

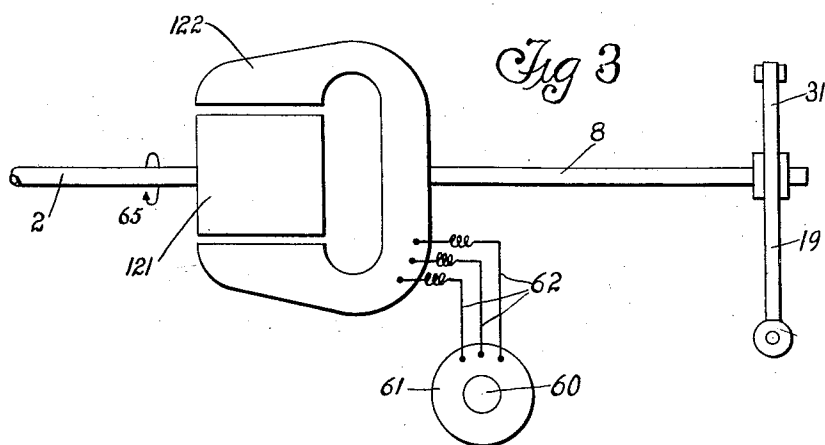
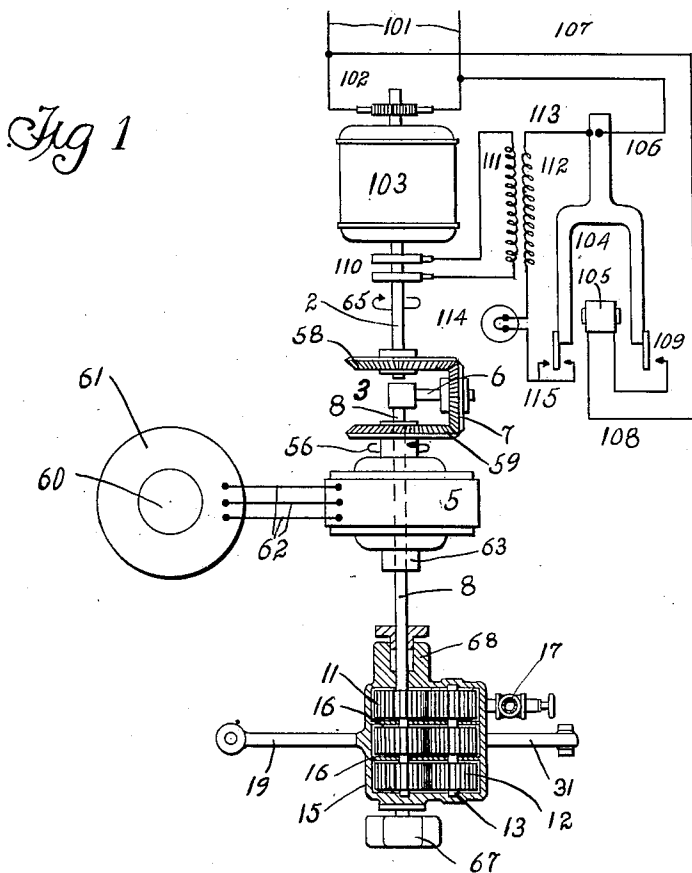
Nov. 25, 1930.

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1,783,157

SYSTEM OF SPEED GOVERNING FOR PRIME MOVERS

Original Filed May 16, 1919 2 Sheets-Sheet 1



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Fig. 2:

