United States Patent [19]

Conrad, Jr. et al.

[11] **3,826,095**

[45] **July 30, 1974**

[54] **GENERAL SYSTEM AND METHOD FOR OPERATING A STEAM TURBINE WITH INDEPENDENT OVERSPEED PROTECTION ESPECIALLY ADAPTED FOR A NUCLEAR REACTOR POWERED STEAM TURBINE**

[75] Inventors: **Joseph D. Conrad, Jr.**, Glen Mills; **Wilmer C. Gangloff, Jr.**, Murrysville, both of Pa.

[73] Assignee: **Westinghouse Electric Corporation**, Pittsburgh, Pa.

[22] Filed: **Oct. 14, 1971**

[21] Appl. No.: **189,320**

[52] **U.S. Cl.** **60/686**, 60/644, 290/40

[51] **Int. Cl.** **F01k 7/16**

[58] **Field of Search** 60/73, 105

[56] **References Cited**

UNITED STATES PATENTS

3,102,394	9/1963	Hartfield et al.	60/105 X
3,421,014	1/1969	Moorganov	60/105
3,630,839	12/1971	Podolsky	60/73
3,643,437	2/1972	Birnbaum et al.	60/73

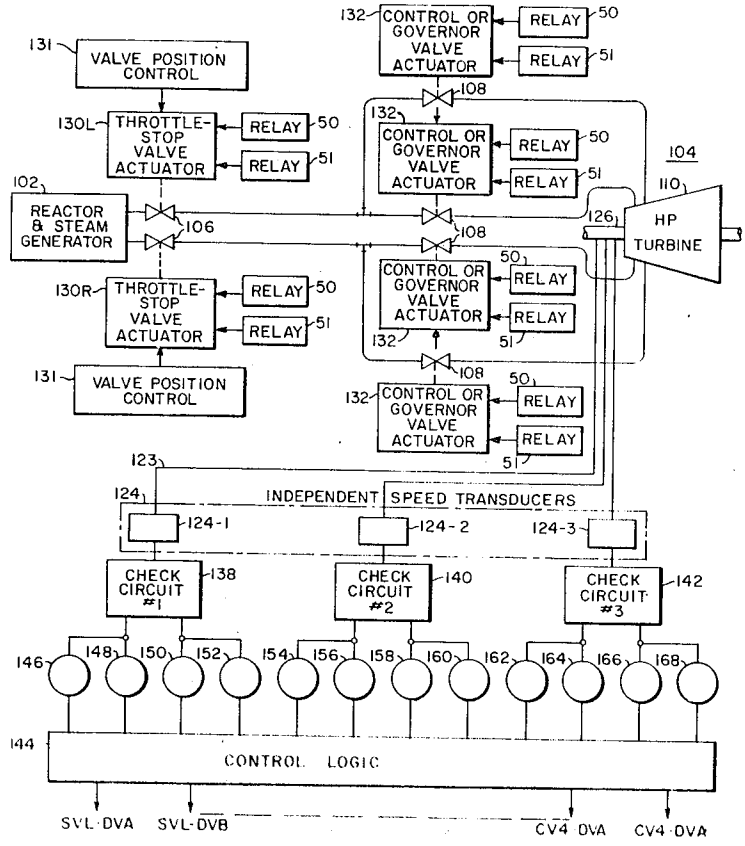
Primary Examiner—Edgar W. Geoghegan
Assistant Examiner—H. Burks, Sr.
Attorney, Agent, or Firm—E. F. Possessky

[57] **ABSTRACT**

In a steam turbine an overspeed protection system and method is provided which operates completely independently of the conventional steam valve controller or governor. Existing hydraulically actuated valves such as stop valves, governor valves, interceptor valves, etc., are deactivated by draining hydraulic control fluid from the aforementioned through the action of specially provided dump valves. A pair of dump valves is provided for each of the steam flow valves.

Three turbine speed sensing transducers operating independently provide signals which are translated through three corresponding check circuits into related overspeed check signals. The three resulting check signals relating to overspeed are translated through majority switching logic into two dump valve trip signals. Each set of such trip signals operates one of the pair of dump valves on each steam control valve.

20 Claims, 10 Drawing Figures



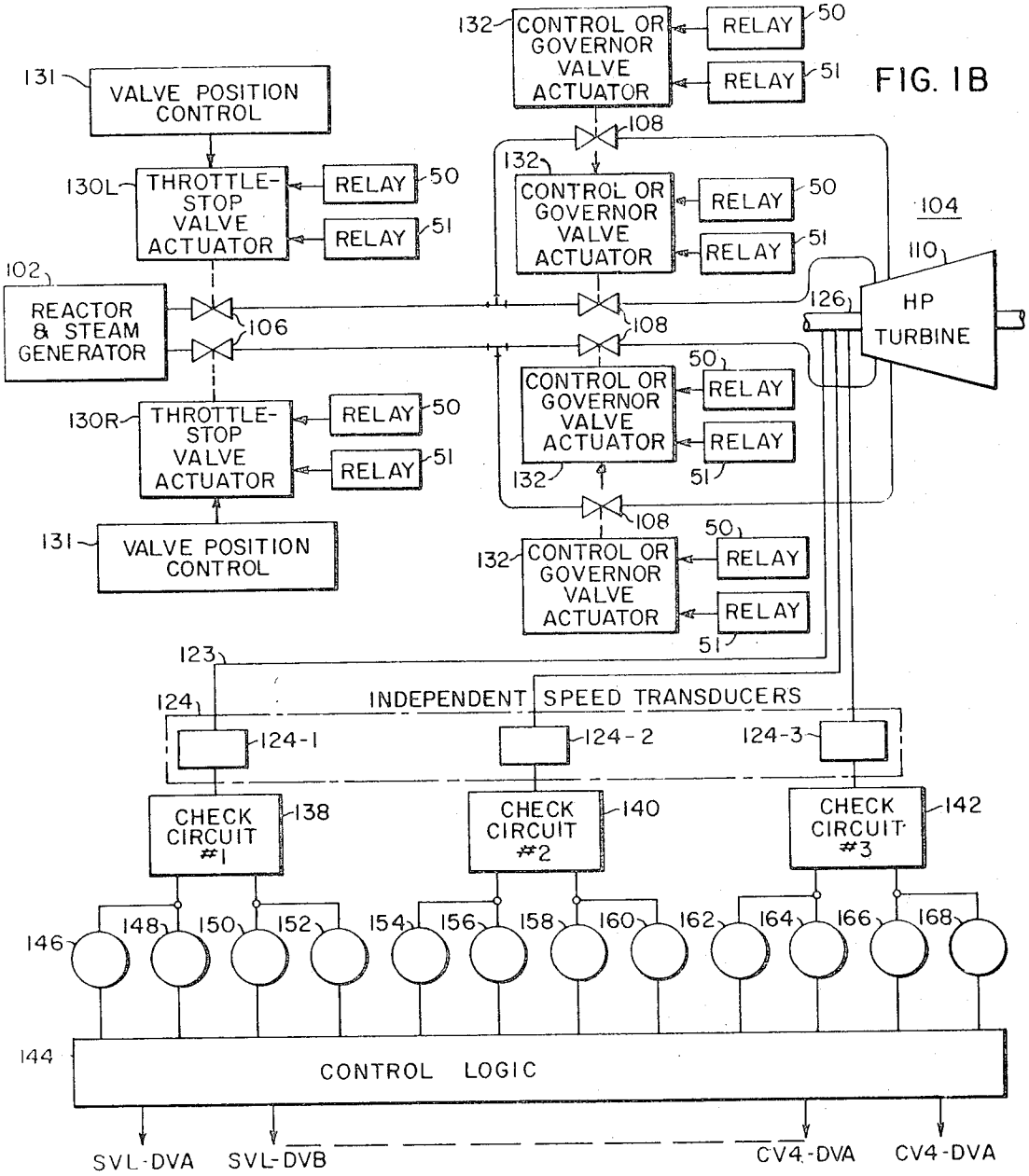

132
CONTROL OR GOVERNOR VALVE ACTUATOR
RELAY
50
RELAY
51
131
VALVE POSITION CONTROL
108
130L
THROTTLE-STOP VALVE ACTUATOR
104
110
102
REACTOR & STEAM GENERATOR
106
126
HP TURBINE
130R
123
124
INDEPENDENT SPEED TRANSDUCERS
124-1
124-2
124-3
CHECK CIRCUIT #1
138
CHECK CIRCUIT #2
140
CHECK CIRCUIT #3
142
146
148
150
152
154
156
158
160
162
164
166
168
144
CONTROL LOGIC
SVL-DVA
SVL-DVB
CV4-DVA
CV4-DVA
THROTTLE-STOP VALVES
GOVERNOR VALVES
V
TURBINE HP LP LP
122
GENERATOR
100
128
INDEPENDENT OVER SPEED PROTECTION SYSTEM

