference of potential thereby increasing or decreasing the strength of the field 61. The shaft 73 carries at one end a member 76 and when the shaft tends to rotate in one direction the member 76 is caused to overcome and rotate a member 77 against the action of the coil spring 78. When the shaft 73 and member 76 is in a normal or retracted position the member 77 is prevented from having any action upon the member 76, because of the coil spring 78, by means of a stop 79. Likewise, at the other end of the shaft 73 is a member 80 which when the shaft rotates in the opposite direction is caused to operate against a member 81 under the action of the coil spring 82. The member 81 is likewise prevented from having any action upon the member 80 when the shaft 83 is in a normal or retracted position by means of a stop 83. When the load on the battery circuit, and the booster voltage has reached a certain predetermined value the field windings 67 will produce sufficient magnetomotive force preponderating the field coil 68 to cause the dynamometer to overcome the opposing action of either spring 78 or 82, according to the direction of rotation of the dynamometer, and will rotate the shaft 73 and thereby operate the variable resistance 64 to increase the excitation of the field 61 of the counter machine. Since the field 61 opposes the field 59 this increase of field strength due to the field windings 61 cuts down the excitation of the counter machine 57 thereby cutting down the regulating action of the booster 55 and preventing further load from falling upon the booster or battery. Likewise when the current in the battery circuit is in an opposite direction the booster voltage is limited in much the same way as before by the dynamometer or motor 66 operating upon the variable resistance 64 to increase the strength of the field windings 61 of the counter machine 57. When in this reverse direction however, the coil 68 will now aid

the coil 67 and the dynamometer will produce the required torque to overcome one of the springs 78 or 82 when the battery voltage has reached a different value from that under the conditions previously described. It will therefore be seen that by including the coil 68 the dynamometer 66 may be made to operate when the booster voltage has reached one value in one direction and may be made to operate when the battery voltage has reached an entirely different and independent value when in the other direction. The same or similar effects may be produced by varying the tension exerted by the springs 78 and 82 and one spring may be adjusted to limit the load on the battery circuit to a certain value when in one direction and the other spring may be adjusted to limit the load on the battery circuit to an entirely different and independent value when in the other direction.

This system also shows means by which the time in which the dynamometer 66 acts, may be adjusted. The gears 71 and 72 are somewhat diagrammatically shown but by using the proper sizes of gears the time that it takes for the motor 66 to bring the battery circuit back to its predetermined condition, may be made substantially anything desired. Under these conditions, when a load fluctuation more than sufficient to cause the operation of the motor 66 falls upon the system, the battery will take part of each load fluctuation until the dynamometer 66 and its related apparatus shall have had time to act; but if the increase or decrease in load is maintained or sustained for any substantial length of time part of such fluctuation will ultimately be thrown upon the generator by the action of said motor 66 and its related apparatus. From the above it is evident that the motor 66 and its related apparatus operating upon the field 61 is much slower in acting and in its regulating functions than the exciter 57 and booster 55. The slower the action of the motor 66 the greater will be the amount of the fluctuations above the predetermined value that will fall upon the battery and vice versa.

In Fig. 1 the dynamometer arrangements are necessarily much slower acting than the counter-machine, exciter and booster, yet the dynamometers shown in Fig. 1, are much quicker in their action than the motor 66 of Fig. 2, and consequently the percentage of the fluctuations above or below the predetermined value, which fall upon the battery circuit in Fig. 1, is comparatively small.

The system and apparatus shown in Fig. 2 is extremely simple and operates very advantageously under certain conditions.