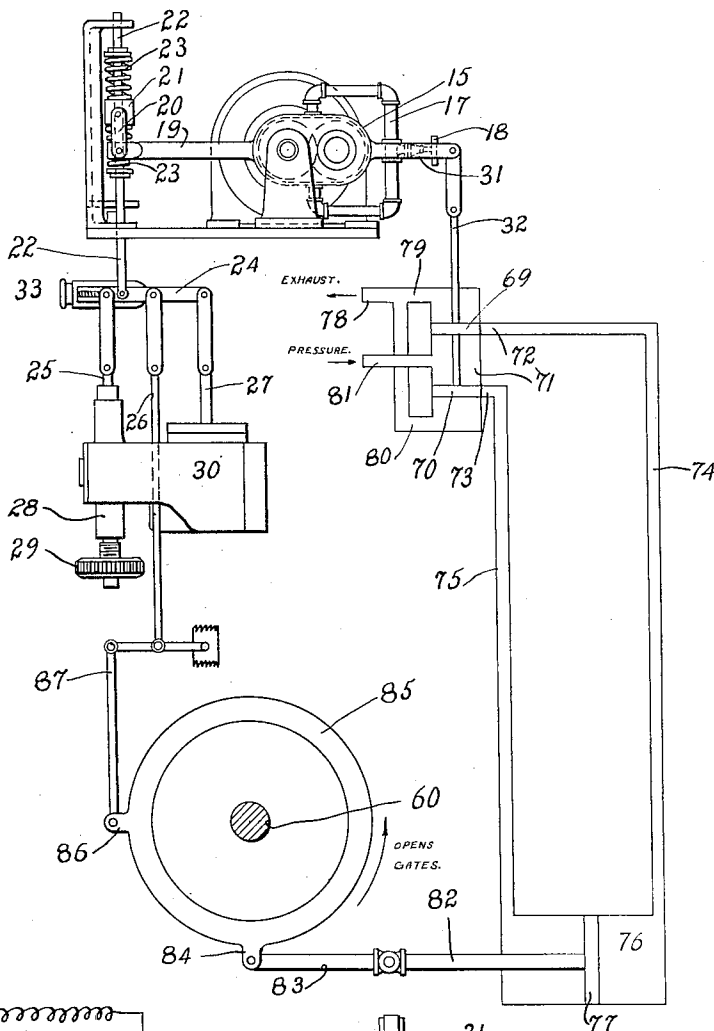
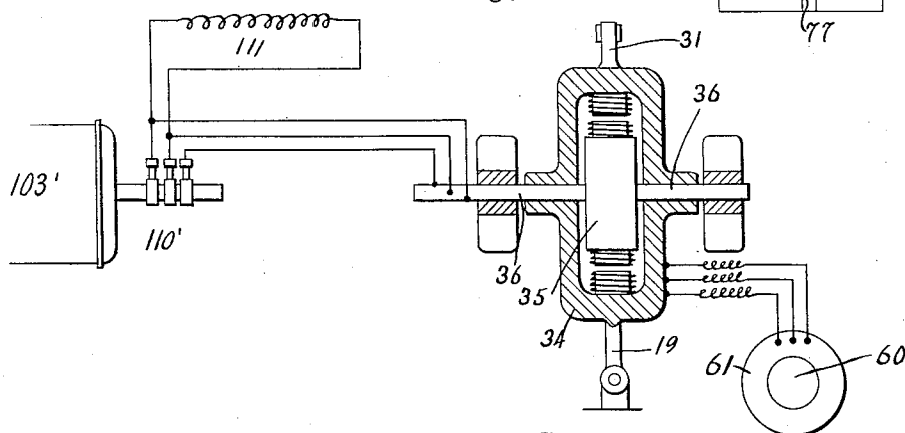


Fig. 4:



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UNITED STATES PATENT OFFICE

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SYSTEM OF SPEED GOVERNING FOR PRIME MOVERS

Application filed May 16, 1919, Serial No. 297,552. Renewed January 19, 1929.

The principal object of my invention is to provide new and improved apparatus and method for governing the speed of a rotary prime mover for power purposes such as a hydraulic turbine. In one aspect my invention involves the employment of an independent frequency standard and an automatic comparison between the same and the speed of the turbine, and an automatic adjustment of the turbine gates in accordance with this comparison. Heretofore the common method of governing a hydraulic turbine has been by means of a centrifugal governor. Aside from the disadvantages due to its mechanical complication, the effects of friction, fatigue of springs, wear of joints, etc. directly affect the speed of the turbine; and any variation in weight of the fly balls, etc. or of the spring characteristics also affects the speed. Moreover, the necessity for rotating the governor at a high speed by a mechanical drive from the main shaft of the turbine, the difficulty of maintaining lubrication in the rotating mechanism, the necessity for shutting down the rotating system for examination of parts of the governor, the effect of small changes in friction of the governor on the normal speed of the turbine,—all these are difficulties that attend the use of centrifugal governors in this connection. By my invention, I employ an independent frequency standard of simple character, whose periodic time is unaffected by the incidents mentioned above as influencing the action of centrifugal governors.

The governing of hydraulic turbines is a problem of particular difficulty as compared to other rotary machines on account of the effects of the inertia of the water which require special means not needed on governors of steam machinery and other motors using fluids having low density. The particular examples of my invention described in this specification are adapted for governing hydraulic turbines. My invention may be embodied in various forms, but in the following specification, I have given a diagram of one particular embodiment thereof and two modifications, and I now proceed to a description of the particular systems shown in the draw-

ings. It will be understood that various modifications may be made within the scope of my invention.

Referring to the drawings, Fig. 1 is a diagram in plan view showing how the comparison of the turbine speed with a frequency standard may be effected, and Fig. 2 is a diagram in elevation showing how the result of the comparison may be made to actuate the turbine gates.

Figs. 3 and 4 are diagrams illustrating modifications.

