

Dec. 27, 1932.

L. L. PERRY ET AL

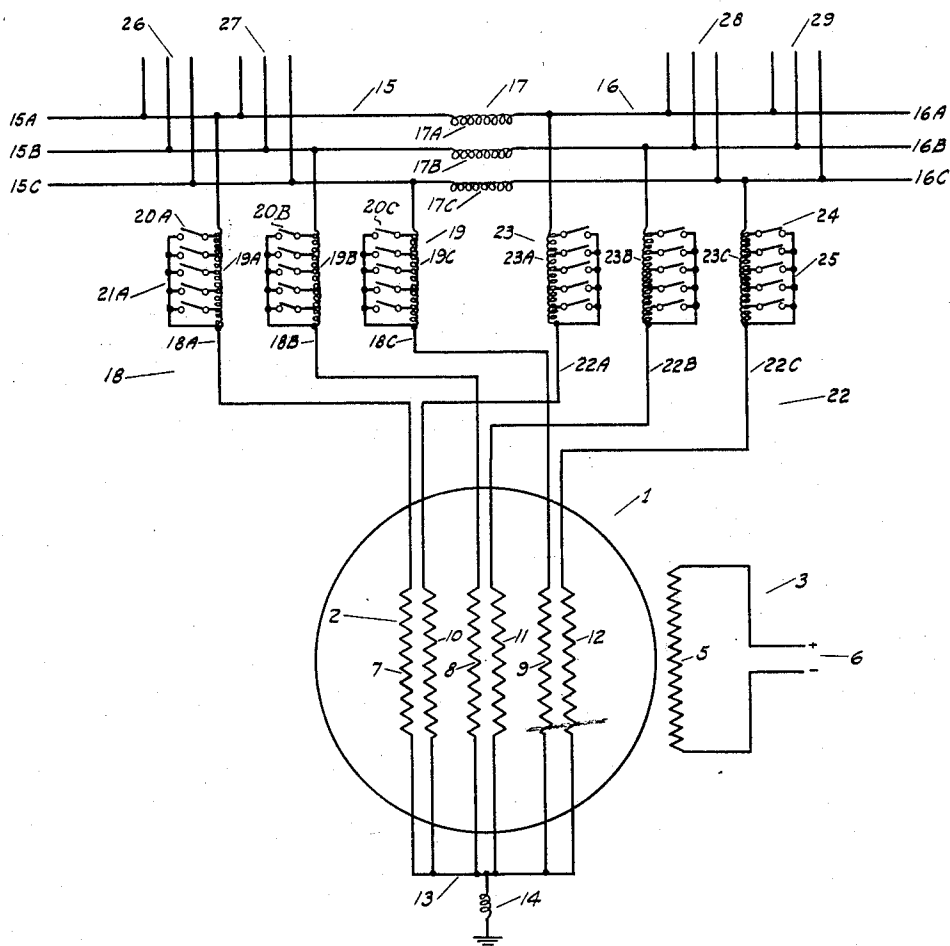
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METHOD OF AND MEANS FOR GENERATING AND DISTRIBUTING CURRENT FLOW

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10 Sheets-Sheet 1

Fig. 1



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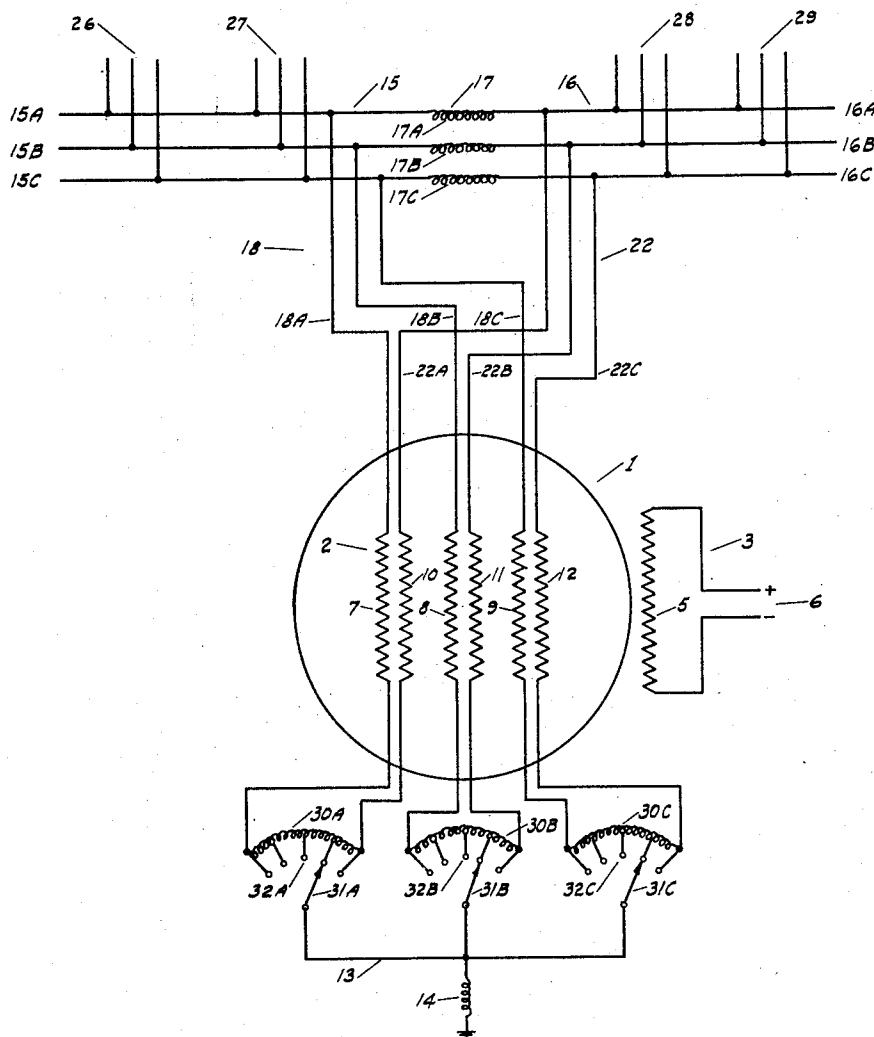
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10 Sheets-Sheet 2

