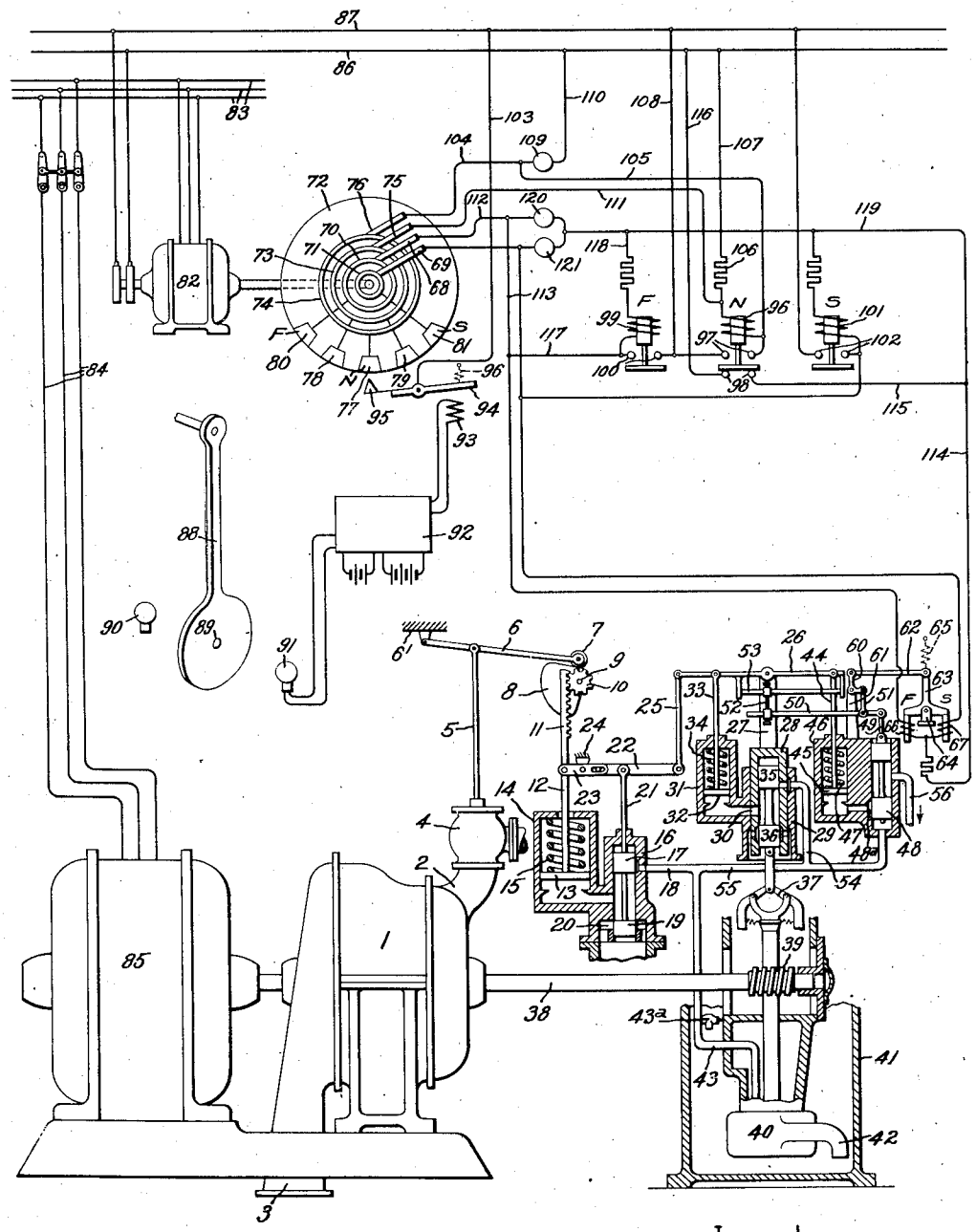
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CONSTANT SPEED CONTROL FOR PRIME MOVERS

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CONSTANT SPEED CONTROL FOR PRIME MOVERS

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In the operation of prime movers, such as elastic fluid turbines, there obtains often a condition where constant speed is required irrespective of the load on the prime mover, it being desired that over a period of time the prime mover shall neither gain nor lose in the total number of revolutions which go to make up constant speed.