The direct current supply mains 101 lead to the direct current motor end 102 of a rotary converter 103, whose alternating current generator end is 110. The tuning fork 104 is kept in vibration at its natural frequency by the magnet 105 receiving current through the conductors 106, 107 and 108 and interrupter 109. From the alternating current generator end 110 of the rotary converter 103, the current is taken to the primary 111 of a transformer whose secondary 112 is in circuit with lamp 114 and double interrupter 115 through conductor 113. When the alternating current frequency from converter 103 is the same as the frequency of the fork 104, the interrupter 115 throws the load of the lamp 114 on the converter 103 for two brief intervals in each cycle. The magnitude of this load depends on the voltage at the moment of contact at 115, and hence for slight variations of direct current voltage at 102, there is a slight change of phase relation between the alternating current and the fork, but the frequency remains substantially the same. If there is any leading in phase of the current produced by the generator which has a tendency to excessive speed, the difference in phase between the current and the tuning fork will cause a change in the resistance of the circuit, which will act as a brake on the motor generator tending to place the current in phase with the tuning fork. By this means the motor generator is kept in synchronism with the tuning fork under all conditions, and the speed of its rotor will thus be made absolutely constant.

The shaft 2 is rotated by the direct current motor end of the converter 103 in the direc-

tion of the arrow 65 and carries with it the bevelled gear wheel 58. The main shaft 60 of the turbine drives a small alternating current generator 61, from which conductors 62 lead to the synchronous motor 5 whose rotor is fixed on the sleeve 63, rotating in the direction of the arrow 56 and carrying the bevelled gear 59 therewith. Within the sleeve 63 is a shaft 8 and between the two bevelled gears 58 and 59 it carries a radial arm 6 with a loose pinion 7 thereon in engagement with both gears 58 and 59. It will be seen that the gears 58, 59 and 7 constitute a differential gear mechanism which is designated generally on the drawing by the reference numeral 3.

The shaft 8 extends through a bushing 68 into a casing 15, which has three compartments separated by partitions 16. In each compartment the shaft 8 carries a gear wheel 11 in mesh with an associated gear wheel 12 on the counter shaft 13. These intermeshing gears constitute the impelling elements of a rotary hydraulic pump. The casing compartments communicate with one another and the casing is entirely filled with oil. A bypass conduit 17 is provided with a restricted passage adjustably controlled by the valve 18. When the shaft 8 rotates relatively to the casing 15, the gears will rotate and the mechanism will act as a pump to drive the oil one way or the other through the bypass conduit 17. The casing 15 is not fixed but swings around shaft 8 and has two projecting arms 19 and 31 projecting therefrom. The arm 31 is connected to a valve rod or stem 32 carrying the two piston valve members 69 and 70 within the valve chamber 71. The conduit 81 admits pressure fluid from any convenient source to the valve chamber 71 between the valves 69 and 70, and the conduit 78 by its branches 79 and 80 serves to exhaust the fluid from either end of the valve casing 71. The two ports 72 and 73 are connected by respective conduits 74 and 75 with the ends of the hydraulic cylinder 76 which contains the piston 77. The piston rod 82 and connecting rod 83 make connection with the arm 84 by which the ring 85 may be rotated around the main turbine axis. This ring 85 is connected to the turbine gates and as shown in the diagram, a counterclockwise movement opens the gates.

If desired another valve may be provided, relay fashion, between the valve 69—70 and the cylinder 76 but for simplicity in the diagram, this is not shown.

In addition to the arm 84, the gate control ring 85 also carries an arm 86 connected by a link 87 with the valve restoring rod 26, which is pivotally connected with the floating lever 24. By means of the rod 27 another point of the floating lever 24 is connected to the piston within the dash pot 30.

The arm 19 extending from the casing 15

oppositely to the arm 31 is connected by links 20 with the block 21 which slides up and down on the rod 22, between the springs 23. This rod 22 is connected to another point of the floating lever 24.

Within the casing 28 there is a spring tending to hold the rod 25 at a certain normal position relative to the casing 28 or to restore it to that position when it is displaced. This rod 25 is also connected to the floating lever 24, the point of the connection being adjustable along the length of the lever 24 by means of the hand wheel 33. The normal position of the spring casing 28 may be adjusted by rotation of the gear wheel 29.

The normal steady state of the apparatus when the turbine is running without variation of speed is for the shafts 2 and 8 to rotate with equal speeds in opposite directions as indicated by the arrows 56 and 65.

Suppose that an increase of load on the turbine tends to slow it down a trifle. This will cause the generator 61 to turn correspondingly slower for a moment and the synchronous motor 5 will likewise slow down. The balance between the oppositely rotating gear wheels 58 and 59 will be momentarily lost and the shaft 8 will rotate differentially in the direction of the arrow 65. The rotation of the shaft 8 will force oil through the by-pass 17, and because of the restricted passage a drag will be exerted on the casing 15 tending to make it rotate in the same direction. Accordingly the arm 31 will be rocked down as viewed in Fig. 2. Similarly a lightening of the load on the turbine will result in an upward movement of arm 31.

