

[54] **OVERSPEED PREVENTIVE APPARATUS
FOR ENGINES**

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[56] **References Cited**

UNITED STATES PATENTS

3,643,437 2/1972 Birnbaum 290/2
3,609,384 9/1971 Strohmeyer..... 290/2
3,614,457 10/1971 Eggenberger..... 415/10
3,578,871 5/1971 Sakamoto 415/10
3,274,443 9/1966 Eggenberger..... 290/40 X
3,340,883 12/1967 Peternel..... 290/40 X

3,238,376 3/1966 Ernst et al. 290/40 X
3,575,603 4/1971 Schlicher 290/40 X
3,211,957 10/1965 Carson et al..... 317/19
3,342,195 9/1967 Wagner..... 317/5
3,097,488 7/1963 Eggenberger et al. 415/17
3,097,489 7/1963 Eggenberger et al. 60/105 X
3,243,596 3/1966 Luft 290/40

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[57] **ABSTRACT**

An electro-hydraulic overspeed preventive apparatus for an engine in which two overspeed preventive control systems are provided in addition to a speed control system including a working fluid flow regulating valve disposed at the inlet of the engine and means for controlling the opening of the working fluid flow regulating valve in response to an error signal representative of the deviation of the actual speed from the desired speed. The two overspeed preventive control systems respectively are operated to close the working fluid flow regulating valve prior to the operation of the speed control system when the acceleration signal representative of the actual acceleration exceeds a predetermined limit and when the difference between two signals respectively representative of the state of flow of the working fluid and the electrical output of the load exceeds a predetermined limit.

13 Claims, 4 Drawing Figures

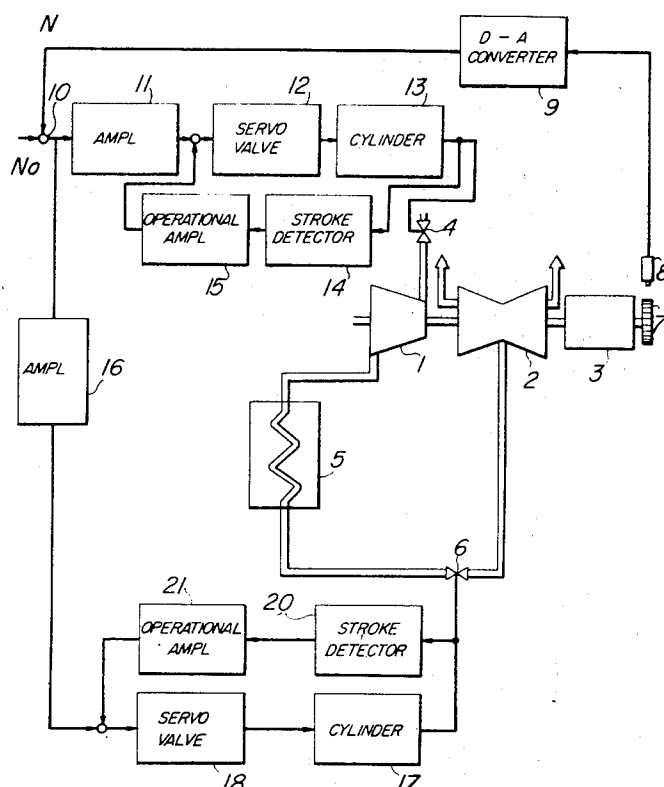
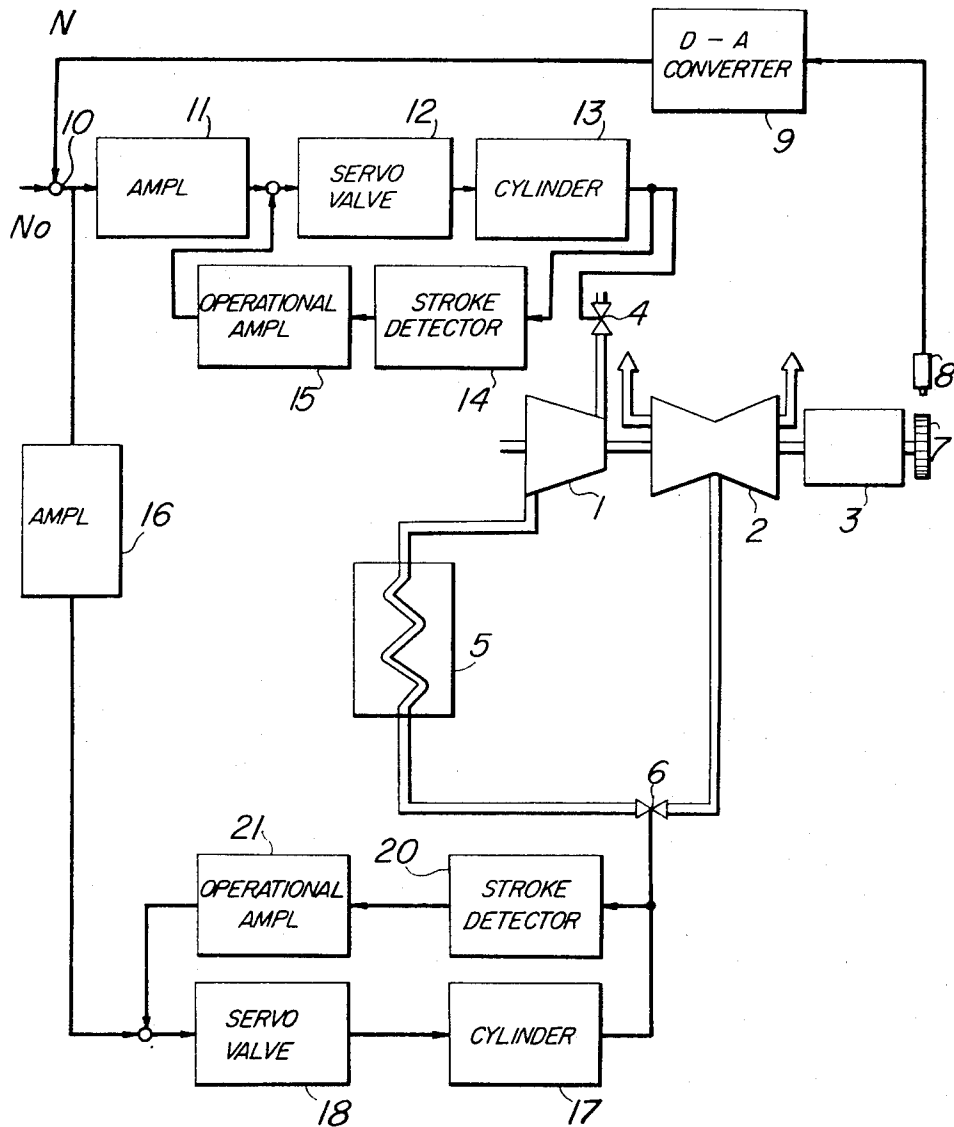