The object of my invention is to provide an improved control mechanism whereby constant speed of operation of a prime mover is obtained, and for a consideration of what I believe to be novel and my invention, attention is directed to the following description and the claims appended thereto.

My invention is well adapted for use with turbine driven alternators for holding constant frequency on an alternating current transmission line, and in the following specification it is described as applied to this use. It is to be understood, however, that the invention is not limited thereto necessarily.

In the drawing, the figure is a diagrammatic view of a speed control mechanism embodying my invention.

According to my invention, I provide a prime mover, such as an elastic fluid turbine, with a governing means which is virtually isocronous, and in connection therewith I provide a correcting mechanism whereby when the prime mover departs a certain number of revolutions in either direction from the integrated number of revolutions which represents constant speed for the total period of time, the governing means is adjusted to either increase or decrease the speed of the prime mover to cause it to either lose or gain such certain number of revolutions. In carrying out my invention, I may utilize any suitable prime mover governing means which is virtually isochronous, but I now prefer to use an arrangement of the general type of that disclosed in my Patent No. 1,629,318, dated May 17, 1927.

I will describe first the virtually isochronous governing means, after which I will describe the application of my speed correcting means thereto.

Referring to the drawing, 1 indicates an elastic fluid turbine provided with an admission conduit 2 and an exhaust conduit 3. In admission conduit 2 is a valve means 4 which controls the flow of elastic fluid to the turbine. The valve means is connected by a stem 5 to a lever 6, pivoted at one end on a fixed support 6′, the arrangement being such that when the lever is raised it lifts valve means 4 to open it, while when the lever is lowered it moves valve means 4 toward closed position. At the free end of lever 6 is a roller 7 which rests on a cam 8 mounted on the cam shaft 9. On cam shaft 9 is a pinion 10 which meshes with a rack 11 on the upper end of a rod 12. The lower end of rod 12 is connected to the piston 13 of a fluid actuated motor the cylinder of which is indicated at 14. 15 is a spring which acts in a direction to move piston 13 down in the cylinder 14. When piston 13 moves downward the cam shaft is turned in a direction to effect movement of valve means 4 toward closed position, while when piston 13 moves upward the cam shaft is turned in a direction to effect opening movement of valve means 4. Admission of actuating fluid to the fluid actuated motor is controlled by a pilot valve structure comprising a pilot valve casing 16 in which is a valve 17 which controls the flow of actuating fluid through a pipe 18 to the under side of piston 13 and a valve 19 which controls the flow of actuating fluid from beneath piston 13 to a discharge conduit 20, which may lead to any suitable point. The pilot valves 17 and 19 are connected by a stem 21 to a floating lever 22, one end of which is connected by a lever 23 pivoted on a fixed support 24 to rod 12, thereby providing a usual form of follow up connection. The other end of lever 22 is connected by a link 25 to one end of a floating lever 26. Lever 26 is pivoted at an intermediate point to a stem 27 which is connected to a pilot valve bushing or sleeve 28. Pilot valve bushing or sleeve 28 is located in a pilot valve casing 29, provided with a port 30 which communicates with the lower end of a cylinder 31 which forms a part of a fluid actuated motor. In cylinder 31 is a piston 32 connected by a stem 33 to lever 26. Piston 32 is biased toward the lower end of cylinder 31 by a spring

34. In pilot valve bushing or sleeve 28 are admission ports and discharge ports which are controlled respectively by pilot valves 35 and 36, the pilot valves being connected to a common stem which is in turn connected to a speed governor 37. Speed governor 37 is driven from the shaft 38 of the turbine by a suitable worm gearing indicated at 39, the worm gearing driving also a pump 40, which may be the pump which supplies lubricant to the turbine, and also fluid pressure for actuating the fluid actuated motors. In the present instance the pump is shown as being located in an oil tank 41, and as being provided with an admission conduit 42 and a discharge pipe 43 which leads to the supply pipe 18. Connected to discharge pipe 43 is a pressure relief valve 43*a* of suitable structure.