Whenever the casing 15 is rotated a small amount displacing the slide block 21, the end of the right hand extension 31 is given a corresponding motion which moves the pilot valve. This admits pressure, either by means of an intermediate relay or directly, to the main valve controlling the operating cylinder of the turbine, which in turn moves the turbine gates. The motion of the turbine gates is communicated to the restoring rod 26, the middle rod connected to the smaller lever 24 and the first effect is to move the left hand rod 25 within the spring case 28 against the pressure of the spring, the lever 24 turning upon the right hand end as a fulcrum.

Whenever there is any quick change in speed of the main turbine unit there will be a corresponding quick motion of the extension 31 of the rotary dash pot. This will raise or lower rod 32 connected to the pilot valve. The opening of the pilot valve will cause through suitable relays a corresponding quick motion of the turbine gates. The gates in turn, through the restoring connection 26 will move the lever 24 at its point of connection with the link joining it to rod 26.

During this quick motion the right hand end of lever 24 where it is joined to the

link from rod 27 will act as a fulcrum since rod 27 will not have time to move within the dash pot 30. The result will be that the left hand end of lever 24 will be moved upward or downward carrying with it rod 25, and compressing or extending the springs within the spring case 28. The motion of the left hand end of lever 24 will raise or lower the rod 22, the effect of which will be to restore the left hand end of extension 19 to its normal position and at the same time to restore the right hand end of extension 31 to normal position, closing the pilot valve.

Any change in speed of the main unit will, therefore, cause a limited movement of the turbine gates, but there will be no further motion of the gates unless the speed of the main unit continues to change. So far the operation is complete, but is not entirely satisfactory for the reason that considerable changes of speed will be necessary to cause a change in the position of the turbine gates. The effect would be to permit too great a speed variation in the main unit between no load and full load.

Unfortunately, the nature of the medium acting within the hydraulic turbine and its penstock will not permit an instantaneous regulation of speed to any smaller degree of variation than the action just described will provide. The inertia of the column of water occupying the turbine passages and penstock does not permit a very rapid opening or closing of the turbine gates since such a rapid gate motion would cause a severe rise or fall of pressure at the entrance to the turbine. This rise or fall of pressure tends to counteract the control imposed by the gate movement. For example, if the turbine gates are opened too quickly the inertia of the water prevents its immediately issuing through the enlarged gate openings at the original velocity. The effect is to reduce the pressure producing the flow through the turbine, and if the gate motion is too rapid this reduction in pressure may more than offset the increase in the quantity flowing, so that instead of the governor causing an increased output of power from the turbine an actual reduction would be the result. It is seen that the action of the restoring connection 26 continually tends to oppose the motion of the turbine gates, and limits its motion so as to permit a considerable variation of speed of the main unit at times of quick changes of load on the generator, and it is clear that this variation of speed is necessary in any water power machine.

In spite of the above considerations there is nothing to prevent a gradual return of the speed to the normal value or to within any desired degree of variation from the normal value, it being merely necessary to make this adjustment sufficiently slow to allow for

the gradual acceleration or retardation of the water column filling the penstock and turbine passages. This is accomplished in this governor by means of dash pot 30 and the spring case 28. The springs within this case will slowly move the rod 25, causing the lever 24 to pivot about the pin connecting it with 26—the rod 27 controlling the speed of this motion by means of dash pot 30. The result of this action is the moving of rod 22 toward its normal position. By means of a small hand-wheel 33 the point of connection between the lever and rod 25 may be shifted with respect to the pin connecting 22 with 24. If these two points are brought together the speed of the main unit may be brought back to normal for all positions of the turbine gates. If a slight difference in position is permitted any desired drop in speed between no load and full load may be provided. This no load to full load drop is used to secure the proper automatic sharing of load between a number of alternators running in parallel. The amount of this allowance is adjustable by means of hand wheel 33.

The position of the spring case 28 is adjustable as already mentioned. The effect of adjusting this spring case is to impose on the unit a tendency toward a constant difference in speed between the unit and the standard speed motor generator. When the unit comprises an alternator running in parallel with other similar units, it will continue to run in step with the other units, and the adjustment of the spring case will merely have the effect of causing the unit to assume a larger or smaller share of the station load.

