E. A. FORSBERG & B. LJUNGSTRÖM.

GAS TURBINE.

APPLICATION FILED APR. 13, 1907.

970,204.

Patented Sept. 13, 1910.

2 SHEETS—SHEET 1.

Fig: 1

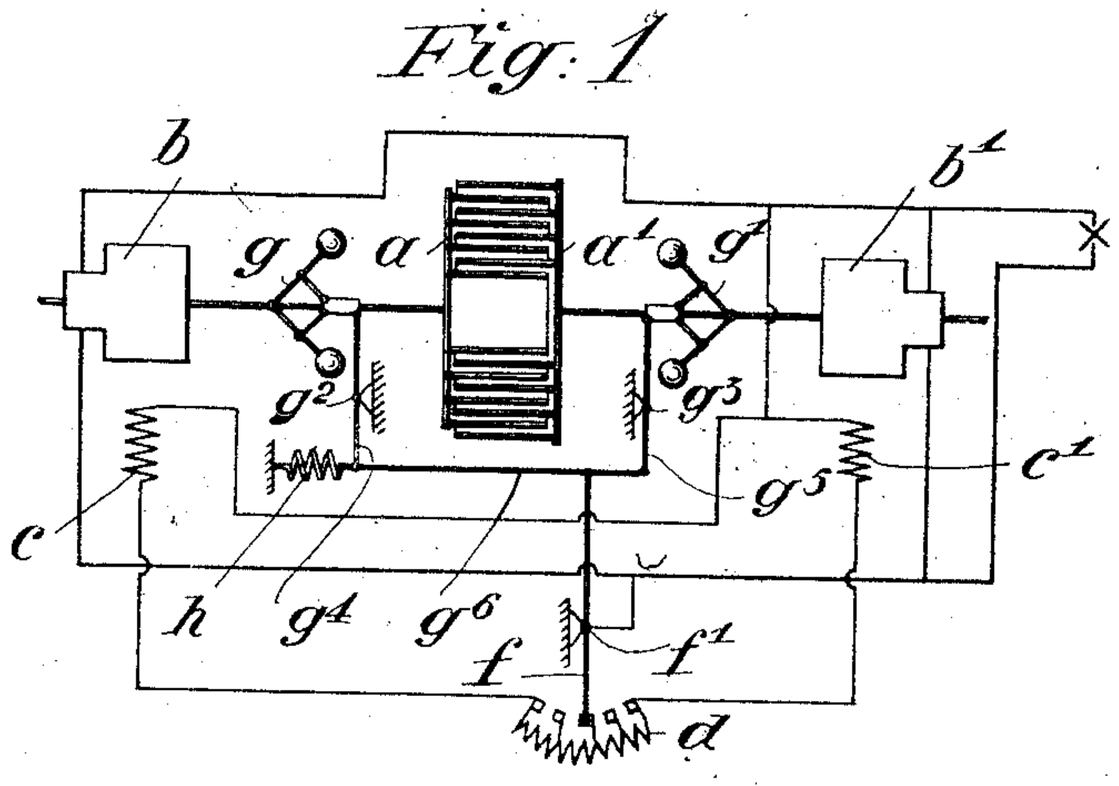
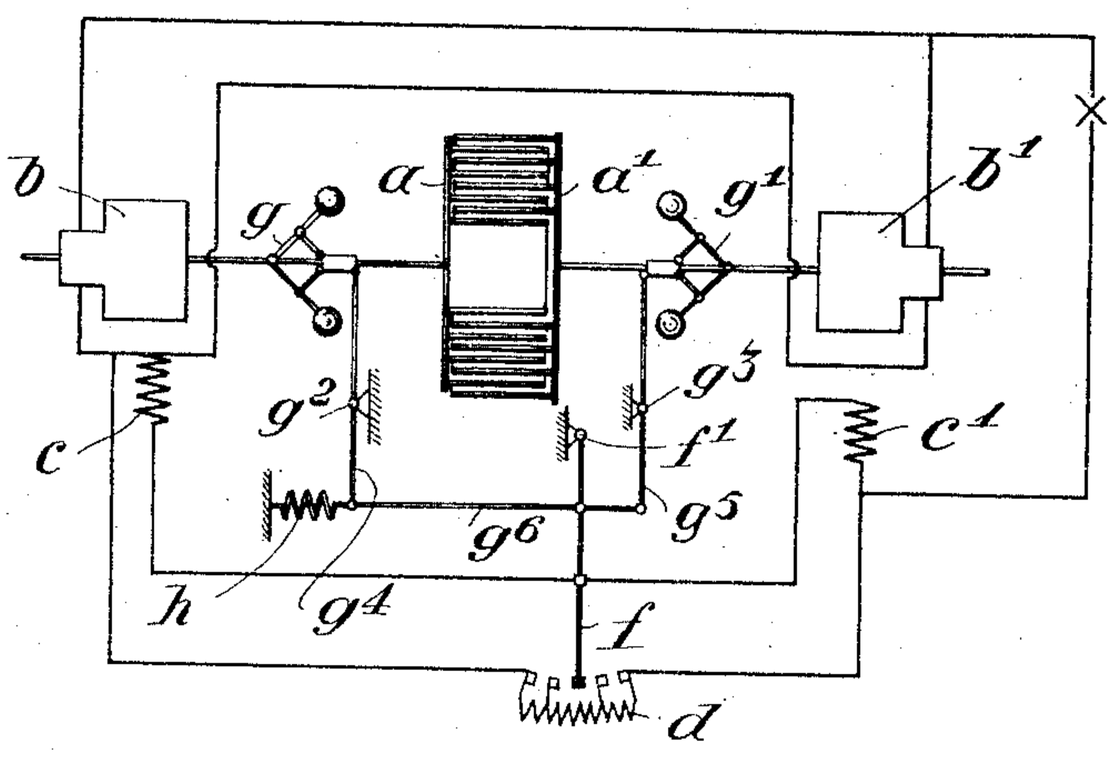