FIG. 1B

FIG. 1

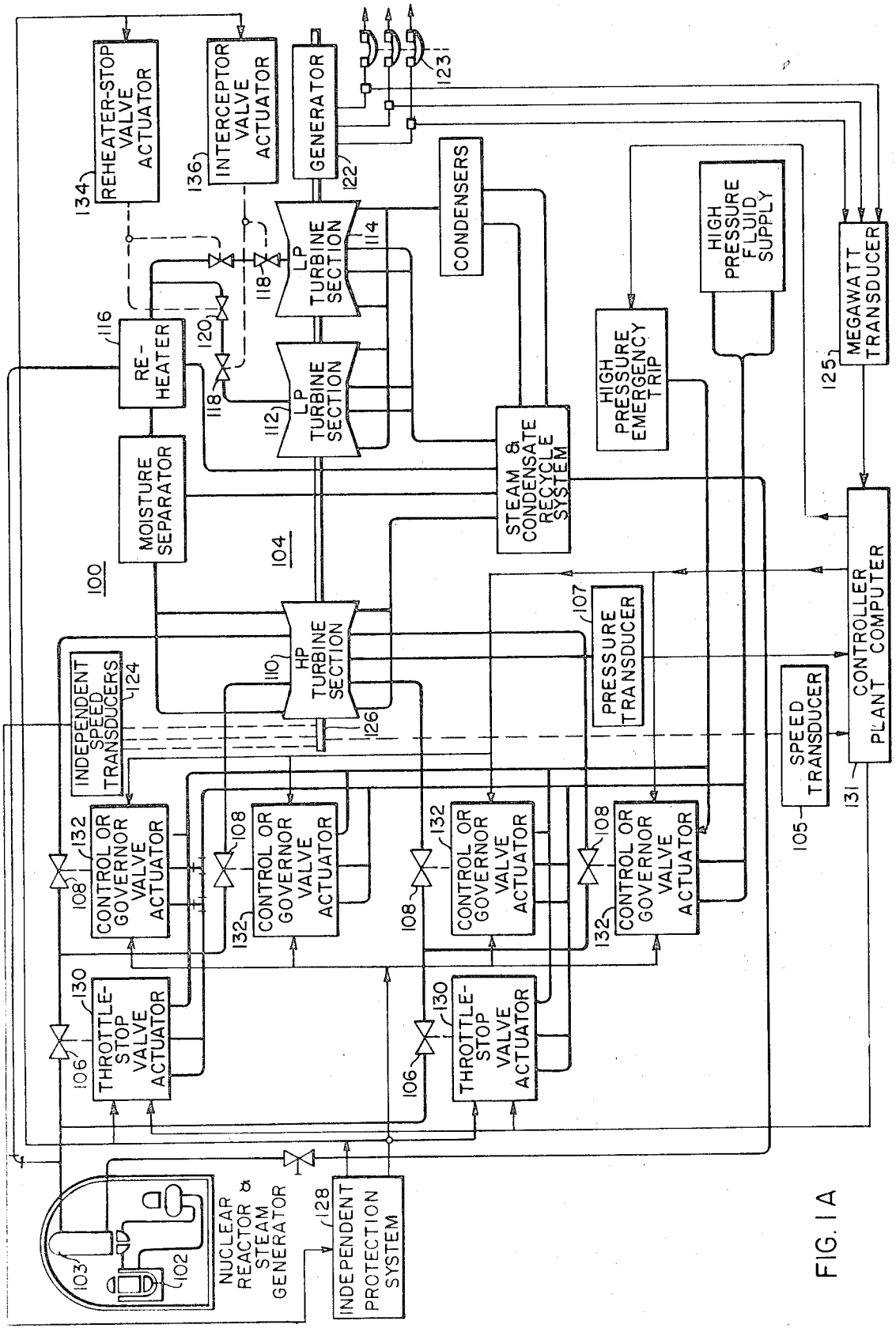

REHEATER-STOP VALVE ACTUATOR
134
INTERCEPTOR VALVE ACTUATOR
136
GENERATOR
122
123
CONDENSERS
HIGH PRESSURE FLUID SUPPLY
MEGAWATT TRANSDUCER
125
LP TURBINE SECTION
114
118
RE-HEATER
116
120
LP TURBINE SECTION
112
HIGH PRESSURE EMERGENCY TRIP
MOISTURE SEPARATOR
STEAM & CONDENSATE RECYCLE SYSTEM
100
104
HP TURBINE SECTION
110
PRESSURE TRANSDUCER
107
INDEPENDENT SPEED TRANSDUCERS
124
126
SPEED TRANSDUCER
105
CONTROLLER PLANT COMPUTER
131
CONTROL OR GOVERNOR VALVE ACTUATOR
132
108
THROTTLE-STOP VALVE ACTUATOR
130
106
NUCLEAR REACTOR & STEAM GENERATOR
103
102
INDEPENDENT PROTECTION SYSTEM
128