FIG. 1



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FIG. 2

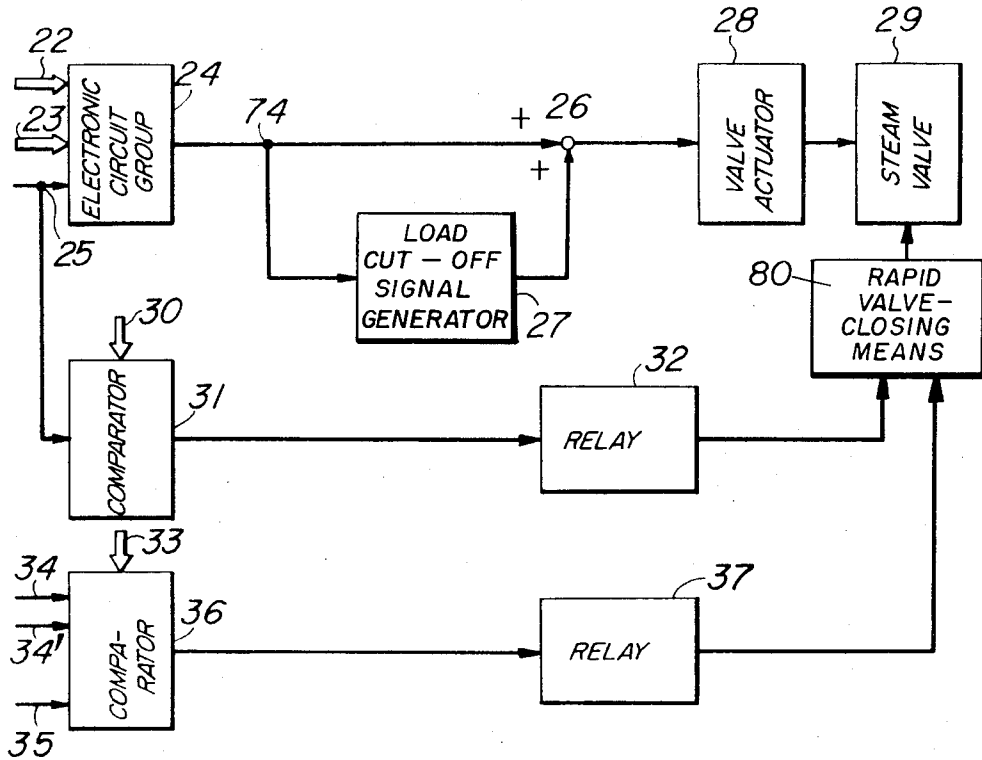
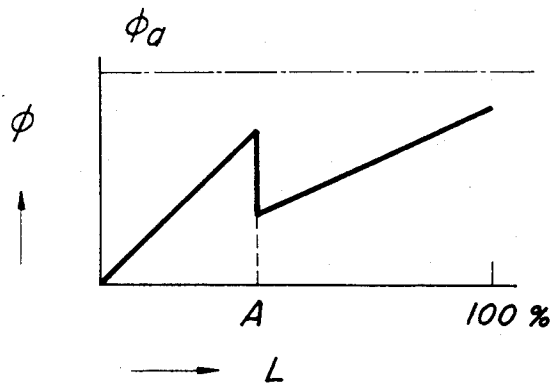


