

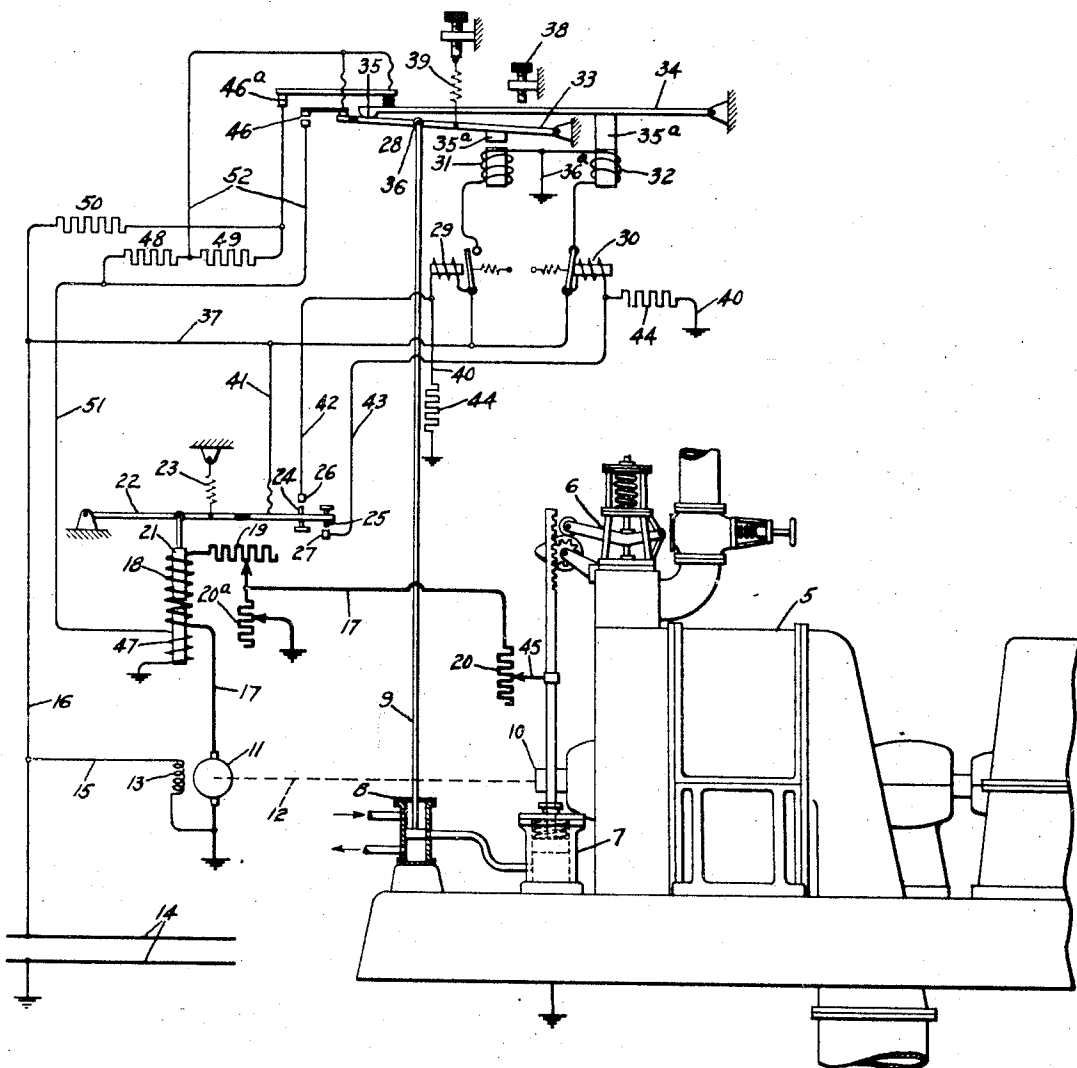
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SYSTEM FOR GOVERNING PRIME MOVERS

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UNITED STATES PATENT OFFICE

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SYSTEM FOR GOVERNING PRIME MOVERS

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The present invention relates to a system for governing prime movers and more particularly it relates to a system for governing servo-motor controlled prime movers by electrical means.

The object of the invention is to provide an improved and simplified system of the character described which permits a governing action over a wider speed range than is permitted by the usual centrifugal speed governor, which is reliable in operation and adapted for remote control, and which may be readily applied to a common form of regulating mechanism, namely, a hydraulic valve gear employing a pilot valve control.

