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Conrad, Jr. et al.

[11] **3,826,094**

[45] **July 30, 1974**

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

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

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

[21] Appl. No.: **189,226**

[52] **U.S. Cl.** **60/686**, 60/644, 290/4

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

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

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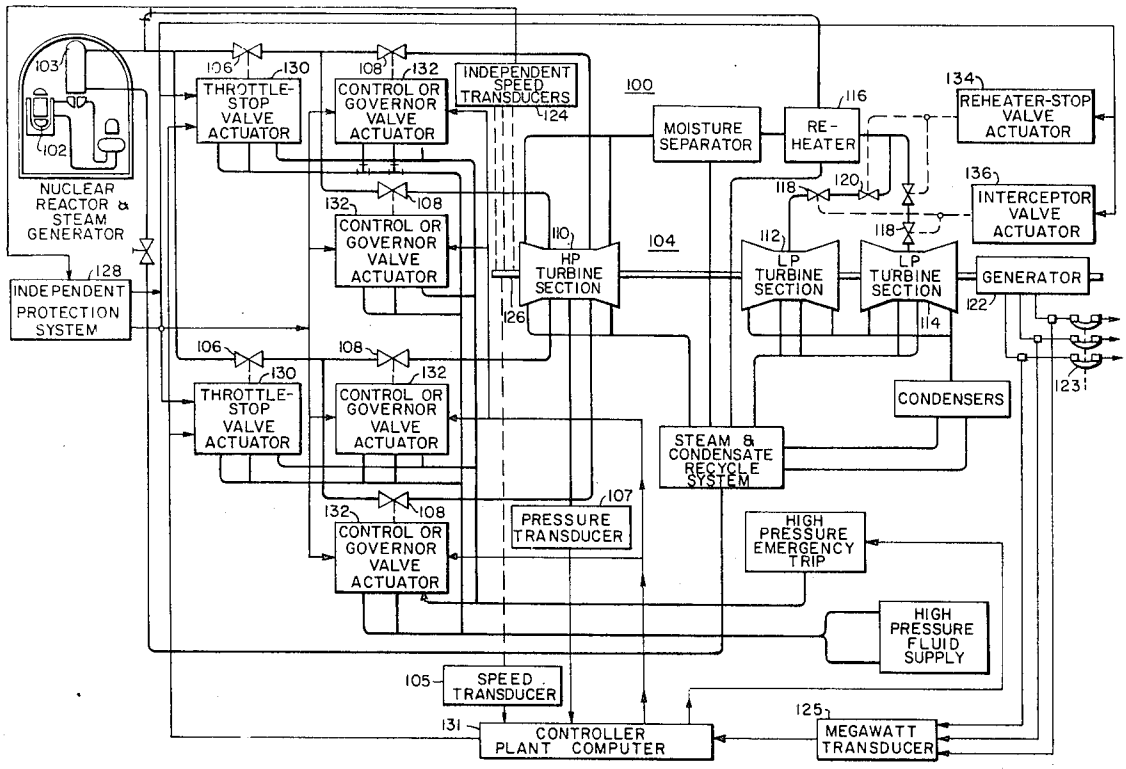
Primary Examiner—Edgar W. Geoghegan
Assistant Examiner—H. Burks, Sr.
Attorney, Agent, or Firm—E. F. Possessky

[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.