FIG. 1A

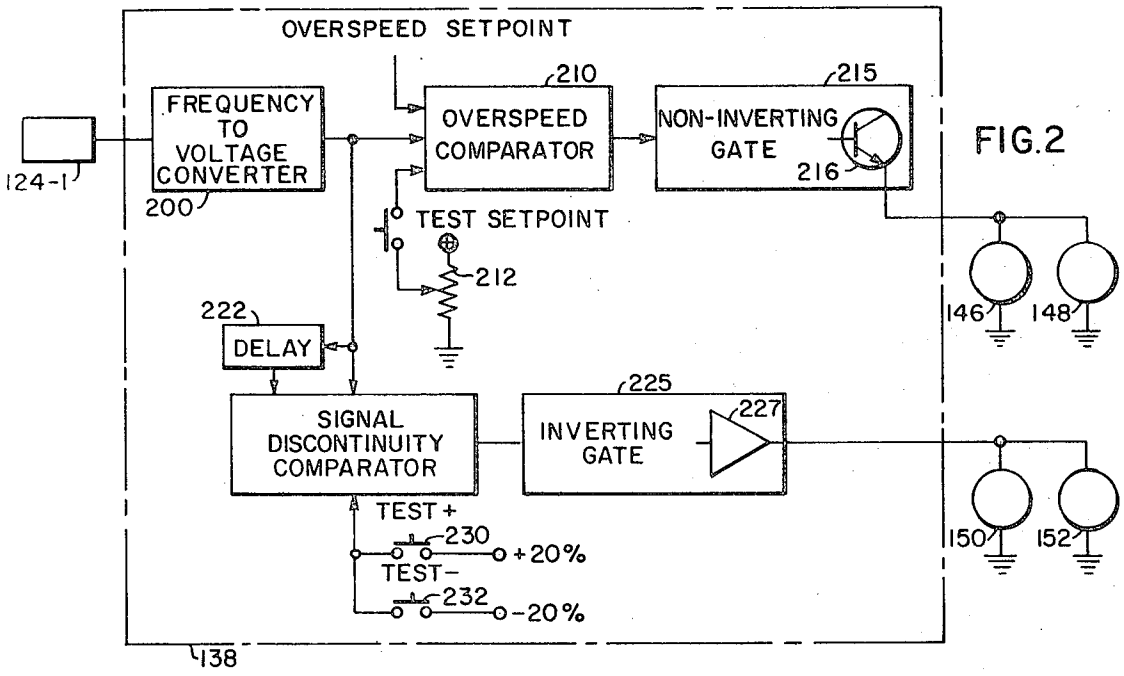


FIG.2

STATE OF RELAYS	S	F
ALL SYSTEMS GO	ON	OFF
PROTECTION POWER FAILURE	OFF	OFF
OVERSPEED	OFF	OFF
SIGNAL DISCONTINUITY	ON	ON

FIG.3

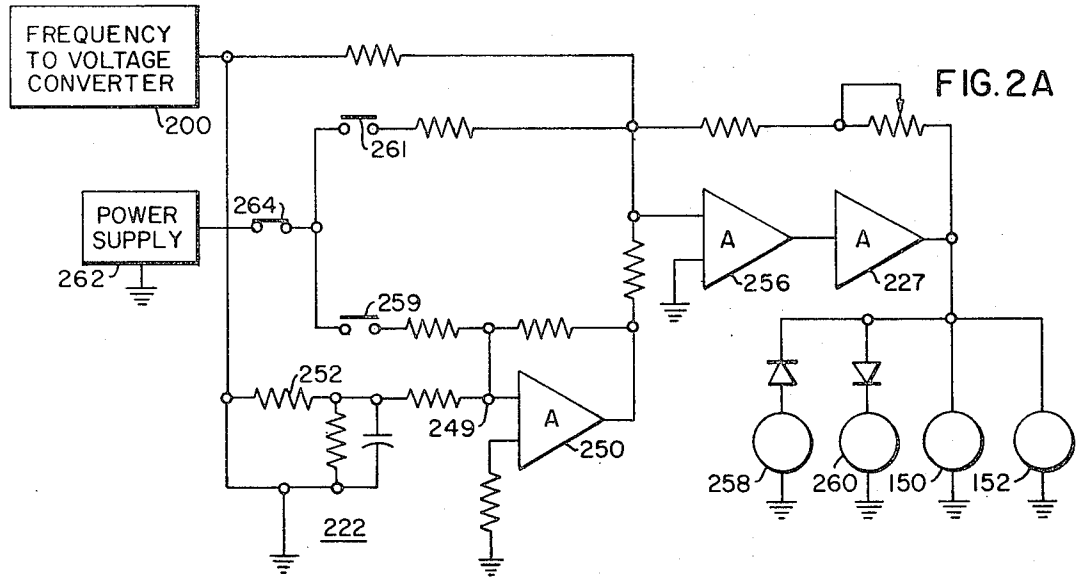


FIG.2A

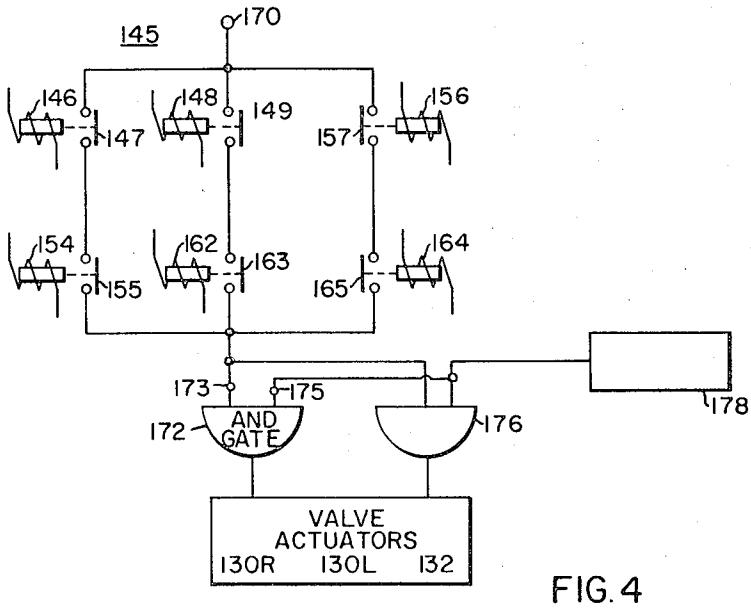

145
170
146
147
148
149
156
157
154
155
162
163
164
165
173
175
172
AND GATE
176
178
VALVE ACTUATORS
130R
130L
132

FIG. 4

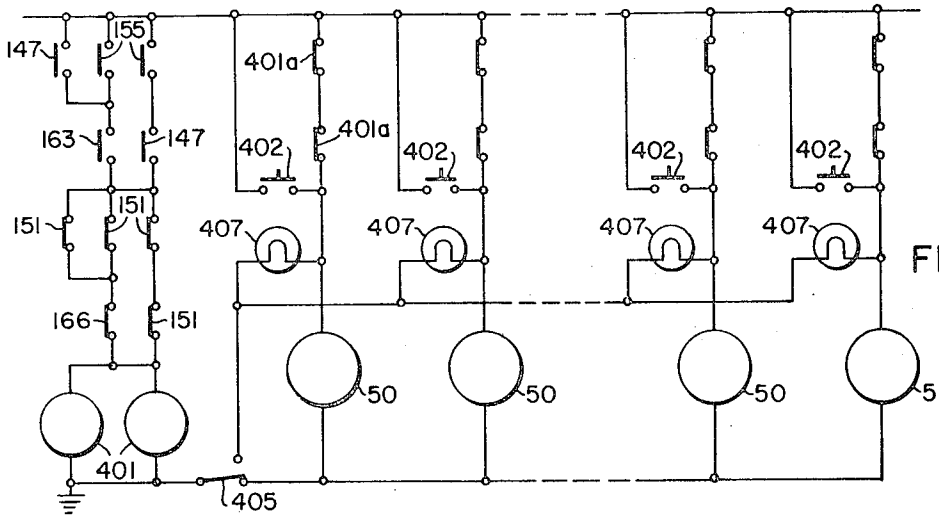


FIG. 4A

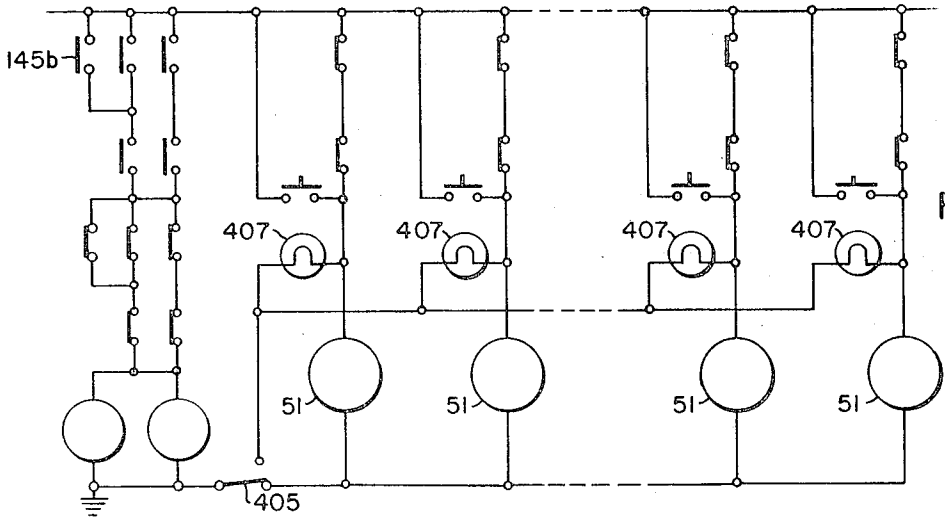


FIG. 4B

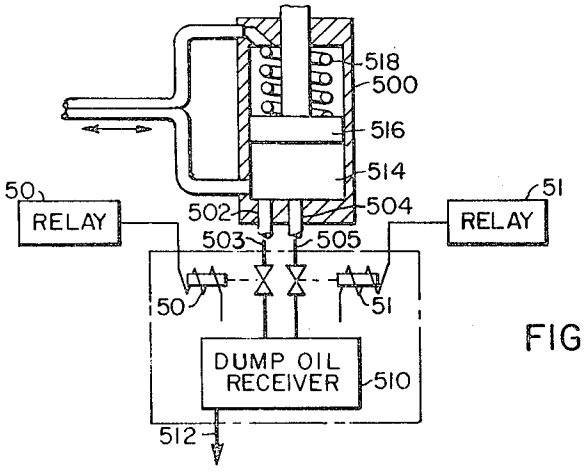


FIG. 5

GENERAL SYSTEM AND METHOD FOR OPERATING A STEAM TURBINE WITH INDEPENDENT OVERSPEED PROTECTION ESPECIALLY ADAPTED FOR A NUCLEAR REACTOR POWERED STEAM TURBINE

CROSS-REFERENCE TO RELATED APPLICATION

1. Overspeed Protection System For Steam Turbine Power Plant, Ser. No. 866,965, filed Oct. 16, 1969 now U.S. Pat. No. 3,643,437 by M. E. Birnbaum et al. and assigned to the present assignee.

