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SYSTEM OF VOLTAGE REGULATION.

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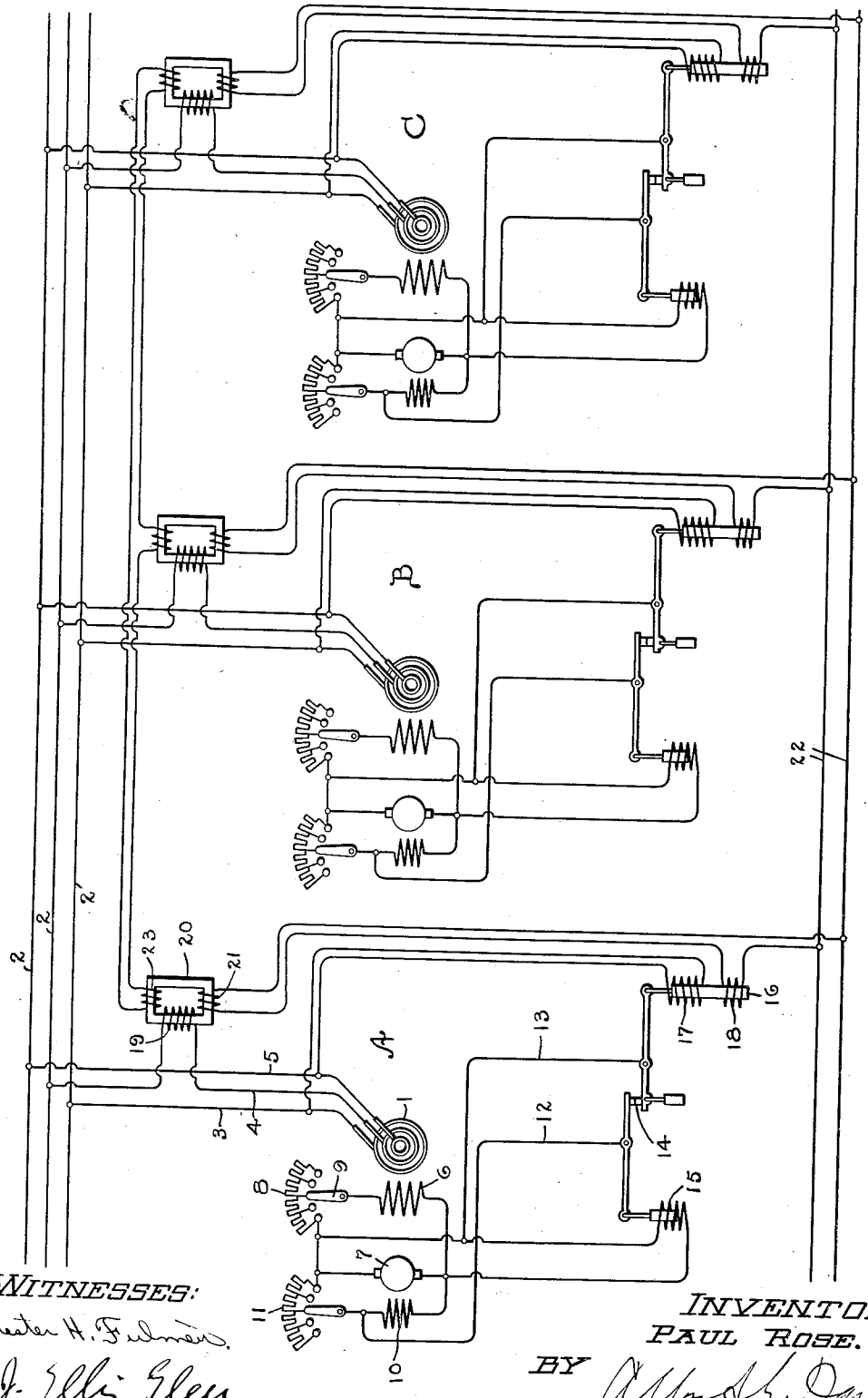

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SYSTEM OF VOLTAGE REGULATION.

937,469. Specification of Letters Patent. Patented Oct. 19, 1909.