The right-hand end of lever 26 is connected by a rod 44 to the piston 45 of a fluid actuated motor, the cylinder of which is indicated at 46. 47 is a spring which acts in a direction to bias piston 45 toward the lower end of cylinder 46. The flow of actuating fluid to cylinder 46 beneath piston 45 is controlled by a pilot valve 48 having its stem 49 connected to one end of a lever 50. Lever 50 is pivoted on the lower end of a link 51 and has its other end connected by a link 52 to a rod 53 which is fixed to and extends parallel to lever 26. Link 52 may be adjusted along lever 50 and rod 53 by means of the set screws shown. This forms in substance an adjustable connection between lever 50 and lever 26, which may be positioned at any desired point along lever 50 and rod 53, and as will be noted, rod 53 extends from a point at the left of the pivotal connection between lever 26 and stem 27 to a point beyond the pivotal connection of lever 26 to stem 44.

Pilot valve 48 is so arranged that when moved the flow of actuating fluid past it either to or away from cylinder 46 will be slow as compared to the flow of actuating fluid in the case of pilot valves 35, 36 and 17, 19. To this end, the passage controlled by pilot valve 48 may be made in the form of a long narrow slot 48*a* of a size to give the desired restricted flow.

Actuating fluid for the fluid actuated motors controlled by pilot valves 36 and 48 is supplied by pipes 54 and 55, which are connected to the pump discharge pipe 43. At 56 is the discharge pipe for pilot valve 48.

The operation of the construction so far described is as follows:—

Assume that the turbine 1 is operating at the predetermined normal speed, valve means 4 being opened an amount to supply sufficient elastic fluid to enable the turbine to carry the load on it, and the other parts being in the positions shown in the drawing. If now for any reason the speed decreases, speed governor 37 will effect an upward movement of pilot valves 35 and 36, whereby pilot valve 35 will uncover slightly the admission port in sleeve 28, thereby admitting fluid through port 30 to the under side of piston 32. Piston 32 is then moved upward, turning lever 26 on the upper end of rod 44 as a pivot. The upward movement of lever 26 through link 25 lifts the right-hand end of lever 22 and pilot valves 17 and 19. The lifting of pilot valve 17 admits actuating fluid to the under side of piston 13 to move it upward in its cylinder to effect an opening movement of valve means 4 whereby additional elastic fluid will be admitted to the turbine, tending to bring the speed back to normal value. When piston 13 moves upward it lifts the left-hand end of lever 23, thereby lowering its right hand end and pilot valves 17 and 18 to restore the pilot valve 17 to its normal position, wherein it cuts off the supply of fluid pressure to cylinder 14, this being a usual arrangement of follow-up mechanism. When piston 32 moves upward, turning lever 26 on the upper end of rod 44 as a pivot, it lifts link 27 and pilot valve sleeve 28, thereby bringing the admission port in sleeve 28 to a position wherein it is again covered by pilot valve 35, this likewise being a usual form of restoring mechanism.