2. Ser. No. 189,226 entitled "System and Method for Operating a Steam Turbine with Independent Overspeed Protection Especially Adapted for a Nuclear Reactor Powered Steam Turbine" by J. D. Conrad, Jr. et al.

3. Ser. No. 189,230 entitled "Electronic System and Method for Operating a Steam Turbine with Independent Overspeed Protection Especially Adapted for a Nuclear Reactor Powered Steam Turbine" by M. C. Luongo.

4. Ser. No. 189,322 entitled "System and Method for Operating a Steam Turbine Dual Hydraulic Independent Overspeed Protection Especially Adapted for a Nuclear Reactor Powered Steam Turbine" by M. Csanady, Jr. et al.

BACKGROUND OF THE INVENTION

In the prior art there exist many systems for preventing a turbine from developing an excessive speed. Protection against this eventuality is extremely important especially where nuclear power is used to generate steam for a turbine. If the turbine should enter a runaway state, centrifugal forces can become so great that rotor discs rupture, causing the throwing of pieces of the rotor around a generating station. These flying pieces are referred to as missiles.

If the rotor of a typical turbine in a nuclear generating plant presently in operation would rupture, the missiles produced thereby could weigh from 50 pounds to several tons. These missiles emanating from the turbine, could pierce the reactor, pipes containing radioactive fluids or steam, the control mechanism for the reactor, etc. The piercing of the reactor or vessels and piping containing radioactive fluids may possibly allow radiation to be dispersed. potential hazards involved in turbine accidents and has therefore promulgated stringent regulations in the design and construction of any nuclear generating plant requiring that the possibility of any accident occurring will be virtually zero. The regulations applicable to nuclear power plant construction are to be found in A.E.C. Regulations, Part 50, Appendix A.

The Atomic Energy Commission has promulgated the above-mentioned safety regulations for nuclear electric power generation plants because of the unique characteristics of nuclear reactors. Unlike fossil fuel reactors where the generation of steam can be terminated relatively quickly by cutting off the fuel supply to a steam generator, a nuclear reactor requires a complex and lengthy shutdown procedure. In order to stop the production of steam in a fossil plant, only the flow of boiler fuel such as gas, oil or coal need be stopped. The resulting shutdown and termination of the generation of steam can be completed in minutes. However, in the case of a nuclear reactor the shutdown procedure requires hours and tens of hours. Therefore, if a pipe or vessel carrying fluid is ruptured by a missile from the turbine, a hazardous condition caused by leaking material may continue for a long period of time until the reactor is shut down.

One solution to this problem of turbine missiles in a nuclear steam generating system was described in "Westinghouse Engineer" July 1966, pages 110 through 113 by Walter Sinton. Walter Sinton's solution to the problem is to provide covers for the reactor and steam turbines. The cover for the steam turbines confines any missiles therein. Unfortunately, in a commercial nuclear steam turbine system, the required size of a cover or shield strong enough to protect the plant from turbine missiles would have to be 6 to 10 ft. thick if made of concrete or 6 to 12 inches thick if made of steel. Such a shield would be extremely expensive, costing many millions of dollars, and require a completely redesigned foundation and building to house the turbine generating system. A shield of this size would also make maintenance, repairs and replacement of any parts in the turbine generator or reactor extremely difficult, time consuming and expensive.

Another solution which has been proposed for the protection of a nuclear plant against rotor missiles is to increase the thickness of the reactor walls and the case of the generator itself. This solution is unsatisfactory for the reasons enumerated above including high cost and extreme maintenance problems.

Another prior art approach is the building of high reliability against turbine overspeed into the existing turbine speed governor system itself. Inherent in the prior art speed governor solution to the problem of operating nuclear plants with turbine missile protection is that the overspeed protection system still remains part of the basic speed control mechanism. If a valve were to stick in the open position in a conventional overspeed system, the governor speed control system could not prevent turbine overspeed under no load or lightly loaded conditions. The compliance of this type of protection with AEC Regulations is, at this time, marginal.

Additionally the speed governor control systems of the prior art are operative in governing the speed of the turbine during operation. Therefore, these governor speed controls must be taken out of service in order to test their responsiveness to an overspeed condition. A system which is independent of the conventional governor speed controls is required which can be checked without disrupting the operation of the conventional speed system.

Therefore, a less expensive, highly reliable system which does comply with the Atomic Energy Commission Regulations is needed.

SUMMARY OF THE INVENTION

The present invention overcomes the limitations and disadvantages of the prior art by providing a power generation system and method for generating electricity which has completely independent protection against turbine overspeed runaway and turbine missiles.

Accordingly, it is a basic concept of the present invention to provide an electric power plant having a steam turbine and a completely independent turbine overspeed protection system. The independent overspeed protection system preferably includes means for dumping hydraulic fluid from the actuators of the vari-

ous governor, interceptor, stop and throttle valves controlling the flow of steam to the turbine. Each valve prefereably has two independent systems for dumping the hydraulic fluid and accomplishing a very fast shutdown of the turbine. These two independent systems can therefore be tested individually while the electrical generating system is on-line. In the preferred embodiment the signals for operating each of the two independent dumping systems for each valve are derived from three independent turbine speed signals. The three speed signals in three independent dual circuitry channels generate three independent electrical speed safe signals and three independent failure or signal discontinuity representing signals.

The three turbine speed safe signals are translated into a majority state signal indicating the mutual state of any of two out of the three speed signals. The three failure signals are translated into a majority state signal of any of two out of three failure signals.

A majority state safe signal is determined by switching logic, such that, if any two speed signals have proper predetermined values, a safe or majority state signal is indicated for the speed channels. The majority safe signal is directed to each of the two independent protection systems attached to each valve actuator. Therefore, if two of the three speed signals and two of the three failure signals have proper predetermined values, the dump values remain closed. If, however, two of the three speed signals or two of the three failure signals do not have the proper predetermined values, the dump valves open, shutting down the system.

The circuitry and operation of any one of three speed safe and three failure channels can be tested independently while the power generating system and protection circuitry are on line and without disrupting the operation of the system or circuitry. Any one speed channel can therefore fail or be under test without shutting down the system. As an added reliability feature, if one speed channel is under test, and another channel fails, the electrical generating system will be shut down since a test signal acts like a malfunction signal.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates a nuclear electrical power generating system as defined by the present invention;

FIG. 1A illustrates a more detailed application of the invention to a nuclear steam turbine system;

FIG. 1B shows the independent turbine speed protection system;

FIG. **2** is a block diagram of a suitable check circuit which is used in the preferred embodiment of schematic diagram shown in FIG. 2A;

FIG. **3** is a chart which summarizes the states of the speed channel and the failure channel relays for various operating conditions of a typical system;

FIG. **4** provides a relay mechanization and logic for one solenoid channel;

FIGS. 4A and 4B provide specific relay mechanization for the two independent dump channels, respectively, to provide appropriate majority switching controls; and

FIG. **5** shows a section through a steam valve actuator to show the manner in which the dump valves of the preferred embodiment are employed in a typical application.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Reference is now made to FIG. **1** where a nuclear reactor system and turbine **100** are shown. The nuclear reactor system and turbine **100** include a reactor **102** and a steam generator **103,** which provides steam for a turbine **104.** Steam from the steam generator **103** passes through a stop valve **106** and a governor valve **108** before flowing into the turbine **104.**

Referring now to FIG. 1A, the steam turbine **104** includes a high pressure turbine (H.P.) **110** and two low pressure sections (L.P.) **112** and **114** with an appropriate reheater **116** and reheater-stop valves **120** and interceptor valves **118** connected thereto. The turbine system **104** drives a generator **122** which produces electricity. A breaker **123** is connected between the generator **122** and a load, not shown. A megawatt transducer **125** is connected to the generator **122,** The megawatt transducer **125** is connected to a controller which in this case includes a plant digital computer **131** having an output connected to throttle-stop valve actuators **130,** control or governor valve actuators **132,** reheater stop valve actuators **134** and interceptor valve actuators **136.**

The reactor **102** in the present embodiment, is of the pressurized water reactor type (P.W.R.). Other reactor types, such as a boiling water reactor, would fall within the scope of the invention.