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To all whom it may concern:

Be it known that I, PAUL ROSE, a subject of the King of Prussia, residing at Berlin, Germany, have invented certain new and useful Improvements in Systems of Voltage Regulation, of which the following is a specification.

My invention relates to a system for the automatic distribution of the load on a plurality of separately excited generators operating in parallel, the excitation of each of which is controlled by an automatic potential regulator.

When a number of generators, whose excitation is influenced by a potential regulator, are operated in parallel certain difficulties arise, due principally to the fact that the magnetic properties of the exciting generators and the mechanical properties of the potential regulators differ more or less. For example, when a fall of potential occurs in the distribution system, the increase of exciter potential necessary to reëstablish the normal potential may and generally will take place in the different generators with a lack of uniformity and with different speeds. The result is an irregular distribution of the load on the generators and the surging of wattless equalizing currents between the same; and these currents persist after the potential regulation is completed. When the normal potential of the current in the distribution system is again attained, the potential regulator for each generator will adjust its regulating activity independently of other conditions in the circuit.

According to my invention, the surging of wattless compensating currents is avoided. For this purpose the main control member of each regulator is influenced by two forces, one of which is dependent upon the potential of its particular generator, and the other upon the differences in load of the various generators and upon the strength of the surging compensating currents flowing from one to the others; and by this means the exciter potential is increased when one of the generators receives less than its share of load, and is reduced when it is overloaded.

The accompanying drawing shows a system of distribution in which three-phase alternating-current generators are shown connected in parallel and provided with potential regulators of the Tirrill type, connected in accordance with my invention. Three such identical sets of apparatus are shown in the drawing, and they are distinguished from each other by the letters A, B and C, respectively.

The generators 1 are connected to the main bus bars 2, 2, 2, by means of branches 3, 4, 5, as indicated. While these generators are here shown, for illustration, as three-phase generators, it will be understood that my invention may apply to generators of any number of phases. Each of these generators is provided with a separately-excited field 6, which is fed by means of an exciter 7, in series with which is a rheostat 8, manipulated by the switch lever 9. Each exciter is provided with a shunt field 10, in series with which is a rheostat 11. The rheostat 11 is provided with a shunt circuit 12, 13, which contains the main contacts 14 of a regulator of the Tirrill type. The relay magnet which is ordinarily used with this type of regulator has been omitted for the sake of simplicity, and the regulator is shown, stripped down to its essentials. The direct-current magnet 15 is connected across the exciter circuit and operates in conjunction with an alternating-current magnet 16, which is provided with two windings 17, 18. The potential winding 17 of the magnet 16 is connected across two phase legs of its corresponding generator, as clearly shown. In the third phase leg is included in series the primary 19 of a transformer 20. The secondary 21 of this transformer is connected in series with the coil 18 of its corresponding regulator. Each of the secondary coils 21 of the transformer 20 for each generator is connected to a common circuit 22, so that a current in any one of them is opposed to the currents flowing in the remaining coils. Each of the transformers 20 is provided with an additional secondary winding 23, and these are connected in series with each other.

When there is a drop of potential in the conductors 2, 2, 2, the regulation of the excitation of the generators 1 is inaugurated in the usual manner by the closure of contacts 14, which short circuit the resistances 11 in the field circuit of the exciters 7. This raises the potential of the exciting generators and thereby increases the excitation of the generators 1, and in turn raises the vol-