Fig. 2



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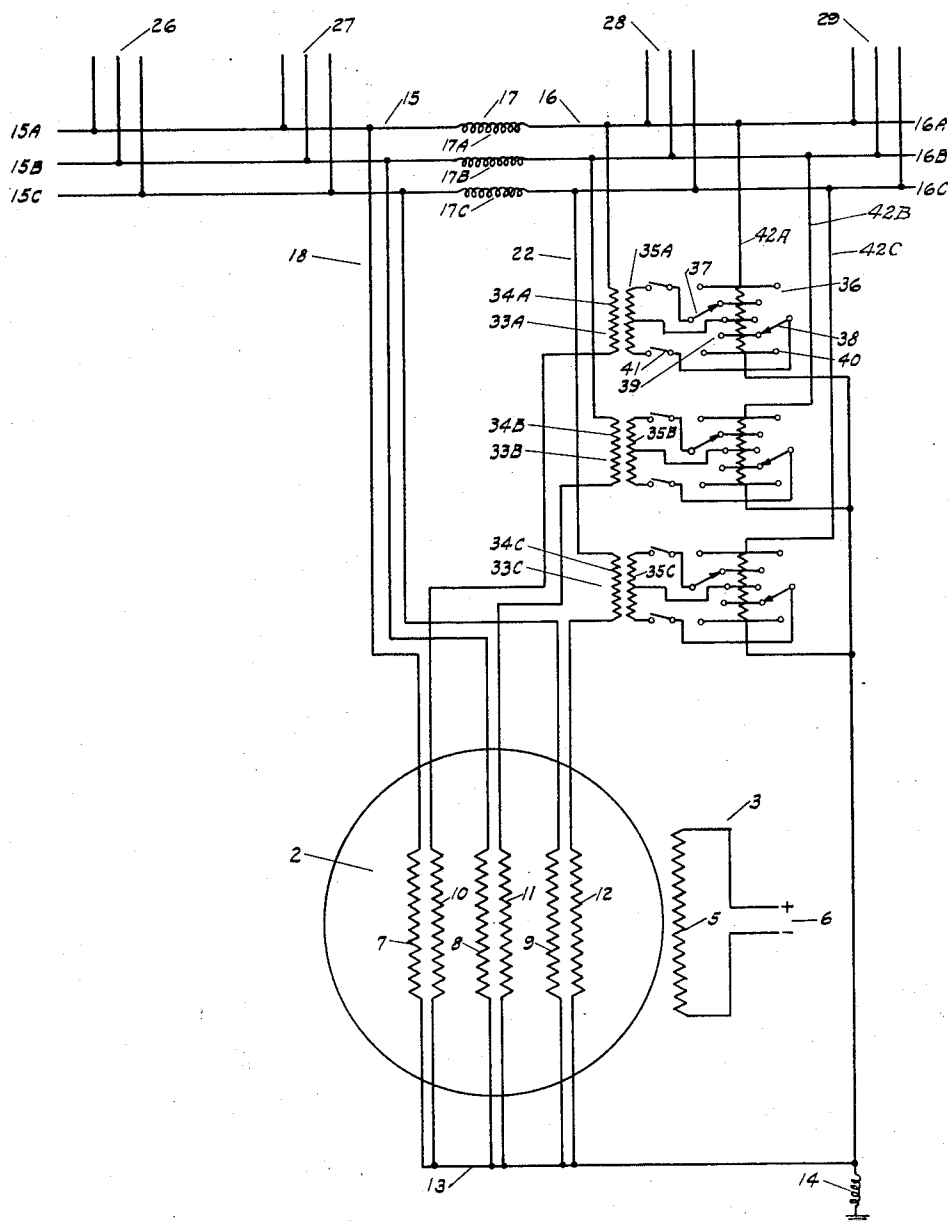
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10 Sheets-Sheet 3

Fig. 3



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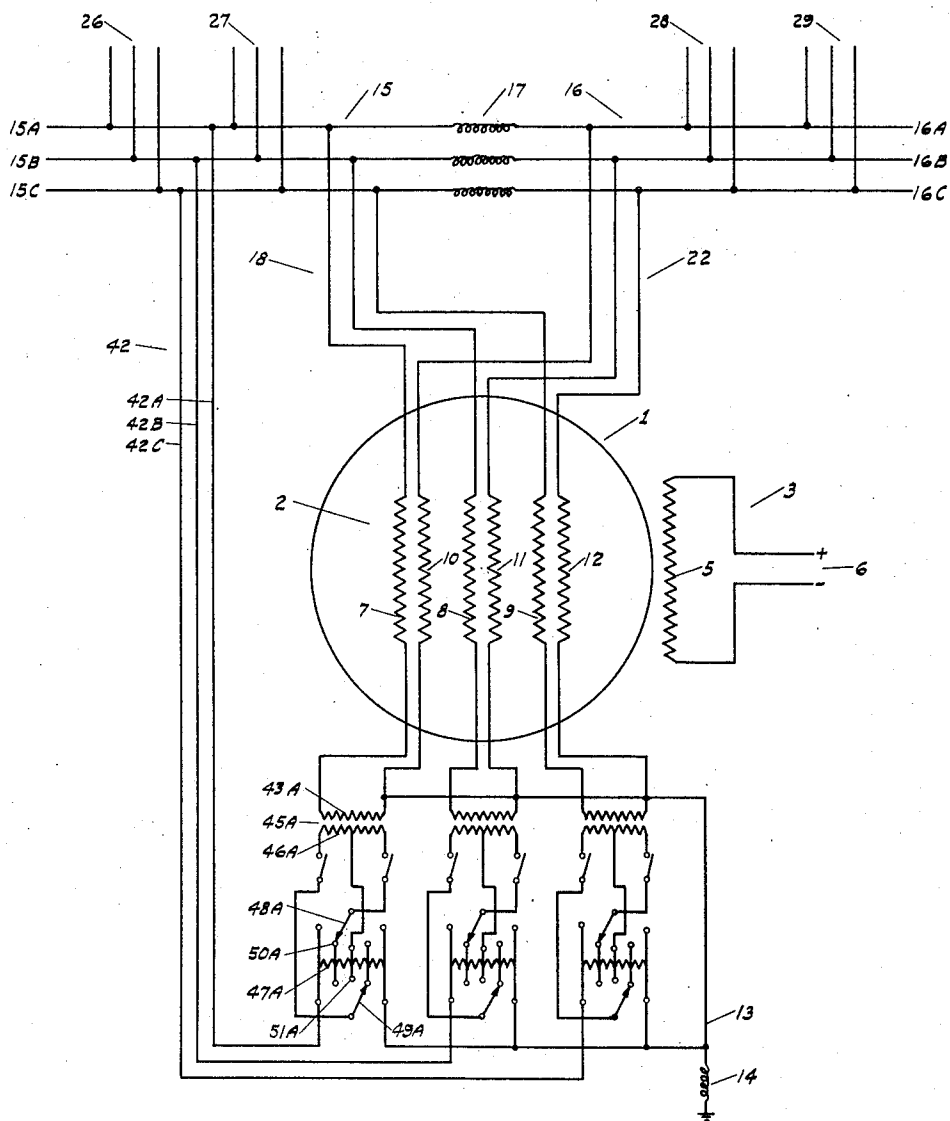
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10 Sheets-Sheet 4

Fig. 4



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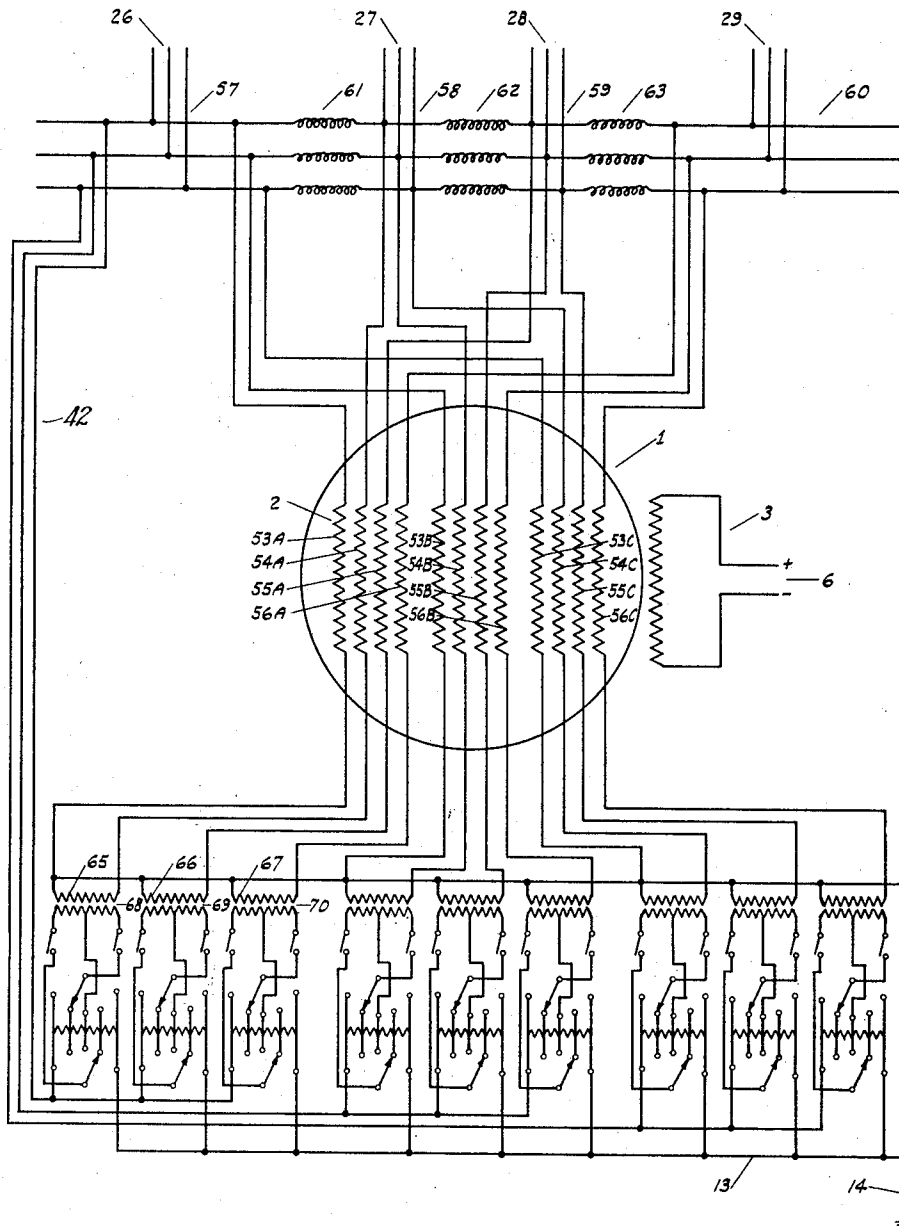
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METHOD OF AND MEANS FOR GENERATING AND DISTRIBUTING CURRENT FLOW