In the modification shown in Fig. 3, the bevel gear 58 on the shaft 2 of Fig. 1 is replaced by the short circuited rotor 121 of an induction motor whose stator 122 is supplied with alternating current from the generator 61 on the turbine shaft 60. The rotating field of the stator 122 will normally be substantially in step with the rotor 121 so that no torque will be transmitted from one member to the other, but a tendency to change of speed of the generator 61 will give a difference of speed between the rotor 121 and the field in the stator 122 and the latter will tend to rotate. The shaft 8 is directly connected to stator 122 and arms 19 and 31 instead of as in Fig. 1. The operation will be readily understood from the description given in connection with Fig. 1.

In the modification of Fig. 4, it is proposed to replace the differential gear 3, the synchronous motor 5 and the rotary dash pot by the following device: This device consists of a swinging frame capable of rotating through small angles, which takes the place of the rotary dash pot casing 15. This frame carries the extensions 19 and 31 and performs the same functions as the rotary dash pot

casing 15 in the above device. The rest of the mechanism, namely, pilot valve 32, lever 24 and the mechanism connected to it all remain as described for Fig. 1.

It is proposed to place in the rotatable or swinging frame mentioned a ring of coils through which is passed the current from the small generator on the main unit shaft mentioned above in connection with the first device. The current passing through these coils is therefore in synchronism with the main unit generator. The coils are to be so arranged that a rotating field will be produced. This frame is marked 34 in Figure 4, and is shown as carrying extensions 19 and 31 corresponding to the extensions having the same numerals in the preceding figures.

Within the frame 34 is a stator 35 mounted on a fixed shaft 36 clamped in suitable supports. The casing 34 is free to rotate or to oscillate on the shaft 36. The stator carries a ring of coils through which passes the current of constant frequency from the standard speed motor generator 103'. The coils of the stator 35 are arranged to give a rotating field which will have constant rotational speed. The coils of the frame 34 as mentioned above are also arranged to produce a rotating field, the speed of rotation of which will be equal to that of the main unit generator. If these two speeds coincide there will be no tendency for frame 34 to move and it will remain in normal position. If, however, owing to a change of speed of the main unit, a difference in speed should occur, frame 34 will tend to rotate in much the same manner as the rotor of an induction motor. This motion will be resisted by the springs 23 and there will result a deflection of the slide block 21.

By designing this electrical device with suitable characteristics the deflection can be made to vary in a suitable manner with respect to the difference in frequency of the two currents. The electrical device is thus seen to give an action equivalent to that of the dash pot and differential gear mechanism first described. The remaining portion of the governor action will be exactly similar to that explained for Fig. 1.

The new governor obviates the use of a complicated rotating mechanism such as is necessary in the centrifugal flyball head of governors heretofore used, avoids the use of a mechanical drive from the main shaft of the turbine to the governor spindle and enables the speed of either one unit or all the units of the power station to be brought to an absolute speed and maintained at that speed. The new governor can thus be applied to an entire system of power plants so as accurately to maintain a constant frequency over the entire system. Other attempts have been made to eliminate the me-

chanical drive for the governor head, one method comprising the substitution for the usual flyballs of large flyballs mounted directly on the main unit shaft. This, however, introduces more serious difficulties than those which it is intended to avoid. The present invention not only eliminates the drive, but dispenses with the centrifugal governor head also. Among other incidental advantages of the new governor, the possibility of locating it at any convenient point should be mentioned. The shaft 2 rotating at constant speed may be used to time other units for instance the control means shown at one end in Fig. 1 may be duplicated at the other end or a plurality of fields like 35 might be supplied from the generator 103' of Fig. 4. The principle of the invention is not confined to the particular systems shown and described but is intended to cover such modifications thereof as fall within the scope of the appended claims.

The modifications shown in Figs. 3 and 4 and not specifically claimed in this case are claimed in my co-pending application Serial No. 371,349 for system of speed governing, filed April 5, 1920.

I claim:—

1. In combination, a prime mover having a rotating element, an electrical circuit having a frequency proportional to the speed of said rotating member, an oscillating element having a given period or frequency of oscillation, means for comparing the frequency of oscillation of said oscillating element with the frequency of said electrical circuit, and means for controlling the speed of said rotating element in accordance with differences of said frequencies.

2. A governing system for a prime mover driving an alternating current generator for a power system, comprising a control valve for said prime mover, and means for effecting actuation of said valve automatically in accordance with variations in frequency from a predetermined value, said means including mechanism having an oscillating member and means for effecting continuous oscillation of said member at a substantially constant rate over a given period of time.