Fig: 2



Witnesses

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2 SHEETS—SHEET 2.

Fig. 3

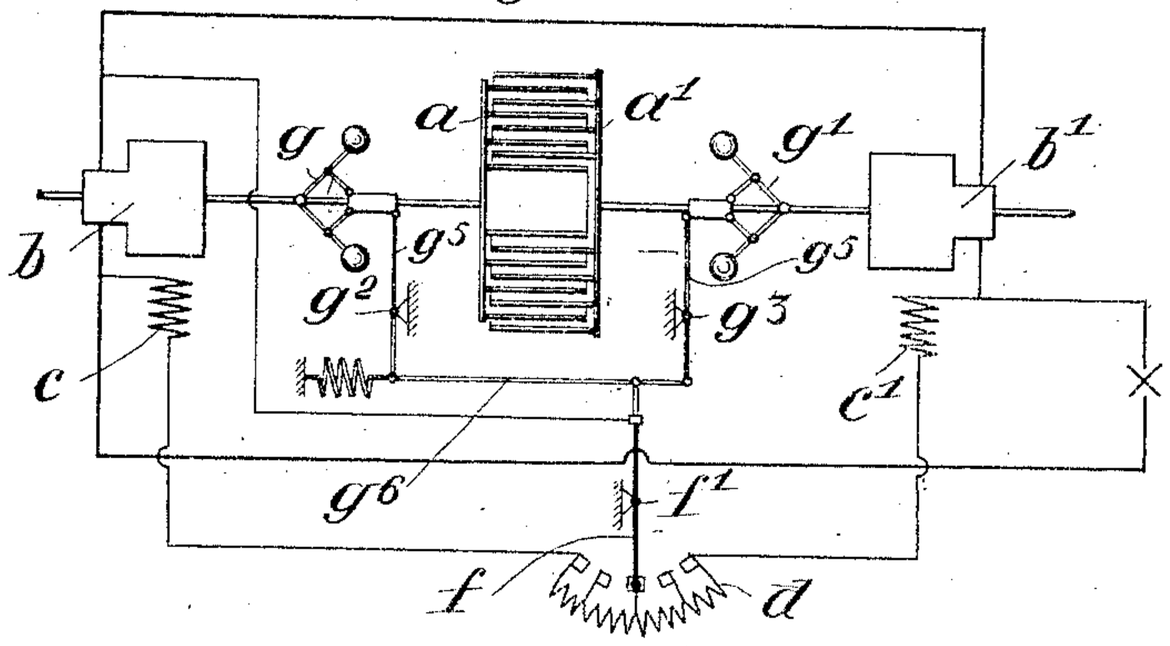