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10 Sheets-Sheet 5

Fig. 5



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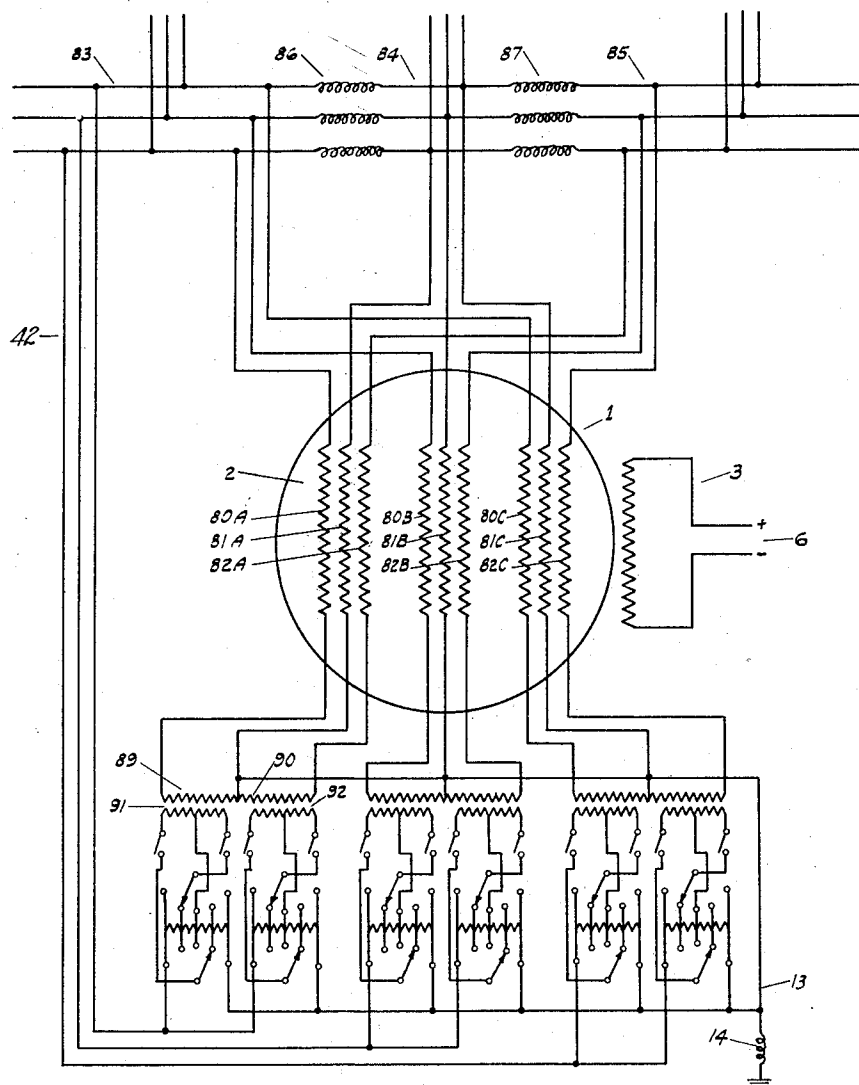
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METHOD OF AND MEANS FOR GENERATING AND DISTRIBUTING CURRENT FLOW

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10 Sheets-Sheet 6

Fig. 6



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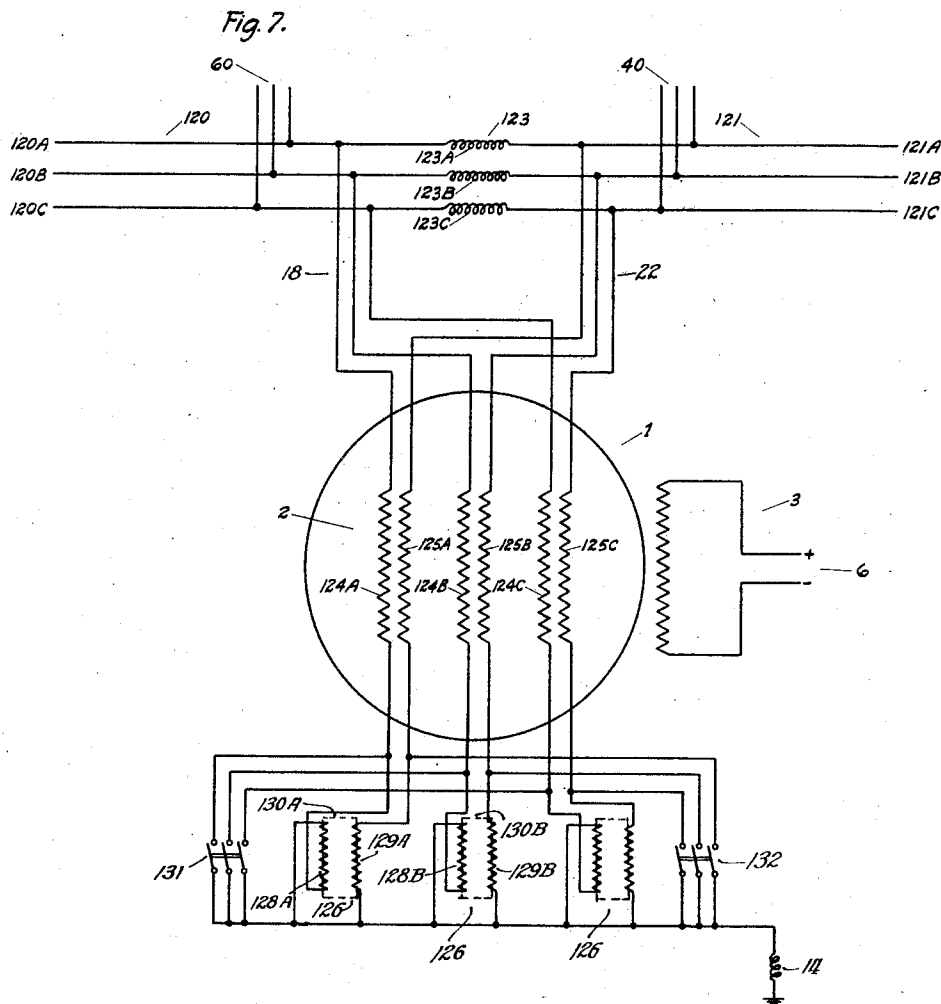
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METHOD OF AND MEANS FOR GENERATING AND DISTRIBUTING CURRENT FLOW