3. A governing system for a prime mover driving an alternating current generator for a power system, comprising a control valve for said prime mover, and means for effecting actuation of said valve automatically in accordance with variations in frequency from a predetermined value, said means including an element continuously rotated at a speed corresponding to the system frequency, an element continuously oscillated at a predetermined rate to provide a predetermined standard for frequency comparison, means co-operating with said rotating and oscillating elements whereby variations in the system frequency from said standard may be de-

ected, and means for effecting operation of said control valve in accordance with the detected variation:

4. A governing system for a prime mover driving an alternating current generator, comprising a control valve for said prime mover, and means for effecting actuation of said valve in accordance with a difference of frequency between the generator current and a standard value of frequency and to adjust the power of the prime mover until its speed is brought back to that corresponding to the standard value of frequency whereby the speed of the prime mover may be brought back to normal or to any predetermined variation from normal for all positions of the turbine gates, said means including electrical instrumentalities inherently responsive to frequency for determining said standard value and adapted to be normally operative even during continued variation from said standard value.

5. A governing system for a prime mover driving an alternating current generator, comprising a control valve for said prime mover, and means for effecting actuation of said valve in accordance with a difference of frequency between the generator current and a standard value of frequency and to adjust the power of the prime mover until its speed is brought back to that corresponding to the standard value of frequency whereby the speed of the prime mover may be brought back to normal or to any predetermined variation from normal for all positions of the turbine gates, said means including electrical instrumentalities inherently responsive to frequency for determining said standard value and adapted to be normally operative even during continued variation from said standard value and a member deflectable only through a limited angular extent, whereby when said deflectable member is in its maximum deflected position said means is adapted to be operative even though said continued variation from said standard frequency is had.

6. A governing system for a prime mover driving an alternating current generator, comprising a control valve for said prime mover, and means for effecting actuation of said valve in accordance with a difference of frequency between the generator current and a standard value of frequency and to adjust the power of the prime mover until its speed is brought back to that corresponding to the standard value of frequency whereby the speed of the prime mover may be brought back to normal or to any predetermined variation from normal for all positions of the turbine gates, said means including electrical instrumentalities inherently responsive to frequency for determining said standard value and adapted to be normally operative even during continued variation from said

standard value and a restoring mechanism for said valve adapted to be operative upon any movement thereof including movements during said continued variation from said standard value of frequency.

7. A governing system for a prime mover driving an alternating current generator, comprising a control valve for said prime mover, and means for effecting actuation of said valve in accordance with a difference of frequency between the generator current and a standard value of frequency and to adjust the power of the prime mover until its speed is brought back to that corresponding to the standard value of frequency whereby the speed of the prime mover may be brought back to normal or to any predetermined variation from normal for all positions of the turbine gates, said means including electrical instrumentalities inherently responsive to frequency for determining said standard value and adapted to be normally operative even during continued variation from said standard value and a member deflectable in opposite directions from a predetermined neutral point, said member, irrespective of the generator load, being normally positioned at said point providing the generator frequency is the same as the standard frequency.

8. A governing system for a prime mover driving an alternating current generator, comprising a control valve for said prime mover, and means for effecting actuation of said valve in accordance with a difference of frequency between the generator current and a standard value of frequency and to adjust the power of the prime mover until its speed is brought back to that corresponding to the standard value of frequency whereby the speed of the prime mover may be brought back to normal or to any predetermined variation from normal for all positions of the turbine gates, said means including electrical instrumentalities inherently responsive to frequency for determining said standard value and adapted to be normally operative even during continued variation from said standard value and an oscillating member for determining the standard value of frequency.

9. A governing system for a gate controlled hydraulic turbine driving an alternating current generator, comprising a gate operating fluid actuated servo-motor having a fluid distributing valve and a pilot valve therefor, and means for effecting actuation of said distributing valve in accordance with a difference of frequency between the generator current and a standard value of frequency and to adjust the power of the prime mover until its speed is brought back to that corresponding to the standard value of frequency whereby the speed of the prime mover and its generator may be brought back to normal or to any predetermined variation from normal for all positions of the turbine

gates, said means including electrical instrumentalities inherently responsive to frequency for determining said standard value, primary restoring mechanism operative directly on said distributing valve upon movements of said servo-motor, and secondary restoring mechanism operative on said pilot valve to effect further restoring action on said distributing valve.

10 10. A governing system for a gate controlled hydraulic turbine driving an alternating current generator, comprising a gate operating fluid actuated servo-motor having a fluid distributing valve and a pilot valve
15 therefor, and means for effecting actuation of said distributing valve in accordance with a difference of frequency between the generator current and a standard value of frequency and to adjust the power of the prime mover
20 until its speed is brought back to that corresponding to the standard value of frequency whereby the speed of the prime mover and its generator may be brought back to normal or to any predetermined variation from normal
25 for all positions of the turbine gates, said means including electrical instrumentalities inherently responsive to frequency for determining said standard value, primary restoring mechanism operative directly on said
30 distributing valve upon movements of said servo-motor, secondary restoring mechanism operative on said pilot valve to effect further restoring action on said distributing valve and a member deflectable within an angular
35 extent of less than 180°, and said means being normally operative even when said member is in its maximum deflected position which might be brought about by a continued variation in frequency from said standard value.