Referring to Fig. 3 the main generator 101 feeds a consumption or work circuit 102 which supplies lamps or other translating devices 103. This system is also provided with the usual battery 104 and a booster 105 in series therewith. The regulation of the booster is accomplished by means of an exciter 106 connected in series with the booster field coil 107 and the exciter 106 has a field coil 108 which is in turn energized by the regulating dynamo 109. The regulating dynamo 109 has field windings 110 connected across the main busses 102 and which produce a constant field excitation in opposition to the regulating field windings 111 in series in the main circuit 102. The booster is driven in any well known manner and is regulated by the field coil 111, the fluctuations of which produce the regulation by means of the dynamo 109 and exciter 106, which regulation is still further magnified by means of the constantly excited field coil 110 in a manner which is not new with this application. The regulating dynamo 109 is also provided with an opposing field coil 112 which operates to limit the load on the battery circuit in the same manner as the coils 13 and 61 in Figs. 1 and 2 respectively. To provide for this latter regulation, the variable resistance 113 is included in the circuit 114 in series with the field coil 112. The circuit 114 is connected across the terminals of the booster and one side of said circuit is connected to the movable contact arm 115 of the variable resistance 113. The arm 115 is arranged to rotate to cut in and out resistance in the circuit 114, by means of beveled gears 116, 117, shaft 118, beveled gears 119, 120 and a shaft 121 operated by dynamometers or motors 122 and 123. A spring 124 tends to maintain or move contact arm 115 to its normal position and the coil spring 125 tends to maintain the member or shaft 121 in its normal or retracted position.

The dynamometer or motor 122 is connected across the booster 105 and is provided with a shunt field coil 126 also connected thereacross. The dynamometer or motor 123 is also connected across the booster 105 but has its field coil 127 connected across a shunt 128 in series in the battery circuit. The dynamometer or motor 122 is therefore made responsive to fluctuations in the booster output while the dynamometer 123 is made responsive to changes in the battery current. When an excessive load falls upon the booster the dynamometer 122 produces a torque and when this torque is sufficient to overcome the opposing action of springs 125 and 124 its member 129 will rotate the shaft 121, and thereby operate the variable resistance 113 to strengthen the field 112 aiding the field of coils 110 and opposing the field of coils 111, thereby reducing the effect of the then predominating field windings 111 and decrease the booster excitation and prevent the load or voltage on the booster exceeding the limits for

which the dynamometer 122 is set. Further increases of load are therefore caused to fall upon the generator 101 until all the resistance of rheostat 113 has been cut out, when further increases in load on the system will cause the booster to take an increase of load. A stop 130 is provided to maintain the dynamometer 122 in the proper position when retracted. When the battery current reaches a certain predetermined value dependent upon the booster voltage the dynamometer 123 will produce a sufficient torque to overcome the action of springs 124, 125, and by means of its arm 131 will operate the shaft 121 thereby causing movement of the arm 115 and regulating the field 112 as before. A stop 132 is also provided for the dynamometer 123 to maintain it in the proper position when retracted. A stop 133 is also provided to limit the movement of the member or shaft 121 so that when the dynamometers 122 and 123 are idle or retracted the springs 124 and 125 will exert no torque upon these dynamometers. It will also be apparent that whichever dynamometer exerts the greater torque will be the dynamometer to control the movement of the arm 115 and the operation of the variable resistance 113. Since the coil 112 is in shunt across the booster the variations in booster voltage will vary to a slight extent its normal effect and the value of battery current at which the dynamometer operates. However, this is sometimes desirable to the end that a large battery current may be permitted if the booster voltage is low or vice-versa. It may happen that both dynamometers will be operating at the same time under certain conditions. When the battery current and booster voltage are both greater than the values for which the respective dynamometers are set to operate, the dynamometers will assist one another in cutting down the resistance at 113. When the load on the system is light and the battery is charging, if the load on the booster or the booster voltage or the battery charging current be greater than that desired, the resistance at 113 will be similarly decreased, thereby increasing the strengh of field coils 112. But the current in coils 112 is in the opposite direction from what it was when the battery was discharging, because coils 112 are connected across the booster and the voltage across the booster on charging the battery is the reverse of that on discharge. Accordingly coils 112 now aid coils 111 and oppose coils 110, so that both on battery charge, as well as on battery discharge, a decrease in resistance at 113 similarly decreases the booster excitation and limits the booster voltage and battery current. It will also be noticed that when the load on the system is normal and the battery is substantially floating and the booster giving no voltage the fields 112 and motors 122 and 123 will be substantially deënergized. As the load on the booster picks up in either direction with a consequent production and increase of current in coils 112, the field produced by coils 112 tends to cut down the booster excitation, but this tendency is not sufficient to prevent the booster from building up to take the desired maximum load in the battery circuit.