Fig. 4

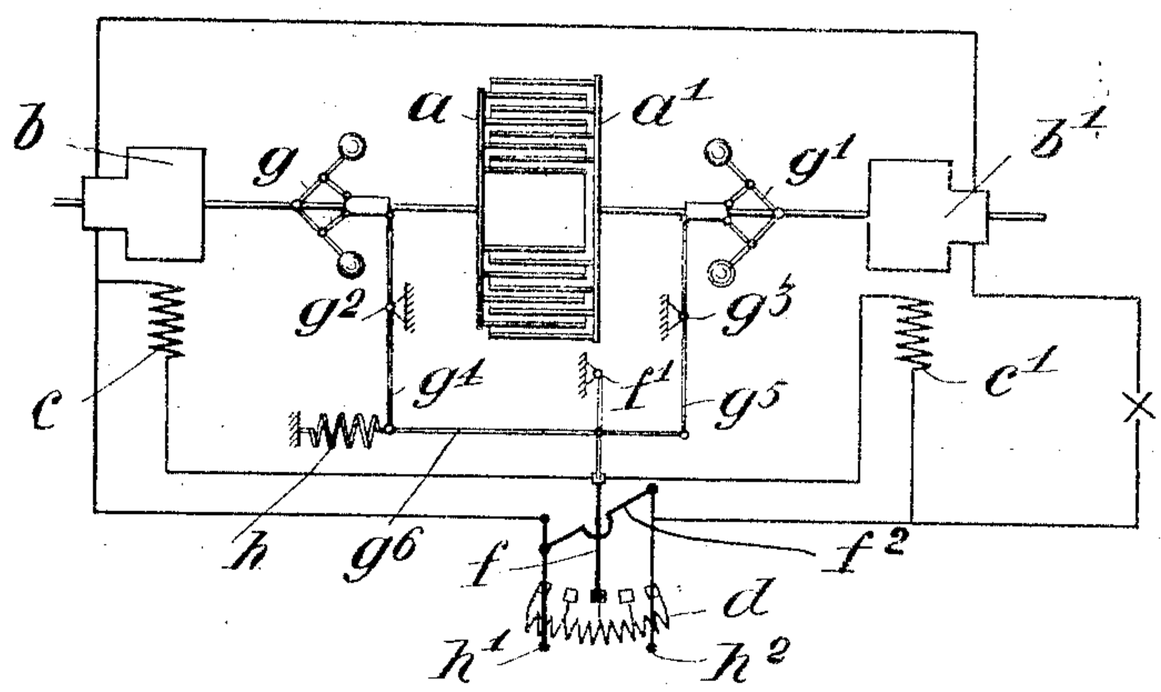


Fig. 5

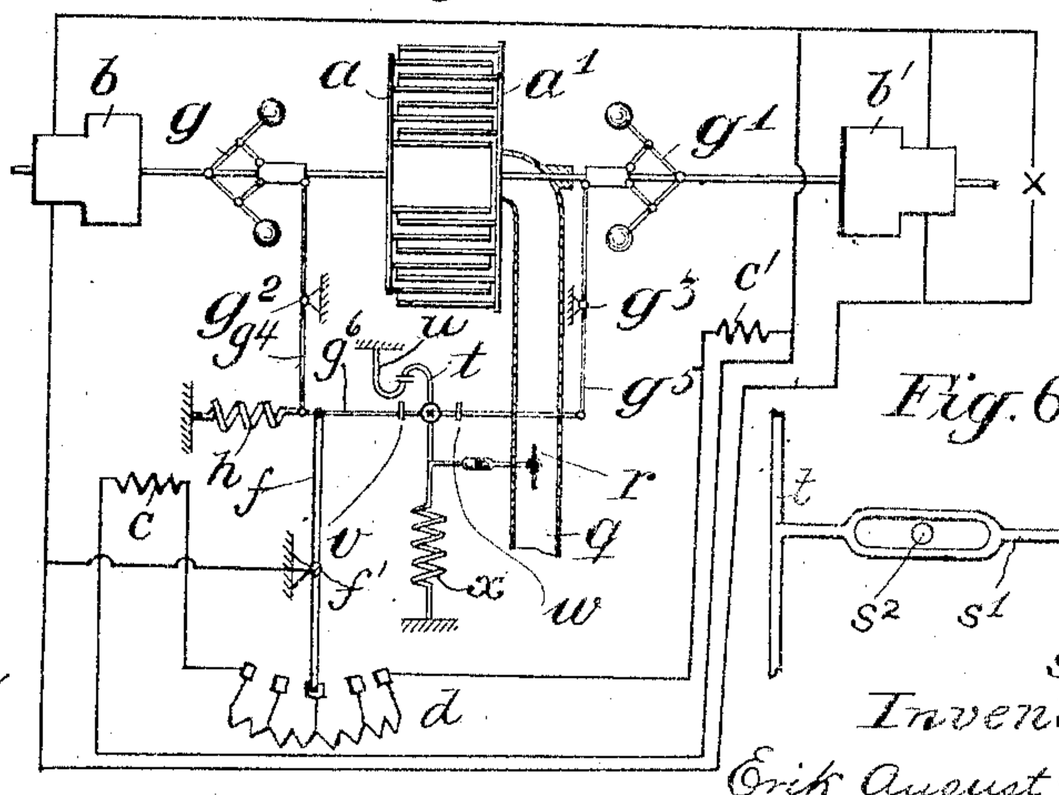
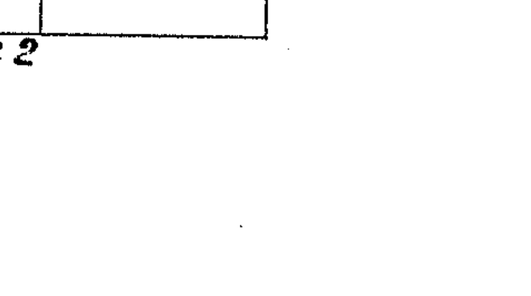