FIG. 4

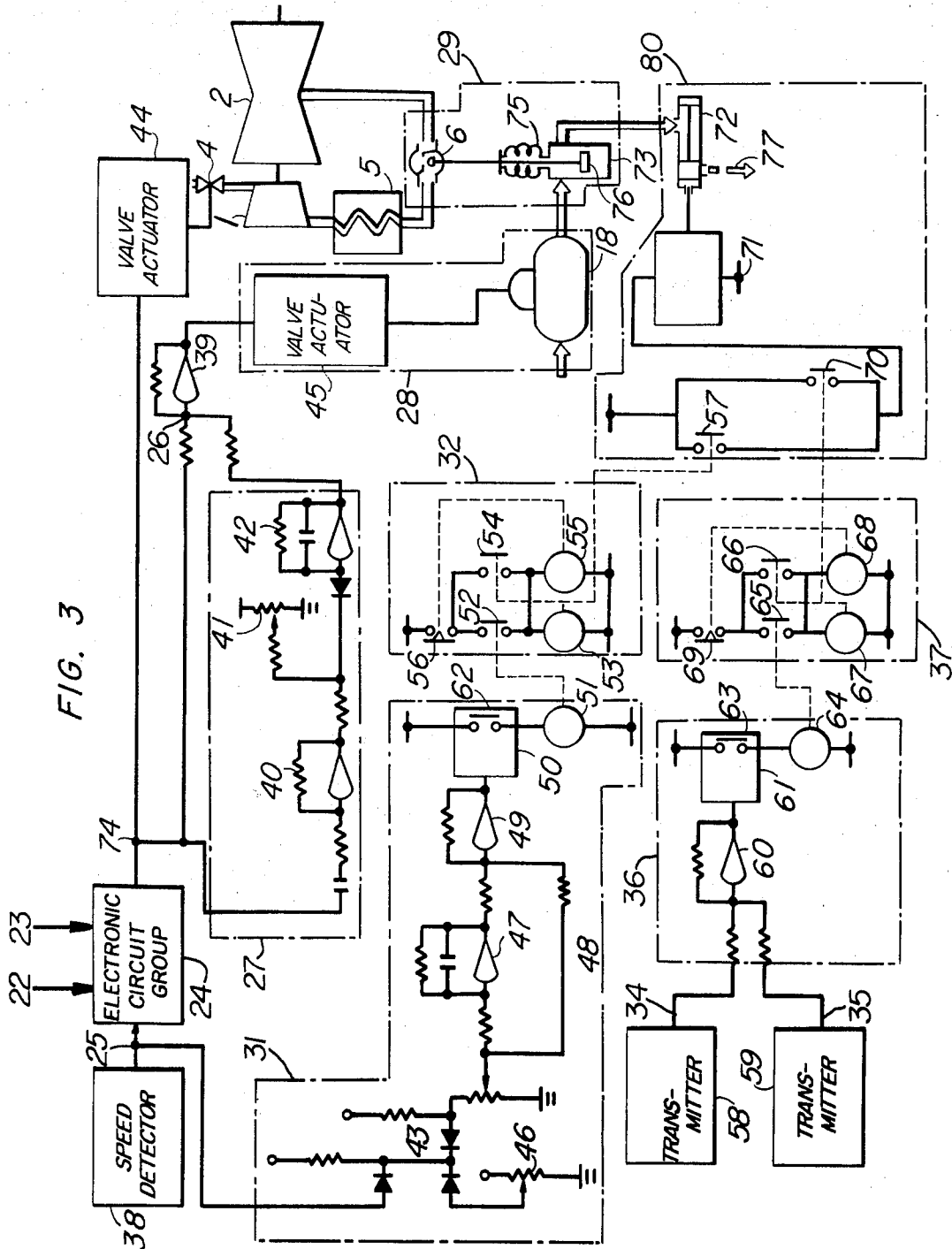


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OVERSPEED PREVENTIVE APPARATUS FOR ENGINES

This invention relates to an apparatus for preventing engines such as steam turbines from an overspeed.

The increase in the unit output of engines such as steam is followed by a general tendency toward reduction in the weight of the turbine rotor compared with the turbine output, and the turbine rotor tends to be more easily accelerated than heretofore. A fairly rapid response to speed is therefore required for the speed governing system for the steam turbine. However, conventional mechanical speed governors employing levers as a component thereof have had a certain limit in the ability to respond to speed due to various factors including mechanical friction, play and inertia.

Further, the increase in the turbine output results in a complex structure of the plant including the turbine equipment and it is necessary to monitor and control the operation of the whole plant by the transfer of signals between it and an electronic computer combined therewith. It is apparent that a speed governor consisting of mechanical elements is not fit for this kind of control. An electro-hydraulic speed governing apparatus has appeared to meet various demands, including the ability to rapidly respond to speed, the complexity of the structure of the control mechanism and the ease of transfer of signals, which are required for the speed governing apparatus for the steam turbine.

It is an object of the present invention to provide an apparatus for preventing an engine such as a steam turbine from an overspeed, which includes two overspeed preventive systems of different characters thereby to positively protect the steam turbine against damage.

Another object of the present invention is to provide an apparatus of the kind above described which is capable of quickly closing a fluid flow regulating valve in response to a signal indicative of the cut-off of a load.

Still another object of the present invention is to provide an apparatus of the kind above described in which a dumping valve is provided for draining hydraulic fluid from the servo valve disposed in the speed control system so as thereby to reduce the size of the servo valve.

A further object of the present invention is to provide an apparatus of the kind above described in which the overspeed preventive systems have valve closing means of different kinds responsive to the cut-off of a high load and a low load respectively so that the overspeed preventive systems are operable within a narrow range.