A governing system embodying the invention and adapted for the control of an elastic-fluid turbine having the above-named type of regulating mechanism is diagrammatically shown by way of example in the figure of the accompanying drawing to which, together with the following description and appended claims, attention is now directed for a consideration of what is believed to be novel and the invention.

Referring to the drawing, 5 is an elastic fluid turbine representing any suitable prime mover for which it is desired to provide a governing means. The turbine is controlled by a suitable valve gear 6, which in turn is operated by a servo-motor 7. The servo-motor of the present example is of the well known hydraulic type and is provided with the usual pilot valve 8. The latter, together with the servo-motor and valve gear, represent any suitable regulating mechanism for the prime mover whereby its speed may be varied. The pilot valve represents the movable element of such mechanism whereby the same is actuated to control the speed of the prime mover.

In the present example the arrangement of the regulating mechanism is such that movement upwardly of the pilot valve rod, indicated at 9, effects a closing of the admission valves and a reduction in speed of the turbine, and a movement of the pilot valve rod in the opposite direction affects a corresponding opening movement of the admission valves and an increase in speed of the

turbines. As such regulating mechanism is old and well understood, further description of the same is believed to be unnecessary.

Connected with the shaft of the turbine, which is indicated at 10, is a pilot generator 11. A direct connection is indicated by the line 12, but any other positive connection may be used between the turbine shaft and generator. The generator is preferably of the direct current type of relatively small size or capacity and is provided with a constant field. In the present instance the field is electromagnetic, as indicated by winding 13, and is separately excited from a pair of house mains or other source of constant, steady voltage 14.

One of the mains is grounded as indicated, so that a grounded return circuit may be used for apparatus connected therewith and throughout the control system, although of course a wire return circuit may be used wholly or in part. With the type of return circuit provided, one side of the field and of the pilot generator armature are also grounded. The field is then placed in circuit with supply mains 14 by a field wire 15 connected with a feeder wire 16 leading from the ungrounded main.

By this arrangement the voltage across the generator field and the field strength is constant so that the voltage generated by the armature is directed proportional to the speed, which in this case is the speed of the prime mover or turbine.

The armature of the generator is connected into a series control circuit 17, in which is located an electro-magnetic device or relay 18, a variable resistance or speed controlling rheostat 19, and a variable resistance or follow-up rheostat 20, the sliding contact of which last-named rheostat is grounded to the grounded frame of the turbine thereby completing the circuit to the grounded side of the generator. The follow-up rheostat is shunted by a third variable resistance or rheostat 20', which operates to change the regulation of the turbine as will hereinafter appear. It will be seen that with the rheostat each adjusted to a fixed value at any given time, a change in the speed of the

prime mover will cause the pilot generator to vary the current flow in the pilot generator circuit 17 and in relay 18 in proportion thereto since the field is constant.

Relay 18 then controls the prime mover in accordance with the variations in current subject to certain limitations as will appear and may be readily provided by a regular contact-making ammeter, the same being illustrated, although any other suitable contact-making current-responsive device or relay may be used.

The relay is a contact making current-responsive device and is provided with a plunger 21 connected to an arm 22 which operates against the pull of a spring 23 in response to the magnetic pull of the coil. The spring gradient allowing a certain range of current or speed change in which the plunger arm is at neither extremity. The plunger arm carries two contacts 24 and 25. Contact 24 breaks connection with a fixed contact 26 when the magnetic pull exceeds a certain value corresponding to a speed approaching normal speed from a lower speed. Contact 25 makes connection with a second fixed contact 27 when a certain increment of magnetic pull corresponding to an increase in speed through and above normal has been added to the above-mentioned value.

The pilot valve 8 or its control rod 9 is arranged to move in accordance with movements of lever 22 of the current-responsive device and takes a neutral position, as shown, when the lever assumes a neutral position, also as shown. This control arrangement between relay 18 and the pilot valve or movable element of admission valve mechanism is effected through an electromagnetic controller 28 and a pair of contactors 29 and 30.

The controller comprises a pair of electromagnets 31 and 32 with each of which is associated one of a pair of substantially parallel levers 33 and 34. The latter are each pivoted at one end and are arranged to lie in contact with each other adjacent their opposite ends, as indicated at 35. Lever 33 associated with magnet 31 is pivotally connected at 36 with the pilot valve rod 9. Through this connection and the contact relation between the levers, both levers and the pilot valve and rod are biased by a tension spring 39 connected with lever 33 to move together in the direction of a stop means 38. The stop means limits the movement of the levers in this direction, and is arranged to meet the upper or free lever 34 and to stop the moving parts when the pilot valve has been carried into the exhaust position, whereby the servo-motor operates to close the admission valves of the regulating mechanism and reduces the speed of the turbine.