40 11. A governing system for a gate controlled hydraulic turbine driving an alternating current generator, comprising a gate operating fluid actuated servo-motor having a fluid distributing valve and a pilot valve
45 therefor, and means for effecting actuation of said distributing valve in accordance with a difference of frequency between the generator current and a standard value of frequency and to adjust the power of the prime
50 mover until its speed is brought back to that corresponding to the standard value of frequency whereby the speed of the prime mover and its generator may be brought back to normal or to any predetermined variation
55 from normal for all positions of the turbine gates, said means including electrical instrumentalities inherently responsive to frequency for determining said standard value, primary restoring mechanism operative directly on said distributing valve upon movements of said servo-motor, and secondary restoring mechanism operative on said pilot valve to effect further restoring action on said distributing valve, said secondary restoring
60 mechanism including a dash-pot or equivalent

means for limiting the secondary restoring action to a slow rate relatively to the primary restoring action.

12. In a governing system for a hydraulic turbine the combination with gate operating means, of means for moving said operating means in opposite directions comprising a control member having a normal intermediate position corresponding to normal speed, a fluid pump having its speed varying with
75 variations in the speed of the turbine so as to develop fluid pressure dependent upon the speed of the turbine, a connection between said pump and said control member adapted to actuate said control member so that it will
80 move in either direction from said normal intermediate position according to the speed of the turbine, and connections between said control member and said operating means for moving the latter in response to movements
85 of said control member.

13. In a governing system for a hydraulic turbine the combination with gate operating means, of means for moving said operating means in opposite directions comprising a control member having a normal intermediate position corresponding to normal speed, a fluid pump having its speed varying with
95 variations in the speed of the turbine so as to develop fluid pressure dependent upon the speed of the turbine, a connection between said pump and said control member adapted to actuate said control member so that it will
100 move in either direction from said normal intermediate position according to the speed of the turbine, and connections between said control member and said operating means for moving the latter in response to movements of said control member, and restoring mechanism for moving said member in response to the movements of said gate operating means.

14. In a governing system for a hydraulic turbine the combination with gate operating means, of means for moving said operating means in opposite directions comprising a control member having a normal intermediate position corresponding to normal speed, a fluid pump having its speed varying with
110 variations in the speed of the turbine so as to develop fluid pressure dependent upon the speed of the turbine, a connection between said pump and said control member adapted to actuate said control member so that it will
115 move in either direction from said normal intermediate position according to the speed of the turbine, and connections comprising a pilot valve and fluid pressure mechanism between said control member and said operating means for moving the latter in response to movements of said control member, and restoring mechanism for moving said member
120 in response to the movements of said gate operating means.

15. In a governing system for a hydraulic turbine the combination with gate operating

means, of means for moving said operating means in opposite directions comprising a control member having a normal intermediate position corresponding to normal speed, a gear pump having an adjustable bypass opening and its speed varying with variations in the speed of the turbine so as to develop fluid pressure dependent upon the speed of the turbine, a connection between said pump and said control member adapted to actuate said control member so that it will move in either direction from said normal intermediate position according to the speed of the turbine, and connections comprising a pilot valve and fluid pressure mechanism between said control member and said operating means for moving the latter in response to movements of said control member, and restoring mechanism for moving said member in response to the movements of said gate operating means.

16. The method of governing the speed of a prime mover which consists in driving an independent electric motor with a tendency to excessive speed, automatically checking its speed by a frequency standard to correspond to a standard speed, combining its speed with that of the prime mover in a differential speed and reaction apparatus, and governing the power supply according to the differential speed and the reaction caused thereby in said apparatus and mechanically transmitting an operating force directly from said apparatus.

17. The method of governing the speed of a hydraulic turbine which consists in driving an independent electric motor with a tendency to excessive speed, automatically checking its speed by a frequency standard to correspond to a standard speed, combining its speed and reaction with that of the turbine in a differential speed apparatus, and governing the turbine gates according to the differential speed and the reaction caused thereby in said apparatus and mechanically transmitting an operating force directly from said apparatus.

18. The method of governing the speed of a prime mover which consists in driving one side of a differential speed apparatus from an independent frequency standard, driving the other side from the prime mover, driving the rotor of a rotary circulating pump according to the differential speed of said apparatus, and regulating the power supply from the torque thrown on the pump casing.

19. The method of governing the speed of a hydraulic turbine which consists in driving one side of a differential speed apparatus from an independent frequency standard, driving the other side from the turbine, driving the rotor of a rotary circulating pump according to the differential speed of said apparatus, and regulating the turbine gates from the torque thrown on the pump casing.