The above and other objects, features and advantages of the present invention will be apparent from the following detailed description taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a block diagram of an electro-hydraulic speed governor system adapted to be used with a reheating steam turbine having a reheater;

FIG. 2 is a block diagram of an apparatus according to the present invention;

FIG. 3 is a diagrammatic view showing the structure of the apparatus of the present invention in more detail; and

FIG. 4 is a graph showing a maximum value of the rotor speed relative to a load when the load is cut off in a reheating steam turbine equipped with the overspeed preventive apparatus according to the present invention.

Quick closure of a steam flow regulating valve is always encountered with two problems. One of the problems is how fast an abrupt increase in the speed due to, for example, cut-off of a load is detected, while the other problem is how fast the valve is closed in response to the signal indicative of the abrupt increase in the speed.

Consider now a case in which a load of a steam turbine generator operating in the steady state while driving the load is momentarily cut off. The phenomenon which takes place in such a condition will be discussed in detail hereunder. During the steady operation of the steam turbine generator, there is an exact balance between the power given by the steam for rotating the turbine rotor and the power transmitted to an associated power system from the generator connected to the turbine for consumption by the electric power system. Cut-off of the load represents a transient state in which the power consumed by the latter is removed momentarily from the state of equilibrium resulting in a great unbalance and steam in a quantity more than is required is supplied to the turbine rotor. The turbine rotor is accelerated due to the unbalance between the power applied thereto and the power consumed by the load, and the speed of the turbine rotor is subject to a variation until the unbalance is eliminated. This power unbalance appears necessarily before the turbine rotor is accelerated. The unbalance corresponds to the deviation of the actual speed of the turbine rotor from the desired speed. Therefore, if it is possible to detect the occurrence of the unbalance and to close the steam flow regulating valve before the turbine rotor is subject to acceleration, an undesirable overspeed can be more effectively prevented than with the speed control system in which control operation is not started until the speed is increased and a signal indicative of the increase in the speed is fed back to the input side.

The load imparted to the rotor of the turbine driving the generator can be quantitatively known by detecting the load of the generator, that is, the output (wattage) of the generator determined by the generated current and voltage, or by detecting the current when the voltage is constant. On the other hand, the power imparted to the turbine rotor can be quantitatively known by detecting whether the working fluid acting upon the turbine rotor has a sufficient potential to flow and the flow occurs actually. In other words, the power imparted to the turbine rotor can be quantitatively known by detecting whether the working fluid flowing downstream of the steam flow regulating valve has a pressure and seeking the value of the fluid pressure if the fluid has a pressure. In the case of a reheating steam turbine especially, the power developed by the intermediate and low pressure turbine disposed downstream of the reheater occupies about 70 percent of the total power, and the steam in the reheater flows into the intermediate and low pressure turbine to transmit the power to the turbine rotor even when the first valve disposed at the inlet of the high pressure turbine is closed. Therefore, the opening of the second valve disposed downstream of the reheater or fluid pressure at the outlet of this valve should be detected in order to know the power imparted to the turbine rotor. Repeating again, the occurrence of an unbalance as described above results in the acceleration of the turbine rotor. The greater the unbalance and the lighter the weight of the turbine rotor, the turbine rotor is accelerated to a

greater degree. Further, the greatest acceleration of the turbine rotor is seen immediately after the unbalance occurs. Thus, if this acceleration could be detected, the tendency and degree of the turbine rotor toward rotation at an overspeed can be known.

In order that the fluid flow regulating valve can be quickly closed, it is necessary to quickly discharge the hydraulic pressure having been imparted to the piston in the hydraulic cylinder for maintaining the valve in the open position. The discharge of hydraulic fluid or oil can be done by the use of the servo valve disposed in the speed control system. However, the servo valve must have a considerably large capacity in order that the turbine valve can be closed at an actually required high speed by the servo valve.

The intermediate flow restricting valve in the reheating steam turbine is maintained in a substantially full opened position during the normal operation of the turbine, and therefore a servo valve of a small capacity may be satisfactorily used in conjunction with the intermediate flow restricting valve. However, when a valve of a large capacity is required for the quick closure of the fluid flow regulating restricting valve in the case of an emergency only, it is economical to provide a second dumping valve to serve for quick closure of the flow restricting valve beside the servo valve. That is, a dumping valve adapted to serve solely for the purpose of the quick closure of the fluid flow regulating valve (adjusting valve or intermediate flow restricting valve) is preferably provided in addition to the servo valve.

The action of the dumping valve for the quick closure of the fluid flow regulating valve is applied from the system external to the speed control system as described above, and it is, as it were, a sort of external disturbance applied to the speed control system when considered from the side of the speed control system. Therefore, there is a need for switch-over from the external system to the speed control system for continuously maintaining the turbine at a controlled speed after the load has been cut off and the turbine has started to run steadily at no load. There is also an interference between the two systems on the same valve. It is therefore desirable that the dumping valve may not be operated except for the quick closure of the fluid flow regulating valve, and the fluid flow regulating valve may normally be closed by the operation of the speed control system, hence by the servo valve. The operation of the dumping valve does not vary depending on the degree of the load cut off, and the designing of the dumping valve so as to respond to a too small unbalance in the upper load is undesirable from the viewpoint of satisfactory operation of the turbine in that the dumping valve operates incessantly in response to a small transient variation in the load. It is therefore desirable to limit the operating range of the dumping valve to a minimum and to arrange so that the fluid flow regulating valve be quickly closed by the speed control system in the case of the cut-off of a low load.