With the operation so far described, the valve gear would come to a condition of equilibrium at a speed slightly lower than normal, because of the fact that a speed change was necessary on the part of the speed governor in order to raise pilot valves 35 and 36. The piston 45 and pilot valve 48 forms what may be termed a speed correcting device to automatically bring the speed back to its former value. The operation of this speed correcting device is as follows: When piston 32 moves upward, turning lever 26 on the upper end of rod 44 as a pivot, through link 52, the lever 50 is turned on link 51 as a pivot, thereby lowering pilot valve 48. The lowering of pilot valve 48 uncovers somewhat the upper end of slot 48*a* and permits actuating fluid to escape from the under side of piston 45, so that the piston moves downward, turning lever 26 on the upper end of rod 33 as a pivot. This lowers pilot valve bushing 28 so that the inlet port in it is uncovered slightly permitting actuating fluid to flow past pilot valve 35 to cylinder 31, raising piston 32. This effects an upward movement of pilot valves 17 and 19 thus admitting actuating fluid past pilot valve 17 to cylinder 14 to raise piston 13 thus opening valve means 4 somewhat to increase the speed of the turbine, the upward movement of piston 13 at the same time restoring pilot valves 17 and 19 to normal position. With the increased speed, speed governor 37 lowers pilot valves 35 and 36 so that pilot valve 35 again covers the inlet port in bushing 28. The downward movement of piston 45, at the same time that it

moves bushing 28 downward, also turns lever 50 on link 51 as a pivot to restore pilot valve 48 to normal position, wherein it exactly covers slot 48*a* thus preventing further movement of piston 45. This restores the speed to normal value.

In the case of an increase in the speed of the turbine, an operation similar to that just described takes place except in the opposite direction.

Each position of pilot valve bushing 28 corresponds to a certain definite turbine speed and as will be clear from a consideration of the drawing and the operation of the device as just described, pilot valve 48 covers slot 48*a* only for one definite position of bushing 28. It follows, therefore, that the corrector comprising piston 45 and pilot valve 48 will always restore the governor mechanism to the same speed after each change in speed. By making the corrector so that it lags definitely behind the primary governor 37, any hunting of the governing mechanism is avoided. Upon change in load, primary governor 37 first responds to effect quickly an adjustment of the valve means 4 after which the speed corrector functions to bring the speed back to the desired normal value.

The foregoing constant speed operation holds good providing the connecting link 52 is in line with the pivot point between lever 26 and stem 27, as shown in the drawing. However, in some instances a definite change in speed between no load and full load may be desirable and this may be obtained by adjusting link 52 along rod 53 and lever 50. As stated, if the link 52 is located as shown in the drawing, the corrector is effective to maintain constant speed, that is, to correct entirely for the inherent width of regulation of the governor. On the other hand, if link 52 is moved to a position where it is in line with the pivot point between stem 44 and lever 26, then the action of the corrector becomes zero because lever 26 moves about the end of stem 44 as a pivot when it is moved by piston 32. By positioning link 52 at points between these two extremes any desired degree of correction may be obtained. And by moving link 52 toward the left from the position shown in the drawing an over correction, i. e., a correction in a negative direction may be obtained.

Referring now to the correcting mechanism, link 51 is connected to one arm of the bell crank lever 60, pivoted on a fixed support 61. The other arm is connected by a rod 62 to the vertical arm of an inverted T-shaped lever 63, pivoted on a fixed support 64, and held normally in vertical position by a spring 65. Connected to the horizontal arms of lever 63 are the plungers of two solenoids, the windings of which are indicated at 66 and 67. These two solenoids may be termed respectively the fast solenoid (marked F) and the slow solenoid (marked S), because of the fact that when the prime mover gains a certain number of revolutions, solenoid winding 66 is energized to turn three-arm lever 63 in an anti-clockwise direction, thereby through bell crank lever 60 and link 51 raising pilot valve 48 so as to permit actuating fluid to enter beneath piston 45, causing the piston to move upward slightly and thereby decreasing slightly the speed of the turbine after the manner already described, and when solenoid winding 67 is energized, three-arm lever 63 is moved in a clockwise direction, thereby effecting a movement of pilot valve 48 in a direction to cause the speed of the turbine to be increased somewhat.