A speed transducer **105** is coupled to the turbine shaft to sense the speed of the steam turbine **104.** An output signal from the speed transducer **105** is fed into an input of the controller and plant digital computer **131.** The plant controller and computer **131** provides signals for each of the valve acutators **130, 132, 134** and **136** which control the positions of associated valves **106, 108, 118** and **120,** and thereby control the speed and/or load of the turbine **104.** The speed of the turbine **104** is monitored by the speed transducer **105** and fed back to the controller and plant computer **131.**

During startup of the turbine system **104** the throttle-stop values **106** are variably positioned by the controller and plant computer **131** thereby allowing for speed control of the turbine system **104.** The throttle-stop valves **106** act as safety valves being either fully open or closed during synchronous operation. The governor valves **108** modulate the flow of steam through the high pressure turbine **110.** The reheater stop valves **120** are either fully open or fully closed. The interceptor valves **118** are usually fully open or fully closed, however, under certain conditions of operation they modulate the steam flow such as during turbine shutdown.

In normal operation signals from the speed transducer **105,** a pressure transducer **107** and the megawatt transducer **125** are used in the controller and plant computer **131** for computing positions of the throttle-stop valves **106,** the control or governor valves **108,** the reheater stop valves **120** and the interceptor valves **118** needed to satisfy turbine load and/or speed demand. The controller and plant computer **131** transmits signals indicative of the valve positions to the respective valve actuators **130, 132, 134** and **136.**

The controller and plant computer **131** in the preferred embodiment is an analog computer. The analog computer dsignated as an Electrohydraulic System is described in Westinghouse Electric Corp. Bulletin No.

139,132, file No. 1005M. An Electrohydraulic System presently being used on Westinghouse Electric Corporation turbine systems is an example of an analog controller and (plant computer) usable in the present embodiment. Computer or automatic control provides for much more efficient and rapid control of the turbine 104 than manual or partially automatic control could provide. In an alternative embodiment the controller and plant computer 131 would be a digital computer programmed to perform the function of the Electrohydraulic System.

In the event of a computer or other system failure the turbine may start accelerating out of control bursting the rotor and producing missiles which could destroy the reactor 102, the turbine 104, piping, the building and injuring personnel and resulting in leakage of radioactive materials.

In order to prevent missiles from destroying the generating system an indpendent protection system 128 includes a speed transducer assembly 124 which is independent of the speed transducer 105 and which is also connected to a shaft 126 of the turbine 104. The independent speed transducer assembly 124 and the protection system 128 are independent of the controller and plant computer 131. If the controller and plant computer 131 or any system connected thereto should fail and an overspeed condition should result, missile generation will be prevented by the independent protection system 128.

An output of the independent speed transducer assembly 124 is connected to the independent overspeed protection system 128 which in turn controls the valve actuators 130, 132, 134 and 136. The independent speed transducer 124 may be of the magnetic type such as described in U.S. Pat. Nos. 3,018,381 and 3,018,382 assigned to the assignee of the present invention. In the protection system, the output signals of the three transducer parts 124–1, 124–2, 124–3 of the independent speed transducer assembly 124 (FIG. 1B) are applied to check circuits 138, 140 and 142, respectively. The circuit details of the check circuits 138, 140 and 142 are shown in FIG. 2 and are described infra. As an alternative embodiment, the check circuits 138, 140 and 142 as well as their control logic, described infra, can be implemented by a digital computer program. The digital computer may be the same as the plant computer 131 thereby realizing considerable savings in hardware expenses; however, with a decrease in operating efficiency.

The check circuits 138, 140 and 142 compare the signal from the independent speed transducers 124–1, 124–2 and 124–3, to a signal representing a predetermined value of speed to determine whether the speed of the turbine 104 is being maintained at a predetermined level. Each of the check circuits 138, 140 and 142 generates two signals, one indicating a failure of the turbine 104 to maintain the predetermined angular velocity and another signal to indicate that the angular velocity is within the limits of the predetermined value. By use of the two signals not only is the turbine 104 monitored for overspeed but any abrupt change in the speed signal is monitored which could indicate a failure of the independent overspeed protection system 128 or a catastrophic failure of the turbine 104. The output terminals of the check circuits 138, 140 and 142 are connected to control logic circuitry 144, to be described infra in reference to FIG. 4. In the present embodiment switching circuits or relays 146 through and including 168 are connected between the check circuits 138, 140 and 142 and the control logic circuitry 144.

The relays 146 and 148 are controlled by the check circuit 138; the relays 154 and 156 are controlled by the check circuit 140; and the relays 162 and 164 are controlled by the check circuit 142 to control paths in the control logic circuitry 144. The relays 146, 148, 154, 156, 162 and 164 during the normal operation of the system with power on, are in the actuated or "ON" state. In the event of the detection of an overspeed condition by any one or more of the check circuits 138, 140 and 142, the switching elements or relays 146, 148, 154, 156, 162 and 164 are called safe or overspeed signal channels.

The switching elements or relays 150, 152, 158, 160, 166 and 168 are connected to operate in an analogous fashion generating discontinuity or failure signals when a speed signal discontinuity has been determined. The circuits connected to and including the relays 150, 152, 158, 160, 166 and 168 are called discontinuity or failure signal channels. Each safe or overspeed channel, e.g., including relays 146 and 148, and each discontinuity or failure channel, e.g., including relays 150 and 152, comprise the two parts of the dual channel connected to and controlled by the check circuit 138. The relays 154, 156, 158 and 160 form the dual channel connected to and controlled by the check circuit 140; and the relays 162, 164, 166 and 168 form the dual channel connected to and controlled by the check circuit 142.

In the event that the speed of the turbine 104 equals or exceeds a predetermined value, in this case 111% of the synchronous speed, an overspeed condition is signaled by the transducer assembly 124 and the overspeed relays 146 and 148 connected to check circuit 138, overspeed relays 154 and 156 connected to check circuit 140 and the overspeed relays 162 and 164 connected to the check circuit 142 drop out or enter the "OFF" state. The failure or discontinuity detection relays 150, 152, 158, 160 and 168 are normally in the "OFF" state when no discontinuity or system failure condition exists. If the electronic systems are not operating properly, the relays 150, etc. are energized, or placed in the "ON" state, thereby indicating a signal failure or discontinuity. If the speed of the turbine 104 equals or exceeds 111 percent of synchronous speed an overspeed condition is signaled and the overspeed or safe relays 146, 148, 154, 156, 162 and 164 change or reverse state, thereby generating a signal indicating an overspeed condition. The overspeed signal actuates the dump valves described infra which prevent turbine overspeed and the generation of turbine missiles.

Referring now to FIG. 2, the internal circuitry of the check circuit 138 is shown. The check circuits 140 and 142 also have the same internal circuitry. A signal from the independent speed transducer 124–1 is applied to a frequency-to-voltage converter 200. The output signal of the frequency-to-voltage converter 200 is applied to an overspeed comparator 210 and to a signal discontinuity comparator 200 and a delay circuit 222. An output of the delay circuit 222 is connected to an input of the signal discontinuity comparator 220. An output of the signal discontinuity comparator 220 is connected to an input of an inverting gate 225.

The frequency-to-voltage converter **200** is typically a monostable multivibrator triggered by the zero crossover of the input signal thereto from the A.C. speed transducer **124–1.** The monostable multivibrator has a constant duration in the unstable state. The output signal from the monostable multivibrator will therefore have a variation in duty cycle which will be proportional to the frequency of the input signal thereto. The output signal from the monostable multivibrator is rectified and filtered thereby producing a D.C. voltage output which is linearly proportional to the input frequency from transducer **124–1.**

The signal discontinuity comparator **220,** the delay circuit **222** and the inverting gate **225** and the power amplifier **227** are shown in greater detail in FIG. **2A.** The output signal from the frequency to voltage converter **200** is connected to an input **249** of amplifier **250** through an appropriate impedance circuit **252.** The output signal from the frequency-to-voltage converter **200** is connected to the delay circuit **222** where it is fed through appropriate impedance **252** and delayed for summation at the input **249** of the amplifier **250** with the original signal from the converter **200.** The delay circuit **222** in the preferred embodiment has a delay of 1.4 seconds.