27 Claims, 10 Drawing Figures



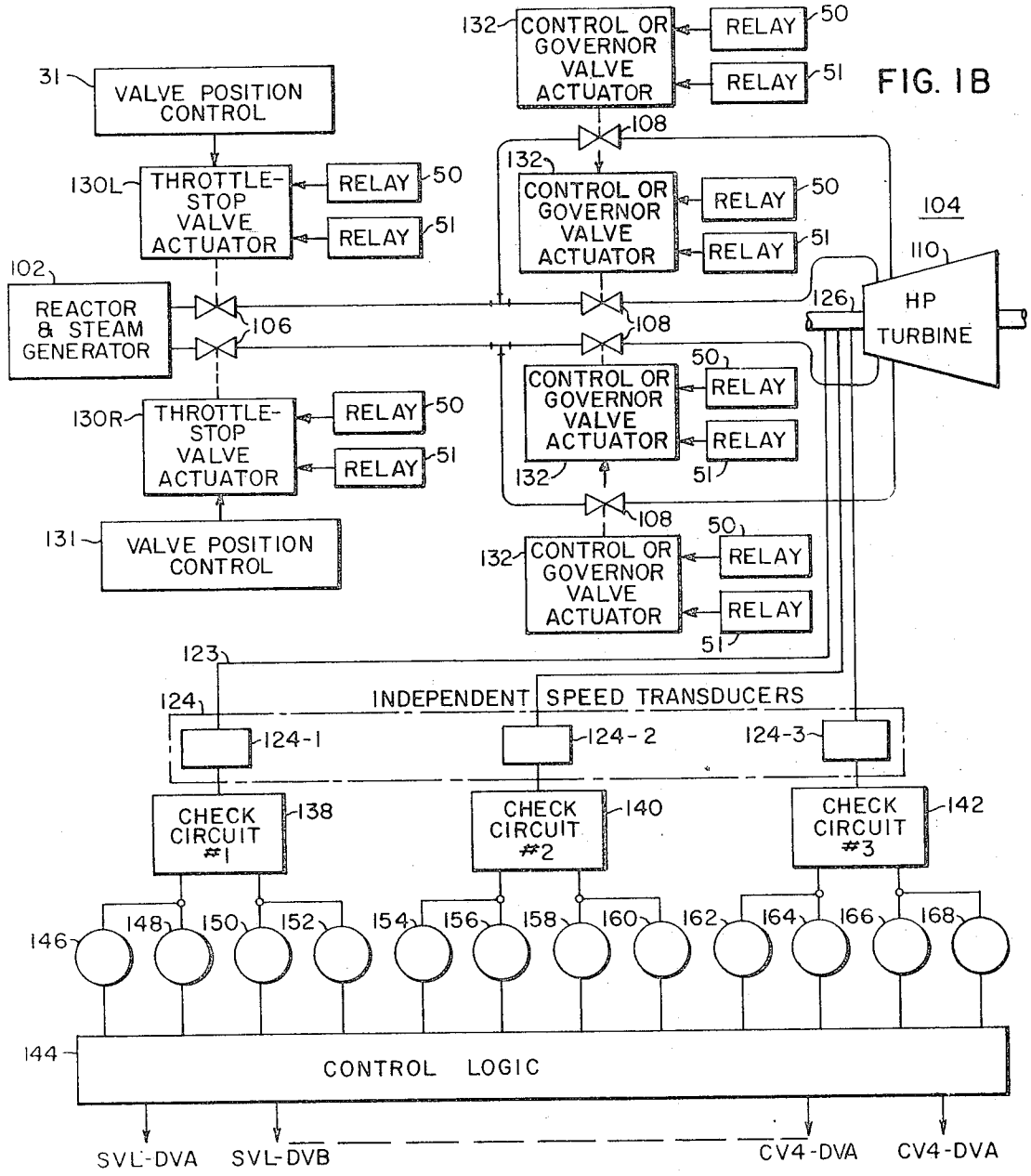

132
CONTROL OR GOVERNOR VALVE ACTUATOR
RELAY
50
RELAY
51
31
VALVE POSITION CONTROL
108
130L
THROTTLE-STOP VALVE ACTUATOR
104
110
102
REACTOR & STEAM GENERATOR
106
126
HP TURBINE
130R
131
VALVE POSITION CONTROL
123
INDEPENDENT SPEED TRANSDUCERS
124
124-1
124-2
124-3
CHECK CIRCUIT #1
138
CHECK CIRCUIT #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