tage on these generators. As the secondary winding 21 of the transformer 20 in any of the sets A, B, C, is opposed to those of the other sets, no current will flow in the coil 18 if the voltage of each of the generators 1 is alike, as the currents flowing in these secondary transformer windings will then neutralize each other. If, however, the potentials of these generators are not alike and the load is not evenly distributed, the secondary potential of the transformer which belongs to the too highly loaded generator is higher than the secondary potential of the remaining transformers. This results in an exchange of current between the secondary windings, and hence current will flow through the windings 18 of the regulator magnets 16. This phenomenon will be intensified if surging compensating currents are flowing between the unequally excited generators. When this is the case the potentials produced in the secondary windings of the transformers by the equalizing currents flowing in the primary coils are no longer opposite, but of the same direction, and will, therefore, be added to each other. Therefore, the currents flowing in the windings 18 of the regulator magnet are now of different directions, according as the particular generator is over-excited or under-excited, and their ampere turns will accordingly either be added to the ampere turns of the potential coils 17 or subtracted therefrom, as the case may be. The current coils are wound in such a manner that their magnetizing effect will be subtracted from those of the potential coils 17 when the generator is over-excited, thereby weakening the effect of the coils 17, opening the contacts 14, throwing the resistance into series with the field of the exciter, and thereby decreasing the excitation of the generator until the equalizing currents flowing between the generators have disappeared and the correct load ratio has been reëstablished.

It is to be observed that the ampere turns of the pairs of coils 17, 18 are added to each other not arithmetically but vectorially, and it is, therefore, of importance whether a phase difference exists between these ampere turns or not. In the drawing, for example, the transformer 20 has been placed intentionally in the middle lead 4 of the three-phase generator, while the potential coils 17 are connected across the two other leads 3, 5. Now, it is known that in a three-phase distribution system the wattless component of the current is displaced in phase in any one lead by 90° with relation to the potential across the two other leads. By reason of this a phase displacement of 90° exists, with unity power factor in the system, between the currents in the secondary coils 21, and hence in the coils 18, on the one hand, and the current in the coils 17 on the other hand. Since the ampere turns of the two coils are added vectorially, and the ampere turns of the current coil should practically amount at most to 10–20% of those of the potential coil, a difference in the pure watt load of the generator will have little effect on the magnet 16. But as soon as the generators furnish wattless currents, and when this wattless current is incorrectly distributed between the generators, so that equalizing currents flow between them, the currents in the coils 17 and 18 will be displaced in phase more or less than 90°, a sthe case may be. In such event, therefore, the regulators are strongly influenced and will tend to rapidly restore the correct distribution of the load.

When single-phase generators are equipped with Tirrill regulators according to my invention, a phase displacement must be artificially produced between the currents in the two coils 17, 18 of the main regulator magnet, either by displacing the current in the voltage winding with respect to the watt component of the generator current, or by displacing the secondary current of the transformer with respect to the primary current. This can be accomplished by means of the well-known connections which are used with measuring instruments according to the Ferraris principle, that is, by means of an inductance and a resistance.

It will be noted that under normal conditions there is no current flowing in the secondary winding 21 of the transformer 20, and, therefore, the current in the primary coil 19 of this transformer produces a powerful field in the iron core, so that a comparatively large fall of potential is obtained across the transformer. In order to obviate this difficulty the secondary coil 23, referred to above, is applied to each transformer, and these coils are so interconnected that with correct load distribution their potentials are added to each other, the coils being connected in series. Hence, with a correct distribution of the load of the distribution system a like secondary current is generated by the primary current of each transformer, which are all added to each other, and their effect is to almost completely neutralize the induction in the iron. The hereinbefore described effect of the coils 21 is not impaired by the reaction upon the same of the coils 23, since in these coils 23, only such current is generated as is prevented from being generated in coils 21 by reason of their neutralizing connections.

What I claim as new and desire to secure by Letters Patent of the United States, is,—

1. Means for producing a uniform distribution of load among a plurality of generators connected in parallel, which consists in a voltage regulator for each generator having two windings, one of which is responsive to changes of voltage of its own generator,

and the other of which is responsive to a difference of voltage between any of the parallel-connected generators.

2. In combination, a plurality of generators connected in parallel, a transformer for each generator having a primary winding included in series with the armature circuit and a secondary winding connected in opposition to the secondaries of transformers corresponding to each of the other generators, a voltage regulator of the Tirrill type for each of said generators, said regulator containing a main control magnet having a shunt coil responsive to changes of voltage of its corresponding generator, and another coil in series with the secondary winding of its corresponding transformer.

In witness whereof, I have hereunto set my hand this third day of May, 1909.

PAUL ROSE.

Witnesses:
JULIUS RUMLAND,
OSKAR SINGER.