From the above it will be clear that I have provided an arrangement and apparatus whereby the division of load between the main generator and the storage battery may be varied in accordance with almost any desired results. The various arrangements are such that the battery may be made to take certain increases or fluctuations of load up to a certain point whereupon the generator may be caused to take the remaining increases of load or fluctuations. And the apparatus may be so adjusted that the load upon the battery when charging may be limited to a value entirely different and independent from the load upon the battery when discharging, and the same effect and result may be attained with relation to the booster voltage and output. I have also provided economical and efficient apparatus for carrying out the above regulations and although I have shown three modifications of such apparatus I desire it to be distinctly understood that each arrangement of apparatus is not limited to the specific system with which it is shown and that any of the various arrangements of apparatus may be used, upon proper adjustment and arrangement, with any of the systems shown or with any system of the class described.

When I refer to the limiting of the battery current or the preventing of the battery from further giving up or receiving energy I do not necessarily mean that under no conditions will the battery current become greater, but that the current is so limited during a certain time or until certain further changes in the condition of the system have taken place.

Although I have shown and described my improvements in great detail I do not desire to be limited to such details but

Having fully and clearly described the same, what I claim and desire to secure by Letters Patent, is:

1. In combination, an electric circuit, a storage battery in operative relation therewith, and connected thereto to give up and receive energy to and from said circuit, and means for preventing the battery from further giving up or receiving energy above a predetermined amount when battery current has reached a predetermined value.

2. In combination, an electric circuit, a storage battery in operative relation therewith, and connected thereto to give up and

receive energy to and from said circuit, and means for preventing the battery from further giving up or receiving energy above a predetermined amount when the difference between the voltage of said circuit and the voltage of said battery has reached a predetermined value.

3. In combination, an electric circuit, a storage battery in operative relation therewith, and connected thereto to give up and receive energy to and from said circuit, and means for preventing the battery from further giving up energy above a predetermined amount when the difference in voltage between said battery and circuit has reached a certain value.

4. In combination, an electric circuit, a storage battery in operative relation therewith, and connected thereto to give up and receive energy to and from said circuit, and means for preventing the battery from further receiving energy above a predetermined amount when its charging current has reached a predetermined value.

5. In combination, an electric circuit, a storage battery in operative relation therewith, and connected thereto to give up and receive energy to and from said circuit, and means for preventing the battery from further receiving energy above a predetermined amount when the difference in voltage between the battery and circuit has reached a predetermined value.

6. In combination, an electric circuit, a storage battery in operative relation thereto, regulating means for causing the discharge and charge of said battery to and from said circuit, means for preventing an increase in the battery current when the difference in voltage between the circuit and battery has reached a predetermined value and means for preventing an increase in battery current when the battery current has reached a predetermined value.

7. In an electrical system of distribution, the combination of a generator, a circuit fed thereby, a storage battery in operative relation therewith, electro-responsive means for causing the battery to charge and discharge, and means for preventing an increase in the battery current when the difference of voltage between the battery and circuit has reached a predetermined value.

8. The combination of an electric circuit, a storage battery in operative relation therewith and connected to be charged therefrom and to discharge thereto, and means for limiting the battery discharge current to a predetermined value and for limiting the charging current also to a predetermined value.

9. The combination of an electric circuit, a storage battery in operative relation therewith and connected to be charged therefrom and to discharge thereto, means for limiting the battery discharge current to a certain value and means for limiting the charging current to an independent value, both of said means being responsive to certain changes in the battery condition.

10. In an electrical system of distribution, an electric circuit, a storage battery in operative relation thereto, a booster for causing the battery to charge and discharge, electro-responsive means for causing the booster to limit the battery discharge current to a predetermined value and electro-responsive means for causing the booster to limit the charging current to a different predetermined value, both of said means being responsive to variations in the electrical condition of the system.