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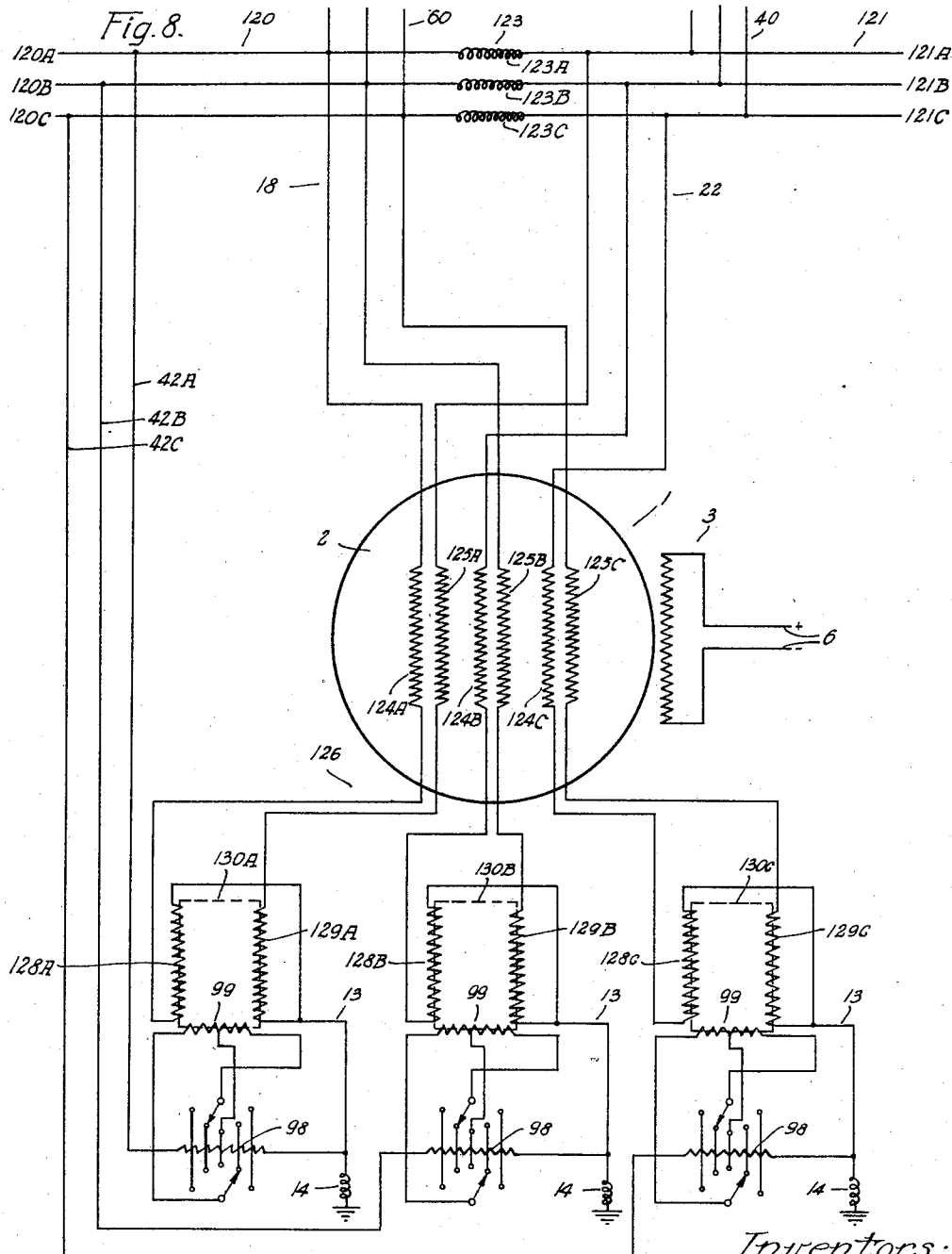
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METHOD OF AND MEANS FOR GENERATING AND DISTRIBUTING CURRENT FLOW

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10 Sheets-Sheet 8



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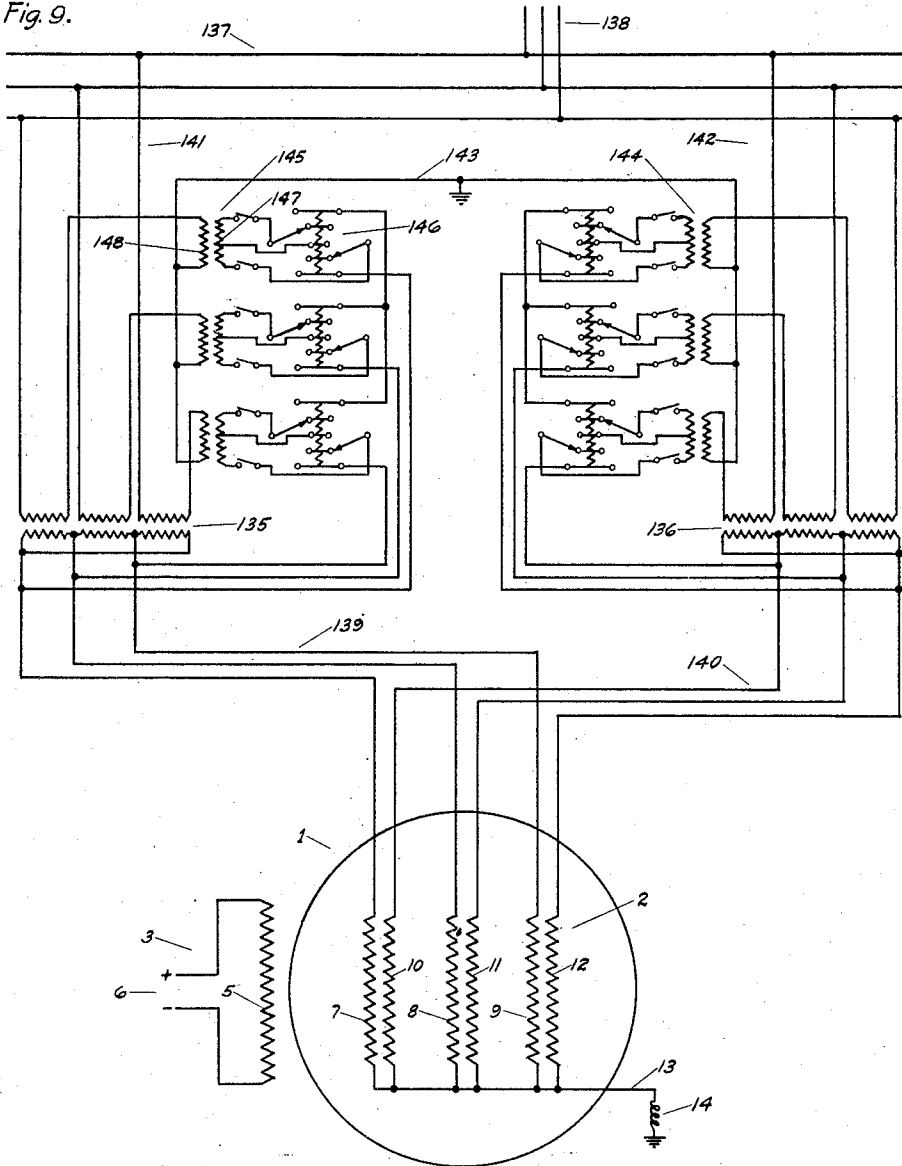
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METHOD OF AND MEANS FOR GENERATING AND DISTRIBUTING CURRENT FLOW

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10 Sheets-Sheet 9

Fig. 9.