The time constant of 1.4 seconds is chosen so that any normal changes in the speed signals of the turbine system will be filtered out. Only signal discontinuities and signals representing catastrophic failure will be passed through the signal discontinuity comparator **220.** If the output signal from the frequency-to-voltage converter **200** which is proportional to turbine speed varies slowly, the output signal of the amplifier **250** will remain at zero. However, if the signal from the frequency to voltage converter **200** varies rapidly, the output signal of the amplifier **250** either swings positive or negative. The output signal from the amplifier **250** is amplified by an amplifier **256** and the amplifier **227.** When a signal appears at the output of the amplifier **227,** either relay **258** or relay **260** will be energized through diode directed paths. When either relay **258** or **260** is energized one of respective contacts **259** or **261** connects a positive power supply **262** to the input of the amplifier **256** thereby generating an output from the amplifier **227** to lock and hold the circuit in the last state. In order to reset the circuit for renewed operation a reset button **264** is provided which breaks the circuit of contact **259** or **261** thereby reducing the output signal of the amplifier **227** to zero.

In other embodiments of the invention, various modifications can be made in the arrangement described herein. For example, the frequency signal provided by the speed detector device **124–1** can be converted to a digital representation and then compared by means of a digital computer or other digital means to a suitable digital setpoint.

Referring again to FIG. **2,** in the preferred embodiment, the setpoint of the overspeed comparator **210** may be tested by applying a variable voltage derived from a potentiometer **212,** thereby determining whether or not the check circuit **138** functions properly in the release of the relays **146** and **148.** The power control of the relays **146** and **148** is handled by a non-inverting gate **215,** which includes an emitter follower transistor stage **216.** The transistor stage **216** is cut off from conduction in the event of an overspeed detection by the comparator **210,** resulting in the dropping out of the relays **146** and **148.** Thus, with a majority logic, which will be discussed in detail infra, the operation of the check circuits **138, 140** and **142** may be tested to insure their proper operation under actual system overspeed conditions without causing any disruption in generating system operation. With one of the check circuits **138, 140** and **142** under test, an overspeed signal or discontinuity signal together with the test signal will act as if two of the dual channels indicated overspeed or discontinuity signals thereby shutting down the electric generation system and preventing generation of missiles. The very high reliability of the protection system **128** is maintained even under test conditions.

Although relays are referred to herein as providing suitable means for the switching logic of the invention, other devices such as solid state switching elements, logic gates, flip-flops or programmed computers may be used without departing from the spirit or practice of the invention.

The signal discontinuity comparator **220** is biased so that if the difference between the directly applied signal from the frequency-to-voltage converter **200** and the signal from the delay circuit **222** exceeds a predetermined value an electrical discontinuity condition is signaled. Test buttons **230** and **232** test the signal discontinuity comparator **220** by applying voltages to the signal discontinuity comparator **220.** If either test button **230** or **232** is depressed, the comparator **220** is designed such that a signal is transmitted which turns on or picks up the relays **150** and **152.** However, because of the majority of two out of three logic, to be described in greater detail infra, the generating system is not shut down.

Referring to FIG. **4,** the majority logic is shown in detail as implemented in a majority circuit **145,** and the checking circuit output relays **146, 148, 154, 156, 162** and **164** are shown with respective contacts in each relay being **147, 149, 155, 157, 163** and **165.** In other words, the relay contact for the relay **146** is the contact **147,** etc. The relay contacts in FIG. **4** are shown in their normally open deenergized position. In operation, the relays of FIG. **4** are energized and the contact closed. With all the relays energized, a voltage source at the input terminal **170** will be connected to an input terminal **173** of conventional AND gate **172,** contained in the control logic box **144** in FIG. **1.** A conventional AND gate requires all inputs to be energized in order for an output signal to be maintained. Referring again to FIG. **1B,** and assuming that the check circuit **138** deenergizes the relays **146** and **148,** the relay contacts **147** and **149** will open. However, the voltage signal at the input terminal **173** of the AND gate **172** will still retain its former value because the relay contacts **157** and **165** remain closed. The majority function is thereby performed since two of the three channels controlled by the check circuitry **138, 140** and **142** must indicate an overspeed condition. Therefore, the failure of only one channel will not trip the turbine system. However, if in addition, the check circuit **140** deenergizes the relays **154** and **156** connected thereto, the relay contacts **155** and **157** would also open. In this latter case, all three branches of the relay circuit **174** in FIG. **4** would be open, and the signal at an input of the AND gate **172** would be zero.

The other input **175** to AND gate **172** is connected to relay switching logic of the checking circuit output relays **150, 152, 158, 160, 162** and **168** in an appropri-

ate fashion in order to provide an input signal to the AND gate **172** as long as two out of the three check circuits **138, 140** and **142** provide the appropriate output signals.

The AND circuit **172** provides one of the inputs to one of the dump valves of each of the valve actuators **130L, 130R** and **132,** to be described in greater detail later herein. Therefore, one dump valve on each of the valve actuators **130, 132, 134** and **136** is tripped, draining hydraulic fluid from the valve actuators **130, 132, 134** and **136** and closing the valves to the turbine **104** thereby preventing a turbine runaway and the generation of missiles which could destroy the generation system **100.**

A similar conventional AND circuit **176** is connected to a similar majority circuit **178** performing the same function for each of the other dump valves connected to each of the valve actuators **130, 132, 134** and **136.**

The functions of the relays **146** through **168** may also be accompanied by solid state switching circuitry or by digital logic or a digital computer. The function of the check circuits **138, 140** and **142** and the relays **146** through **168** may in alternative embodiments be included in the program of the plant digital computer, thus integrating the total system operation.

Referring now to FIG. **4A,** the majority logic circuitry **145** associated with the valves **130** and **132** is shown in an alternative embodiment. The relay contacts **147, 151, 155, 163** and **166** are shown connected in a series parallel combination thereby performing the operation of the AND gates **172** and **176** of FIG. **4.** The relay logic combination actuates two relays **401** for purposes of redundancy. Contacts **401a** of the relays **401** are connected in series in order to minimize the possibility of the welding shut of one relay contact from disabling the system.

A test relay **405** is provided which disconnects the coils of dump valve solenoids **50** mounted on the valve actuators **130, 132, 134** and **136** and connects the indicator lights **407** to ground. Pushbuttons **402** are provided in order to test the continuity and operation of the circuitry connected to the dump valve solenoids **50.** The indicating lights **407** are connected to the relay **405** in order that a continuous path for test purposes is provided for the pushbutton circuits **402** connected across the relay contacts **401***a* of the relays **401.** In FIG. **4B** there is shown an identical circuit **145***b* for the other dump channel which actuates the second dump valve in each of the valve actuators **130, 132, 134** and **136.**

Referring now to FIG. **5,** a schematic diagram of the dump valves **506** and **508,** connected to a typical valve actuator such as one of the valve actuators **132, 134** and **136,** is shown. A valve actuator cylinder **500** with two ports **502** and **504** is also shown. The ports **502** and **504** are connected by tubing **503** and **505** to the two dump valves **506** and **508.** The output side of the dump valves **506** and **508** are connected to a dump oil receiver **510.** Dump oil **514** is discharged through a vent **512.** When an overspeed condition in the turbine **104** occurs, the solenoids **50** and **51** are actuated thereby opening the dump valves **506** and **508** and the oil **514** is dumped at a very rapid rate from under the piston **516** into the dum oil receiver **510.** A spring **518** returns the piston and the valve connected thereto to a closed position very rapidly to close the associated steam valve. Dump valves similar to the dump valves **506** and **508** dump the oil from all the actuators **130, 132, 134** and **136** and thereby closing the valves **106, 108, 118** and **120.** With dump operation, the steam flow in the turbine **140** is cut off very quickly thereby preventing an overspeed condition from rupturing the turbine rotor and throwing missiles which could cause extensive damage to the entire generating and reactor system. Specific details as to a preferred form of turbine steam valves as well as apparatus suitable for hydraulic control are found in U.S. Pat. Nos. 3,152,601 and 3,169,451 assigned to the assignee of the present invention.