FIG. 1B

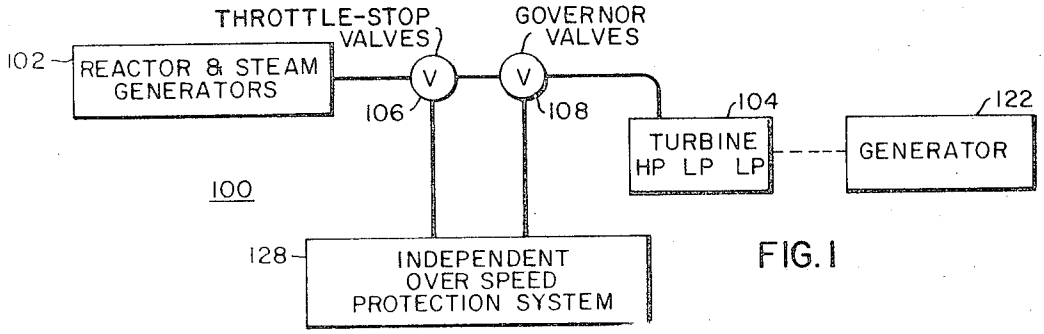

THROTTLE-STOP VALVES
GOVERNOR VALVES
102
REACTOR & STEAM GENERATORS
V
V
106
108
104
TURBINE HP LP LP
122
GENERATOR
100
128
INDEPENDENT OVER SPEED PROTECTION SYSTEM