Fig. 6.



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UNITED STATES PATENT OFFICE.

ERIK AUGUST FORSBERG AND BIRGER LJUNGSTRÖM, OF STOCKHOLM, SWEDEN.

GAS-TURBINE.

970,204. Specification of Letters Patent. **Patented Sept. 13, 1910.**

Application filed April 13, 1907. Serial No. 367,955.

To all whom it may concern:

Be it known that we, ERIK AUGUST FORSBERG and BIRGER LJUNGSTRÖM, subjects of the King of Sweden, and residing at 8 Fleminggatan, Stockholm, Sweden, have invented certain new and useful Improvements in Gas-Turbines; and we do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same, reference being had to the accompanying drawings, and to letters or figures of reference marked thereon, which form a part of this specification.

In elastic fluid turbines one of the greatest constructive difficulties to be overcome is the great peripheral speed which is necessary for an economical utilization of the kinetic energy set free at the streaming out of the steam. A very good means for reducing these difficulties consists in constructing the turbine in the form of two systems rotating in opposite directions, each system consisting of one or more rows of vanes by which arrangement the necessary speed of each system is reduced to half of that speed which otherwise would be developed. Turbines of this kind have been carried out in practice but it has been difficult to regulate the speeds of both the rotating systems so that they will have practically the same value. Each system has, in order to overcome these difficulties, been connected to an electric generator, which generators have been allowed to work in parallel upon the same circuit. As far as generators for alternate currents and machines for direct currents are concerned an exact synchronism and often sufficient conformity in speed is attained. In machines for direct currents it is often desirable to get a greater exactness of the speed regulation without further means and besides it may sometimes be desirable to couple the machines in question in series instead of in parallel.

In the arrangement above mentioned an inconvenience will be encountered in that it will be necessary to regulate the electric tension by means of a shunt regulator to simultaneously alter the shunt resistance of both generators in the same manner, because inequality between the speeds of the systems would otherwise arise.

Turbines constructed in accordance with the principles above mentioned have also another inconvenience; for instance, if on account of damage to one generator one system of vanes is unloaded it can increase its speed to a dangerous extent, and in order to remove this inconvenience it is necessary to provide each system with an independent safety regulator intended to shut off the steam admission, if a certain speed is exceeded.

The present invention relates to an arrangement which attains firstly, the partial assurance of a speed which is as far as possible equal for both systems, whether the generators are provided with shunt or series magnetization or coupled together in parallel or in series, secondly, the partial possibility of varying the tension by means of magnetizing regulation without the necessity of controlling the magnetizing resistance of both generators for that purpose, and also the partial assurance that neither system can increase in speed above a certain degree, if any damage should occur to one or other generator or to its connecting conductors. Each system is provided with a speed regulator of any suitable construction, the regulators being mechanically connected to each other in such a manner as to counteract each other. The regulators remain in equilibrium as long as both systems have the same speed, but if the speed of the one system should be greater than that of the other system the equilibrium will be perturbed and the regulators will move. The movement caused thereby operates the contact arm of a resistance, regulating the admission of current to the field windings of the generators in such a manner that the magnetism of the generator running more rapidly is increased relatively to that running more slowly. The momentum of inertia necessary for the rotation of the generator running more rapidly is increased and the difference of speed between the systems and the generators can be kept within any limit depending upon the sensibility of the regulators and upon the nature of the resistance. The regulators themselves are shown in the

form of centrifugal regulators and this arrangement might be the most suitable in practice, but other kinds of regulators may be used. The regulators mentioned are in the following description called differential regulators.