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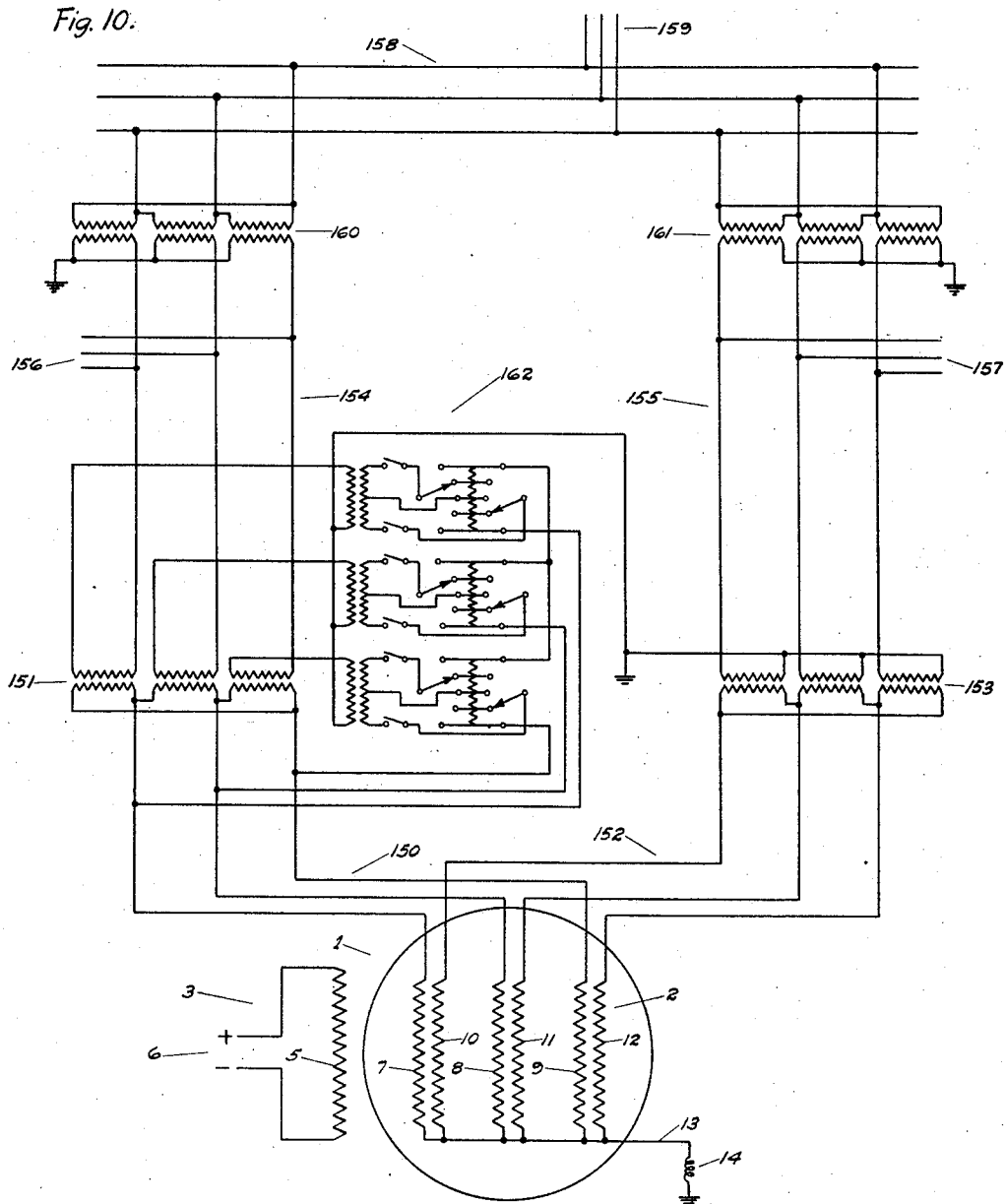
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METHOD OF AND MEANS FOR GENERATING AND DISTRIBUTING CURRENT FLOW

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10 Sheets-Sheet 10



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UNITED STATES PATENT OFFICE

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METHOD OF AND MEANS FOR GENERATING AND DISTRIBUTING CURRENT FLOW

Application filed April 25, 1929. Serial No. 353,090.

This invention relates to a method of and means for generating and distributing current flow. More particularly this invention is concerned with the generation and distribution of currents in and from large turbo-generator units.

As turbo-generator units have been increasing in size, the problem of handling the large current flow incidental to increased capacity has become more and more difficult. On some recent units the problem has been partially solved by increasing the terminal voltage from the previous standards of 11,500 and 13,800 to 22,000 volts. In the still larger units now under consideration the current even at 22,000 volts becomes too large to be handled readily. The difficulty resides largely in the protective and switching mechanism.

During the past two or three years another partial solution has been to put two independent windings on the same generator, each winding being of one-half the normal capacity of the entire machine. Each winding has a definite maximum current carrying capacity which cannot be exceeded without overheating it and damaging its insulation. It is permissible to operate both windings at their maximum capacity simultaneously, but it is not permissible to increase to an appreciable extent the current of one winding to compensate for a decrease in current on the other. To get maximum capacity from the units it is necessary to effect a balance of current in the two windings. This solution of the double winding generator has, therefore, been successful only where external means were available for balancing the currents on the two windings. This can be done either by connecting the two windings to the same section of the bus, which the double winding was really designed to avoid, or by connecting them to independent sections of the bus and then balancing the load by shifting circuits from the heavier loaded section to the lighter loaded one. The first method has the objection of concentrating on one bus section too much normal current and too much short circuit energy. The second method is not always possible, for ex-

ample where the unit circuits are of such large capacity that shifting one of them from the heavily loaded section to the lightly loaded one would merely reverse the unbalanced condition.

In large power stations it is customary to tie all generators together electrically but with a certain definite amount of impedance in the form of transformers or reactors between them. Under normal conditions of operation there is practically always some unbalanced current flowing over these impedances and this current sets up a voltage difference between the terminals of the generators on the two sides of the impedance. The flow of current can then be regulated and balanced between generators by adjusting the field currents of the respective generators. If instead of between two independent generators the voltage difference is set up between the terminals of two independent windings on the same generator, any manipulation of the field current will affect the voltages of both windings in practically the same degree. To date this lack of means for independently controlling the voltage of each winding and hence of equalizing the currents between the two windings has limited the field of application of the two winding generator.

To remove this limitation our invention aims to provide means for changing the voltage relation of one winding with respect to the other. According to the present invention this is accomplished by means included in series relation with the windings themselves. This may be done by introducing a positive or negative balancing force, which may be self-excited as, for example, an impedance, or may be excited from an external source of energy, as through a transformer.

In practice it may be accomplished in the following ways:

1. By varying the impedance of either or both windings, either independently or simultaneously;

2. By bucking or boosting the voltage of either or both windings, either independently or simultaneously;

3. By change in transformer ratios when

transformers are interposed between the windings and the point of interconnection, or by a combination of any two, or all.

The means for accomplishing this control may be located in the phase leads of the generator, or, where the generator is star connected, in the neutral leads, or if transformers are interposed between the generator windings and the point where they are connected together, such differential effect may be accomplished in such transformers or lines.

The variable impedance required by the first method preferably consists of reactors having taps brought out to switching equipment. With this equipment the amount of reactance in the circuit may be varied by shunting or switching more or less reactance out of the circuit.

The second method of control by boosting or bucking the voltage may be accomplished by the induction regulators, by a booster generator in series with one circuit of the main generator, or by load ratio control transformers. The last named equipment appears to be less expensive and to give a better design than the others.

When transformers are interposed they may be provided with suitable taps or load ratio control transformers.

The booster transformer has the advantage over the reactor scheme in that it can be designed to handle smaller currents at higher voltages which, in the ranges being considered, may be switched much more easily than larger currents at low voltages.

The present invention provides a method of generating and distributing current flow by generating a common voltage in a plurality of parallel generator windings which are subjected to the same field excitation and connecting the windings to load circuits through the intermediary of busses, a bus for each winding, which busses are tied together through impedances for limiting short circuit currents. Then if the loads are unequal, the windings will be unbalanced due to the impedance being a barrier to current flow from the more lightly loaded winding to the more heavily loaded bus. We modify the terminal potential of the two windings until the effective potential of the winding of less load is relatively higher than the effective potential of the winding of greater load to a degree sufficient to cause a balancing flow of current through the bus reactor or impedance. This may be done by depressing the voltage of the more heavily loaded winding or by boosting or raising the voltage of the winding which is less heavily loaded.