FIG. 1

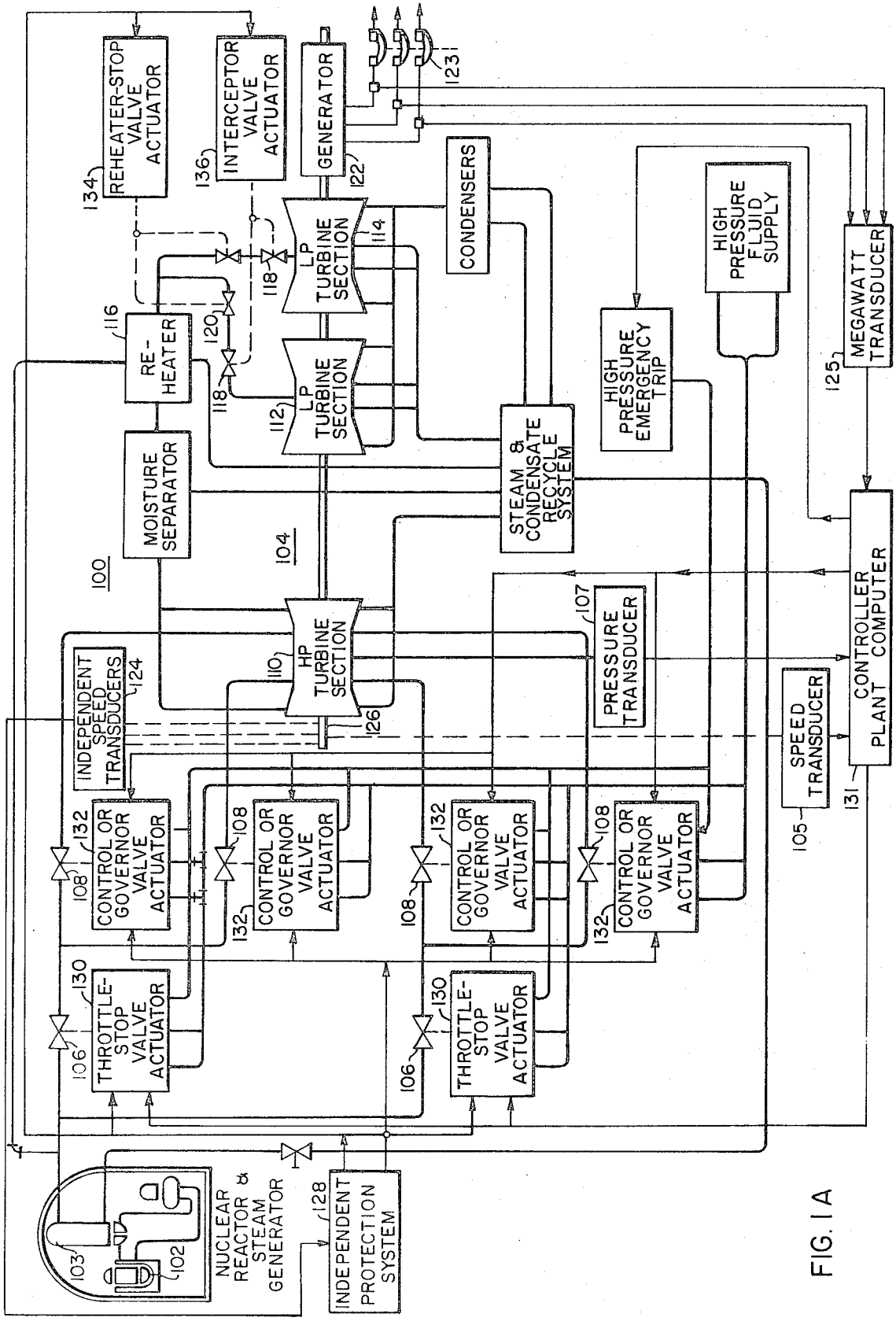

REHEATER-STOP VALVE ACTUATOR
134
INTERCEPTOR VALVE ACTUATOR
136
GENERATOR
122
123
CONDENSERS
HIGH PRESSURE FLUID SUPPLY
MEGAWATT TRANSDUCER
125
LP TURBINE SECTION
114
118
RE-HEATER
116
120
LP TURBINE SECTION
112
HIGH PRESSURE EMERGENCY TRIP
MOISTURE SEPARATOR
STEAM & CONDENSATE RECYCLE SYSTEM
100
104
HP TURBINE SECTION
110
126
PRESSURE TRANSDUCER
107
CONTROLLER PLANT COMPUTER
INDEPENDENT SPEED TRANSDUCERS
124
SPEED TRANSDUCER
105
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