11. In an electrical system of distribution, an electric circuit, a storage battery in operative relation thereto, a booster for causing the battery to charge and discharge, means for controlling the booster to limit the battery charging current and means controlling the booster to limit the battery discharging current.

12. In an electrical system of distribution, an electric circuit, a storage battery in operative relation thereto, a booster for causing the battery to charge and discharge, a dynamometer for controlling the booster to limit the battery charging current when the charging current has reached a predetermined value, and a dynamometer for controlling the booster to limit the discharging current when it has reached a predetermined value independent of the first.

13. In an electrical system of distribution, an electric circuit, a storage battery in operative relation thereto, a booster for causing the battery to charge and discharge, dynamometers for controlling the booster to limit the battery current, one of said dynamometers being responsive to battery charging current, another of said dynamometers being responsive to battery discharging current and others of said dynamometers being responsive to the booster voltage.

14. In an electrical system of distribution, an electric circuit, a storage battery in operative relation thereto, a booster for causing the battery to charge and discharge, means for controlling the booster to limit the battery current, a coil acting upon said means responsive to battery charging current, a coil acting upon said means responsive to battery discharging current, a coil acting upon said means responsive to the booster charging voltage and a coil acting on said means responsive to the booster discharging voltage.

15. In an electrical system of distribution, an electric circuit, a storage battery in operative relation thereto, a booster for causing the battery to charge and discharge, means for controlling the booster to cause

it to limit the battery current, a variable resistance for controlling said means, and dynamometers for varying said resistance responsive to certain fluctuations in the electrical condition of the system.

16. In an electrical system of distribution, an electric circuit, a storage battery in operative relation thereto, a booster for causing the battery to charge and discharge, an exciter for controlling the action of the booster, a counter-electromotive force machine for controlling said exciter, a coil for controlling the action of said machine, means for acting upon said coil responsive to certain variations in the battery current and in the booster voltage, to cause the booster to limit the battery current to a certain value in one direction and to a different value in the other direction.

17. In an electrical system of distribution, an electric circuit, a storage battery in operative relation thereto, a booster for causing the battery to charge and discharge, an exciter for the booster, a coil governing the exciter, a resistance controlling said coil, a mercury bath for short-circuiting said resistance by steps, and a plurality of dynamometers for operating upon said mercury bath to vary said resistance, some of said dynamometers having field coils responsive to battery current and some of said dynamometers having field coils responsive to booster voltage.

18. In an electrical system of distribution an electric circuit and a source of electrical energy therefor, a storage battery operatively related to deliver and receive energy to and from said circuit, electroresponsive means for controlling the charge and discharge of the battery, a device for regulating the action of said controlling means, and two dynamometers acting to control said device responsive to variations from different electrical conditions of the system.

19. In an electrical system of distribution an electric circuit and its source, a storage battery operatively related to deliver and receive energy to and from said circuit, electroresponsive means for controlling the charge and discharge of the battery, a device for regulating the action of said controlling means, two dynamometers acting to control said device responsive to variations from different electrical conditions of the system, and means for preventing said dynamometers from acting on the device until they have developed a predetermined torque.

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

ALBERT S. HUBBARD.

Witnesses:
EDWIN SEGER,
GORHAM CROSBY.

Corrections in Letters Patent No. 1,160,608.

It is hereby certified that in Letters Patent No. 1,160,608, granted November 16, 1915, upon the application of Albert S. Hubbard, of Belleville, New Jersey, for an improvement in "Electrical Systems of Distribution," errors appear in the printed specification requiring correction as follows: Page 3, line 15, for the word "not" read *now;* page 8, line 47, claim 19, for the words "its source" read *a source of electrical energy therefor;* and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 29th day of February, A. D., 1916.

[SEAL.]

R. F. WHITEHEAD,
Acting Commissioner of Patents.

Cl. 171—310.