In order to prevent a runaway overspeed condition valves **106, 108, 118** and **120** are all closed as quickly as possible by the independent protection system **128.** The steam generated by the reactor and steam generator **103** as shown in FIG. **1A** is vented to the atmosphere such as by a vent connected to a secondary steamline.

In summary, to prevent overspeed runaway of the turbine **104** with the possible resultant rupture of the rotor and the throwing of missiles which could seriously damage the reactor **102** and injure personnel, an overspeed protection system **123** is provided which is independent of the turbine system for normal speed control comprising the speed transducer **105** and the controller and plant computer **131.** Taking over the control of the turbine **104** during overspeed conditions which could lead to a runaway and the destruction of an entire generation station, the overspeed protection system **123** obviates the shortcomings of the prior art.

The turbine **104** is provided with three independent speed transducers **124,** which generate three independent speed signals. These three signals are then translated through the use of appropriate logic circuitry into two signals which actuate the dump valves and allow the rapid closing of the steam control valves thereby foreclosing the possibility of disastrous overspeed runaway. Because of the majority logic for sensing the three independent speed signals, any one speed or failure channel can be tested independently without disrupting the turbine system. Thus, the present invention provides a high degree of assurance that when the dump valves are actuated, an actual verified overspeed or signal failure has occurred which warrants such drastic action; and further makes the performance tests possible during short periods of time to determine whether or not the individual check circuits are operating properly.

Even though a governor valve **108** may be stuck open, the stop valves **106,** interceptor valves **120,** and the control valves **118** will close and prevent an accident.

What is claimed is:

1. An electric power generating system comprising:
means for generating steam, a steam turbine having at least one high pressure and at least one low pressure turbine section, a generator rotated by said turbine,
means for valving a flow of steam through said steam turbine system,
means for moving said valving means from one position to another,
means for determining a position for said valving means,
first means for sensing the speed of at least one of said steam turbine sections,

first means for deactivating said valve moving means upon the exceeding of a predetermined speed,
means connecting said first sensing means and said first deactivating means,
second means for sensing the speed of at least one of said steam turbine sections,
second means for deactivating said valve moving means independently of said first deactivating means, such that, said valving means stops said flow of said steam through said steam turbine with greatly improved reliability upon the exceeding of a second predetermined speed upon the failure of said first deactivating means from preventing said turbine section from exceeding said second predetermined speed,
means connecting said second sensing means and said second deactivating means.

2. The system of claim **1** wherein
said valve position determining means includes means for computing valving means position to operate said turbine at a predetermined load and/or speed.

3. The system of claim **2** wherein
said computing means is connected to and receives signals from said first sensing means, whereby a representative magnitude of said signals from said first sensing means are used by said computing means in determining a position for said valving means.

4. A method for preventing overspeeds in a steam turbine generating system including the steps of:
a. generating steam to rotate a steam turbine;
b. sensing the speed of said steam turbine generating system;
c. determining a position of steam valves;
d. controlling said position of said steam valves;
e. sensing the speed of said turbine generating system independently of step (b);
f. determining by comparing said sensed speed of step (b) with a representation of a predetermined speed whether said predetermined speed has been exceeded;
g. closing said steam valves upon determination in step (f) that said predetermined speed has been exceeded;
h. determining with the use of the independently sensed speed of step (e) whether a predetermined condition associated with said sensed speed has occurred;
i. stopping the flow of said steam through said turbine when said predetermined condition has occurred.

5. The method as defined in claim **4** including the additional step of:
j. calculating the position of a valve in said steam turbine generating system utilizing the determined valve position and said speed of step (b);
k. moving the valve of the previous step (j) to the position calculated in said previous step (j).

6. An electric power generating system comprising:

means for generating steam, a steam turbine having at least one high pressure and at least one low pressure turbine section, a generator roJated by said turbine,
valving means including at least a throttle-stop valve and a governor valve whereby the flow of steam through said steam turbine is controlled,
means for moving said throttle stop and said governor valve from one position to another,
first means for sensing the speed of said turbine,
first means for deactivating said turbine,
said sensing means connected to said deactivating means,
means for measuring the magnitude of the electric power delivered by said generator to an electric load,
means for determining throttle and governor valve position as a function of power and speed, said determining means connected to and receiving signals from said first speed sensing means and said power measuring means,
said first deactivating means deactivating said turbine system upon detection of a first predetermined value representing an overspeed condition,
second means for independently sensing the speed of said turbine,
second means for deactivating said valve moving means,
said second deactivating means connected to and receiving signals from said second speed sensing means whenever the speed exceeds a second predetermined value upon failure of said first deactivating means from preventing said turbine section from exceeding said second predetermined value.

7. An electric power generating system comprising:
means for generating steam, a steam turbine having at least one high pressure and at least one low pressure turbine, a generator rotated by said turbine, means for valving a flow of steam through said steam turbine including at least one throttle-stop valve, at least one governor valve and at least one interceptor valve,
means for moving said valving means from one position to another,
means for determining a position for said valving means including means for computing a desired valve position,
first means for sensing the magnitude of the speed of said turbine system,
means for measuring the magnitude of the flow of energy from said generator to an electric load,
means for measuring a pressure of said steam in said steam turbine system,
said moving means moving said throttle-stop valve in a direction and to a position determined by said computing means upon the receipt of signals by said computing means from said first rotational sensing means, said electric energy flow measuring means and said pressure measuring means whereby the direction of motion and the position of said throttle stop valve are determined during the startup of said turbine,
said moving means moving said throttle-stop valve, and said governor valve in a direction and to a position determined by said computing means upon the receipt of signals from said first sensing means, said electric energy flow measuring means and said pressure measuring means whereby the positions of said throttle-stop valve, and said governor valve are determined during synchronization and power gen-

eration phases of said electric power generating system,

said moving means moving said throttle-stop valve and said governor valve to a closed position and said interceptor valve to a position determined by said computing means whereby said positions and directions of movements, speeds of movement, changes in position of said valves are determined by said computing means during a shutdown of said electric power generating system,

first means for deactivating said means for moving said valving means to stop said flow of steam to said turbine,

second deactivating means,

second speed sensing means, means connecting said second deactivating means and said second sensing means,

said second sensing means independently sensing the magnitude of the speed of said steam turbine system whereby a signal from said second sensing means is used to determine within said second deactivating means whether said second deactivating means deactivates said means for moving said valving means, to stop the flow of steam through said steam turbine.

8. A method for preventing over-speeds in a steam turbine generating system including the steps of:

a. generating steam in a suitable steam generator;

b. controlling the flow of said steam through said steam turbine generating system to rotate a steam turbine;

c. sensing the speed of said steam turbine;

d. determining a steam valve position during the start-up;

e. controlling a steam valve position;

f. determining by the use of the sensed speed of step (c) whether a predetermined condition associated with a signal representative of speed has occurred;

g. stopping the flow of said steam when said predetermined condition of step (f) has occurred;

h. sensing the speed of said generating system independently of step (c);

i. determining by the use of independently sensed speed of step (h) whether an independent and second predetermined condition associated with said speed of step (h) has occurred;

j. stopping the flow of said steam when said second predetermined condition has occurred;

9. The method of claim **8** including the additional steps of:

k. calcuating the position of a valve in said steam turbine generating system utilizing a desired rate of flow of said steam, the steam pressure and the measured magnitude of the electric load;

1. moving said valve to said calculated position.

10. A nuclear electric power generating system comprising: means for generating steam, a steam turbine having at least one high pressure and at least one low pressure turbine section, a generator rotated by said turbine,

means for valving a flow of steam through said steam turbine system,

means for moving said valving means from one position to another,

means for determining a position for said valving means,

first means for sensing the speed of at least one of said steam turbine sections,

first means for deactivating said valve moving means upon the exceeding of a predetermined speed,

means connecting said first sensing means and said first deactivating means,

second means for sensing the speed of at least one of said steam turbine sections,

second means for deactivating said valve moving means independently of said first deactivating means, such that, said valving means stops said flow of said steam through said steam turbine with greatly improved reliability upon the exceeding of a second predetermined speed upon the failure of said first deactivating means from preventing said turbine section from exceeding said second predetermined speed,

means connecting said second sensing means and said second deactivating means.