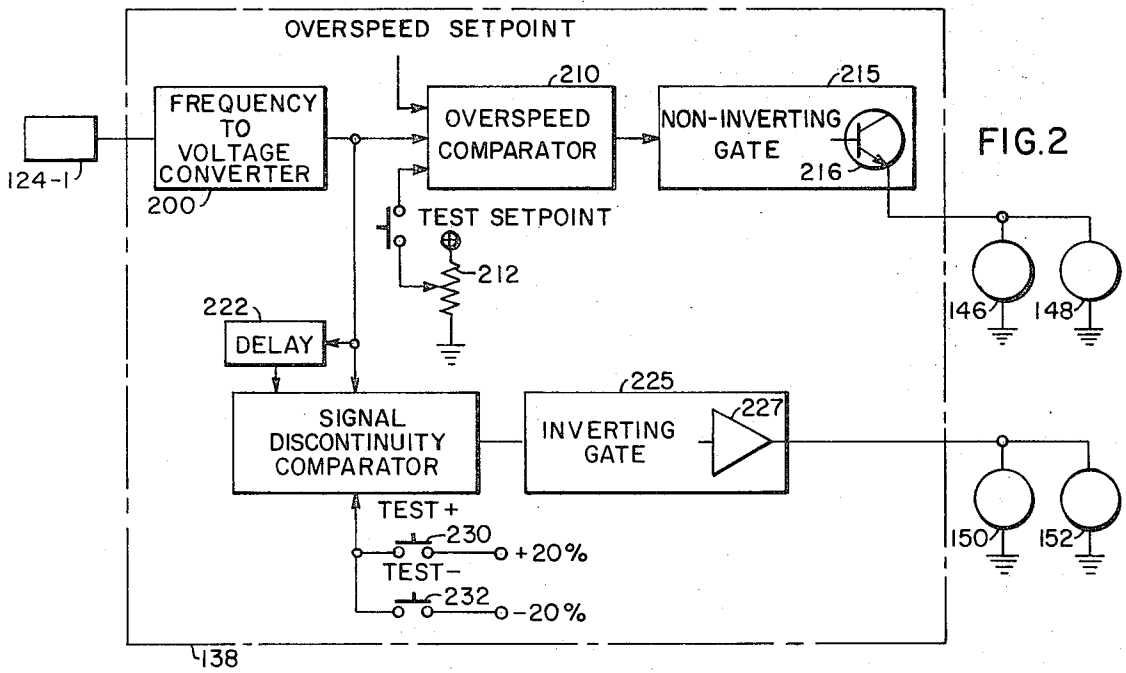


FIG.2

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

FIG.3

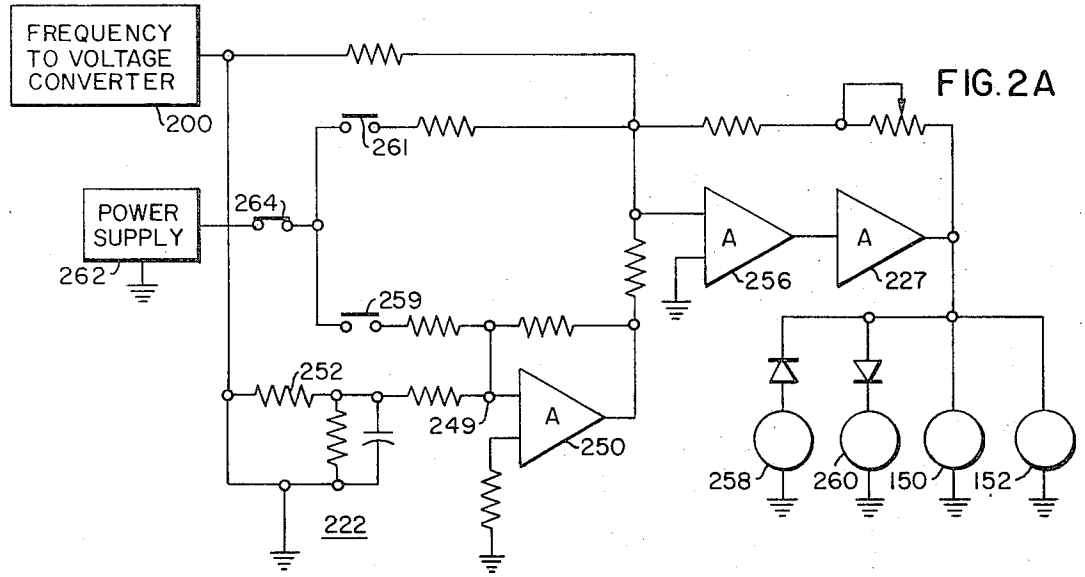


FIG.2A

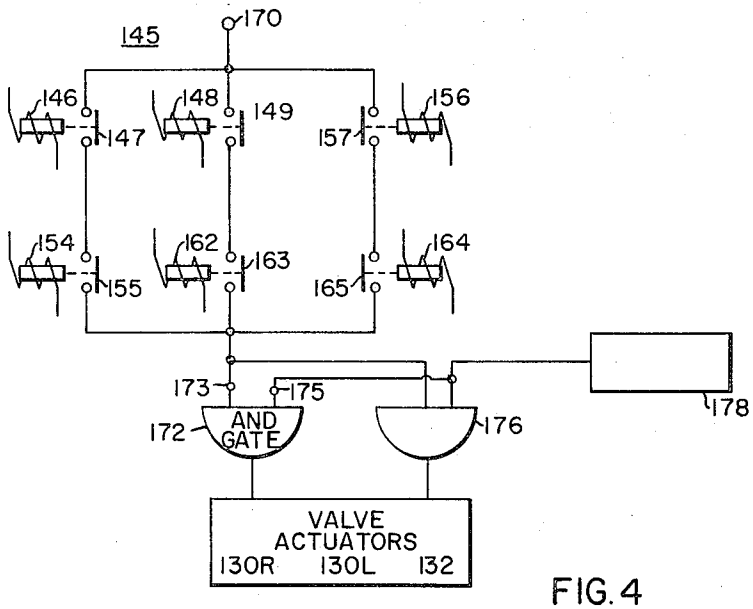

145
170
146
147
148
149
156
157
154
155
162
163
164
165
173
175
172
AND GATE
176
178
VALVE ACTUATORS
130R
130L
132

FIG. 4

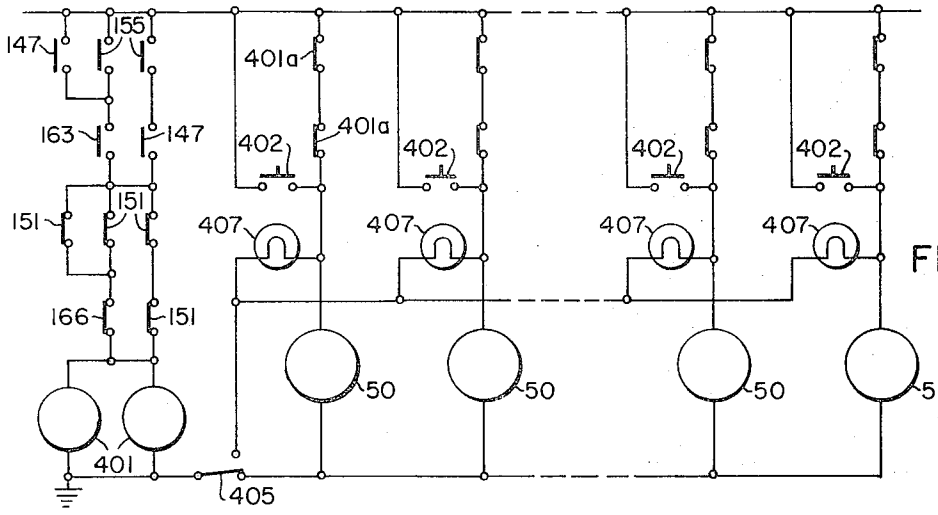


FIG. 4A

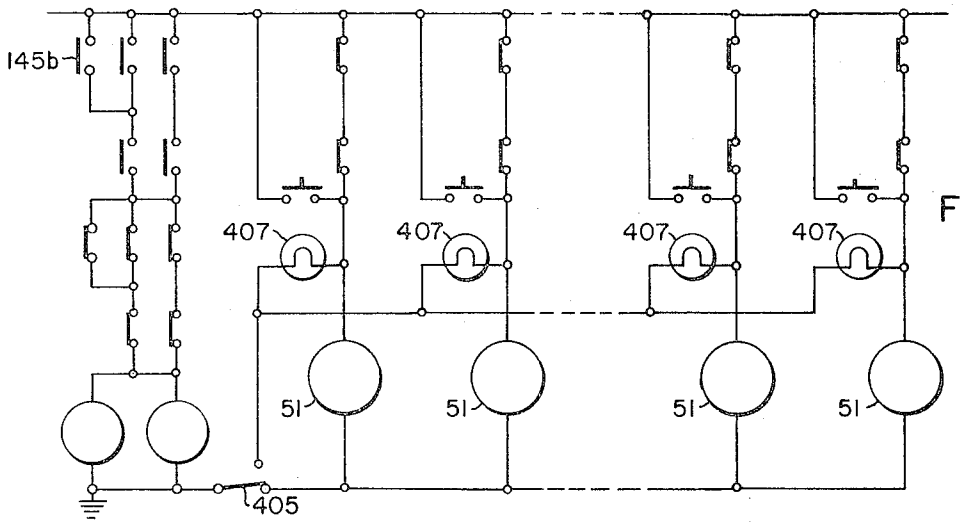


FIG. 4B

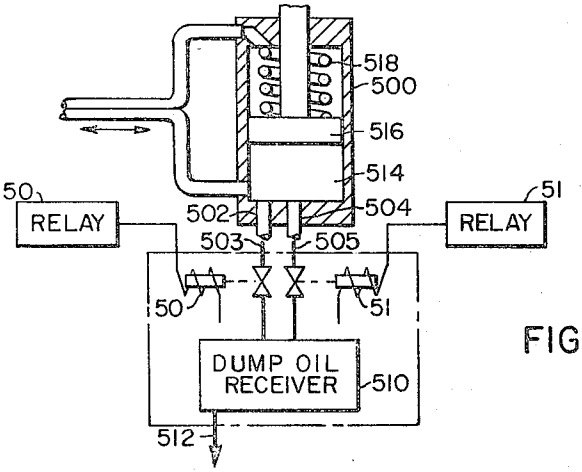


FIG. 5

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 APPLICATIONS

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. 189,320 entitled "General System and Method for Operating a Steam Turbine with Independent Overspeed Protection Especially Adapted for Nuclear Reactor Powered Steam Turbine" by J. D. Conrad, Jr. et al.

3. Ser. No. 189,332 "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.

The Atomic Energy Commission has recognized the 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 preferably 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 **112** 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 actuators **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 designated 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 independent 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. No. 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 show 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 passes 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** and **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.** Thepower 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 wth tthe 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 relays 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 **401***a* 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 **401a** 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 dump 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.

We claim as our invention:

1. An electric power generation system comprising:

a steam turbine system having means for generating steam, 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 system,

means for actuating said valving means,

means for controlling said actuating means whereby position of said valving means is controlled,

first means for sensing the magnitude of the rotational velocity of said steam turbine system, said first sensing means feeding signals to said controlling means,

second means for sensing the magnitude of the rotational velocity of said steam turbine system,

said second sensing means including a plurality of channel means,

means for determining whether a predetermined number of said channel means have representations of turbine system conditions corresponding to predetermined conditions, and

means for deactivating one or more of said actuating means upon the determination by said determining means whether a predetermined number of said channel means have representations of conditions corresponding to predetermined conditions whereby said deactivating means deactivates said actuating means and said actuating means closes said valving means thereby stopping the flow of steam through said turbine system.