One of the problems inherent in the electrohydraulic speed governor is the reduction of reliability due to the increase in the number of component parts. In other words, the electronic circuit of the electrohydraulic speed governor includes a very large number of transistors, resistors, condensers, etc., and it is quite probable that even carefully selected parts may fail to properly function. Accordingly, the unbalance detecting and valve actuating system should be provided in duplex for

improving the safety taking into consideration possible failure of the safeguard means.

Referring now to the drawings wherein like parts are indicated by like reference numerals throughout the figures and referring particularly to FIG. 1, a high pressure steam turbine 1 and an intermediate and low pressure steam turbine 2 are connected to an electric generator 3. Steam is supplied through a first steam flow regulating valve 4 into the high pressure turbine 1 to impart a portion of its effective energy to the turbine rotor. The exhaust from the high pressure turbine 1 is reheated by a reheater 5, and the reheated steam is supplied through a second steam flow regulating valve 6 into the intermediate and low pressure turbine 2 to be finally exhausted therefrom.

A contact-less electromagnetic pickup 8 disposed adjacent to a gear 7 mounted on the rotary shaft of the generator 3 detects the rotational speed of the turbine rotor and delivers a pulse signal which is proportional to the speed of the turbine rotor. A digital-analog converter 9 converts the pulse signal into a d.c. voltage which is proportional to the rotational speed of the turbine rotor. The d.c. voltage signal indicative of the actual speed N is compared in an adder 10 with a desired speed N_0 , and the difference is amplified by an amplifier 11. The deviation or error signal thus amplified is applied to a servo valve 12 in which the electrical signal is converted into a corresponding displacement of the valve spool for actuating the piston in a hydraulic cylinder 13 which actuates the valve 4. The motion or stroke of the piston is converted into an electrical signal by a stroke detector 14 and the electrical signal is fed back through an operational amplifier 15 to the input side of the servo valve 12 to set the position of the valve 4 relative to the actuating signal.

In the meantime, the speed deviation or error signal is amplified by an amplifier 16 to be applied to a servo valve 18 in which the electrical signal is converted into a corresponding displacement of the valve spool for actuating the piston in a hydraulic cylinder 17 which actuates the valve 6. The motion or stroke of the piston is converted into an electrical signal by a stroke detector 20 and the electrical signal is fed back through an operational amplifier 21 to the input side of the servo valve 18 to set the position of the valve 6 relative to the actuating signal. During the normal operation, the flow rate of the fluid is regulated by the valve 4, while the valve 6 which has a greater opening than the valve 4 is opened fully and does not regulate the fluid flow. The amplifier 16 acts to establish such a static relationship between the valves 4 and 6 relative to the speed error signal.

It will be seen that, when the rotational speed of the turbine rotor is increased to bring a large deviation of the actual speed from the desired speed due to an unbalance between the fluid supplied to the turbine and the load resulting from the cut-off of the load, the valve 4 is first closed and the valve 6 is subsequently closed in response to the error signal appearing in such a basic control system. However, with the recent general tendency toward a higher unit output of the turbine and a larger capacity of the reheater, it has become the absolutely essential condition that the valves 4 and 6, especially the valve 6 be closed more quickly. More precisely, it has become the essential condition that the valve 6 be transiently quickly closed, or in some cases, closed earlier than the valve 4 to quickly shut off the

flow of working fluid in the event of an unusual state such as an abrupt increase in the speed of the turbine rotor, while the static relationship between the valves 4 and 6 is maintained by the basic speed control system in the manner described above during the normal operation.

An apparatus according to the present invention which meets the above requirement is diagrammatically shown in FIG. 2. Referring to FIG. 2, the apparatus comprises a basic speed control system which includes an electronic circuit group 24 and a valve actuating means 28. The electronic circuit group 24 generates a valve actuating signal 74 in response to the application of a signal 22 representative of the speed setting, a signal 23 representative of the load demand and a signal 25 representative of the actual speed of the turbine rotor. The valve actuating means 28 actuates a steam valve means 29 in response to the valve actuating signal 74.