The introduction of such regulating force may be made entirely automatic, either through the use of automatically regulated apparatus or by an external interlinkage

magnetically or electromagnetically, as will appear more in detail later.

The broad concept herein involved is the introduction of means for compelling a transfer of load from the more heavily loaded winding to the less heavily loaded winding by compelling current to flow through a transfer connection which current would otherwise not flow because of a barrier either in the transfer connection or in the connections of the windings thereto. In other words, we compel more current to flow across the barrier than would flow thereacross under the influence of the generated voltages of the windings.

Now, in order to acquaint those skilled in the art with the manner of constructing and operating a device embodying our invention, we shall describe in connection with the accompanying drawings the apparatus and mode of use embodying the invention in means and method of our invention.

In the drawings:

Fig. 1 is a diagram of a system embodying our invention;

Fig. 2 is a modification of the same;

Fig. 3 is a diagram of a modified form in which transformers are employed for providing the regulating voltage;

Fig. 4 is a further modification similar to the modification of Fig. 3;

Fig. 5 is a modification in which the generator has four parallel windings;

Fig. 6 shows a modification in which the generator has three parallel windings in which a transformer scheme of regulation is employed;

Fig. 7 is a diagram of a system which is inherently self regulated;

Fig. 8 is a diagram of a system embodying a modification of Fig. 7;

Fig. 9 is a diagram of a system employing transformers between the generator windings and the tie or interconnection; and

Fig. 10 is a diagram of a system employing transformers and transmission lines between the generator windings and the tie or interconnection.

Referring now to Fig. 1, the generator 1 comprises two main parts, namely, the portion 2 containing the generator winding and the portion 3 comprising the field winding. In practice the portion 2 is preferably a stationary frame comprising a part of the magnetic circuit of the generating winding; the part 3 is a rotating member comprising a part of the magnetic circuit and the field winding. Windings here are shown at 5 as connected together to the direct current exciter busses 6.

The stator portion which carries the generator winding comprises two separate three phase windings consisting of coils 7, 8 and 9 for the three phases of one winding and the coils 10, 11 and 12 for the three phases of the other winding. The inner terminals of

the windings 7, 8, 9, 10, 11 and 12 are tied together by a common star connection 13 which may be grounded through a reactance 14, as is well known to those skilled in the art.

The outer terminals of these windings are connected to two separate sections 15 and 16 of a bus system in which the two busses 15 and 16 are connected together through a set of reactors 17. The leads 18 from the first set of windings 7, 8, 9 are connected to the bus 15 through reactors 19 comprising the separate reactors 19A, 19B and 19C. These reactors are provided with taps and switches such as 20A, 20B and 20C in the three phases and which are spoken of generally as the switches 20 for connection to short circuiting bars or busses 21 as, for example, the bar 21A for the lead 18A. By means of these switches 20 and the bars or busses 21, the reactors 19 or impedances which they provide may be cut out of the circuit by short circuiting for the purpose of balancing the load on the two sets of windings. In the leads 22 for the windings 10, 11 and 12 similar reactors 23 and short circuiting bars 25 and switches 24 are provided for cutting out more or less of the impedance presented by the reactances for the purpose of balancing the load upon the windings, as will more readily be apparent later.

Assuming that load circuits, such as 26, 27, 28 and 29, are to be supplied with current and that the loads carried for each of these circuits are substantially equal, it will be apparent, therefore, that when the generator windings are energized by interaction with the same field winding equal or substantially equal potentials will appear upon them, that is the potentials on the two sets of windings will be substantially equal and each winding, therefore, delivers to its corresponding bus section substantially the same amount of current.

The potentials upon the bus sections 15 and 16 will be equal and hence the potentials at the terminals of the reactors 17 will be equal. Under these circumstances the full load of the generator is delivered without unbalance and consequently without overheating of either winding.

Assume now that the load 26 is 35% of the rated capacity of the generator and the loads 27 and 28 are 20% of the rated capacity of the generator, and the load 29 is 25% of the rated capacity of the generator. It will be seen, therefore, that the first winding comprising the coils 7, 8, 9 is connected to 55% of the load directly and the second winding is connected to 45% of the load directly. Under these conditions the first winding is overloaded and will become overheated. The bus reactors 17 introduce sufficient opposition to the current flow from the bus section 16 to the bus section 15 that this 10% difference is not altogether equalized.

The result is that the first winding remains overloaded unless some means is introduced for balancing the load.

In the present case we accomplish this by depressing the effective voltage of the first winding comprising the coils 7, 8, 9 by the introduction of a corresponding amount of impedance at the reactors 19.

While this requires the relative preponderance of voltage on the bus section 16 over that in the section 15 no practical objection to the same occurs since the lines 28 and 29 are operated on a slightly higher voltage than the lines 26 and 27 and this may be taken into account as by means of the induction regulators or regulating devices at the terminals of the lines in a manner well known to those skilled in the art.

It will be seen, therefore, that we provide for a redistribution of the voltages or a differential arrangement of the voltages on the terminals to secure the desired balancing of loads. The arrangement is somewhat like adjusting the arms of a Wheatstone bridge. Instead of resistance inductance is employed, since resistance would waste too much energy.

This reveals the fundamental scheme. Instead of inserting the regulating means in series relation in the leads from the outer ends of the windings to the busses the regulating means may be inserted at the inner ends in a star connected generator, such as that shown in Figure 1, by the arrangement shown in Figure 2.

In this case the inner terminals of the windings are connected together through reactances 30A, 30B and 30C with taps taken out from said reactances and cooperating contactors 31A, 31B and 31C connected together by the common star connection 13. The contactors 31A, 31B and 31C are adapted to engage with the contacts 32A, 32B and 32C, the said three contactors or switch arms being operated in unison according to the preferred embodiment.

It can be seen at once that the reactors 30 are in a differential relation with respect to the two windings, that is to say by shifting of the arms 31 to one side or the other of center with respect to the winding 30 the major part of the reactance is thrown to one winding or to the other in respect to the neutral connection 13.

Obviously, as in Figure 1, the reactances may be connected in series in each lead, that is instead of three reactances as shown in Figure 2 leading to the common neutral wire 13 through the selector switches 31, 31 there may be six such reactances and each one being either shunted out or switched out to a variable degree. Also it is to be noted in connection with Figure 1 that while we have shown the switching arrangement as providing for short circuiting a part or all of the reactance in each case, it is to be noted that

instead of short circuiting, the reverse operation of open circuiting a portion thereof may be employed.

In the arrangement of Figure 2 the regulating action is substantially the same as disclosed in connection with Figure 1 so far as the fundamental principle is concerned, the variation being in the position of the reactors and the fact that they are differentially connected instead of merely additively or subtractively in each lead.

In Figure 3 instead of having reactances in the leads 18 and 22, we have provided transformers in the leads 22 and these transformers may be operated differentially, that is to say, their potential may be added to or subtracted from the generated voltage so as to depress or raise the voltage of one set of windings with respect to the other.

That is to say, transformers 33 are inserted in the leads 22, the secondary windings 34A, 34B and 34C being connected in series with the leads 22A, 22B and 22C, the secondary windings being inductively related to the primary windings. The secondary windings 35 are connected to auto-transformers 36, one for each phase, these auto-transformers being connected between the corresponding bus bar and the neutral connection 13 and having selector switches 37 and 38 for regulating the voltage impressed upon the primary windings 35, as desired. These selector switches 37 and 38 are adapted for cooperation with contacts connected to the taps, the contacts being indicated at 39 and 40. The switching of the contacts on the contacts 39 and 40 of auto-transformer winding 33 permits a change of impressed voltage on primary 35 of transformer 33 without breaking the circuit in accordance with a known scheme of changing the transformer ratio under load.