2. The system of claim **1** wherein

said means for determining including second means for determining whether a predetermined number of channel means have representations of rotational velocity exceeding a predetermined rotational velocity limit.

3. The system of claim **2,** wherein said actuating means includes at least two independent means for rapidly closing said valving means.

4. The system of claim **3,** wherein said determining means including number determining means which determines whether a predetermined number of channel means have representations of turbine conditions not corresponding to said predetermined conditions, whereby determination of said representations not corresponding to said predetermined conditions in any two of said measuring channel means causes deactivating means to deactivate said actuating means thereby closing said valving means and stopping the flow of steam through said turbine system.

5. The system of claim **4,** wherein said number determining means including means for generating said representations correspond to the turbine velocity and said predetermined conditions correspond to a predetermined rotational velocity.

6. The system of claim **5,** wherein said deactivating means including at least two independent means for rapidly closing said valving means.

7. An overspeed protection system for a steam turbine comprising:

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

means for actuating said valving means,

means for sensing the rotational velocity at said steam turbine system,

said sensing means including sensing channel means,

means for determining whether a predetermined number of said channel means have representations of turbine system conditions corresponding to predetermined conditions, and

means for activating one or more of said actuating means upon the determination by said determining means whether a predetermined number of said channel means have representations of conditions corresponding to predetermined conditions whereby said deactivating means deactivates said actuating means and said actuating means closes said valving means thereby stopping the flow of steam through said turbine system.

8. The system of claim **7** wherein

said means for determining includes second means for determining whether a predetermined number of channel means have representations of rotational velocity exceeding a predetermined rotational velocity limit.

9. A method of preventing overspeeds in a steam turbine system resulting from partial or total load losses, said steam turbine system comprising governor valves for regulating a flow of steam through said turbine, actuators for actuating said valves, a first transducer for transducing the rotational velocity of said steam turbine into an electrical signal, a second transducer for transducing the rotational velocity of said steam turbine into electrical signals, said second transducer providing independent speed signals, two dumping signal channels including two separate dump valves connected to at least one of said actuators independently actuated and connected for dumping hydraulic fluid contained therein, including the steps of:

transducing the speed of said turbine into independent electrical signals;

checking said signals against predetermined conditions;

determining whether said signals check against said predetermined conditions of the immediately preceding step.

10. The method of claim **9** including the additional step of:

activating each of said dump valves upon determining whether said signals do not correspond to said predetermined conditions.

11. The method as defined in claim **10** including the additional step of:

dumping the hydraulic fluid from each of said hydraulic actuators.

12. The method as defined in claim **11** including the additional step of:

actuating each of said separate dump valves on each of said actuators.

13. An electric power generating system comprising:

a steam turbine system having means for generating steam, at least one high pressure and at least one low pressure turbine, a generator rotated by said turbine, an electric load connected to said generator, 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,

first means for sensing the magnitude of the rotational velocity of said turbine system,

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

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

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

said computing means connected to and receiving signals from said first rotational velocity sensing means, said energy flow measuring means and said pressure measuring means whereby said computing means upon receipt of said signals determines a direction of motion, and a position for said throttle-stop valve, said governor valve and said interceptor valve during the start-up phase, the synchronization and the power generation phases of operation of said electric power generating system,

said moving means moving said throttle-stop valve, said governor valve, and said interceptor valve in a direction and to a position determined by said computing means,

second means for sensing the magnitude of the rotational velocity of said steam turbine system,

said second sensing means including a plurality of signal path means,

means for determining whether a predetermined number of said signal path means have representations of turbine system conditions corresponding to predetermined conditions,

means for deactivating one or more of said moving means upon determination by said determining means whether a predetermined number of said signal path means have representations of conditions corresponding to predetermined conditions whereby said deactivating means deactivates said moving means and said moving means closes said valving means thereby stopping the flow of steam through said steam turbine system.