Solenoid windings 66 and 67 are connected to brushes 68 and 69, which engage conducting slip rings 70 and 71 on a rotating commutator 72. Commutator 72 is provided also with slip rings 73 and 74, with which brushes 75 and 76 engage, and with five contact segments 77, 78, 79, 80 and 81. Contact segment 77 which may be termed the "normal" contact segment (marked N) is connected to slip ring 74. Contact segments 78 and 79 which may be termed the "resetting" segments are connected to slip ring 73. Contact segment 80 which may be termed the "fast" contact segment (marked F) is connected to slip ring 70. Contact segment 81 which may be termed the "slow" contact segment (marked S) is connected to slip ring 71. The commutator is driven by a synchronous motor 82, the connection being through suitable reducing gears, whereby the commutator will be driven at the desired constant speed as hereafter pointed out. Synchronous motor 82 is connected to the bus bars 83, to which also is connected by conductors 84 the alternating current generator 85 driven by turbine 1. Synchronous motor 82 is thus rotated at a speed corresponding to the speed of turbine 1. The field winding for the synchronous motor is connected to a source of direct current comprising conductors 86 and 87.

At 88 is indicated the pendulum of a master clock of any suitable type. Pendulum 88 is provided with an opening 89, so located that each time the pendulum reaches the middle of its arc of swing it permits light from a suitable light source 90 to impinge on a photo-electric cell 91, which is connected through a suitable power amplifier 92 to an electromagnet 93. Electromagnet 93 is provided with an armature 94 having at its one end a contact 95 adapted to engage with the segments 77, 78, 79, 80, and 81. A spring 96 normally holds contact 95 away from engagement with the commutator. Each time pendulum 88 swings between lighting source 90 and photo-electric cell 91, light from light source 90 passes through opening 89 and impinges on photo-electric cell 91, thereby pro-

ducing momentarily an increase of current in the photo-electric cell circuit, which increase is amplified by the power amplifier 92 to a value sufficient to cause electromagnet 93 to move armature 94 downward and bring contact 95 into engagement with commutator 72. It will be seen that the contact 95 will be actuated each time the pendulum swings past its center. Associated with the commutator brushes and the solenoid windings 66 and 67 is wiring, including a normal relay 96 (marked N) having contacts 97 and 98, a fast relay 99 (marked F) having contacts 100, and a slow relay 101 (marked B) having contacts 102. The wiring arrangement and the function of the relays will now be described in detail in connection with the operation of the mechanism.

For purposes of description, it is assumed that the generator 85 supplies 60-cycle alternating current to bus bars 83, and that it is desired to hold the turbine speed substantially constant and to correct for any increase or decrease in total revolutions so that over a period of time there will be no departure from the correct total number of revolutions. For this operating condition, synchronous motor 82 will be connected to commutator 72 in a manner such that the commutator makes one complete revolution each second, and the master clock pendulum will be of a character such that it beats seconds. With this arrangement, electromagnet 93 will be energized each second and will move contact 95 into engagement with the commutator each second. If the commutator is set so that the normal contact segment 77 is over contact 95, when the opening in pendulum 88 passes between the light source and the photo-electric cell, it will be seen that if commutator 72 makes exactly one revolution per second, then electromagnet 93 will be energized at a time such as to bring contact 95 into engagement with contact segment 77. When contact 95 engages contact segment 77, a circuit is closed as follows: line wire 87, conductor 103, contact 95, contact segment 77, slip ring 74, brush 76, conductor 104, conductor 105, winding of relay 96, resistance 106 and conductor 107 to line wire 86. This causes electromagnet 96 to be energized and pick up its armature, which then bridges contacts 97, closing a holding circuit for the winding of relay 96 as follows: line wire 87, conductor 108, contacts 97, the winding of relay 96, resistance 106, conductor 107 to line wire 86. At the same time, a branch circuit is closed by way of conductor 105 through a lamp 109 and conductor 110 to line wire 86. Relay 96 thus remains energized and lamp 109, which may be a green lamp, burns continuously. As the mechanism continues to operate, contact 95 will be brought each second into engagement with contact segment 77, but since relay 96 is held energized no change in the mechanism takes place. As long now as there is neither an increase nor a decrease in the desired total number of revolutions of the turbine, the mechanism will remain in the condition described, and light 109 burns continuously to indicate that the operation is normal.