If it is desired, as above mentioned, to attain the regulation of the tension of the generators by means of magnetizing regulation, a part of the resistance above mentioned can be formed as magnetizing resistance. Though the regulation on the first hand takes place only for the magnetizing of the one generator the differential regulator evidently takes care of the resistances for the several generators are distributed in such a manner that equality of speed is attained.

The invention is diagrammatically shown on the accompanying drawings in several forms, in which,

Figure 1 illustrates an arrangement of continuous current generators wound in shunt, and parallel connected. Fig. 2 illustrates dynamo machines connected in parallel and series wound. Fig. 3 illustrates an arrangement of electric generators connected in series and shunt wound. Fig. 4 illustrates an arrangement of generators connected in series and series wound, and Fig. 5 illustrates a form of differential regulator. Fig. 6 is a detail view of the valve operating mechanism.

Referring to Fig. 1, a and a^1 are the two steam turbine elements carrying the vane systems and rotating in opposite directions. The armatures b and b^1 of the electric generators are connected to these elements. c and c^1 are the field magnet windings of the generators, these windings being, as shown, parallel connected between the brushes of the machine. As long as the oppositely rotating turbine parts rotate with the same speed and no disturbing influences make themselves felt, the current is distributed equally from both generators, the two parts performing the same work, and requiring for this driving the same turning moments. If the moment should be reduced on the one side, for instance, on account of increased friction in the bearing, or on account of unequal heating, or the like, the speed of this part of the machine will diminish, whereby the electric tension induced in the generator driven by that part diminishes and a smaller proportion of the power is transmitted thereto. In such a case, which might when the difference of speed is very great, result in one side working as a motor and the other as a generator, the moment of the part rotating more rapidly is decreased in order to reduce the difference of speed. Even by this form of construction, *i. e.*, without the use of a differential regulator, it would be possible to get sufficient regulation of the speed for practical requirements. If a still greater exactness should be considered necessary, especially in order to keep the speeds equal during starting, when the magnetism is inconsiderable, the differential regulator herein referred to acts upon the magnetization, and when desired may exert a braking action.

The differential regulator is here shown as composed of two centrifugal regulators, g and g^1 of usual construction counteracting each other and stabilized by the spring h. The action of that regulator rotating with the greater speed becomes at different speeds of the vane systems predominant, and, by means of the rods g^4 and g^5 pivoted at g^2 and g^3 respectively connected by the bar g^6 correspondingly displaces the contact arm f of a shunt rheostat d, said arm f being pivoted at f^1. The field magnetization is consequently increased for the dynamo rotating with the higher speed and reduced for the dynamo rotating with the lower speed. The difference between the two tensions induced by the dynamo machines is hereby still more increased so that a greater stability is attained. The difference of speed may by this arrangement be limited within any desired degree.

Fig. 2 shows an arrangement of dynamo machines parallel connected and wound in series. Both magnet windings c and c^1 are here connected in series, the regulating resistance d being connected in parallel to the same. The connecting conductor between the magnet windings is connected to the contact arm f so that the resistance included in parallel with one of the magnet windings will be increased by the movement of this arm and the other will be reduced, so that the magnetization is reinforced in the machine having the increased speed and is weakened in the machine having the reduced speed.

Fig. 3 shows an arrangement of generators connected in series and shunt wound. The armatures of the machines are connected in series in the usual manner, the magnet windings of the same being included between the brushes of their appertaining armatures. The current passing through the armatures is under all circumstances the same, and can, consequently, not aid in the regulation of the speed, this being completely left to the magnetization currents. If the speed of one vane system, for instance a^1, increases, and the speed of the system a is reduced, that part of the total tension induced by a^1 is increased, and that of a is reduced. The magnet winding c^1 will then be traversed by a reinforced and the winding c by a weakened magnetizing current, by reason of which the moment at a^1 is increased and at a

reduced, so that the regulation of the speed takes place in the manner described. In order, however, that this regulation may be effective, it is necessary that the iron of the magnet be not too highly saturated, in which case the differences between the speeds may become too great. In order to attain an effective regulation in such a case, the differential regulator is used, which regulator may, even in other cases, be suitable for attaining an increased stability, as above mentioned. Its function is sufficiently described above, so that its action will be evident from an inspection of Fig. 3.