In addition to the basic speed control system described above, the apparatus comprises an overspeed preventive control system which includes means 36 and a relay means 37. A signal 34 representative of the fluid pressure downstream of the steam valve means 29 or a signal 34' representative of the opening of the steam valve means 29 and a signal 35 representative of the power or current at the load are applied to the means 36 to be compared with each other in the means 36. When the difference or unbalance between the signal 34 or 34' and the signal 35 is greater than a predetermined setting 33 which is also applied to the means 36 in the form of a signal, the means 36 energizes the relay means 37 for quickly urging the steam valve means 29 into the fully closed position. That is, this system monitors the operation of the turbine by detecting any unbalance between the power input and power output to and from the turbine rotor on the basis of the signals 34 or 34' and 35, and actuates immediately the relay means 37 and a rapid valve-closing means to quickly close the steam valve means 29 when the unbalance exceeds the predetermined setting 33 resulting in the danger of rotation of the turbine rotor at an overspeed. Thus, this system acts to quickly close the steam valve means 29 independently of the basic speed control system. By virtue of the provision of such a system, a servo valve of a relatively small capacity can be used for the speed control during the normal operation in which the quick control described above is not required, while the steam valve means 29 can be quickly closed in the case of an overspeed which occurs quite rarely. Another overspeed prevention control system in the apparatus includes an acceleration comparing means 31 and a relay means 32. The speed signal 25 is applied to the acceleration comparing means 31 in which the speed signal 25 is differentiated to obtain the acceleration and this acceleration is compared with an acceleration setting 30. In the event that the acceleration exceeds the fixed value resulting in the possibility of overspeed, the acceleration comparing means 31 actuates the relay means 32 and the rapid valve-closing means 80 to close the steam valve means 29 independently of the basic speed control system. The two systems for energizing the respective relay means 32 and 37 are provided for the purpose of improving the safety of the electro-hydraulic speed governor which includes a large number of parts. That is, the provision of the two unbalance detecting and valve actuating systems is ad-

vantageous in that the operation of any one of these two systems can safely prevent an undesirable overspeed and the safety can be ensured even in the event of failure of either system.

The relay means 32 and 37 are restored to the original de-energized state after the overspeed is eliminated and the basic speed control system including the electronic circuit group 24, the valve actuating means 28 and the steam valve means 29 is now ready to carry out the normal speed control.

The systems for externally closing the steam valve means 29 operate whenever the respective operating conditions are satisfied and make on-off operation to close the valve means 29 at a maximum speed regardless of the magnitude of the load cut off. The operation of these external systems may provide a sort of external disturbance when considered from the side of the basic control system, and there may be an interference between the basic speed control system and the external systems. It is therefore desirable to prevent the external systems from operation as much as possible except the case in which quick closure of the valve means 29 is required and to close the valve means 29 by the basic control system in the case in which the load is low. It is therefore preferred that the setting 33 of unbalance may have a greatest possible value and any unbalance smaller than this value may be dealt with by a load cut-off signal generator 27. The operation of the load cut-off signal generator 27 may be such that it differentiates the valve actuating signal 74, and after suitable amplification of the differentiated value, delivers a signal which has such a polarity as to work in the valve closing direction. This signal is applied to an adder 26 to be added to the valve actuating signal 74. More precisely, the load cut-off signal generator 27 does not deliver any signal during the normal operation, but delivers a valve closing signal which is dependent upon the magnitude of acceleration when a large unbalance occurs resulting in the acceleration. This valve closing signal is added by the adder 26 to the valve actuating signal 74 representative of the speed deviation and a signal of great magnitude is transiently applied to the valve actuating means 28 to quickly close the valve means 29. By this arrangement, the function of the basic speed control system can be improved more effectively than when it is responsive solely to the speed deviation or error signal thereby to close the valve means 29.

In FIG. 3, there is shown an embodiment of the present invention in which the the present invention is applied especially to the quick closure of steam flow regulating valve 6 provided in a steam valve means.

A speed detector 38 detects the speed of the turbine rotor and applies a signal 25 proportional to the actual speed of the turbine rotor to an electronic circuit group 24. The electronic circuit group 24 compares the signal 25 with a signal 22 representative of the speed setting and a signal 23 representative of the load demand to provide the valve actuating signal 74, in the same manner as described with respect to FIG. 2. The valve actuating signal 74 is applied to valve actuating circuits 44 and 45 for actuating the respective steam flow regulating valves 4 and 6. The valve actuating circuit 45 and a servo valve 18 constitute a valve actuating means 28. The means 38, 24, 44 and 45 constitute a basic speed control system similar to a prior art system which operates in response to the speed deviation.

According to the present invention, a system including a load cut-off signal generator 27 having means 40, 41 and 42 is associated with the basic speed control system. The valve actuating signal 74 for actuating the valve 6 is applied to a differentiator 40 to be differentiated thereby. The greater the variation in the valve actuating signal 74, that is, the higher the speed with which the valve 6 is closed in response to the increase in the speed of the turbine rotor due to the cut-off of the load, the output signal delivered from the differentiator 40 has a correspondingly greater magnitude. A slide resistor 41 acts as a selective circuit which does not allow the passage of the output signal of the differentiator 40 until the valve closing signal delivered from the differentiator 40 exceeds a fixed value which is set up on the basis of the value when the load has been cut off. Thus, no signal is delivered from the selective circuit 41 during the normal operation in which the rate of speed variation is small, while the valve closing signal which is dependent upon the rate of speed increase is delivered transiently from the selective circuit 41 only when the rate of speed increase exceeds a fixed value to an extent that the valve 6 must be quickly closed, namely, when the load has been cut off. An amplifier 42 maintains the transiently generated signal until it disappears gradually so as not to urge the valve 6 into an open position due to an abrupt reduction in the magnitude of the signal resulting from a reduction in the rate of speed increase. The signal delivered from the system described above is applied to an adder 26 provided in the speed control system. The output signal of the adder 26 is amplified by an amplifier 39 and then applied to the valve actuating circuit 45. By virtue of the provision of the system described above, the function, for actuating the valve 6, of the basic speed control system responsive solely to the speed deviation can be effectively improved.