To permit this the neutral point of the auto transformer winding and its cooperating primary winding 35 are connected together by a tie wire 41. It can be seen that the selector switches 37 and 38 may be adjusted to provide either a raising or depressing voltage upon the winding 34 of the transformer 33 to raise or depress the generated voltage applied to the corresponding bus 16. Hence, if one bus section, such as 15, be more heavily loaded than the companion bus section 16 by boosting the voltage at the transformers 33 to increase the voltage on the bus 16, the load upon the two windings of the generator 1 may be balanced. Likewise if the load on the bus 16 should be too great, the transformers 33 may depress the generated voltage, that is subtract from the generated voltage, so as to cause a differential between the potentials of the two generator windings which results in balanced current flows.

The amount of raising or depression of

voltages need be only that which corresponds to the drop across the bus reactors.

In Figure 4, instead of inserting the transformers in the generator leads between the generator winding and the bus, the transformers are connected at the inner ends of the windings between the generating coils of corresponding phase and the neutral connection 13, which is in this case connected to the secondary windings 43 of the transformers 45, the primary windings 46 being connected to auto transformer windings 47, which auto transformer windings are connected between the bus bars 15 and the neutral connection 13.

Selector switches 48 and 49 cooperating with the contacts 50 and 51 permit the selection of voltage of the proper potential and value to provide the necessary balancing force. These selector switches have the same function as like parts 37 and 38 in the previous embodiment. It is to be observed that the effect of the primary windings 46 upon the secondary windings 43 is, with respect to the two windings of the generator, differential in its effect, namely, that such effect is additive as to one winding and subtractive as to the other, or vice versa. Thus except for the use of transformers instead of reactors the system of Figure 4 is similar to Figure 2, Figure 2 showing the use of inductances as the means for supplying the necessary force to secure balancing of the load of the two windings.

It is to be understood that the generator need not be limited to two sets of windings, as three or four or any number may be employed, as will be apparent from Figures 5 and 6, respectively.

In Figure 5 we have shown four windings 53, 54, 55 and 56, each constituting a complete three phase winding, each winding being connected to a corresponding bus section 57, 58, 59 and 60 with the connecting reactors 61, 62, and 63 connecting the bus sections together. If desired an additional reactor 64 may be connected between the bus section 57 and the bus section 60 to make a complete ring bus. In the present case, the inner ends of the three phases of the winding 53, that is, the coils 53A, 53B and 53C, are connected directly to the neutral connection 13 whereas the windings 54, 55 and 56 are connected to said neutral winding through coils 65, 66 and 67, respectively, these coils being the secondary winding of regulating transformers 68, 69 and 70, respectively.

In this construction the winding 53 is connected directly between the bus sections and the neutral wire 13 and its voltage is not altered. The other windings 54, 55 and 56 are connected between the bus sections and neutrals through the transformer windings and, hence, a voltage may be added algebraically through these transformer windings to

the voltage of the corresponding generating coils. The voltage of the windings 54, 55 and 56 may be adjusted relative to the voltage of the winding 53 so as to secure an equal distribution of load. The three transformers 68, 69 and 70 for each phase may be independently regulated so as to secure a proper distribution of load on the four windings of the generator.

In Figure 6 we show a method of balancing three windings 80, 81 and 82 which are suitably connected to three bus sections 83, 84 and 85 with connecting reactors 86 and 87 by the introduction of transformer secondary windings 89 and 90 of the transformers 91 and 92. In this case the winding 81 is connected directly to the neutral connection of the star connected windings whereas the generator windings 80 and 82 are connected through the secondary windings 89 and 90 of the transformers 91 and 92. Through the independent regulation of transformers 91 and 92 for each phase the voltage of the corresponding multiple windings 80 and 82 may be independently depressed or raised to bring about voltage control of distribution for equalizing the load upon the various multiple windings.

In Figure 7 we have shown a system of inherent regulation in which the differential flow of current between bus sections acts automatically to boost the voltage of the lighter loaded winding so as to bring about inherently a regulation of load. The bus sections 120 and 121 are connected together through reactors 123. The generator is provided with double windings 124 and 125, which are connected to the sections 120 and 121, respectively, of the bus. The windings at their inner ends are connected to the common star connection 13 through current transformers 126.

These transformers 126 are in series relation with the generator windings as, for example, by having windings 128 and 129 in series with corresponding generator windings 124 and 125, respectively, and disposed preferably between the generator coils and the neutral star connection 13.

The transformer windings 128 and 129 for each phase are inductively related through magnetic connections indicated by cores shown in dotted lines at 130. Now it may be seen that by causing the windings 128 and 129 to oppose each other magnetically any unbalanced flow of current will automatically produce a boosting potential in the coil of less current flow. So long as the current flows are balanced the transformer acts substantially like so much resistance only.

However, if the circuit of one of the windings 128 or 129 should be opened, an abnormal potential will be induced in the open circuited winding somewhat as is the case of opening the secondary of a current transformer. It is desirable to avoid this and

hence switches 131 and 132 may be provided for shorting or shunting out the windings of either or both windings. Either the loaded or the unloaded winding may be short circuited or both upon opening the circuit of either generator winding. The switches may be interlocked with switches in the generator leads 18 and 22, or may be controlled otherwise automatically to be operated in accordance with the presence or absence of current flow in the corresponding generator windings.

In Figure 8 we have shown a modification of the system of Figure 7 in which an additional control is provided for governing the distribution of current flow in the two generator windings.

Each transformer 126 has the additional winding 99 upon the core 130. The winding 99 is energized from the leads 42 from the busses 120 or 121 to the auto-transformer winding 98 which is provided with suitable taps for engagement by selector switches permitting the selection of a positive or negative potential of predetermined value, and permitting also change of connections under load.

By suitable regulation of the energization of winding 99 a bucking or boosting effect may be produced for regulating the distribution of current flow in the generator windings as desired.

Referring now to Fig. 9, the two windings 7, 8, 9 and 10, 11, 12 are connected to the same bus 137 through transformer banks 135 and 136 respectively. The primaries are connected in delta to the generator leads 139 and 140 respectively. The secondaries of the transformers are connected in star through the leads 141 and 142 respectively to the bus 137 which bus may have one or more loads such as 138 connected thereto.

Now it will be apparent at once that even though the secondary leads 141 and 142 are connected directly to the same bus with no reactance in the inter-connection the impedance of the two transformer banks 135 and 136 may not be the same. If that is the case then the load upon the two windings will not be equal and one may be overloaded and the other underloaded. If the power factors of the two circuits are not substantially the same, the heating effect will not be the same in the two windings.

To compensate for this we preferably insert load ratio control transformers 145 and 146 in series relation to the secondaries of the power transformers 135 and 136 respectively.

While we have shown these transformer connections in both lines 141 and 142 it may be sufficient to dispose them in one of the lines.

These transformers comprise auto-transformer windings such as 146 connected in star to the generator leads 139 for example. To

these auto-transformer windings 146 we connect primary windings 147, through taps and selector switches suitable for changing connections under load. The secondaries 148
 5 are connected in series with the secondaries of the power transformers 145 preferably between said secondaries and their grounded neutral connection 143.

Now it may be seen that by suitable control
 10 of the voltage developed in the load ratio transformers 144 and 145 the relative distribution of power between the two generator windings may be controlled. If one transformer bank 135 or 136 has higher reactance
 15 than the other such barrier as this interposes to equal distribution of load in the generator windings may be overcome by suitable control of one or the other of the transformers 144, 145. Either a bucking or a boosting
 20 voltage may be developed in either transformer 145—146 by appropriate switching of the connections.

While we have shown two such transformers, one in each of the lines 141 and 142, it is to
 25 be understood that a sufficient difference might be made by a single transformer, that is, either the bank 145 or the bank 144, since a single transformer may be used for either bucking or boosting the voltage in the corresponding line.

In Fig. 10 we have shown a system involving the double winding generator 1 in which
 30 the winding 7, 8, 9 has the leads 150 extending to a transformer bank 151 and the winding 10, 11, 12 has the leads 152 extending to the transformer bank 153. In this case the two generator windings may deliver load independently through an interconnected net
 35 work of transmission line and the like without being connected together with busses at the generator or at the generating station.