Fig. 4 shows an arrangement of generators connected in series and wound in series. The regulation in this case is left entirely to the differential regulator acting in the manner previously described. It is, however, possible to use other arrangements than those above mentioned.

From the above it will be clear to every specialist what to do in a given case to get the best results, and under what circumstances the arrangement of the differential regulator is necessary, or only suitable or advantageous. The magnet windings may thus in each case, independent of the machines connected in parallel or in series to which they appertain, be connected in parallel or in series with each other, the regulating resistances being in the former case connected in series, and in the latter case in parallel to the several windings.

The machines may, in order to regulate the tension, be provided in the ordinary manner with magnet regulating resistances. Such resistance may consist of resistances of known construction and be connected to both or to one of the magnetic windings, it being practicable to use parts of the differential regulating resistances for this purpose. Such an arrangement is shown in Fig. 4.

The conducting wires leading to the resistance d are not directly connected thereto, but are joined to contact arms h^1 and h^2 intended to be acted upon in any suitable manner. If it is desired to move the contact arms simultaneously they are connected mechanically by a rod, f^2. It is, however, not necessary that both of the arms h^1 and h^2 be used, as one is sufficient. The differential regulator will, in this case operate to regulate the tension.

It is evident that in compound wound machines the devices mentioned above may be used unaltered.

In all the forms cited above it may be suitable to provide any device by means of which it is possible to prevent one or both vane systems from increasing their speed too much, should the system, from any reason, get out of order. In such case, as it is not evident beforehand which of the systems will race, the usual speed regulator is consequently not suitable for the purpose, but each vane system must be provided with a regulating device. Such an arrangement is shown in Fig. 5.

The inlet pipe q is provided with a cut-off valve r (Fig. 6) centrally pivoted on a pin r^1 journaled in the pipe. The pin r^1 carries a pinion r^2 which is engaged by a segmental rack s carried by a lever s^1 slidably mounted on a fulcrum s^2 and connected with an operating rod t, which normally rests on a support u and holds the valve in its open position. The arm g^6, connected with the differential regulator, is provided with two abutments v and w which, in case of too great difference of speed between the vane systems a and a^1, are adapted to disengage the rod t from its support whereupon said rod is actuated, by a spring or weight x, and the lever s^1 caused to rock and close the valve r so that the steam inlet is instantly cut off.

We claim:—

1. In a steam or gas turbine, the combination with two oppositely rotating vane systems and a direct current electric generator connected to each system connected to the same circuit; of counteracting speed regulators connected to the systems, the movement of the regulators changing at a variance of speed between the systems, a circuit regulator operated by the speed regulators to regulate the exciting circuit to the field magnets of the generators in proportion to the different speeds of the systems.

2. In a steam or gas turbine, the combination with two oppositely rotating vane systems and a direct current electric generator connected to each system connected to the same circuit; of counteracting speed regulators connected to the systems, the movement of the regulators changing at a variance of speed between the systems, a variable electrical resistance inserted in the exciting circuit to the field magnets and controlled by the regulators and thereby automatically regulating the exciting circuit to the field magnets of the generators.

3. In a steam or gas turbine, the combination with two oppositely rotating vane systems and a direct current electric generator connected to each system connected to the same circuit; of a speed regulator for each system, movable means to connect the regulators, a variable resistance in circuit with the field magnets of the generators and controlled by said movable means and a steam throttling device actuated by said movable means.

4. In a steam or gas turbine, the combination with two oppositely rotating vane systems and a direct current electric gen-

erator connected to each system connected to the same circuit; of counteracting speed regulators and means to connect them, said means actuated by the regulators, and a variable resistance in circuit with the field magnets of the generators controlled by said means.

In testimony, that we claim the foregoing as our invention, and have signed our names in presence of two subscribing witnesses.

ERIK AUGUST FORSBERG.

BIRGER LJUNGSTRÖM.

Witnesses:

CARL FRIBERG.

E. RÅBERG.