20. The method of governing the speed of a prime mover which consists in independ-

ently producing at all times in a differential speed apparatus two rotating areas of magnetic flux in synchronism respectively with a frequency standard and the prime mover, and controlling the power supply to the prime mover in accordance with the differential speed of said areas by transmitting a non-electrical operating force directly from said apparatus as a result of said differential speed.

21. The method of governing the speed of a prime mover which consists in operating at all times two independent rotating areas of magnetic flux, one in synchronism with said prime mover, the other in synchronism with a frequency standard, and controlling the power supply to the prime mover in accordance with the differential speed between said areas and by mechanically transmitting the reaction force between said areas.

22. The combination in a governing mechanism for a hydraulic turbine having a gate therefor, comprising a frequency standard, apparatus to compare the speed of the turbine with said standard, and means to control said gate from said apparatus in accordance with the comparison, said means consisting of a hydraulic valve mechanically operated by said apparatus arranged to control the position of the turbine gates, a restoring mechanism actuated by the turbine gates and arranged to restore said valve to neutral position, and a secondary restoring mechanism arranged to bring the speed of the turbine gradually back to normal after a deviation therefrom.

23. The combination in a governing mechanism for a hydraulic turbine having a gate comprising a frequency standard, a differential speed apparatus, means to operate one side at a speed determined by said standard, means to operate the other side at a speed varying with the speed of the turbine, and means to move the gate gradually by the differential speed of said apparatus, said moving means including means for mechanically receiving directly from said apparatus an operating force caused by the differential speed.

24. The combination in a governing mechanism for a hydraulic turbine having a gate comprising an electric motor having a tendency to run at an excessive speed, a constant frequency device arranged to check the speed of the motor to cause it to correspond to a standard speed, another motor adapted to run in synchronism with the turbine, a differential speed apparatus having its sides driven by said motors respectively, and means to control the gate by the differential speed of said apparatus.

25. The combination in a governing mechanism for a prime mover having an adjustable element to control its speed, a frequency standard, two associated means for independently producing at all times two rotating

areas of magnetic flux respectively in synchronism with said mover and said standard, and means to actuate said element in accordance with the differential speed of said fields.

26. In a system of speed governing for prime movers the combination with an element rotatable at desired speed of a second element having a rotary speed variable with that of the prime mover, means combining the rotation of said elements and getting a resultant control force thereby, means for regulating the power supply to the prime mover by said resultant control force, comprising a rotatable member the angular position of which is adjusted to control the speed of the prime mover, and means for limiting the rate of change of said regulation comprising means for controlling the movement of said rotatable member.

27. In apparatus for governing the speed of a hydraulic turbine the combination with a deflectable member, means for normally holding said member in an intermediate position and resiliently resisting its movement in either direction, a fluid pump for causing a deflection of said member in an amount varying with the speed of the turbine, and means for controlling the regulating mechanism of said hydraulic turbine by the deflection of said member.

28. In apparatus for governing the speed of a hydraulic turbine the combination with a deflectable member, means for normally holding said member in an intermediate position and resiliently resisting its movement in either direction, a fluid pump for causing a deflection of said member in an amount varying with the speed of the turbine, and means for controlling the regulating mechanism of said hydraulic turbine by the deflection of said member comprising fluid pressure operating means for the turbine gates and a pilot valve controlling said operating means.

29. In apparatus for governing the speed of a hydraulic turbine the combination with a deflectable member, means for normally holding said member in an intermediate position and resiliently resisting its movement in either direction, a fluid pump for causing a deflection of said member in an amount varying with the speed of the turbine, and means for controlling the regulating mechanism of said turbine by deflection of said member comprising restoring mechanism between said member and said regulating mechanism.

30. The combination in a governing system for a hydraulic turbine having adjustable gate mechanism, comprising means for controlling the same including differential speed apparatus including means for producing two movable areas of magnetic flux one of which always moves in synchronism with said turbine and the other of which moves at a standard speed, and means operative during

turbine rotation for effecting operation of said gate mechanism in accordance with the differential speed of said areas, said latter means including mechanism for mechanically receiving directly from said apparatus an operating force.

31. In apparatus for governing the speed of a prime mover having regulating mechanism, the combination with a frame capable of angular deflection about an axis, resilient means for normally holding said frame in an intermediate position and resiliently resisting its movement in either direction therefrom, means for causing a deflection of said frame in an amount varying with the speed of the prime mover, and means for controlling the regulating mechanism of said prime mover by deflection of said frame.

32. In a system of speed governing, the combination with means for producing current of substantially constant frequency, of means for always producing current in synchronism with the part to be governed, and means for comparing said currents and developing a resultant control therefrom comprising an oscillatory deflectable member.

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