Movement of each lever in the opposite direction is limited by a separate stop means,

lever 33 being stopped when it has moved a full stroke of the pilot valve or from the exhaust position through the neutral position to the other extreme or inlet position of the pilot valve, wherein the latter effects an opening of the admission valves and an increase in the speed of the turbine. Lever 34 is stopped when, together with lever 33, it has moved substantially halfway between the extreme positions, that is, when in contact with lever 33 it has moved sufficiently to carry the pilot valve into the neutral position, thereby stopping movement of the admission valve gear. It is shown in this position.

Movement of the levers and of the pilot valve in the above manner is effected by the magnetic pull of magnets 31 and 32 in opposition to the spring pull, both magnets 31 and 32 being deenergized for the first of the above positions, magnet 32 being energized for the second or neutral position and both magnets being energized for the inlet or other extreme position of the pilot valve. Each lever carries an armature 35*, which with the respective magnets form stops for the levers, although other stop means may be provided. The arrangement is such that when lever 34 is stopped in the mid-position and held there by magnet 32, lever 33 is free to move therefrom to the extreme or inlet position when magnet 31 is energized.

Control of magnets 31 and 32 and hence of the pilot valve and regulating mechanism of the prime mover is placed with relay 18 by suitable circuit connections therewith through contactors 29 and 30 which relieve the contacts of the current-responsive device of the heavier current required to operate the controller magnets.

In the present example magnets 31 and 32 of the controller are energized from the common supply mains 14, being grounded on one side as indicated at 36* to connect with the grounded main and being connected with the other main through feeder 16, a lead 37 and the contacts of contactors 29 and 30. The contactor coils are also grounded on one side through leads 40 and are connected on their opposite sides to lead 37. The coils are thus arranged to be continuously energized from the supply mains. In the present example the contactor coils are deenergized by short circuiting them through a circuit wire 41 and a pair of leads 42 and 43 which connect the contacts of relay 18 with said coils. Circuit wire 41 connects movable contact arm 22, or an insulated portion thereof which carries the contacts, with lead 37 and one side of both of the relay coils, while contacts 26 and 27 are connected with the other sides of the relay coils by control leads 42 and 43 respectively, relay 29 being connected with contact 26 through lead 42 and relay 30 being connected with contact 27 through lead 43.

With the above-circuit arrangement when

contacts 24 and 26 close, the coil of contactor 29 is short-circuited, thereby closing its contact and energizing controller magnet 31 along with controller magnet 32. When contacts 25 and 27 close, the coil of contactor 30 is short circuited, thereby opening its contact and deenergizing magnet 32. To prevent short circuiting the main supply source by this arrangement, a resistor 44 is placed in each ground lead 40 leading from a contactor coil, the resistor being placed in the leads between the ground and the points of connection with leads 42 and 43.

Relay 18 is thus placed in control of the prime mover through controller 28 and the movable element of the prime mover regulating mechanism and operates in response to changes in current flow in control circuit 17 as produced by changes in speed of the pilot generator and by varying the setting of each of the rheostats 19, 20 and 20^a.

Briefly considering the above, the making or breaking of the contacts of relay 18 energizes or deenergizes a magnetic controlling means which in turn operates the pilot valve or movable control element of the regulating means of the turbine or prime mover, thereby increasing or decreasing its speed in response to changes in current flow in series control circuit 17.

The use of two contacts in the current-responsive device and two magnets in the controller is desirable in order to secure three definite conditions with a pilot valve or similar definite position control element as employed in the present example.

Follow-up rheostat 20 is provided for the purpose of preventing over-travel of the admission valve mechanism following each change in speed and to prevent hunting. Its purpose is thus similar to and it is adapted to take the place of well known mechanical follow-up mechanisms, being simple and effective in connection with control circuit 17. The present type is built with a suitable number of steps of proper magnitude. Its application results in governing with the desired amount of regulation, which is measured by the difference between no load and full load speeds.