Assume now that for some reason the frequency of the system should be slightly high, which would be due to an increase in the speed of turbine 1. When this occurs commutator 72 will be rotated slightly more than one complete revolution per second, and after a predetermined gain in fractional revolutions contact 95 will engage contact segment 78. When this occurs a circuit is closed as follows: line wire 87, conductor 103, contact 95, contact segment 78, slip ring 73, brush 75, conductor 111, resistance 106 and conductor 107 to line wire 86. This shunts the winding of relay 96, whereupon it releases its armature which drops into engagement with and bridges contacts 98. This opens the circuit of lamp 109, which now ceases to burn. If now, the system continues still to gain, then some time later contact 95 will engage contact segment 80, closing a circuit as follows: line wire 87, conductor 103, contact 95, contact segment 80, slip ring 70, brush 68, conductor 112, conductor 113, solenoid winding 66, conductor 114, conductor 115, contacts 98 and conductor 116 to line wire 86. Energization of solenoid winding 66 will move three-arm lever 63 in a direction to decrease slightly the speed of turbine 1 after the manner already described. At the same time the circuit just described is closed, there is closed also a circuit through winding of solenoid 99 as follows: line wire 87, conductor 103, contact 95, contact segment 80, slip ring 70, brush 68, conductor 112, conductor 113, conductor 117, winding of solenoid 99, conductor 118, conductor 119, conductor 115, contacts 98 and conductor 116 to line wire 86. This energizes the winding of solenoid 99 which operates to bridge its contacts 100, thereby closing a holding circuit for the winding as follows: line wire 87, conductor 108, contacts 100, winding of solenoid 99, conductor 118, conductor 119, conductor 115, contacts 98 and conductor 116 to line wire 86. The bridging of the contacts of solenoid 99 closes also a holding circuit for winding 66, which may be traced as follows: line wire 87, conductor 108, contacts 100, conductor 113, solenoid winding 66, conductor 114, conductor 115, contacts 98 and conductor 116 to line wire 86. It will thus be seen that solenoid winding 66 now remains energized independently of contact 95 and contact segment 80. At this time there is closed also a branch circuit through a red lamp 120, which may be traced as follows: line wire 87, conductor 108, contacts 100, conductor 113, lamp 120, conductor 119, conductor 115, contacts 98 and conductor 116 to line wire 86. The valve

gear for the turbine is now set to cause the turbine to operate at a slightly lower speed and it will continue to so operate, losing gradually the revolutions which have been gained. As the gained turbine revolutions are lost, commutator 72 will make slightly less than one complete revolution in each second, and eventually will be brought to a position such that contact 95 will engage contact segment 77. During this time it engages contact segment 78 but this has no operative effect. When contact 95 again engages contact 77 the circuit first described through the winding of relay 96 will be again closed, thereby operating the relay to open contacts 98 and to close contacts 97. The opening of contacts 98 opens the circuit through solenoid winding 66, thereby permitting three-arm lever 63 to return to its normal position and again adjust the valve gear of the turbine for normal 60 cycle frequency. At the same time the holding circuit for winding 99 is opened and circuit through red light 120 is opened. The closing of contacts 97 again closes the holding circuit for relay 96 and lights green lamp 109.

If for any reason the frequency of the system should be low, then first contact 95 will be brought into engagement with contact segment 79, thereby deenergizing relay 96 in the manner already described to cause it to bridge contacts 98. Then following this, when contact 95 engages contact segment 81, it energizes the slow relay 101, which operates after the manner already described in connection with fast relay 99, except that the slow solenoid winding 67 is now energized to effect operation of the valve gear in a direction to increase the speed of the turbine, whereby the lost revolutions will be regained. At this time red lamp 121 burns. The mechanism will be reset after the manner already described when contact 95 again engages normal contact segment 77.