11. A nuclear electric power generating system comprising:

means for generating steam, a steam turbine having at least one high pressure and at least one low pressure turbine section, a generator rotated by said turbine,

valving means including at least a throttle-stop valve and a governor valve whereby the flow of steam through said steam turbine is controlled,

means for moving said throttle stop and said governor from one position to another,

first means for sensing the speed of said turbine,

first means for deactivating said turbine,

said sensing means connected to said deactivating means,

means for measuring the magnitude of the electric power delivered by said generator to an electric load,

means for determining throttle and governor valve position as a function of power and speed, said determining means connected to and receiving signals from said first speed sensing means and said power measuring means,

said first deactivating means deactivating said turbine system upon detection of a first predetermined value representing an overspeed condition,

second means for independently sensing the speed of said turbine,

second means for deactivating said valve moving means,

said second deactivating means connected to and receiving signals from said second speed sensing means whenever the speed exceeds a second predetermined value upon failure of said first deactivating means from preventing said turbine section from exceeding said second predetermined value.

12. A nuclear electric power generating system comprising: means for generating steam, a steam turbine having at least one high pressure and at least one low pressure turbine, a generator rotated by said turbine, means for valving a flow of steam through said steam turbine including at least one throttle-stop valve, at least one governor valve and at least one interceptor valve,

means for moving said valving means from one position to another,

means for determining a position for said valving means including means for computing a desired valve position,

first means for sensing the magnitude of the speed of said turbine system,

means for measuring the magnitude of the flow of energy from said generator to an electric load,

means for measuring a pressure of said steam in said steam turbine system,

said moving means moving said throttle-stop valve in a direction and to a position determined by said computing means upon the receipt of signals by said computing means from said first rotational sensing means, said electric energy flow measuring means and said pressure measuring means whereby the direction of motion and the position of said throttle stop valve are determined during the startup of said turbine,

said moving means moving said throttle-stop valve, and said governor valve in a direction and to a position determined by said computing means upon the receipt of signals from said first sensing means, said electric energy flow measuring means and said pressure measuring means whereby the positions of said throttle-stop valve, and said governor valve are determined during synchronization and power generation phases of said electric power generating system,

said moving means moving said throttle-stop valve and said governor valve to a closed position and said interceptor valve to a position determined by said computing means whereby said positions and directions of movements, speeds of movement, changes in position of said valves are determined by said computing means during a shutdown of said electric power generating system,

first means for deactivating said means for moving said valving means to stop the flow of steam to said turbine,

second deactivating means,

second speed sensing means, means connecting said second deactivating means and said second sensing means,

said second sensing means independently sensing the magnitude of the speed of said steam turbine system whereby a signal from said second sensing means is used to determine within said second deactivating means whether said second deactivating means deactivates said means for moving said valving means, to stop the flow of steam through said steam turbine.

13. A method for preventing overspeeds in a nuclear steam turbine generating system including the steps of:

a. generating steam in a nuclear steam generator;

b. controlling the flow of said steam through said steam turbine generating system to rotate a steam turbine;

c. sensing the speed of said steam turbine;

d. determining a steam valve position during the start-up;

e. controlling a steam valve position;

f. determining the use of the sensed speed of step (c) whether a predetermined condition associated with a signal representative of speed has occurred;

g. stopping the flow of said steam when said predetermined condition of step (f) has occurred;

h. sensing the speed of said generating system independently of step (c);

i. determining by the use of the independently sensed speed of step (h) whether an independent and second predetermined condition associated with a signal representative of said speed of step (h) has occurred;

j. stopping the flow of said steam when said second predetermined condition has occurred.

14. An independent overspeed protection system for a steam turbine comprising:

means for valving a flow of steam through said steam turbine system,

means for moving said valving means from one position to another,

means for determining a position for said valving means,

first means for sensing the speed of at least one of said steam turbine sections,

first means for deactivating said valve moving means upon the exceeding of a predetermined speed,

means connecting said first sensing means and said first deactivating means,

second means for sensing the speed of at least one of said steam turbine sections,

second means for deactivating said valve moving means independently of said first deactivating means, such that, said valving means stops said flow of said steam through said steam turbine with greatly improved reliability upon the exceeding of a second predetermined speed upon the failure of said first deactivating means from preventing said turbine section from exceeding said second predetermined speed,

means connecting said second sensing means and said second deactivating means.

15. An independent overspeed protection system for a steam turbine comprising:

valving means including at least a throttlestop valve and a governor valve whereby the flow of steam through said steam turbine is controlled,

means for moving said throttle stop and said governor from one position to another,

first means for sensing the speed of said turbine,

first means for deactivating said turbine,

said sensing means connected to said deactivating means,

means for measuring the magnitude of the electric power delivered by said generator to an electric load,

means for determining throttle and governor valve position as a function of power and speed, said determining means connected to and receiving signals from said first speed sensing means and said power measuring means,

said first deactivating means deactivating said turbine system upon detection of a first predetermined value representing an overspeed condition,

second means for independently sensing the speed of said turbine,

second means for deactivating said valve moving means,

said second deactivating means connected to and receiving signals from said second speed sensing means whenever the speed exceeds a second predetermined value upon failure of said first deactivating means from preventing said turbine section

from exceeding said second predetermined value.

16. An independent overspeed protection system for a steam turbine, said steam turbine having valving means including at least one throttle-stop valve, at least one governor valve and at least one interceptor valve,

said independent overspeed protection system comprising:

means for moving said valving means from one position to another,

means for determining a position for said valving means including means for computing a desired valve position,

first means for sensing the magnitude of the speed of said turbine system,

means for measuring the magnitude of the flow of energy from said generator to an electric load,

means for measuring a pressure of said stem in said steam turbine system,

said moving means moving said throttle-stop valve in a direction and to a position determined by said computing means upon the receipt of signals by said computing means from said first rotational sensing means, said electric energy flow measuring means and said pressure measuring means whereby the direction of motion and the position of said throttle stop valve are determined during the startup of said turbine,

said moving means moving said throttle-stop valve, and said governor valve in a direction and to a position determined by said computing means upon the receipt of signals from said first sensing means, said electric energy flow measuring means and said pressure measuring means whereby the positions of said throttle-stop valve, and said governor valve are determined during synchronization and power generation phases of said electric power generating system,

said moving means moving said throttle-stop valve and said governor valve to a closed position and said interceptor valve to a position determined by said computing means whereby said positions and directions of movements, speeds of movement, changes in position of said valves are determined by said computing means during a shutdown of said electric power generating system,

first means for deactivating said means for moving said valving means to stop said flow of steam to said turbine,

second speed sensing means, means connecting said second deactivating means and said second sensing means,

second deactivating means,

said second sensing means independently sensing the magnitude of the speed of said steam turbine system whereby a signal from said second sensing means is used to determine within said second deactivating means whether said second deactivating means deactivates said means for moving said valving means, to stop the flow of steam through said steam turbine.

17. A method for preventing overspeeds in a steam turbine including the steps of:

a. sensing the speed of said steam turbine;

b. determining the use of the sensed speed of step (a) whether a predetermined condition associated with a signal representative of speed has occurred;

c. stopping the flow of said steam through said turbine when said predetermined condition of step (a) has occurred;

d. sensing the speed of said generating system independently of step (a);

e. determining by the use of the independently sensed speed of step (d) whether an independent and second predetermined condition associated with a signal representative of said speed of step (d) has occurred;

f. stopping the flow of said steam when said second predetermined condition has occurred upon the failure of the stopping of the flow of steam in step (c) to prevent said turbine from exceeding said second predetermined condition of step (e).

18. The method as defined in claim **4** in which said predetermined condition of steps (h) and (i) is a predetermined speed.

19. The method as defined in claim **4** in which said predetermined condition of steps (h) and (i) includes a malfunctioning of an overspeed prevention system.

20. The method as defined in claim **18** in which said predetermined condition of steps (h) and (i) includes a malfunctioning of an overspeed prevention system.

* * * * *