The rheostat is rigidly fixed to a suitable stationary part of the control valve (not shown). The rheostat arm 45 travels with a suitable moving part of the admission valve mechanism and in the present example is linked directly to the piston rod of the servomotor. For each position of the admission valve there is thus a different value of resistance in the circuit of the current-responsive device. This change in resistance necessitates a change in speed to obtain the operating value of current in the operating coil of said device. Thus there is a definite speed for every position of the controlling valve: The change in resistance varies the amount

of speed change that is necessary to return the governor arrangement to the normal motionless state. This, as does the follow-up in a mechanical governor, reduces the hunting.

Considering the following figures on regulation not as limitations and only by way of example, in governing operation 5% is the usual value of regulation, that is, the speed will be 2½% above normal at no load and 2½% below normal at full load. With the electric governor, this necessitates a 5% change in resistance in the follow-up rheostat. It is evident that for a very small movement of the controlling valve there would be an extremely small change in resistance. If the valve moved 1%, the change in resistance would be 1% of 5% or 5/100 of a per cent. The major tendency to bring the governor mechanism to normal position must, therefore, come from speed change. The tendency to prevent hunting for small movements is thus quite small. Due to the physical constants of the system causing other than instantaneous and infinitesimal motions of the controlling valve, a hunting is possible and it is desirable to increase this anti-hunting effect of the follow-up mechanism.

A means is therefore provided in which an opposing effect is put into play whenever the movable element of the regulating mechanism would be in a position to increase or decrease the speed. Two pairs of contacts 46 and 46^a are arranged in connection with the pilot valve, that is, in this case in connection with levers 33 and 34 respectively, which short out resistances in series with an auxiliary winding 47 in relay 18, the winding having a cumulative effect magnetically on the main coil of the relay. The resistances are indicated at 48, 49 and 50, and may be considered as one resistance, the value of which is changed by short circuiting portions of it and being thus variable is a means for varying the current flow in the auxiliary winding as the pilot valve or control element moves. It effects such variation in the current flow by varying or adjusting the total resistance in circuit, two pairs of contacts giving three values of current. In the circuit arrangement provided, the auxiliary winding is energized from the supply mains 14 through feeder 16 and a grounded return. A lead 51 completes the circuit through resistors 48, 49 and 50 to feeder 16, and contacts 46 and 46^a are connected across resistors 48 and 49 respectively by suitable leads 52. The highest value of resistance comes with both contacts open, next when the first set of contacts 46^a are closed, and the lowest when both sets of contacts are closed.

The auxiliary relay winding and arrangement of such contacts and resistances is such that the effect of change in current flow in the main coil is modified and a strong tendency to cease the motion which does not de-

pend upon speed change is put into play thereby whenever the pilot valve goes into a position permitting motion of the regulating mechanism. This amounts to an adjusting means for the electromagnetic device or relay to vary its responsiveness or rather to change its setting immediately after each change of speed.

In other words, the increase or decrease in the magnetic pull of the relay coil is partially neutralized by the effect of the auxiliary winding as soon as the controller moves, thereby tending to restore the floating lever 22 or contacts of the relay to the neutral position each time a correction of speed is initiated and before the correction is completed. With the arrangement shown, with an increase in speed the correction therefore causes a decrease in the current flow in the auxiliary winding partially compensating for the increase in current flow through the main winding. For a decrease in speed a reverse action may be followed.

The magnitude of the effect of the auxiliary winding and resistances in series with it must be large enough to prevent continual hunting. Yet the effect must be small enough not to cause continual swinging of the main contacts of the current-responsive device from one extremity to the other. The contacts must also be adjusted to make and break advantageously at the proper point in the stroke of the pilot valve piston. While the use of an auxiliary winding provides a readily controlled isolated circuit, the same effect upon the relay operation may be obtained by other means as will be readily appreciated from the foregoing. In any case, however, the motion of the pilot valve piston—whether limited mechanically or hydraulically—controls the action of the anti-hunting contacts. In the present example this is effected by connecting the pilot valve rod 9 directly with lever 33, which forms a part of the auxiliary winding control means.

The governor is adapted for a long range control which may be provided by suitable rheostats in the series control circuit 17, such as rheostat 19. From Ohm's law the voltage necessary to produce a given current is proportional to the resistance. Thus, for example, if the resistance is changed from 25% to 115%, the voltage impressed by the pilot generator must change likewise. Since speed and voltage vary directly, then such change in resistance will give 25% to 115% speed variation of the prime mover. A wide speed range is thus provided by this arrangement.