In accordance with the provisions of the patent statute, I have described the principle of operation of my invention, together with the apparatus which I now consider to represent the best embodiment thereof, but I desire to have it understood that the apparatus shown is only illustrative and that the invention may be carried out by other means.

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

1. The combination with a prime mover having governing means for regulating it, whereby it operates at substantially constant speed, of a master control means, means operated in synchronism with the prime mover, means for comparing the operation of the master control means with the operation of said synchronously operated means, said comparing means comprising a source of light, a light sensitive cell periodically excited by said source of light and a relay periodically actuated by said light sensitive cell, and means for adjusting said governing means to temporarily change the speed of rotation of the prime mover when the prime mover either gains or loses a predetermined number of revolutions as compared to said master control means.

2. The combination with a prime mover having governing means for regulating it, whereby it operates at substantially constant speed, an alternating current generator driven by said prime mover, and a power line connected to said generator, of a master control means, means operated in synchronism with the frequency of the power line, means for comparing the operation of said master control means with said synchronously operated means, said comparing means comprising a source of light, a light sensitive cell periodically excited by said source of light and a relay periodically actuated by said light sensitive cell, and means for adjusting said governing means to temporarily change the speed of rotation of the prime mover when the prime mover either gains or loses a predetermined number of revolutions as compared to said master control means.

3. The combination with a prime mover having governing means for regulating it whereby it operates at substantially constant speed, of a master clock, means operated in synchronism with the prime mover, means for comparing the operation of the master clock with the operation of said means, said comparing means comprising a source of light, a light sensitive cell periodically excited by said source of light and a relay periodically actuated by said light sensitive cell, and means for adjusting said governing means to temporarily change the speed of rotation of the prime mover when the prime mover either gains or loses a predetermined number of revolutions as compared to said clock.

4. The combination with a prime mover having a governing means and correcting means for rendering said governing means substantially isochronous, of means for moving said correcting means to increase or decrease the speed of the prime mover whereever the prime mover loses or gains a predetermined number of revolutions and for restoring said correcting means to normal position when the predetermined number of revolutions has been gained or lost.

5. The combination with a prime mover having a governing means and correcting means for rendering said governing means substantially isochronous, of electromagnetic means for moving said correcting means to increase the speed of the prime mover, electromagnetic means for moving said correcting means to decrease the speed of the prime mover, circuits for said electromagnetic means, means for closing said circuits when

the prime mover loses or gains a predetermined number of revolutions, and means for effecting the opening of said circuits when the predetermined number of revolutions have been gained or lost.

6. The combination with a prime mover having governing means for regulating it whereby it operates at substantially constant speed, of a commutator having contact segments, means for rotating said commutator at a speed which bears a definite relation to the speed of the prime mover, a contact, means whereby said contact engages certain contact segments in case the prime mover loses or gains a determined number of revolutions, and means whereby when said contact engages certain contact segments said governing means is adjusted to cause the prime mover to gain or lose said predetermined number of revolutions.

7. The combination with a prime mover having governing means for regulating it whereby it operates at substantially constant speed, an alternating current generator driven by said prime mover, and a power line connected to said generator, of a master control means, a commutator having contact segments, means for rotating said commutator in synchronism with the frequency of the power line, a contact, means operated by said master control means for bringing said contact into engagement with said commutator, said contact engaging one of said segments in case the prime mover loses or gains a predetermined number of revolutions, and means whereby when said contact engages a segment, said governing means is adjusted to cause the prime mover to gain or lose said predetermined number of revolutions.

In witness whereof, I have hereunto set my hand this seventeenth day of October, 1929.

REGINALD G. STANDERWICK.