14. The system of claim **13** wherein

said means for determining including second means for determining whether a predetermined number of said signal path means have representations of rotational velocity exceeding a predetermined rotational velocity limit.

15. The system of claim **14,** wherein said deactivating means includes at least two independent means for rapidly closing said valving means.

16. The system of claim **15,** wherein said determining means including number determining means which determines whether a predetermined number of said signal path means have representations of turbine conditions, whereby determination of said representations not corresponding to said predetermined conditions in any two of said measuring signal path means causes deactivating means to deactivate said moving means thereby closing said valving means and stopping the flow of steam through said turbine system.

17. The system of claim **16,** wherein said number determining means including means for generating said representations correspond to the turbine velocity and said predetermined conditions correspond to a predetermined rotational velocity.

18. The system of claim **17,** wherein said deactivating means includes at least two independent means for rapidly closing said valving means.

19. An independent overspeed protection system for a steam turbine system having speed control including independent overspeed protection, said independent overspeed protection system comprising:

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

means for sensing the rotational velocity of said steam turbine,

means for actuating said valving means,

means connecting said sensing means and said actuating means,

means for independently sensing the rotational velocity at said steam turbine system,

means including sensing signal path means having a plurality of signal paths,

means connecting said independent sensing means and said signal path means,

means for determining whether a predetermined number of said signal paths of said signal path means have representations of turbine system conditions corresponding to predetermined conditions,

means connecting said signal path means and said determining means, and

means for deactivating said actuating means upon the determination by said determining means whether a predetermined number of said signal paths have representations of conditions corresponding to predetermined conditions whereby said deactivating means deactivates said actuating means and said actuating means closes said valving means thereby stopping the flow of steam through said turbine system.

20. The system of claim **19** wherein

said determining means include second means for determining, said second determining means determines whether a predetermined number of said signal paths have representations of signal exceeding a predetermined rotational velocity limit.

21. A method of preventing overspeeds in an electric power generating system, a steam turbine system having means for generating steam, at least one high pressure and at least one low pressure steam turbine, a generator rotated by said turbine, an electric load connected to said generator, 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, first means for sensing the magnitude of the rotational velocity of said steam turbine system, means for measuring the magnitude of the flow of energy from said generator to said electric load, means for measuring the pressure of said steam in said steam turbine system, independent second means for sensing the magnitude of the rotational velocity of said steam turbine system, two dumping signal channels including two separate dump valves connected to at least one of said actuators moving means independently actuated and connected for dumping hydraulic fluid contained therein, 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;

c rotating said steam turbine in said steam turbine generating system;

d measuring the rotational velocity of said steam turbine generating system;

e measuring the flow of electric energy from said steam turbine generating system to said electric load;

f measuring the pressure of said steam in said steam turbine generating system;

g determining the rate of flow of said steam through said steam turbine during the startup of said steam turbine generating system;

h computing the position of said valve in said steam turbine generating system utilizing a value of desired rate of flow of said steam, said steam pressure and said measured magnitude of electric load and said rotational velocity;

i computing a desired rate of flow of said steam in said generating system;

j controlling the rate of flow in said generated steam through said steam turbine generating system utilizing the values computed in the previous steps;

k independently measuring the rotational velocity of said generating system;

l determining by the use of the independent measurement of rotational velocity whether a predetermined condition associated with said velocity of said steam turbine system has been exceeded;

m activating each of said dump valves upon determination whether said predetermined condition has been exceeded.

22. The method as defined in claim **21** including the additional step of:

dumping the hydraulic fluid from each of said hydraulic actuators.

23. The method as defined in claim **22** including the additional step of: leading the hydraulic fluid into a container.

24. The method as claimed in claim **23** including the additional step of:

calculating the position of the throttle-stop valve in said steam turbine generating system utilizing a desired rate of flow of said steam and the steam pressure during the startup of said turbine.

25. The method of claim **24** including the additional step of:

computing the direction of travel and a displacement for said throttle-stop valve, said governor valve and said interceptor valve.

26. The method of claim **25** including the additional step of:

moving said throttle-stop valve, said governor valve and said interceptor valve in the direction and to the displacement computed previously.

27. The system of claim **20** wherein

said determining means includes third means for determining, said third means determining whether a predetermined number of said signal paths have an interruption of any of said signals.

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