The valve actuating signal delivered from the valve actuating circuit 45 is applied to the servo valve 18 to control the position of a piston 76 in a hydraulic cylinder 73, which is provided in the steam valve means 29, against the force of a spring 75 thereby to actuate the valve 6. Meanwhile, in a rapid valve-closing means 80, a dumping valve 72 is normally kept in the closed position, but when it is required to quickly close the valve 6, the dumping valve 72 is urged into the open position to drain hydraulic fluid or oil from a drain port 77 so that the valve 6 can be closed quicker than when it is closed by the servo valve 18. It will thus be seen that the dumping valve 72 operates in the case in which the operation of the servo valve 18 cannot prevent an overspeed higher than an allowable value, thereby protecting the turbine from damage. The dumping valve 72 is actuated by a solenoid 71 which is energized when one of relay contacts 57 and 70 is in the on state.

A transmitter 58 for detecting the state of flow of the working fluid passing through the engine thereby producing an electrical output signal, for example, for converting the steam pressure at the outlet of the valve 6 into an electrical output signal 34, and a transmitter 59, for converting the electrical output of the load or the output current of the generator, into an electrical output signal 35, apply the respective output signals 34 and 35 to a summing amplifier 60, which constitutes a comparing means 36 together with a comparator 61, a contact 63 and a solenoid 64. In the summer amplifier 60, one of the signals 34 and 35 is subtracted from the

other and the difference signal is applied to the comparator 61. The comparator 61 compares the difference signal with a reference voltage and the contact 63 is closed when the difference between the difference signal and the reference voltage exceeds a fixed value. The closure of the contact 63 energizes the solenoid 64 to thereby close a contact 65. The reference voltage is set up to be larger than the difference signal produced by the summing amplifier 60 in response to the cut-off of a predetermined load. Thus, this overspeed preventive control system, including the comparing means 36, is capable of operating in response to the cut-off of a high load which is higher than the predetermined load. However, when a low load, which is lower than the predetermined load, is cut-off, this overspeed preventive control system is not operative, and the signal delivered from the load cut-off signal generator 27 is applied to the adder 26, to thereby rapidly close the valve 6, through the valve actuating means 28 short of a tripping of the machine. The closure of the contact 65 energizes solenoids 67 and 68 of a relay means 37, and a contact 66 is closed to establish a self-holding circuit so that the solenoids 67 and 68 are kept energized even when the contact 63 is opened due to the disappearance of the operating condition which has appeared before. The energization of the solenoid 67 closes the contact 70 resulting in the energization of the solenoid 71. A timer relay disposed in the relay means 37 is energized in response to the energization of the solenoid 68, and its contact 69 is opened after a predetermined length of time to cut off the energizing current supplied to the solenoids 67 and 68 with the result that the contact 70 is urged into the original open position. The length of time ranging from the actuation of the contact 70 to the restoration thereof is so determined that the dumping valve 72 may not be restored to the original closed position until a sufficiently large signal for closing the valve 6 is applied to the piston 73 from the basic speed control system through the servo valve 18 due to the increase in the speed of the turbine rotor. After the restoration of the dumping valve 72 to the original closed position, the valve 6 is actuated under the control of the basic speed control system.

The speed signal 25 is also applied to a limiter 43 disposed in a comparing means 31 which includes a potentiometer 46, an amplifier 47, an element 48, a summing amplifier 49, a solenoid 51 and a contact 62. The limiter 43 is connected to the potentiometer 46 so that a signal is delivered from the limiter 43 only when the speed exceeds the rated speed. This signal is applied to the amplifier 47 for giving a time lag of first order and to the element 48. The amplifier 47 and element 48 apply their output signals to the summing amplifier 49 in which one of the signals is subtracted from the other so that the summing amplifier 49 delivers a signal which is representative of the acceleration obtained by differentiating the speed signal 25 and has a higher voltage level at a greater rate of speed increase. This signal representative of the acceleration is compared in the comparator 50 with a reference voltage, to thereby produce a difference signal. The contact 62 is closed to energize a solenoid 51 thereby to close a contact 52 when the difference signal which indicates a danger due to the acceleration exceeds predetermined setting. Thus, this overspeed preventive control system, including comparing means 31, is capable of operating in response to the cut-off of a high load, which is higher

than a predetermined load. However, when a low load which is relatively lower than the predetermined load, is cut-off, this overspeed preventive control system is not operative, but the signal delivered from the load cut-off signal generator 27 is applied to the adder 26, to thereby rapidly close the valve 6 through the valve actuating means 28, in the same manner as discussed in connection with the above overspeed preventive control system including comparing means 36. The closure of the contact 52 energizes solenoids 53 and 55 of a relay means 32, and a contact 54 is closed to establish a self-holding circuit, so that the solenoids 53 and 55 remain energized even when the contact 62 is opened due to the disappearance of the operating condition which has previously appeared. The energization of the solenoid 53 closes the contact 57, so as to actuate the rapid valve-closing means 80, to thereby rapidly close the valve 6 in the same manner as previously discussed in connection with the above-mentioned overspeed preventive control system. A timer, having a contact 56, disposed in the relay means 32, also functions in the same manner as the timer in the relay means 37. It will thus be seen that the apparatus according to the present invention ensures an increased reliability and can protect the turbine from damage in a more positive manner than heretofore by virtue of the provision of the two independent unbalance detection and signal transmission systems for energizing the solenoid 71.