The transmission net work may comprise the high tension lines 154 and 155 connected
 40 to an extensive transmission system which may have load connections such as 156 or 157 before the lines are interconnected as at the bus or tie 158 which may be at a remote station. From the bus or tie 158 which may
 45 be a part of an extensive system, further load connections such as 159 may be led off. Now it can be seen that due to the different points
 50 at which load may be taken off the interconnected system the resistance between the generator winding and any particular point of take-off may be less for one winding than
 55 for the other winding with the result that even though the system might comprise a normally balanced load, any change in the amount of load led off from each branch or
 60 connection would disturb the balance.

Load ratio control transformers, such as 162, connected in the previously described
 65 manner in series with one set of leads 150 and the generator bank 151 may be employed for bucking or boosting the voltage of that

winding so as to compensate for differences
 in impedance between the load and each of the windings. A similar load ratio control
 transformer may be employed in connection
 70 with the generator leads 152 and transmission line 155. Only one has been shown since the other would be of similar construction and need not be described.

The tie wire 158 may be a low tension connection relative to the transmission lines 154
 75 and 155, the transformers 160 and 161 being interposed.

Even if the load 159 were the only load and were connected to the tie or bus 158 the
 80 various transformer banks having different impedance would tend to produce an unbalanced load upon the two windings. This, as above explained, may be directed by a load ratio transformer in either one or both of the
 85 leads extending to the tie connection such as 158.

Assume that the load 159 is connected to the winding 10, 11, 12 through a circuit of less
 impedance than it is connected to the winding 7, 8, 9. In that case the load ratio transformer 162 is set so as to boost the voltage
 90 of the winding 7, 8, 9 to cause it to deliver an increased current flow to the load.

Assume that the load 157 is supplied by the two windings, it can be seen at once that
 95 this load is connected more directly to the winding 10, 11, 12 than it is to the winding 7, 8, 9. It is necessary for current from the winding 7, 8, 9 to pass through the transformers 151 and 160 to the tie 158 and from
 100 the tie 158 to return through the transformer 161 to reach the load 157. The load ratio control transformer 162 may be so manipulated as to secure the desired result. Likewise, in any inter-connected system where
 105 the current flow may vary from time to time through one route or the other the load ratio control transformers may be manipulated to secure the desired balance.

We do not intend to be limited to the details shown and described, as we believe that
 110 we are broadly the first to provide means for regulating the distribution of load between or among the windings of a multiple winding generator.

We claim:

1. In combination a generator having multiple windings and a common field, bus sections connected individually to the windings, reactors connecting said bus sections in
 115 series with each other, and means connected in series relation to one of said windings for equalizing the load upon said windings.

2. In combination a star connected generator having multiple windings and a common field, bus sections connected to said
 120 windings, loads connected to said bus sections, reactors tying said bus sections together in series with each other, and means connected in series relation between the ter- 125

minals of one of said windings and the bus section for causing a substantially equal distribution of the load between said windings.

3. In combination a generator having multiple windings star connected and having a common field, bus sections connected individually to the terminals of said windings, load circuits connected to said bus sections, reactors connecting said bus sections in series with each other, and means connected in series relation between the generator windings and the star connection thereof for controlling the distribution of current flow in said windings.

4. In combination a star connected generator having multiple windings and having a common field, bus sections connected individually to said winding, reactors tying said bus sections together in series with each other and regulating reactors connected in series relation between the windings and the star connection for distributing the current flow through said windings.

5. In combination a generator having multiple windings, a star connection for said windings and a common field for the winding, bus sections connected individually to said winding, reactors tying said bus sections together in series with each other, and transformer means connected in series relation with the generator windings for introducing a modifying potential to equalize the load upon said windings.

6. In combination a generator having multiple windings, a star connection for said windings and a common field for the windings, bus sections connected individually to the windings, reactors connecting said bus sections together in series with each other and transformers connected in series relation between the star connection and said windings for introducing modifying potentials for distributing the load between or among said windings.

7. In combination a generator having multiple windings and having a common field, bus sections connected to said windings, reactors tying said bus sections together in series with each other, and means energized by unequal current flow in said windings for modifying the effective potential of the windings.

8. In a system of the class described a generator having plural windings, means for connecting said windings in parallel to a load, said means comprising a barrier to the free flow of current equally from both windings to the load, and means in series relation to one of the windings for compelling a substantial equal distribution of load among the windings.

9. In a system of the class described, the combination of a generator having plural windings, a bus for connecting the windings in parallel, transformers of unequal imped-

ance between the windings and the bus and means for compelling a greater flow of current from one of said windings than would flow therethrough under the influence of the generated voltages of the windings.

10. In a system comprising a generator having an armature provided with two separate windings, separate bus bars for the windings tied together through reactors, the method of equalizing the current flow of the two windings for unequal loads on the bus bars which comprises modifying the potential impressed on the bus bars by one of the separate windings to bring the bus bar potential of the winding of less current flow above that of the bus bar potential of the winding of greater current flow.

11. In a generating and distributing system having a plural winding generator, a bus section connected to each winding, reactors connected between bus sections, unequal loads connected to the bus sections, the method of equalizing the current flow in the generator windings which comprises modifying the potential impressed on the bus bars by one of the separate windings to bring the potential of the bus section of less load above that of the potential of the bus section of greater load thereby transferring sufficient current flow from the winding less heavily loaded to the greater load through the connecting reactor to equalize the current flow in the said two windings.

12. In combination, an alternator having an armature with two separate armature windings and a common field for exciting said armature windings simultaneously and substantially equally, two bus sections connected to the two windings respectively, a connection between the bus sections serving to permit the transfer of energy from one bus section to the other but serving as a limiting barrier in case of an interphase short on either bus section, and means for compelling more current to flow across said barrier than would otherwise flow due to generated voltages in order to equalize the current flow in the two windings and hence to equalize the heating of said two windings.

13. In combination, a star connected generator having a plurality of generator windings connected in multiple to a common neutral, a common field for exciting said windings, a load circuit connected in multiple to said windings and means in series relation with said windings for modifying the voltage drops in the multiple winding circuits between said common neutral and the load for effecting an equalization of output of said generator windings.

14. In combination, a multiple winding star connected generator having the windings connected to a common neutral connection, a common field for exciting said windings and individual bus sections for each winding, cur-

rent limiting devices connecting said bus sections, a load connected to one of said bus sections and means in series relation to said windings for modifying the voltages impressed upon the bus sections to equalize the output of said windings.

15. In combination, an alternating current generator having a plurality of armature windings and having a common field for exciting said windings, a load circuit, circuits connecting said armature windings in multiple with said load circuit, and current transformer means interlinking said connecting circuits for compelling a substantially equal distribution of current in the windings.

16. In combination, an alternating current generator having a plurality of armature windings and having a common field for exciting said windings, a load circuit, circuits connecting said armature windings in multiple with said load circuit, current transformer means interlinking said connecting circuits for compelling a substantially equal flow of current in the windings, and means for short-circuiting said current transformer means to prevent undesirable voltage rises when the multiple connection between armature windings is opened.

17. In a system for generating and distributing electrical energy, a generator having a plurality of armature windings and having a common exciting field, said armature windings being connected in multiple by means of circuits of unequal impedances, a load circuit connected in multiple with said connecting circuits, and adjustable means in series with one or more of said connecting circuits for controlling the division of current flow between the several windings.

18. In a system for generating and distributing electrical energy, a generator having a plurality of armature windings and having a common exciting field, a network consisting of a plurality of load circuits interconnected by circuits of unequal impedances, circuits connecting each of said armature windings to different points in the network, and adjustable means in series with one or more of said connecting circuits for controlling the division of current flow between the several windings.

In witness whereof we hereunto subscribe our names this 19th day of April, A. D. 1929.

LESLIE L. PERRY.

ALLEN M. ROSSMAN.