If it is desired to have a changing regulation in this type of governor, it is secured by placing a variable resistance, such as resistance 20, for example, in shunt with follow-up rheostat 20. Change of value of the shunting resistance will change the effectiveness of the follow-up rheostat and this changes the

regulation. This is often desirable in operating electrical generator units in parallel.

The operation is as follows:—

Assuming that the turbine is running at normal speed and that the pilot valve is in the neutral position as shown. There is therefore no motion of the controlling valves. The plunger arm of the contact-making device will thus be floating between the two principal contacts 26 and 27. Controller magnet 32 will be energized, as indicated, keeping the pilot valve in the dead position and contacts 46^a of the auxiliary winding or adjusting means will be closed, short circuiting resistance 49 all substantially as shown in the drawing.

The plunger arm 22 will close with contact 26 if the current through relay 18 should fall to a certain minimum value, representing a lower than normal speed or if a change should be made in the speed controlling rheostat 19 calling for an increased speed. This will energize the second controller magnet 31 through operation of relay 29, pulling lever 33 and the pilot valve downwardly to the extreme inlet position. This will permit oil to flow into the hydraulic cylinder, and the admission valves will open thereby increasing the speed.

If, however (instead of the operation just described) the current in relay 18 should use a certain higher value, representing a higher than normal speed, or if a change should be made in the speed controlling rheostat calling for a decreased speed, the second contact 27 will be made. Both pilot valve controller magnets will then be deenergized. The pilot valve piston will be raised by spring 39, permitting the oil to flow out of the hydraulic cylinder and the controlling valves will close. After each correction for speed the change in speed of the pilot generator produces a current change tending to effect a return to the relay lever or contacts to the neutral position and a corresponding action on the part of the apparatus controlled thereby. The return to neutral is accelerated by the means provided for momentarily changing the setting of the relay, that is, the auxiliary winding in the present example.

Resorting to specific figures for the purposes of illustration and assuming a sudden increase of load upon the generator, the turbine slows down and the generated voltage of the pilot generator falls accordingly. When the current flowing through the current-responsive device reaches a minimum of 1.000 ampere for example, the contact is made which energizes the controlling magnet 31. The pilot valve is then forced downward from the neutral position, permitting oil to flow into the hydraulic cylinder and opening the admission valves. As soon as the pilot valve moves past a predetermined point of its travel, contacts 46 close, thereby short-

circuiting resistance 48 in addition to resistance 49, which is already short-circuited by contacts 46 and increases the magnet pull on lever 22 of relay 18 to value corresponding to a current flow of 1.004 amperes in the main winding. The plunger arm 22 of the current-responsive device is thus quickly returned to the neutral position. The return of this arm to neutral position causes the pilot valve piston to return to the neutral position. Motion of the admission valve mechanism ceases and anti-hunting contacts 46 are broken again.

It is now a question if the time elapsed and the motion of the admission valves resulted in a sufficient increase of speed or change of follow-up resistance to give a current of more than 1.000 ampere. If the speed continues to drop, the same cycle will be repeated. The follow-up resistance may have permitted an increase of $\frac{1}{100}$ of 1% of current in the first step. This, together with a slight increase in speed, may have brought about a current through relay 18 in excess of 1.000 ampere.

It should be noted that for a large change of speed, the anti-hunting effect of $\frac{1}{100}$ of 1% would not hinder rapid closing or opening of the valves. If the speed dropped 1% due to sudden load addition, the current would drop to .994 ampere. Thus the plunger arm of the relay would hold until the speed and follow-up resistance change would bring the current beyond 1.000 ampere.

For a drop in load, a similar cycle can be readily traced.

The above current values, while representing actual values as used in one embodiment of the invention, are given only for purposes of illustration and do not represent any limiting values, as any suitable current flow may be used depending upon the size of the pilot generator, the resistance in circuit therewith and various other factors.

The above-described method of governing may be called three position governing because of the three positions of the pilot valve and controlling apparatus, permitting oil to flow into or out of the servo-moto cylinder, and a neutral position blocking oil flow. The neutral position stops motion of the controlling valves. By omitting this motionless position, two position or constant motion governing may be used if desired.

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

1. The combination with a prime mover having a regulating mechanism and a movable control element therefor by which its speed is varied, of a governing system for said prime mover comprising a generator connected with the prime mover, a current-responsive device having circuit control contacts and a coil for actuating said contacts, said coil being connected with the generator

whereby it is responsive to the current flow therefrom, a magnetic controller for the movable control element connected in circuit with the control contacts of the current-responsive device to be operated thereby, means connected with the generator for controlling the current flow therefrom through the coil of the current-responsive device, said means comprising a control circuit, a rheostat in said circuit, a second rheostat in series with the first and a third rheostat in parallel with at least one of said first and second named rheostats.