Referring to FIG. 4, the dumping valve 72 is actuated when the load exceeds a point A, and in the range in which the load is lower than that shown by the point A, the speed control by means of feedback is solely carried out. It will be seen from FIG. 4 that the speed can be maintained at a value lower than the maximum allowable speed ϕ_a over the entire range of the load.

What is claimed is:

1. An apparatus for preventing an engine from overspeed comprising:

a working fluid flow regulating valve disposed at the inlet of the engine;

first means, responsive to the speed of the engine, for detecting a deviation between the actual speed of the engine and a predetermined speed, and for selectively controlling the opening and closing of said working fluid flow regulating valve in response to said deviation;

second means, responsive to the rate of change of the speed of the engine, for detecting a deviation between the actual acceleration of the engine and a predetermined acceleration and for generating a first electrical signal representative of said deviation;

third means, responsive to the state of flow of the working fluid passing through said engine, for generating a second electrical signal representative thereof;

fourth means, responsive to the output load of said engine for generating a third electrical signal representative thereof;

fifth means, coupled to the outputs of said third and fourth means, for combining said second and third electrical signals and for generating a fourth electrical signal when said combined second and third electrical signals exceed a predetermined fixed value; and

sixth means, coupled to said second and fifth means, for controlling the rapid opening and closing of

said working fluid flow regulating valve, in response at least one of said first and fourth electrical signals, independently of the control of the opening and closing of said working fluid flow regulating valve by said first means.

2. An apparatus according to claim 1, wherein said first means includes a hydraulic servo valve means, coupled to said working fluid flow regulating valve, for controlling the opening of said working fluid flow regulating valve, and wherein said sixth means includes a dumping valve, coupled to said hydraulic servo valve means, for draining hydraulic fluid from said hydraulic servo valve means, in response to at least one of said first and fourth electrical signals.

3. An apparatus according to claim 1, wherein said first means includes valve actuator means, coupled to said working fluid flow regulating valve, for controlling the actuating thereof in response to an electrical signal applied thereto, and further including seventh means coupled to said first means, for generating a fifth electrical signal to be supplied to said valve actuator means, in response to the rate of change of said deviation exceeding a preselected amount.

4. An apparatus according to claim 1, wherein said second and fifth means include means for enabling the generation of said first and fourth electrical signals prior to the selective control by said first means in response to the cut-off of a high load from said engine, while preventing the generation of said first and fourth electrical signals in response to the cut-off of a relatively lower load from said engine, to thereby permit said first means to control the opening and closing of said working fluid flow regulating valve at a cut-off of a relatively lower load.

5. An apparatus according to claim 2, wherein said second and fifth means include means for enabling the generation of said first and fourth electrical signals prior to the selective control by said first means in response to the cut-off of a high load from said engine, while preventing the generation of said first and fourth electrical signals in response to the cut-off of a relatively lower load from said engine, to thereby permit said first means to control the opening and closing of said working fluid flow regulating valve at a cut-off of a relatively lower load.

6. An apparatus according to claim 5, wherein said first means includes valve actuator means, coupled to said working fluid flow regulating valve, for controlling the actuating thereof in response to an electrical signal applied thereto, and further including seventh means coupled to said first means, for generating a fifth electrical signal to be supplied to said valve actuator means, in response to the rate of change of said deviation exceeding a preselected amount.

7. An apparatus according to claim 2, wherein said first means includes valve actuator means, coupled to said working fluid flow regulating valve, for controlling the actuating thereof in response to an electrical signal applied thereto, and further including seventh means coupled to said first means, for generating a fifth electrical signal to be supplied to said valve actuator means, in response to the rate of change of said deviation exceeding a preselected amount.

8. An apparatus according to claim 7, further including delay means, coupled between at least one of said second and fifth means and said sixth means, for continuing the actuation of said dumping valve until a suffi-

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ciently large signal for closing said working fluid flow regulating valve is supplied from said first means through said servo valve means.

9. An apparatus according to claim 8, wherein said delay means is coupled between each of said second and fifth means and said sixth means.

10. An apparatus according to claim 8, wherein said fifth means comprises a first summing amplifier to which said second and third signals are applied, a first comparator circuit for comparing the output of said first summing amplifier with a first reference voltage and a first solenoid switch coupled to the output of said first comparator circuit for enabling the coupling of said fourth electrical signal to said sixth means.

11. An apparatus according to claim 10, wherein said second means comprises a first differentiator circuit to which a signal representative of the actual speed of the engine is applied, a second comparator circuit for comparing the output of said first differentiator circuit with

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a second reference voltage and a second solenoid switch coupled to the output of said second comparator circuit for enabling the coupling of said first electrical signal to said sixth means.

12. An apparatus according to claim 11, wherein said seventh means comprises a second differentiator circuit to which a signal representative of said speed deviation is applied and a voltage threshold responsive amplifier circuit for enabling the generation of said fifth signal to be supplied to said valve actuator means when the load of the engine has been cut off.

13. An apparatus according to claim 12, wherein each of said delay means comprises a pair of solenoid switches the windings of which are connected in parallel with a slow release contact responsive to one of said windings, coupled to the supply line therefor, while the output of the other winding is connected to said sixth means.

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