2. The combination with a prime mover having a regulating mechanism and a movable control element therefor by which its speed is varied, of a governing system for said prime mover comprising a generator connected with the prime mover, a current-responsive device having a coil and contact means actuated by said coil, said coil being connected with the generator, a pair of levers, one of which is connected with the movable control element, an electromagnet associated with each lever for moving it in one direction, each electromagnet being connected with the contact means of said device to be controlled thereby, a spring means for moving the levers in the opposite direction, a resistor connected with the current-responsive device to control the operation thereof, and contact means carried by each of said levers for short circuiting a portion of said resistor.

3. The combination with a prime mover, of a governing means therefor comprising an admission valve mechanism, a pilot valve therefor, a controller for moving the pilot valve to operate said admission valve mechanism, said controller comprising a pair of levers, one of which is connected with the pilot valve, a spring means for moving said levers and pilot valve in one direction and a pair of magnets associated each with one of said levers for moving the latter and the pilot valve in the opposite direction, a generator connected with the prime mover and a contact-making current-responsive relay connected in circuit with and between the generator and said magnets for energizing and deenergizing the latter in response to changes in the current flow from the generator.

4. The combination with a prime mover, of a governing means therefor comprising an admission valve mechanism, a pilot valve therefor, a controller for moving the pilot valve to operate said admission valve mechanism, said controller comprising a pair of levers, one of which is connected with the pilot valve, a spring means for moving said levers and pilot valve in one direction and a pair of magnets associated each with one of said levers for moving the latter and the pilot valve in the opposite direction, a generator

connected with the prime mover, a contact-making current-responsive relay connected in circuit with and between the generator and said magnets for energizing and de-energizing the latter in response to changes in the current flow from the generator, and a control rheostat in circuit between the generator and the relay.

5 5. The combination with a prime mover having a regulating mechanism and a movable control element therefor by which its speed is varied, of a controller connected with said movable element for moving the same to regulate the prime mover, said controller comprising a spring-actuated part connected with the movable element to move it in one direction, electromagnets associated with said part to move the same in the opposite direction, a relay for energizing and deenergizing said electromagnets, said relay having an actuating coil, a constant field generator connected with the prime mover to be driven thereby said generator and relay coil being connected whereby the relay operates in response to the electrical output of the generator, said relay being set to respond when said output varies outside of limits above and below a certain normal value, and means connected with and operated by the controller for changing the setting of the relay.

6. The combination with an elastic fluid prime mover having valve means controlling the flow of elastic fluid to it, a fluid-actuated motor for moving the valve means and a pilot valve for the motor, of a generator connected with the prime mover, a current-responsive device having circuit control contacts and a coil for actuating said contacts, said coil being connected with the generator whereby it is responsive to the current flow therefrom, electromagnetic means connected with said contacts for moving the pilot valve from normal position, resistance means associated with the current-responsive device and adjusted by the position of the fluid-actuated motor for modifying the flow of current through said coil, and resistance means associated with the current-responsive device and adjusted by the pilot valve for modifying the flow of current through said coil whenever the pilot valve occupies a position other than normal whereby said contacts are actuated to operate the electromagnetic means to return the pilot valve to normal position.

7. The combination with an elastic fluid prime mover having valve means controlling the flow of elastic fluid to it, a fluid-actuated motor for moving the valve means and a pilot valve for the motor, of a generator connected with the prime mover, a current-responsive device having circuit control contacts and a coil for actuating said contacts, said coil being connected with the generator whereby it is responsive to the current flow therefrom, electromagnetic means connected with said

contacts for moving the pilot valve from normal position, resistance means associated with the current-responsive device and adjusted by the position of the fluid-actuated motor for modifying the flow of current through said coil, a second coil associated with said current-responsive device, means for supplying current to said second coil resistance means in circuit with said second coil, and contacts actuated by movement of said pilot valve for adjusting the value of said last-named resistance means when the pilot valve occupies a position other than normal whereby the current in the second coil combines with the current in the first coil to actuate said contacts to operate the electromagnetic means to restore the pilot valve to normal position.

In witness whereof, I have hereunto set my hand this 30th day of September, 1927.

ANTHONY J. NERAD.